Description of document: Fifteen (15) Federal Highway Administration (FHWA) studies/reports, 1954-2008

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Posted date: 03-September-2018

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RECORDS INCLUDED

1. Borehole Jacking Tests at the Forest Glen Station Site, 1978
2. Benefit-Cost Analysis of Roadside Features: Task G White Paper, 1985
3. Conceptual Plan for an interactive highway safety design manual, 1994
4. The conduct of socio-economic impact assessments: a manual for State highway personnel. Volume I, The impact assessment process, 1983
5. The conduct of socio-economic impact assessments: a manual for State highway personnel. Volume II, Resource Materials, 1983
6. The costs of complying with federal-aid highway regulations, 2008
7. Freeway Management Handbook, 1997
8. A guide for highway traffic regulation in an emergency, 1967
9. A guide for highway traffic regulation in an emergency, 1974
10. Guide for the protection of street and highway transportation facilities from sabotage and enemy attack, 1954
11. Highway innovation clearinghouse study: Draft, 1998
12. Legacy Plan, 1996
13. Nuclear radiation hazards to highway transportation, 1967
14. The police function in highway traffic regulation in an emergency, 1967
15. Potential advancements in freeway surveillance and control techniques: a technical report, 1970

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center

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July 10, 2018

In Reply Refer To:
FOIA Control Number: 2018-0271
FHWAHQ

Your June 11, 2018 request for records under the Freedom of Information Act has been processed.

We are enclosing all records identified as responsive to your request, with the exception of records that contain information exempt from FOIA's mandate of disclosure as provided in 5 U.S.C. 552(b) and 49 C.F.R. § 7.23. Please be advised that you have not been assessed fees for the search, review, and duplication of the records released to you. The records responsive to your request are being provided to you free of charge. Enclosed is a compact disc containing 13 of the 15 documents you requested including:

1. Borehole Jacking Tests at the Forest Glen Station Site
2. Benefit-Cost Analysis of Roadside Features: Task G White Paper
3. Conceptual Plan for an interactive highway safety design manual
4. The conduct of socio-economic impact assessments: a manual for State highway personnel. Volume I, The impact assessment process
5. The costs of complying with federal-aid highway regulations
6. Freeway Management Handbook
7. A guide for highway traffic regulation in an emergency
8. Guide for the protection of street and highway transportation facilities from sabotage and enemy attack
9. Highway innovation clearinghouse study: Draft
10. Legacy Plan
11. Nuclear radiation hazards to highway transportation
12. The police function in highway traffic regulation in an emergency
13. Potential advancements in freeway surveillance and control techniques: a technical report

Please note that some of these documents are unpublished drafts and did not become final publications. As drafts, the documents do not reflect the official stance or policy of the agency and have been maintained as historical artifacts for knowledge retention purposes. In addition, the drafts may contain inaccurate technical information that are the opinion of the author and not the official position of the Federal Highway Administration.

Two of the records you requested are copyright protected under 17 U.S.C. § 101 (Copyright Act of 1976). The two documents include: a dissertation, "Driving Anger, Sensation Seeking, Narcissism, and Driver's Angry Thoughts in Prediction of Unsafe Driving" and an unpublished final report, Maintenance Work Zone Safety: An Unpublished Final Report." We are unable to release these records on behalf of these individuals or organizations and recommend you work directly with the organization that produced these records to obtain copies. We have provided the following two contact links for seeking the information you requested.

University of Southern MS: https://aquila.usm.edu/dissertations/1047/
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Pursuant to U.S. Department of Transportation regulations (49 C.F.R. § 7.32), you have the right to appeal this decision in writing to Mr. Arlan Finfrock, Acting, Associate Administrator for Administration, Federal Highway Administration. Your appeal may be mailed to 1200 New Jersey Avenue, S.E., E66-322, Washington, D.C. 20590-9898, or sent via e-mail at FHWA.foia.appeals@dot.gov or via fax at 202-366-7499. Should you wish to exercise this right, the agency decision on the appeal will be the final administrative action. Your appeal must be postmarked or, in the case of electronic or facsimile transmission submitted, within ninety (90) calendar days from the date the initial determination is signed and should include the FHWA file or reference number assigned to the request and all information and arguments relied upon in making the appeal.

You also have the right to seek dispute resolution services from the FHWA FOIA Public Liaison, Christopher Richardson, FOIA.PublicLiaison@dot.gov, via phone (202) 366-0740; or the Office of Government Information Services (https://ogis.archives.gov) via phone (202) 741-5470/toll free 1(877) 684-6448; fax (202) 741-5769; or e-mail ogis@nara.gov.

Sincerely,

Shana V. Baker

Shana V. Baker
Acting Director, Office of Corporate Research, Technology, and Innovation Management

Attachments: one DVD

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Borehole Jacking Tests at the Forest Glen Station Site.		5. Report Date March, 1978 6. Performing Organization Code
7. Author(s) Donald J. Dodds & Frank S. Shuri		8. Performing Organization Report No.
9. Performing Organization Name and Address Foundation Sciences, Inc. 520 S.W. 6th Avenue Portland, Oregon 97204		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-FH-11-9272
12. Sponsoring Agency Name and Address Department of Transportation Federal Highway Administration Office of Research & Development Washington, D.C. 20590		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contract Manager: Dr. D.A. Linger

16. Abstract

This paper contains the results of Foundation Sciences, Inc. in situ investigation at Forest Glen. The static modulus of elasticity was obtained both by in situ (borehole jacking) and laboratory methods. The report contains description of the test, the results and a discussion of the pertinent results and the possible application.

17. Key Words Cavern & tunnel design, downhole loading tests, engineering properties of rock	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	35	

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NOTICE

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. Introduction

The studies presented herein were made to increase preliminary knowledge of the engineering properties of the rock material at the Forest Glen Station site. Figure 1 shows the location of the project. The results of the work will be utilized to:

(a) provide basic information for cavern and tunnel design, and

(b) evaluate the performance of pre-construction explorations in estimating actual conditions.

The work was authorized by Department of Transporation Contract No. DOT-FH-11-9272, dated May 25, 1977. The scope of the work may be summarized as follows:

1.1 Scope of the Work

The work was divided into two main sections:

(a) Downhole loading tests using the Goodman jack to measure the static deformation properties of the rock, and

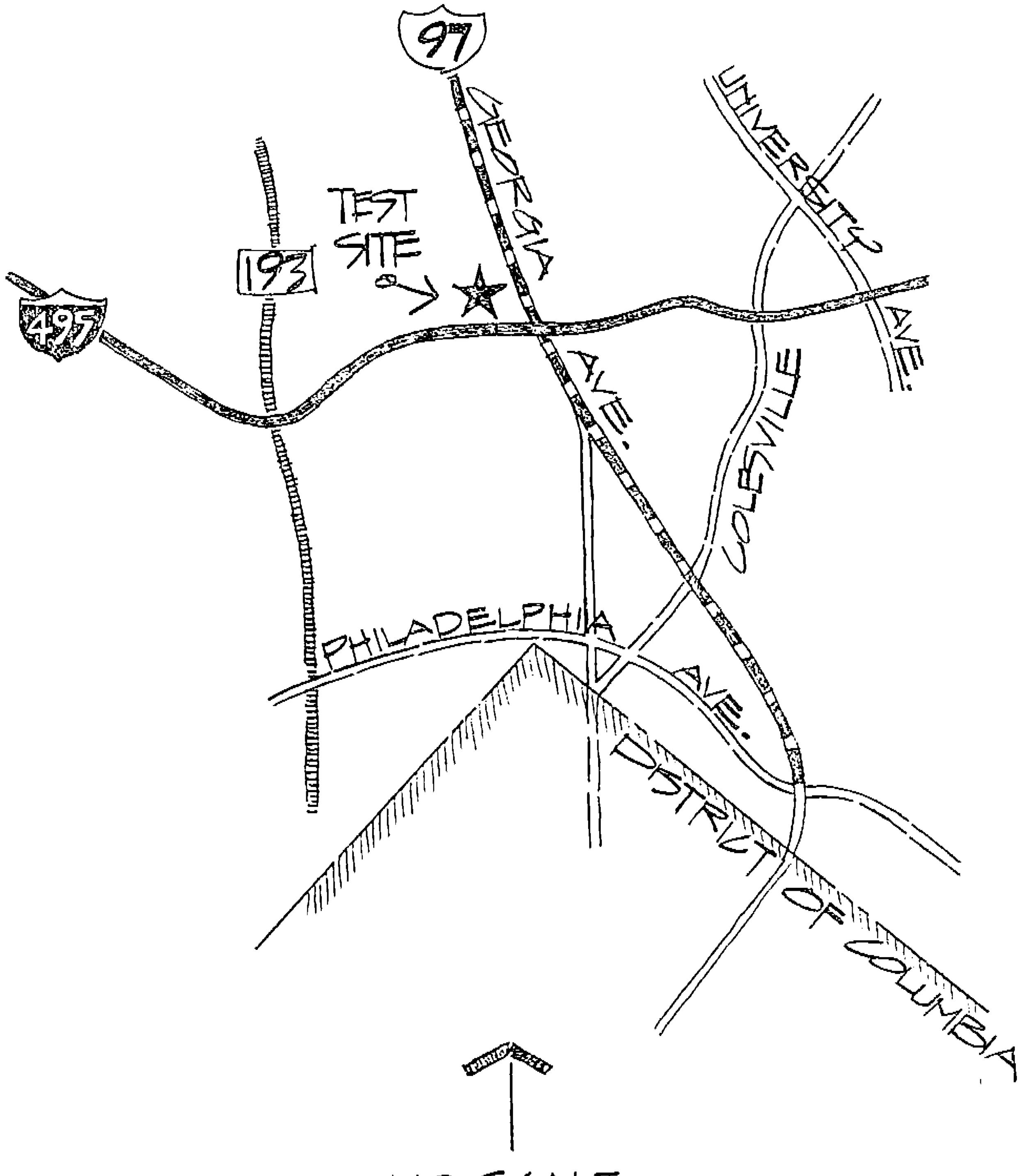
(b) Laboratory tests of selected rock cores at, or near, the locations of the downhole tests to determine the deformation constants and compare them with in situ results.

1.2 Synopsis of Work

Field work began on January 5, 1978, and concluded on January 14, 1978. Laboratory testing and report writing began on January 17, 1978, and is concluded with the submission of this report. The field work and report writing were performed by Donald J. Dodds and Frank S. Shuri, and the laboratory testing was performed by Frank S. Shuri and E. Christine Petersen.

1.3 General Commentary

In the design or evaluation of the stability of an underground cavity, knowledge of the mechanical properties of the material in which the cavity is to be constructed is essential. During this study, static mechanical properties were obtained by both laboratory and in situ tests. These methods complement one another in that the laboratory tests allow wider and more precise control over the variables affecting the properties to be measured. However, the exact field conditions are difficult to reproduce



LOCATION MAP

Fig. 1

during the test and were often difficult to measure adequately in the field. The field tests, of course, provided the exact environment under which the rock properties need to be known, but allowed for very little independent control of those variables. During the examination or utilization of these test results, the following points must be remembered and the data utilized accordingly.

1.3.1 Non-Distribution

The field testing was conducted in one borehole, and laboratory samples were taken in two borings. The actual volume of material tested is only a minute fraction of the total cavern volume; the small number of tests does not permit the application of statistical methods to the resultant data. Conditions away from the borings could be different, but this report cannot reflect any such variations.

1.3.2 Absence of Joints

The effects of joints, faults, and fractures on the material cannot be assessed by laboratory tests. Generally the values of the physical properties are lowered by the presence of joints.

The rock affected by the Goodman jack is a cylinder some 12 inches long with a diameter of approximately three feet. The amount of joints, cracks, and weak areas contained in this volume is minimal, and so the results of the test generally show values for in-place intact rock. If an abnormality does pass under the plate, the relatively large area allotted to the abnormality compared with that allotted to the normal rock tends to overwhelm the results and produce a very low value of the modulus; the end result then being that the upper and lower bounds are obtained rather than the deformation modulus of the material mass.

1.3.3 Changed Conditions

The laboratory samples have been removed from their normal environment and subjected to surface conditions. The resulting change in physical characteristics due to this exposure is difficult to ascertain; it is expected, however, that the physical properties measured on in-place rock would be somewhat higher.

1.3.4 Optimization by Selection

The weaker rock in the mass is subject to breakage during drilling and recovery because this rock generally contains more natural joints and other weak structures. In badly broken or jointed rock, it is difficult to find a piece of core large enough to obtain a sample for testing in the laboratory. In the field, care must be taken to prevent broken rock from falling out of the sides of the hole and wedging the instrument into the hole. As a result, the field technician tends to select test areas in sound rock. Borh of these selection processes tend to favor testing the better material in any given situation and could produce material properties for the stronger material.

2. Static Deformation Characteristics

2.1 The Borehole Jack

The borehole jack is a borehole probe with movable rigid bearing plates for measuring wall deformation as a function of applied load. Calculation of directional deformation in the rock is determined through load-deformation measurements using an assumed Poisson's ratio. The probe is designed to operate in a three inch, NX dimater borehole; the pressure plates can span diameters ranging between 2.75 and 3.25 inches, creating an effective working borehole size of approximately 2.9 to 3.1 inches to allow for average rock deformation during testing. Hydraulic pressure is transmitted to the rock through 17 square inch movable plates, transmitting a maximum bearing plate pressure of 9,300 psi to the rock surface. Two LVDT displacement transducers are mounted within the jack at each end of the movable plates allowing precission measurements of deformation to be made. The system also includes a portable solid-state indicator for measuring displacement, hydraulic pump, pressure gauges, two hydraulic hoses and electrical cable.

The advantages of this test are its relatively low cost in comparison with other in situ tests, its ability to measure properties at depth, and minimal disturbance of the in situ conditions. The disadvantages are the relatively small bearing surfaces, which sample material properties at selected points along the borehole , and poor mating of bearing plates to the rock surface. The U.S. Corps of Engineers, Missouri River Division Laboratory (Ohnishi, 1971), and the U.S. Bureau of Mines, Spokane Mining Research Center (1969) have tested the Goodman jack and report low results relative to other methods of modulus measurement.

2.2 Field Testing

The borehole jack was used to obtain the static material properties of the rock in situ at Forest Glen . Three borings of sufficient length to intersect the cavern were available at the site. These borings were made on a small angle of the vertically grouted areas, to prevent failure of the borehole walls, and redrilled to three inches with a rotary bit. This method of drilling produces an oblong hole with the short axis parallel to the strike of the hole. This eliptical nature of the resulting hole was not disclosed by the caliper log because it measures the average diameter, which was shown to be slightly under three and one-half inches. While lowering the probe into hole T-2, an obstruction was encountered at approximately 113 feet (inclined distance) which prevented the probe from going any deeper. Similar obstructions were encountered in boring T-3 and RP-27 just below the casing. The borehole jack is, of course, designed to operate in a circular hole with a nominal diameter of three inches. By expanding the jack parallel and perpendicular to the strike, the diameters were measured at less than two and seven-eighths and greater than three and one-half, respectively. The lack of time and funds available to redrill the holes to three inches in diameter prevented the test from being performed, except in the top 25 feet of T-2, where two tests were performed at 109.6 feet. Of these two, test number 1 was conducted with the applied stress perpendicular to the direction of Georgia Avenue at the site, and test number 2 was performed with the stress parallel to Georgia Avenue. The tests were conducted using the equipment described below, as shown in Figure 2 , according to the procedure outlined below:

2.2.1 Equipment

(a) Model 52102 Goodman jack,

(b) Schaevitz TR 100 LVDT (linear variable displacement transducer) readout box,

(c) 600 feet of hydraulic line,

(d) 300 feet of electric cable,

(e) 300 feet of BX casing, and

(f) hydraulic pump and pressure gauge.

2.2.2 Procedure

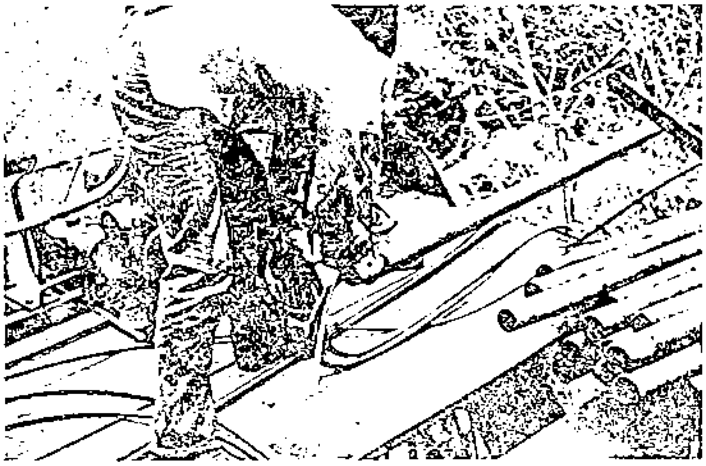
(a) Low pressure and high pressure hydraulic lines and electric readout cable were threaded through the first section of BX casing, Figure 2A.

(b) The hydraulic lines and cable were attached to the Goodman jack which was threaded onto the cable by twisting it to prevent fouling of lines and cable, Figure 2C.

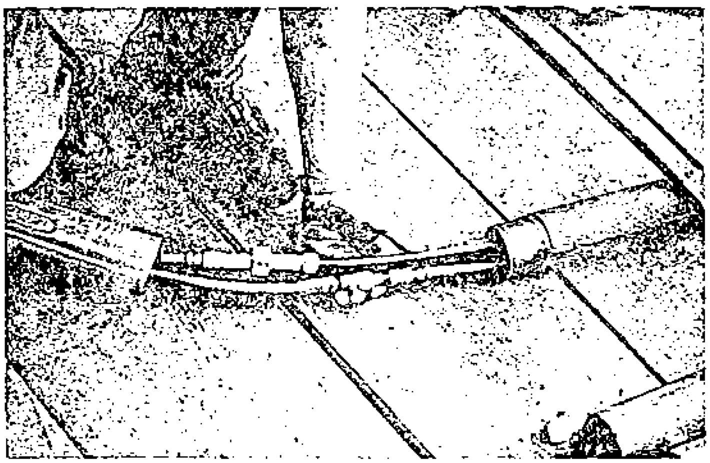
(c) The jack and casing were placed in the borehole, Figure 2E, and additional casing and lengths of cable and lines were added as necessary to position the jack at the desired depth.

(d) The test surfaces were oriented and the bearing was recorded.

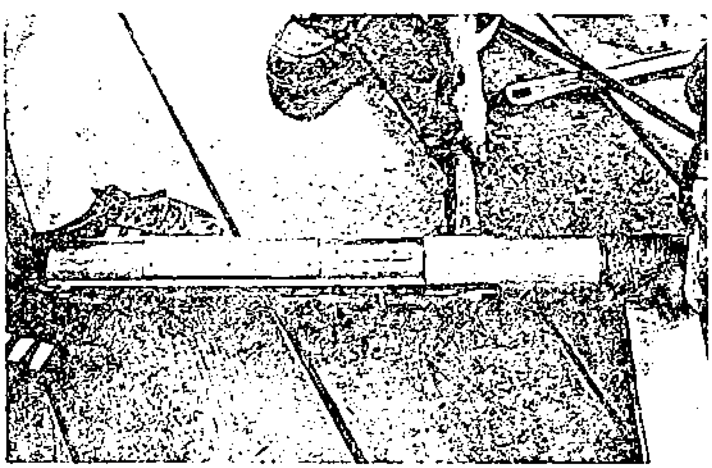
(e) The hydraulic lines were attached to the pump and the electric cable to the readout box.



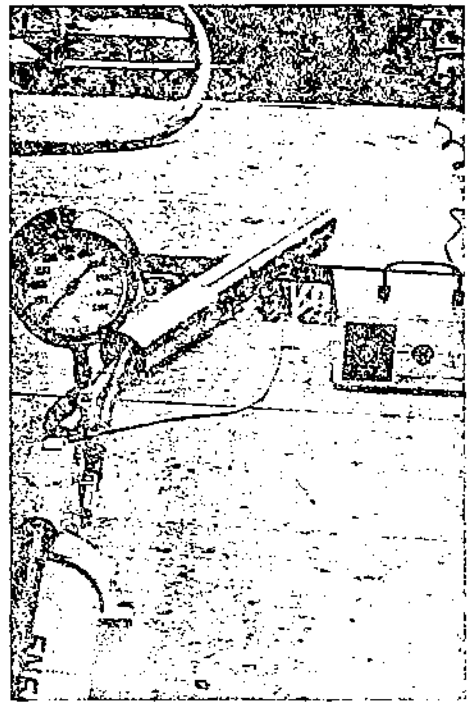
A. Threading the lines into casing.



B. Jack and casing.



C. Connecting jack to casing.



D. Goodman jack, readout box and hand pump.

E. Installing jack in the hole.

Fig. 2

(f) Pressure was applied until the jack contacted the sides of the drill hole. The LVDT readings were recorded as the zero readings.

(g) The load was applied in 10 equally spaced increments.

(h) The load was held 15 minutes at the peak of each cycle to determine if the material exhibited time-dependent strain characteristics.

(i) The load was removed in 10 equal decrements to obtain an unloading curve, and the minimum load was held for 15 minutes to allow the rock to rebound.

(j) Two additional and similar cycles of loading were performed to successively higher loads.

(k) The jack was collapsed and rotated 90 degrees, and steps 6 through 10 were repeated.

(l) Upon completion of the second test, the jack was collapsed and moved to the next test position.

2.2.3 Data Reduction

The equation used to obtain the modulus values was derived by assuming the actual pressure to be a constant radial boundary pressure plus shear and radial pressures distributed sinusoidally over the width of the plate. If the angle subtended by the width of the plate is about 45 degrees, little effect on the results occurs from the finite plate width. The results of a finite element program (Hall, 1972) show that a reduction of 14 percent in the value of the modulus is necessary to adjust to the actual length of the jack. The modulus was obtained by the use of the following equation:

$$E = 0.86 \frac{P\ h}{w_h}$$

where P = applied load

h = diameter of borehole

w_h = diametrical deformation

2.2.4 Results

The results of the borehole jacking tests are summarized in Table 1 and displayed as stress-strain curves in Figures 3 and 4. The values obtained from each orientation are essentially the same, considering the small number of tests and the statistical scatter of results typical of all rock mechanics testing. The modulus values are relatively low; inspection of the stress-strain curves reveals crack-closing at the start of each cycle, and a moderate amount of permanent deformation. In addition, a significant amount of time-dependent strain occurred at the top of each cycle; this behavior has been plotted as strain vs. time in Figure 5. During test number 1, similar creep rates took place at all stresses, while the total time-dependent strain increased in proportion to the applied stress. Total time-dependent strains in test number 2 were less than in test number 1, indicating that working of the material had taken place during the first test.

The borehole jacking test results compare well with the laboratory test results. The jacking measurements were made in situ and will, of course, reflect the effects of confining pressure, cracks, joints, and moisture. The confining pressure would tend to increase the moduli, while the macro-rock quality would tend to decrease them. In addition, strongly foliated materials such as these will sometimes show a modulus dependent upon the orientation of the applied stress. When the stress is applied normal to alternating low and high modulus layers, the low modulus material compresses and controls the bulk modulus of the rock. When the stress is applied parallel to such layers, the high modulus material controls the amount of strain and, thus, the modulus. While this effect was not observed in the unweathered sample, it could well exist in the weathered rock because of the different weathering characteristics of quartz, feldspar, and the micas. The jacking test was conducted with the stress basically parallel to the foliation, which dipped 23° to the axis of the core. Thus, the values are similar, rather than the jacking test results being lower, as might be expected. Vertical in situ modulus values may proved to be lower than the figures presented here.

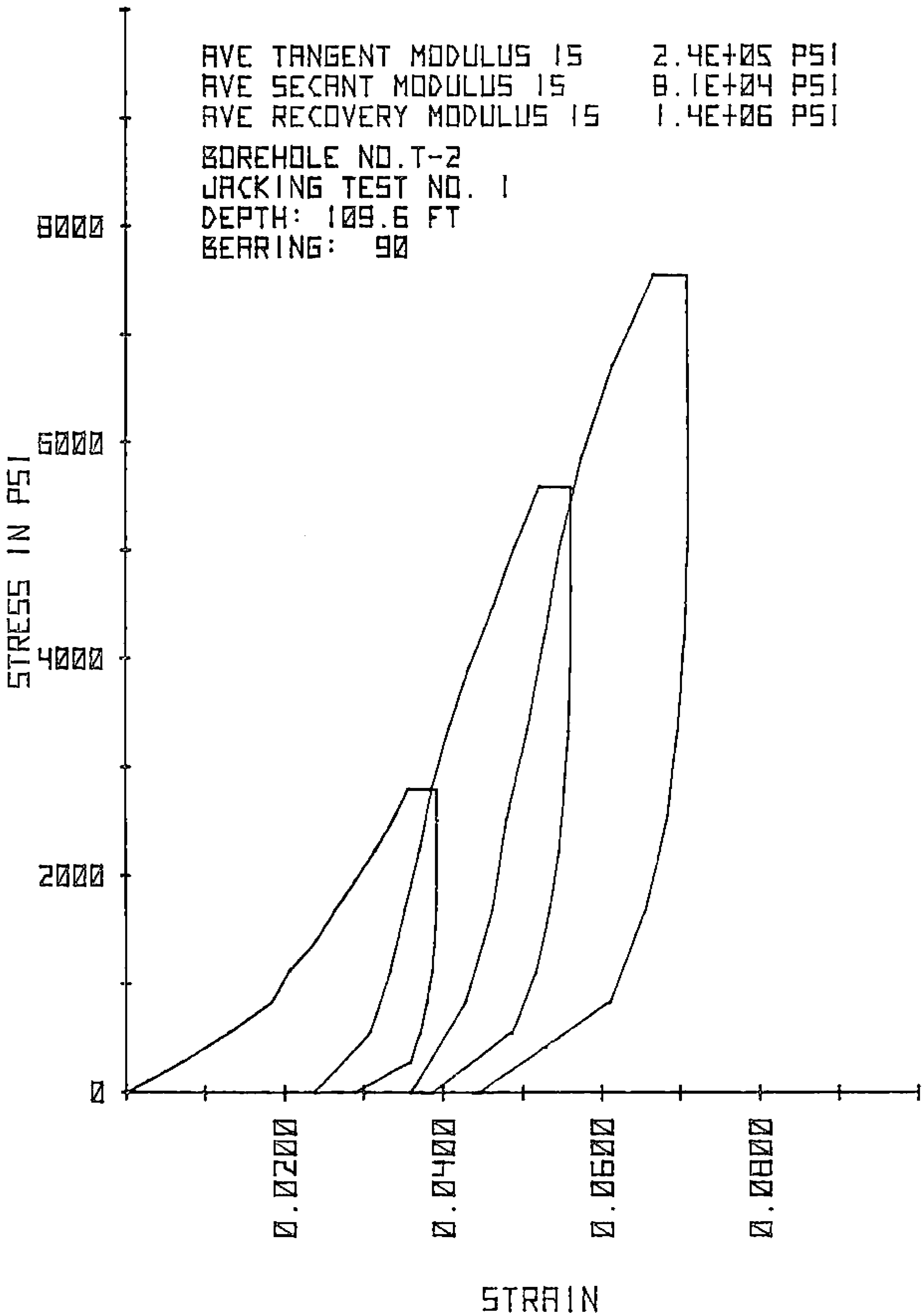
2.3 Laboratory Tests

A total of 11 unconfined uniaxial compression tests were performed on air-dried rock core specimens to determine their deformation constants. Ten tests were performed on unweathered material, five from boring T-2, five from boring RP-27, and one on slightly weathered material from boring T-2. Eleven core samples were returned to Portland and tested for modulus of deformation values and Poisson's Ratio using the equipment and procedures as follows:

Table I

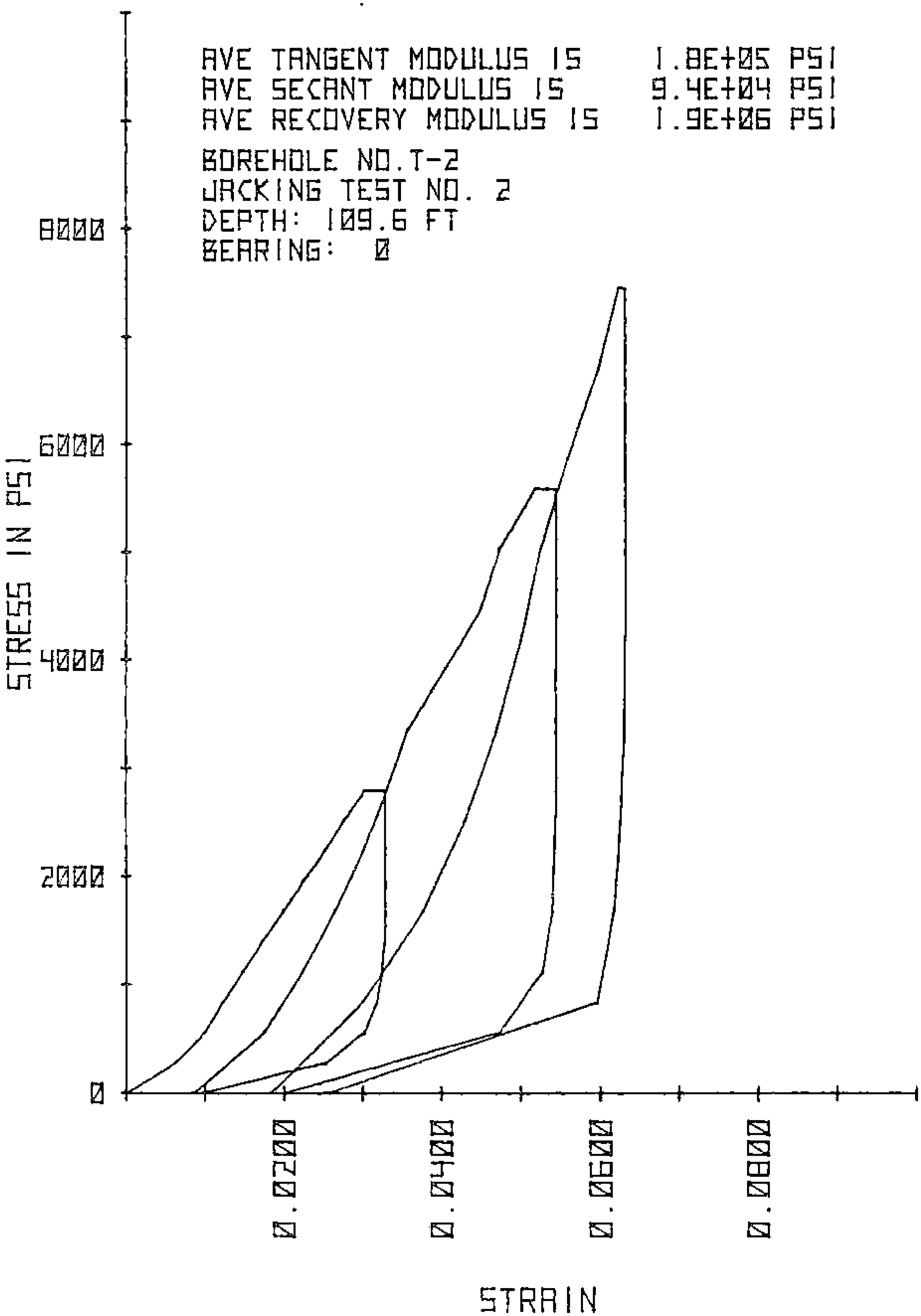
Borehole Jacking Test Results

	Test No. 1	Test No. 2
Depth, Ft.	109.6	109.6
Orientation, degrees relative to Ga. Ave.	90	0
Tangent Modulus x 10^6 psi	0.24	0.18
Secant Modulus x 10^6 psi	0.08	0.09
Recovery Modulus x 10^6 psi	1.4	1.9



AVE TANGENT MODULUS IS 2.4E+05 PSI
AVE SECANT MODULUS IS 8.1E+04 PSI
AVE RECOVERY MODULUS IS 1.4E+06 PSI
BOREHOLE NO.T-2
JACKING TEST NO. 1
DEPTH: 109.6 FT
BEARING: 90
STRESS IN PSI
8000
6000
4000
2000
0
0.0200
0.0400
0.0600
0.0800
STRAIN

Fig. 3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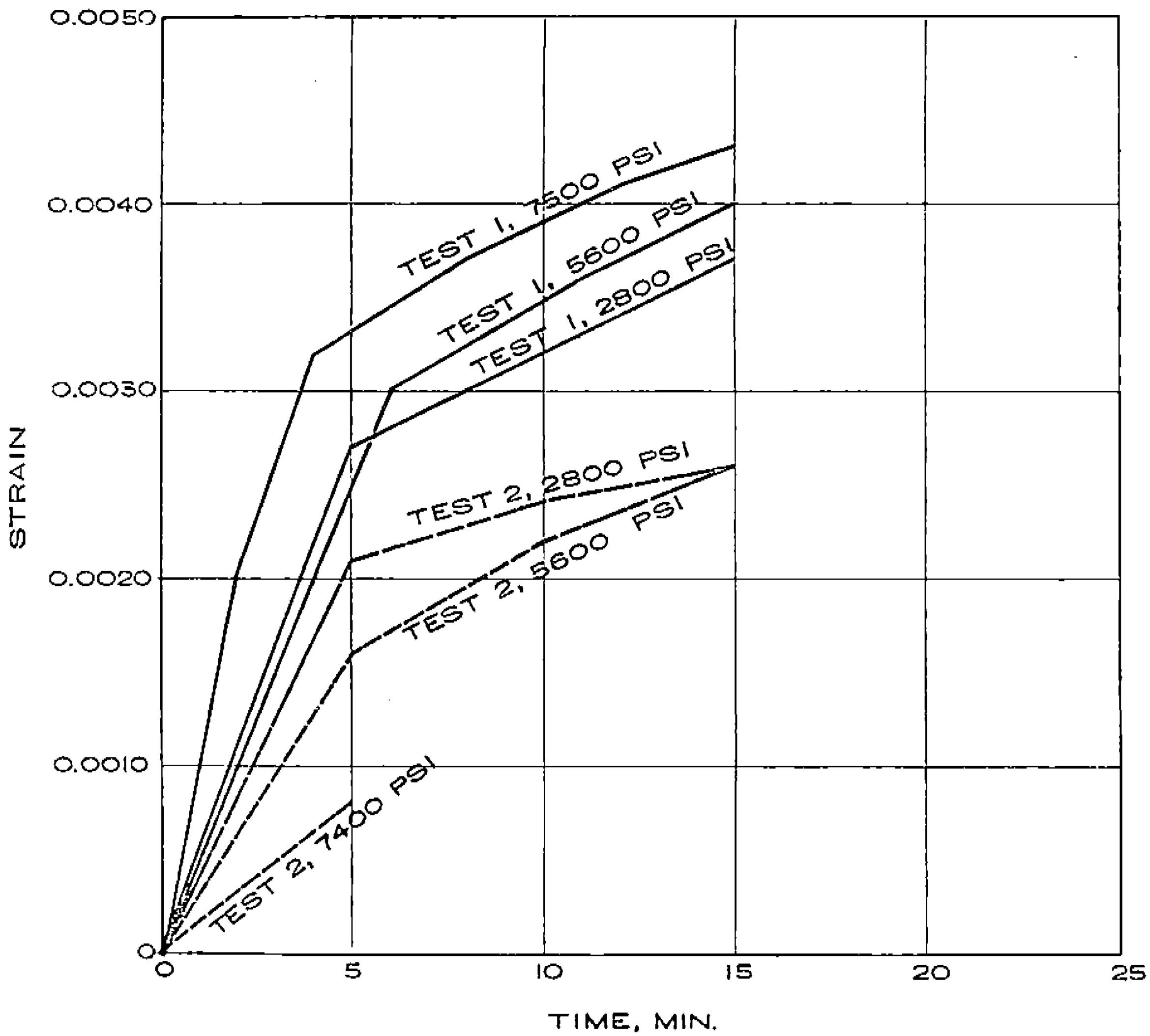
AVE RECOVERY MODULUS IS 1.9E+06 PSI
BOREHOLE NO.T-2
JACKING TEST NO. 2
DEPTH: 109.6 FT
BEARING: 0
STRESS IN PSI
8000
6000
4000
2000
0
0.0200
0.0400
0.0600
0.0800
STRAIN

Fig. 4



CREEP DURING BOREHOLE
JACKING TESTS

Fig. 5

2.3.1 Equipment

(a) A 250,000 pound compression tester with a 2.25 inch ram operated by a hand pump.

(b) Four SR-4 type strain gauges mounted on opposite sides of the core in two T-shaped rosettes.

(c) A 6.5 volt solid state DC power source, a 10 channel switch and balance unit, and a high impedance digital voltmeter in a Wheatstone bridge circuit.

(d) A Hewlett-Packard 9830 computer in direct hookup with the voltmeter for data acquisition and calculations.

2.3.2 Procedure

(a) The samples were cut and their ends ground in accordance with ASTM D2938.

(b) Strain gages were applied according to the gage manufacturer's recommendations.

(c) A spherical seat and hardened steel platens were cleaned and inspected to see that they would perform properly.

(d) The test specimen bearing surfaces were cleaned, and the specimen was placed on the bearing platens.

(e) The axis of the specimen and the center of thrust of the spherical seat block were carefully aligned.

(f) The load was applied in 10 equally spaced increments at a constant rate without shock.

(g) Readings were taken of axial and radial strain after each increment of loading.

(h) The peak load was maintained for several minutes to observe time-dependent strain behavior, if any.

(i) The sample was unloaded in 10 equally spaced increments with strain readings at each step.

(j) Two additional and similar cycles of loading were performed to loads of twice and three times the first cycle's peak load.

2.3.3 Results

Because rock is not actually an elastic material, its behavior may be described by the use of the three deformation moduli shown on Figure 6.

(a) The tangent modulus of deformation is the slope of the stress-strain curve obtained between two adjacent sets of data points. It neglects the end effects of the curve and is better suited to small stress changes.

(b) The secant modulus of deformation is the slope of the line between zero stress and the stress in question. This modulus should be used for complete load steps from zero to the desired load. Sometimes the initial portion of a curve is concave upwards. This is often attributed to closing of microcracks caused by stress release, blasting, etc. and lowers the value of the secant modulus. The ratio between the secant modulus and tangent modulus, then, can be used as a means of measuring the micro-damage of the material. A ratio of one indicates no damage.

(c) The recovery modulus of deformation is a tangent modulus on the stress-releasing portion of the stress-strain curve. This modulus is generally higher than the other two moduli and is used in calculations where unloading conditions are present. The difference between the tangent and recovery moduli indicates the material's capacity for hysteresis or energy storing. In a linearly elastic material all three moduli would be identical.

The results of the unconfined uniaxial deformation tests are presented in Table 1. Stress-strain curves for each sample are shown in Figures 7 through 16.

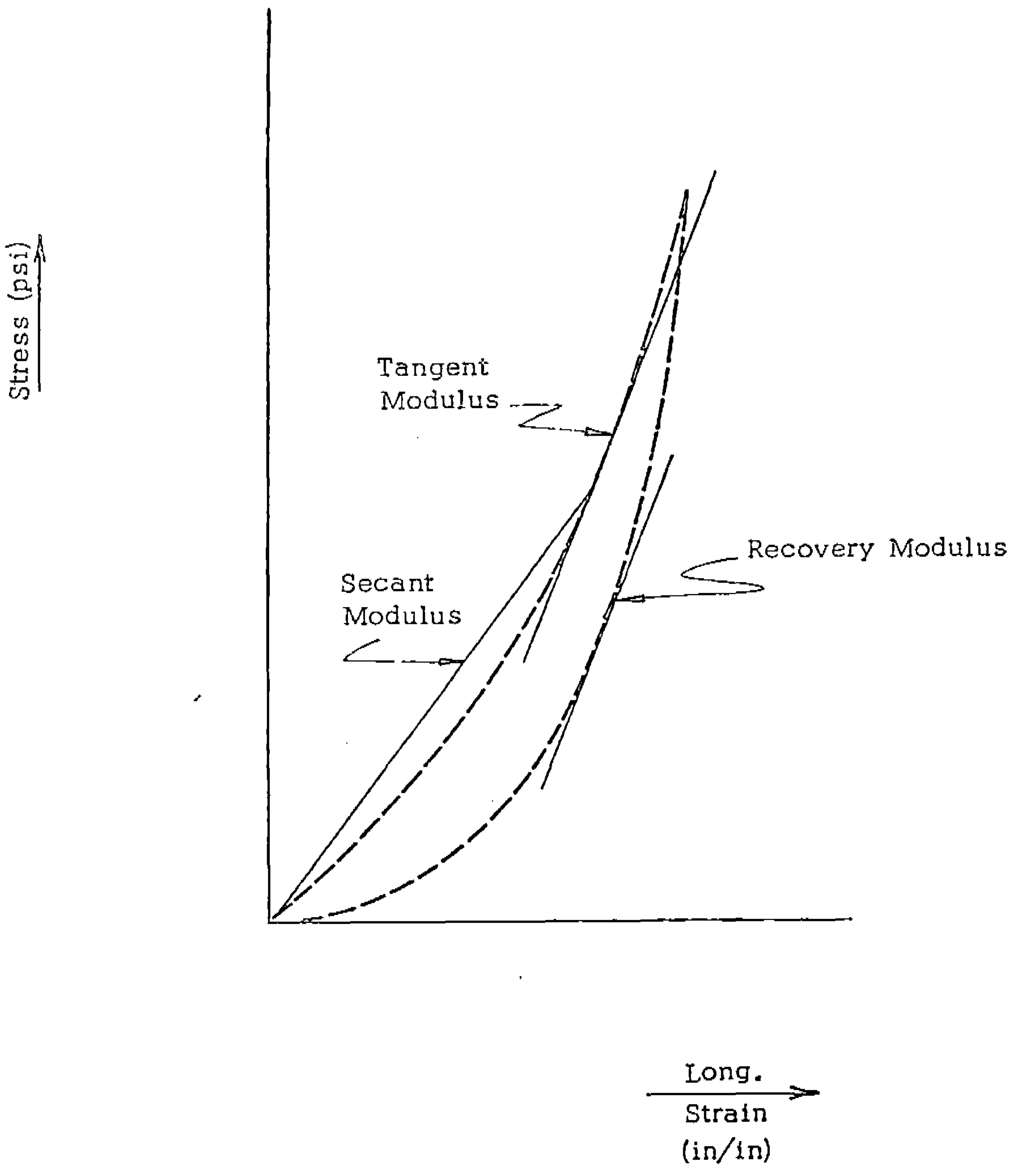
The modulus values for unweathered material generally range between 7 and 12 x 10^6 psi with relatively little spread in the data. Poisson's Ratio averages 0.187. These figures are representative of relatively high modulus material. The stress-strain curves are fairly linear, with unloading cycles similar to loading cycles. Very little permanent deformation (plastic deformation) was observed, and almost no time-dependent strain (creep) at peak stress levels. This material is highly elastic in its behavior.

This slightly weathered rock, on the other hand, exhibits modulus values ranging from 0.2 to 0.4 x 10^6 psi and a Poisson's Ratio of 0.037. Inspection of the stress-strain curve for this material, Figure 17, reveals unloading curves which are substantially different from loading curves, indicating that much of the energy is stored until low stress levels are reached. In addition, there is significant creep exhibited at the peak of

Table 2

Modulus of Deformation Results

Sample No.	Depth, Ft.	Tangent x 10^6 psi	Secant x 10^6 psi	Recovery x 10^6 psi	Poisson's Ratio
Weathered Material:					
T-2-1	113.6-114.3	0.24	0.20	0.40	.037
Unweathered Material:					
T-2-2	190.8-192.3	12.4	14.2	12.0	.179
T-2-3	198.0-198.7	8.2	8.0	8.4	.167
T-2-4	208.0-208.7	7.2	6.9	7.5	.111
T-2-5	218.4-219.0	10.3	10.4	10.3	.187
T-2-6	226.9-227.5	10.2	10.7	10.1	.268
RP-27-1	193.4-194.3	9.4	9.6	9.7	.198
RP-27-2	201.5-202.3	10.0	10.2	10.1	.175
RP-27-3	213.0-214.1	7.1	6.7	7.6	.179
RP-27-4	223.0-223.9	7.7	7.8	7.9	.198
RP-27-5	233.0-234.2	8.1	8.0	8.4	.205
Ave. Unweathered Material:		9.1	9.2	9.2	.187
Range:		7.1-12.4	6.7-14.2	7.5-12.0	.111-.268



Relationship between tangent, secant, and recovery moduli.

Fig. 6

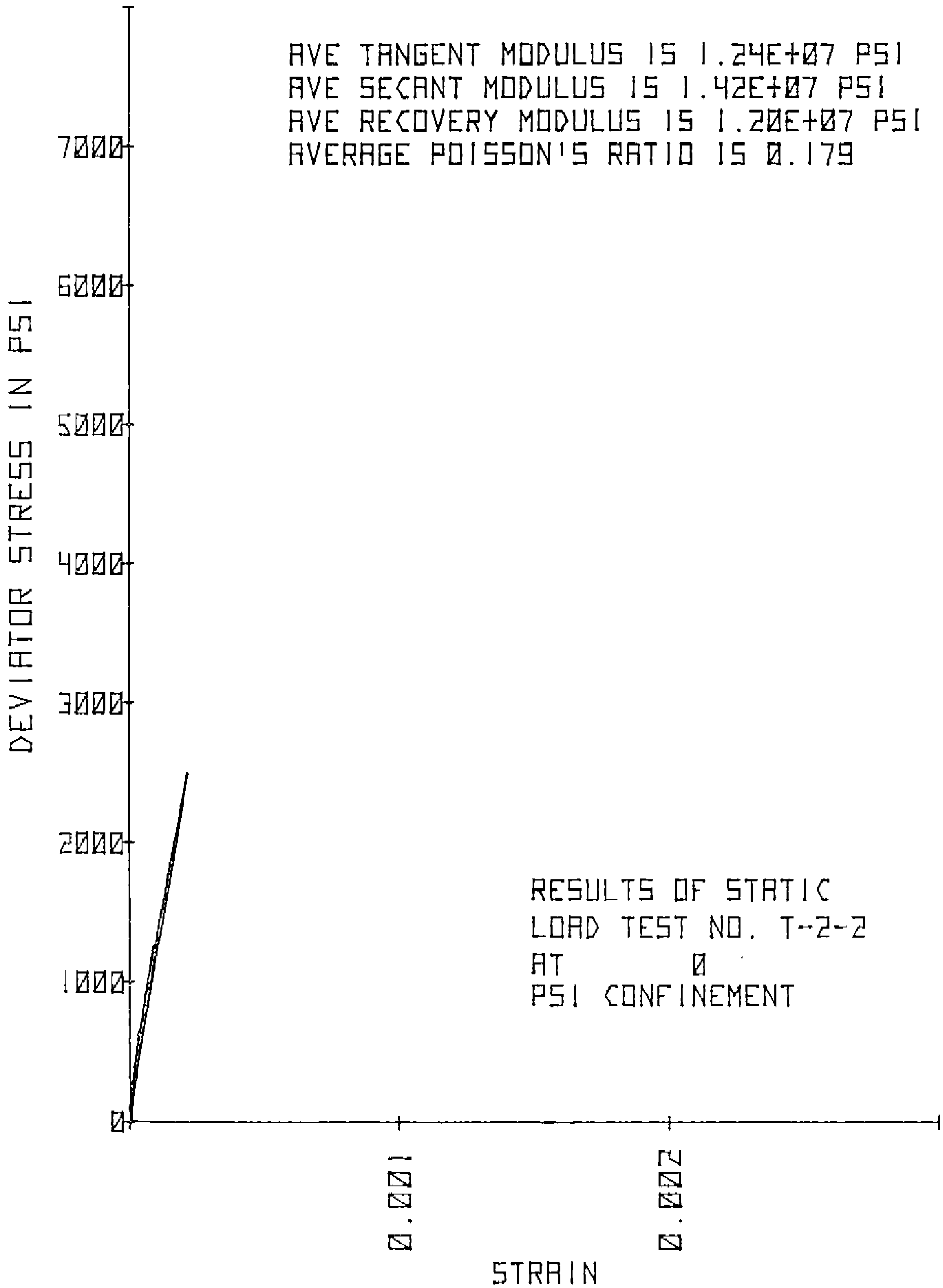

AVE TANGENT MODULUS IS 1.24E+07 PSI
AVE SECANT MODULUS IS 1.42E+07 PSI
AVE RECOVERY MODULUS IS 1.20E+07 PSI
AVERAGE POISSON'S RATIO IS 0.179
7000
6000
5000
4000
3000
2000
1000
0
DEVIATOR STRESS IN PSI
RESULTS OF STATIC
LOAD TEST NO. T-2-2
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 7

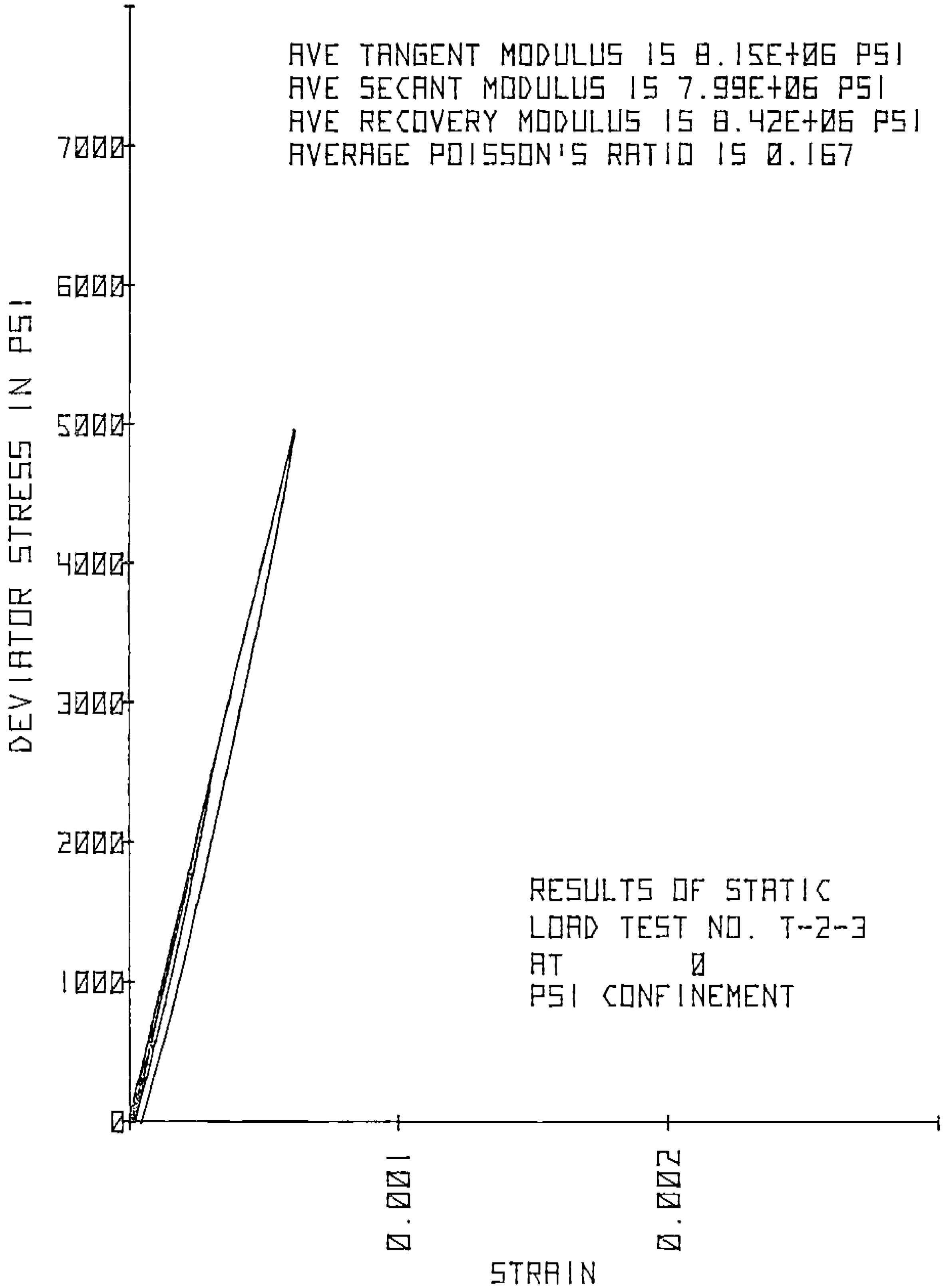
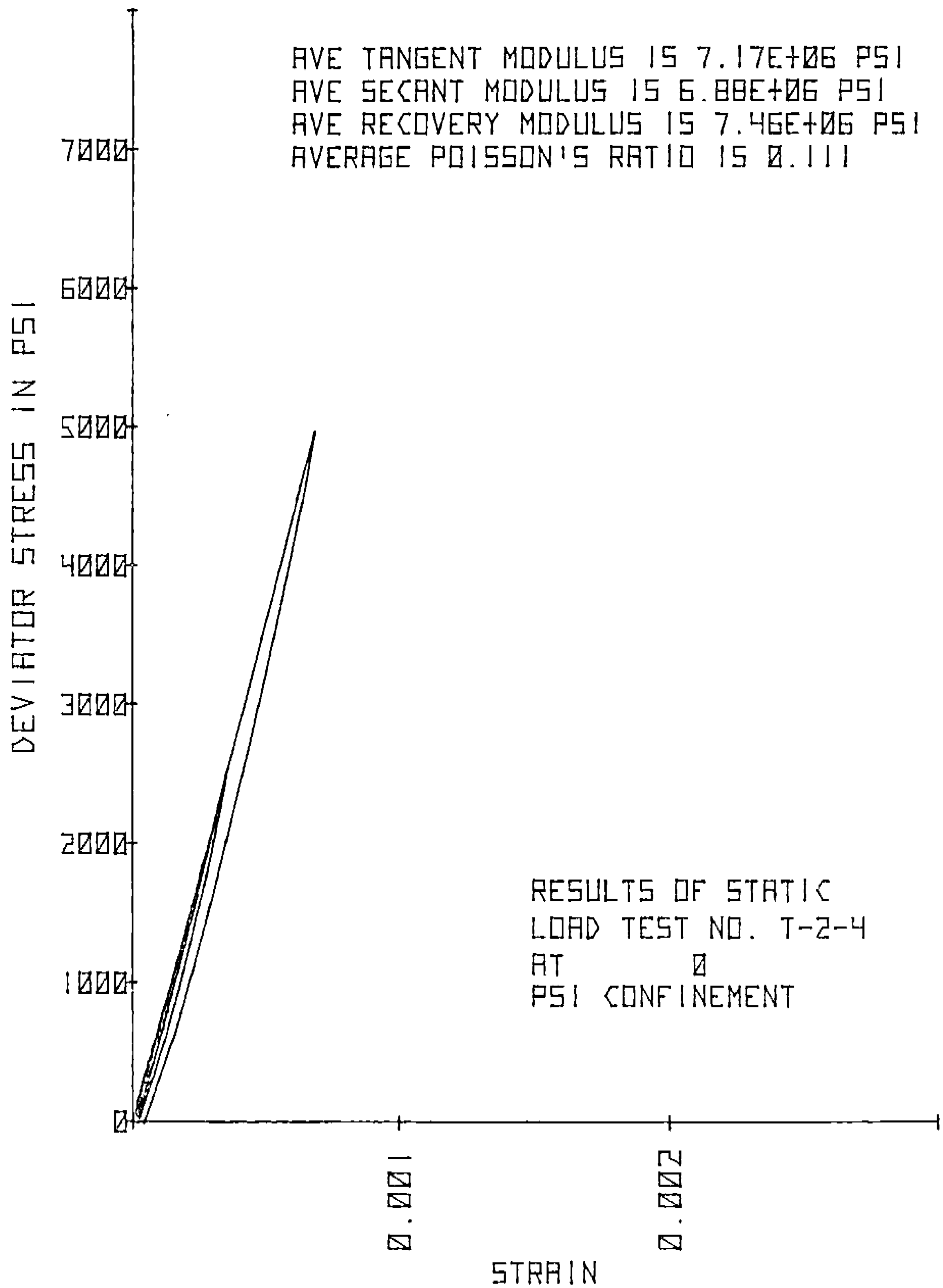

AVE TANGENT MODULUS IS 8.15E+06 PSI
AVE SECANT MODULUS IS 7.99E+06 PSI
AVE RECOVERY MODULUS IS 8.42E+06 PSI
AVERAGE POISSON'S RATIO IS 0.167
DEVIATOR STRESS IN PSI
0
1000
2000
3000
4000
5000
6000
7000
RESULTS OF STATIC
LOAD TEST NO. T-2-3
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 8



AVE TANGENT MODULUS IS 7.17E+06 PSI
AVE SECANT MODULUS IS 6.88E+06 PSI
AVE RECOVERY MODULUS IS 7.46E+06 PSI
AVERAGE POISSON'S RATIO IS 0.111
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
RESULTS OF STATIC
LOAD TEST NO. T-2-4
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 9

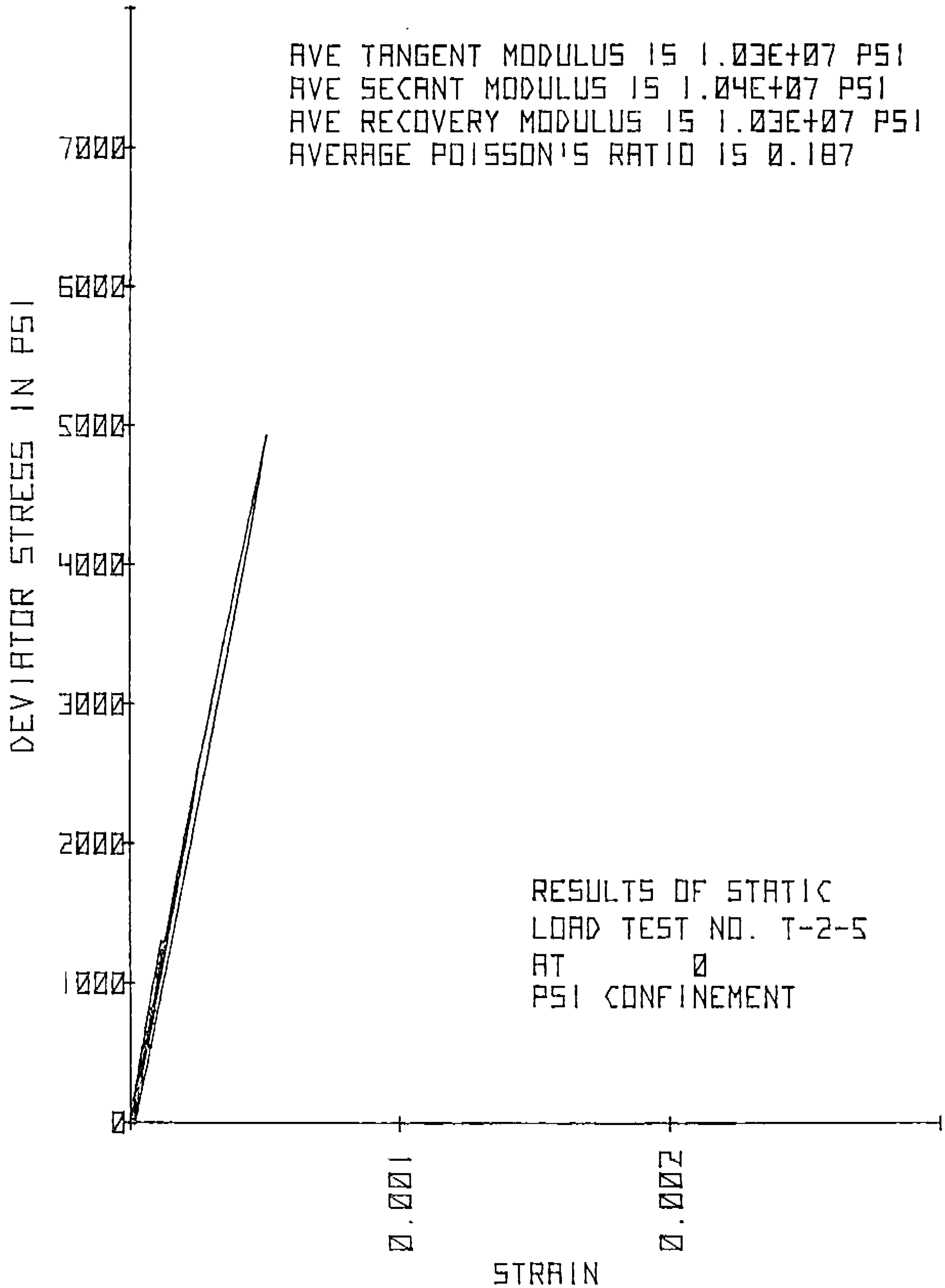
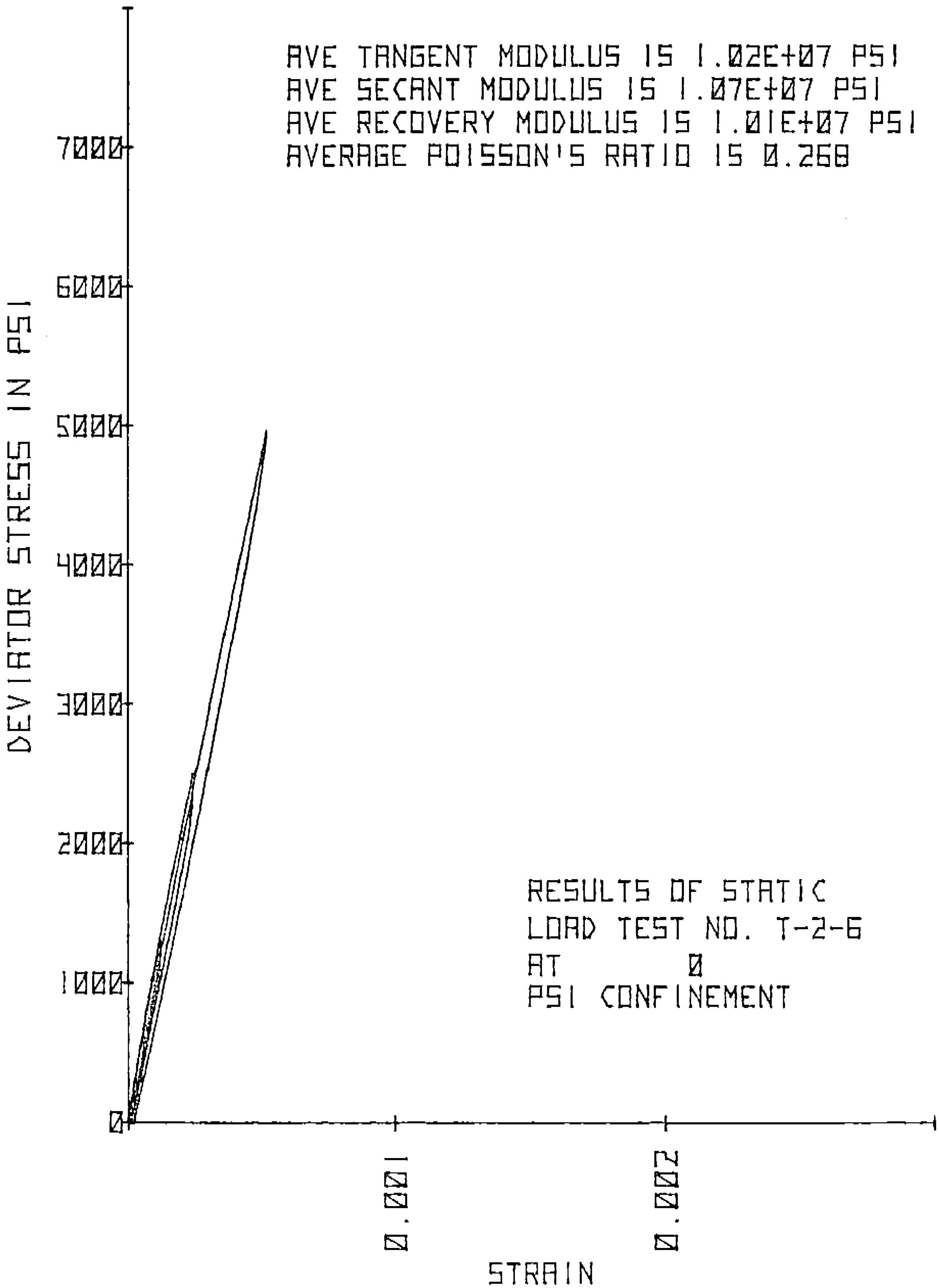

AVE TANGENT MODULUS IS 1.03E+07 PSI
AVE SECANT MODULUS IS 1.04E+07 PSI
AVE RECOVERY MODULUS IS 1.03E+07 PSI
AVERAGE POISSON'S RATIO IS 0.187
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
RESULTS OF STATIC
LOAD TEST NO. T-2-5
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 10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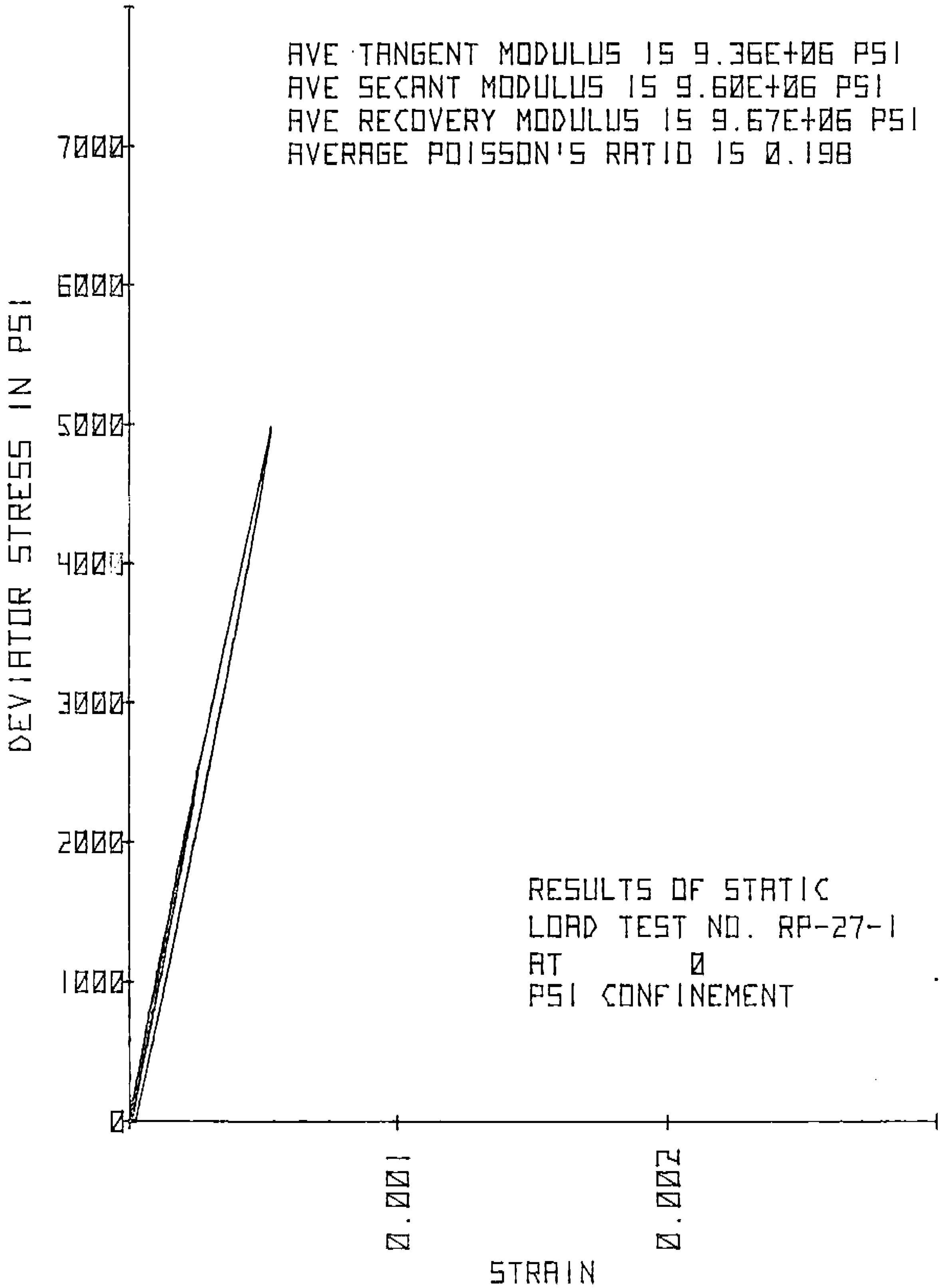
AVE SECANT MODULUS IS 1.07E+07 PSI
AVE RECOVERY MODULUS IS 1.01E+07 PSI
AVERAGE POISSON'S RATIO IS 0.268
7000
6000
5000
4000
3000
2000
1000
0
DEVIATOR STRESS IN PSI
0.001
0.002
STRAIN
RESULTS OF STATIC
LOAD TEST NO. T-2-6
AT 0
PSI CONFINEMENT

Fig. 11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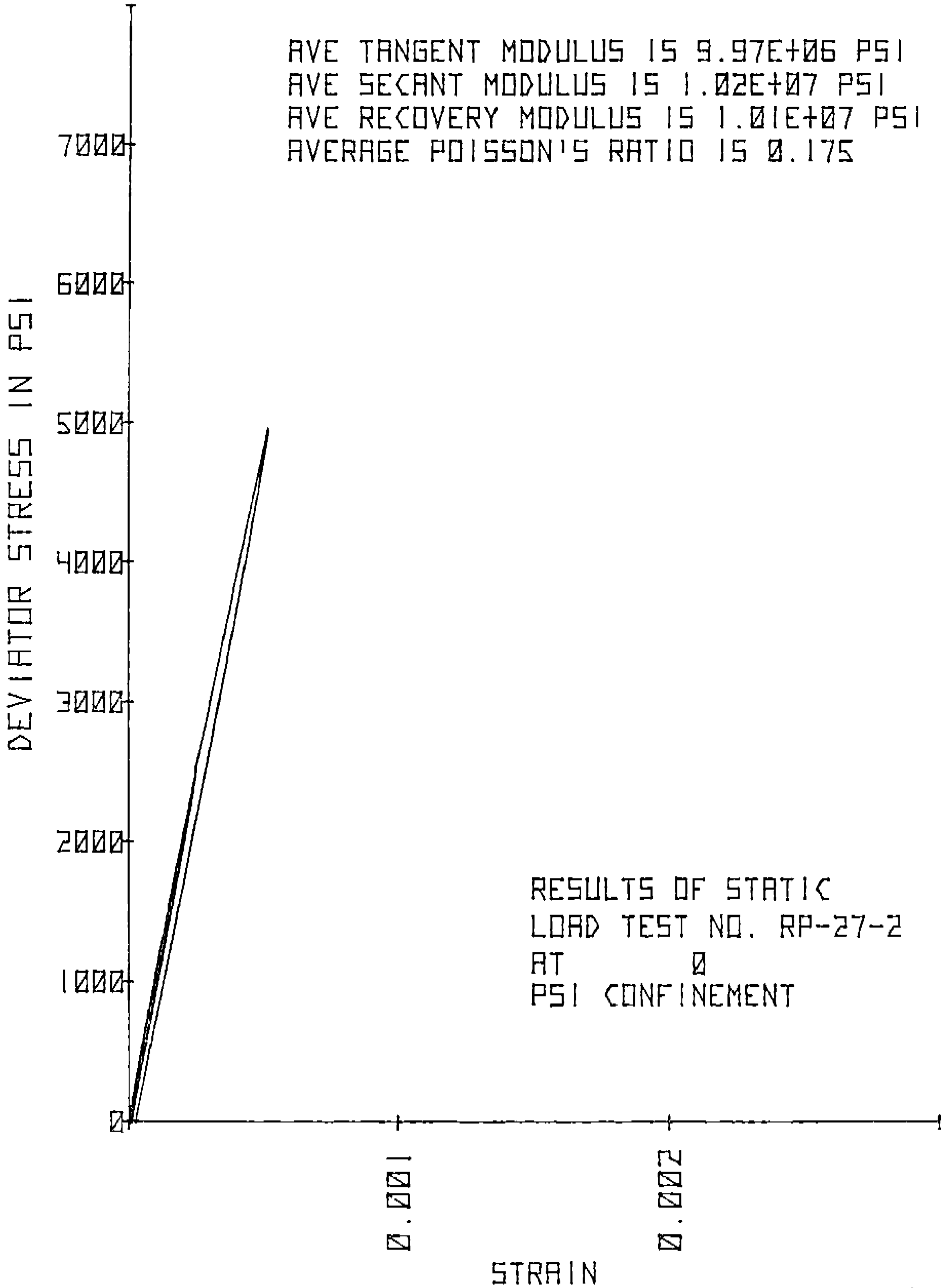
AVE SECANT MODULUS IS 9.60E+06 PSI
AVE RECOVERY MODULUS IS 9.67E+06 PSI
AVERAGE POISSON'S RATIO IS 0.198
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
RESULTS OF STATIC
LOAD TEST NO. RP-27-1
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 12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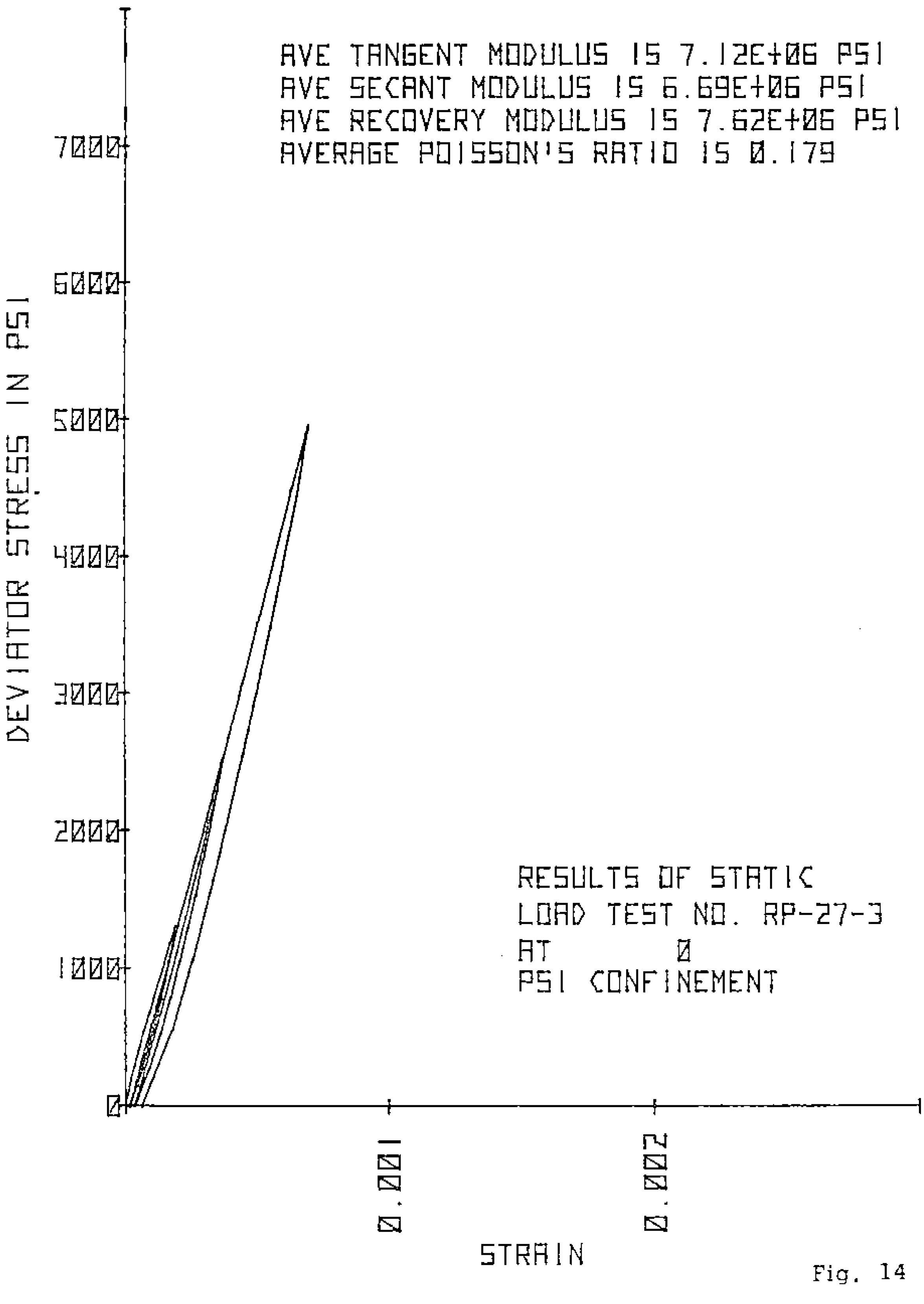
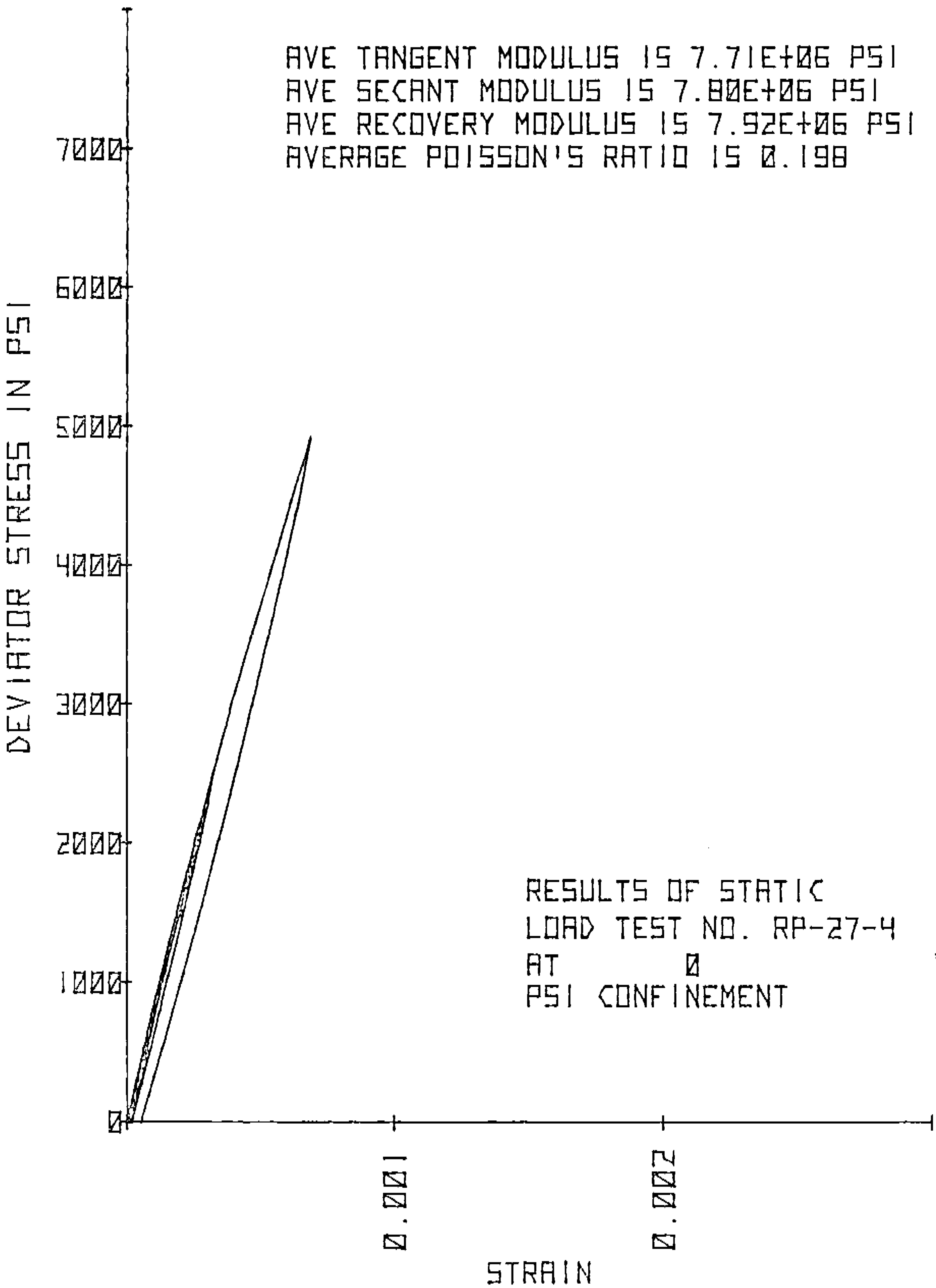
AVE RECOVERY MODULUS IS 1.01E+07 PSI
AVERAGE POISSON'S RATIO IS 0.175
7000
6000
5000
4000
3000
2000
1000
0
DEVIATOR STRESS IN PSI
RESULTS OF STATIC
LOAD TEST NO. RP-27-2
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 13



AVE TANGENT MODULUS IS 7.12E+06 PSI
AVE SECANT MODULUS IS 6.69E+06 PSI
AVE RECOVERY MODULUS IS 7.62E+06 PSI
AVERAGE POISSON'S RATIO IS 0.179
7000
6000
5000
4000
3000
2000
1000
0
DEVIATOR STRESS IN PSI
RESULTS OF STATIC
LOAD TEST NO. RP-27-3
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 14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AVE RECOVERY MODULUS IS 7.92E+06 PSI
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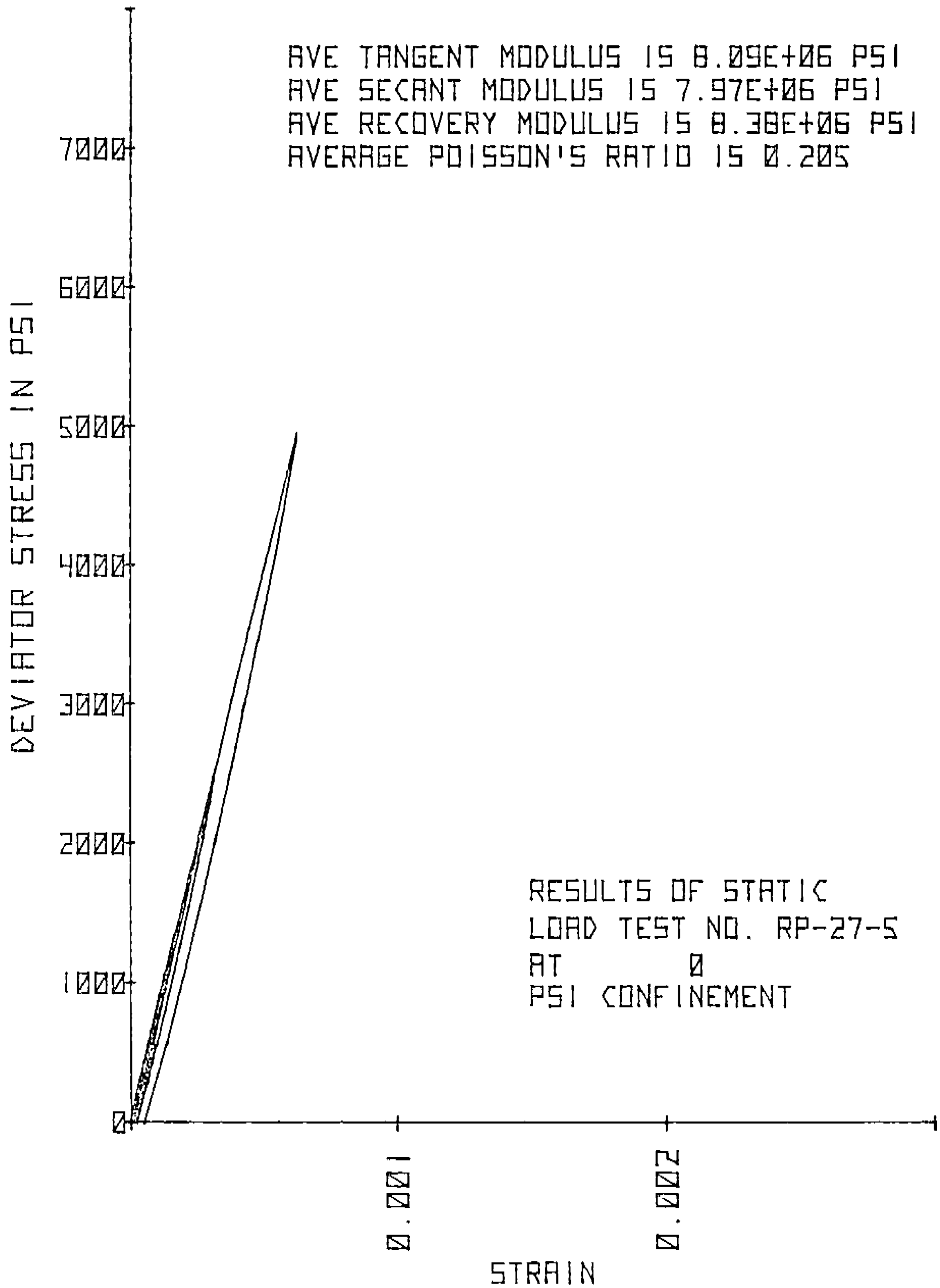
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
RESULTS OF STATIC
LOAD TEST NO. RP-27-4
AT 0
PSI CONFINEMENT
0.001
0.002
STRAIN

Fig. 15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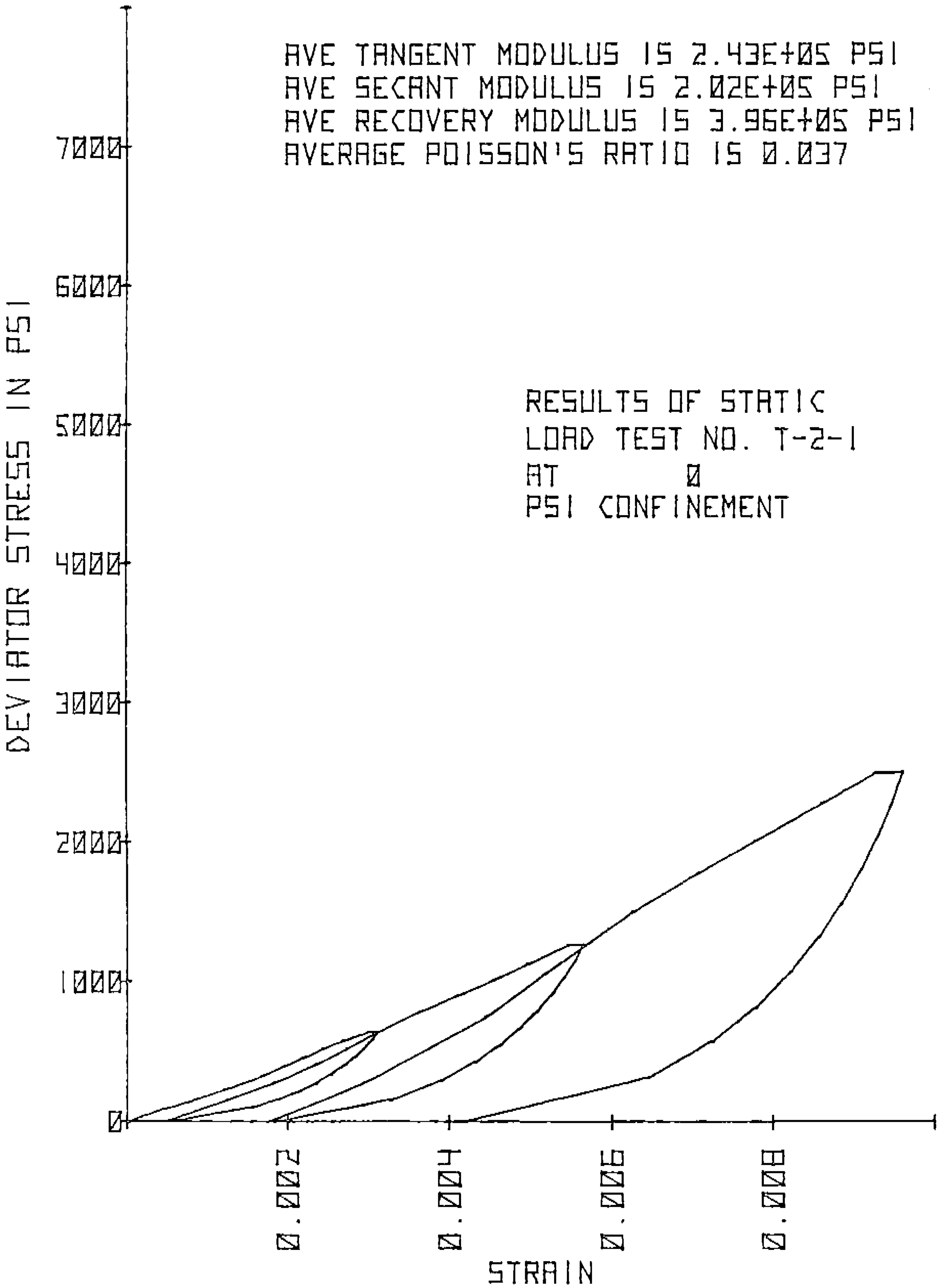
AVE SECANT MODULUS IS 7.97E+06 PSI
AVE RECOVERY MODULUS IS 8.38E+06 PSI
AVERAGE POISSON'S RATIO IS 0.205
RESULTS OF STATIC
LOAD TEST NO. RP-27-5
AT 0
PSI CONFINEMENT
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
0.001
0.002
STRAIN

Fig. 16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AVE SECANT MODULUS IS 2.02E+05 PSI
AVE RECOVERY MODULUS IS 3.96E+05 PSI
AVERAGE POISSON'S RATIO IS 0.037
RESULTS OF STATIC
LOAD TEST NO. T-2-1
AT 0
PSI CONFINEMENT
DEVIATOR STRESS IN PSI
7000
6000
5000
4000
3000
2000
1000
0
0.002
0.004
0.006
0.008
STRAIN

Fig. 17

each cycle and a large amount of permanent deformation at the bottom. This material shows a combination of elastic, plastic, and viscoelastic behavior, and the deformation values are in the low range of rock values. The behavior of this rock reflects the weathering it has undergone and may indicate the presence of a significant amount of clay minerals.

TASK G WHITE PAPER

BENEFIT-COST ANALYSIS OF ROADSIDE FEATURES

CONTRACT NUMBER: DTFH61-84-C-00008

SUBMITTED TO:

FEDERAL HIGHWAY ADMINISTRATION
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20590

PREPARED BY:

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FEBRUARY 28, 1985

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Contract Number: DTFH61-84-C-00008

Submitted to:

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February 28, 1985

TABLE OF CONTENTS

LIST OF FIGURES

1. SUMMARY OF FINDINGS

Although only limited useful information has been developed from the literature review, it has been possible to produce three equations that predict the probability of impacting roadside signs, trees, mailboxes, luminaire supports, culverts, underpasses, overpasses, piers, abutments, bridge railings and guardrails. These equations apply to both single fixed objects such as luminaires, trees, or sign posts and to linear types of fixed objects such as guardrails, underpasses and lines of closely spaced trees.

Taking such impact probabilities and information on accident severity, the costs of accidents may be developed. By correlating accident costs with information on the costs of roadside improvements such as guardrails, tree removal, and break-away signs, it is possible to produce benefit-cost analyses of proposed roadside improvements.

Although such benefit-cost analyses are beyond the scope of this report, simple examples are provided so that their use may be made clear. For example, these analyses could answer questions such as the following:

1) Should a line of trees be left in place, removed or protected by guardrail when the ADT is 3,000 vehicles per day? When the ADT is 500 vehicles per day?

2) For ADT = 6,000, should a sign be made break-away if it costs an additional $100 per sign to do so? An additional $1,000 per sign?

Use of the procedures developed in this report may aid those responsible for safety related benefit-cost analyses as part of resurfacing, reconstruction or rehabilitation (RRR) projects on the nation's highways.

The procedures developed have been programmed for an IBM PC computer to analyze tree removal or protection and use of break-away signs. The documentation for these programs are being delivered to FHWA.

2. INTRODUCTION

There is little question that Interstate freeways should and do have their roadsides protected to the maximum extent possible. Signs and luminaires are made break-away or protected by guardrails. Piers, abutments, underpasses and overpasses are protected by guardrails and other types of barriers or by impact attenuators. Close-in trees are removed wherever possible and culverts are covered with grates. Median barriers are employed where traffic volumes are high and medians are narrow.

When conventional highways and particularly two-lane rural roads are programmed for resurfacing, rehabilitation or reconstruction (RRR), there is often a question as to whether concurrent upgrading of safety devices is cost-effective. These decisions depend upon many variables of which traffic volume is one of the most important. Because the number of accidents per mile of highway is highly dependent upon the average daily traffic (ADT), it may be cost effective to remove nearby trees when the ADT is 6,000 vehicles per day but not when the ADT is only 500 vehicles per day.

The objective of this report is to review available literature and develop a procedure that may be used to estimate accident impact probabilities with various types and configurations of roadside hardware on highways with various ADTs, roadside development, curvature and other variables. Methods for estimating accident severity and cost are also included, and it is shown how these may be employed in the benefit-cost analysis of the safety of roadside features.

The roadside features include: mailboxes, sign supports, trees, luminaire supports, culverts, barriers, bridge railings, overpasses, underpasses, piers and abutments. Utility poles are being extensively covered

In a separate effort by Zegeer and Parker for the Federal Highway Administration and are, therefore, not included here. Sideslopes are being covered in a separate report for the Transportation Research Board (TRB).

The literature review was initially based on a computer print-out of TRB's information storage and retrieval system (TRIS) and involved about 500 references. Review of the print-out and further review of the reports themselves reduced the list to 102 references which are listed in a related effort for the Transportation Research Board. Some 12 of the most pertinent references are shown at the end of this report. In general, crash test results, although very important in determining the exact configuration of roadside hardware, were not included because the purpose of the present analysis is directed toward benefit-cost analysis which requires accident and injury data. Although reports relevant to RRR analysis were of primary interest, some studies encompassing freeways were included where the information was pertinent and/or no other information was available.

One final point needs to be made. The objective of this analysis is not to summarize everything that is known about the safety of roadside features. Rather, it is to review the literature and use the pertinent available information plus judicious analytic techniques to produce estimates of impact probabilities and severity relative to roadside features suitable for use in RRR benefit-cost analyses. This has been done. Those who wish an extensive summary of safety and roadside features are urged to consult an excellent publication by the Federal Highway Administration, (Reference 1) Chapter 3.

3. CRITICAL REVIEW AND ANALYSIS OF THE LITERATURE

At the outset of this analysis, it was believed that it would be possible to obtain at least some information on the probability of impacting various types of roadside objects directly from the literature. This was not the case. The available accident studies provide information on accident severity but very little on impact probability.

Fortunately, available information on total accidents and on single-vehicle accidents combined with logical analysis can produce reasonable estimates of the probability of impacting various types of roadside objects. Methods for estimating severity are also included.

It would be desirable at some future time to approach this problem in a more direct manner by employing a detailed inventory and measurement of roadside objects on thousands of miles of roadside coupled with accident data. The presence of roadside objects could then be associated with the probability of impacting these objects. The results of such a study could be compared to the results of the present analysis as a form of validation. In the meantime, the analysis developed here may be used for benefit-cost analysis applied to RRR projects.

The next section will provide a method for estimating impact probability for break-away and nonbreak-away highway signs. The following section will extend the method to other types of roadside obstacles. Both sections will show how the method may be used to predict accident severity and accident costs over 10 years. Finally, examples of applying the method to a benefit-cost analysis will be provided.

3.1 Signs

On freeways and other major highways, supports for highway signs need to be protected by guardrails or made break-away. On two-lane rural highways, particularly on lower volume roads, there is a question as to whether break-away treatment is cost-effective.

It has been clearly shown that the break-away concept comes close to eliminating severe injuries and fatalities in collisions with signs. For example, in Texas during the mid 1960's, a study (Reference 2) of 82 accidents involving break-away sign supports showed the following:

43 accidents:	vehicle did not remain at scene
38 accidents:	8 cases of minor injury
1 accident:	1 severe injury when vehicle passed through sign support and struck culvert headwall

Most existing sign support structures were designed for heavier vehicles, weighing 4500 pounds. The weight of 1984 model small cars averages about 2100 pounds. In 1979, only 31 percent of car registrations in California were under 2500 pounds; the comparable figure nationwide in 1985 will probably be about 67 percent (Reference 3).

Because of this continuing trend towards smaller and lighter weight vehicles, newly installed break-away sign support structures need to be designed to accommodate vehicles weighing 2000 pounds or less. Existing sign structures need to be modified to accommodate these smaller cars (References 3, 4). Several studies have provided data and suggestions for modification of these sign structures (References 4, 5, 6). The results shown above in the Texas study may not be as favorable for the current vehicle mix unless the break-away features have been modified to accommodate smaller vehicles. The present analysis assumes that this will be accomplished, at least for new installations.

While it is clear that properly designed break-away sign supports nearly eliminate severe injuries and deaths, it has not been possible to find any information that shows the probability of impacting a sign structure. The latter information is essential in order to perform a benefit-cost analysis of break-away signs on conventional rural highways. The next section provides an indirect procedure for computing such impact probabilities and shows how they may be employed in benefit-cost analyses.

3.1.1 Probability of Sign Impact

It has been shown that break-away signs, when properly designed, nearly eliminate fatalities and severe injuries and substantially reduce less severe injuries. It has also been shown that nonbreak-away signs account for about 3 percent of all impacts and 1 percent of fatal impacts involving roadside objects. These data, however, are not sufficient for a benefit-cost analysis of roadside signs. Required is a determination of the probability that a sign will be impacted. A combination of geometric analysis and available data will be employed to develop that probability.

Figure 1 illustrates the hazard length along the highway for any sign, given its width between posts, the car width and the departure angle of the car. Thus, for example, a sign with outside posts 20 feet apart, which may be impacted by a car 6 feet wide at a departure angle of 15 degrees, results in a hazard length, as computed from Equation 1, of 97.8 feet. The average departure angle is taken as 15 degrees (Reference 7); the car width of 6 feet is typical of medium size cars; small cars now average about 5.3 feet.

The width "W" in Equation 1 assumes that posts for each sign are spaced less than 6 feet apart and that some signs may have 3 or more posts. If the posts are more than 6 feet apart, all spaces greater than 6 feet must be omitted in computing "W" (the post spacing), i.e., if the sign has four posts, and they are 8 feet apart, its effective width (W) is 18 feet. This

Let:

W = Width between sign posts in feet.

θ = Departure angle of car in degrees.

C = Car width in feet.

H = Hazard length along highway in feet.

Then:

$$H = \frac{W}{\tan\theta} + \frac{2C}{\sin\theta} \qquad \text{(Equation 1)}$$

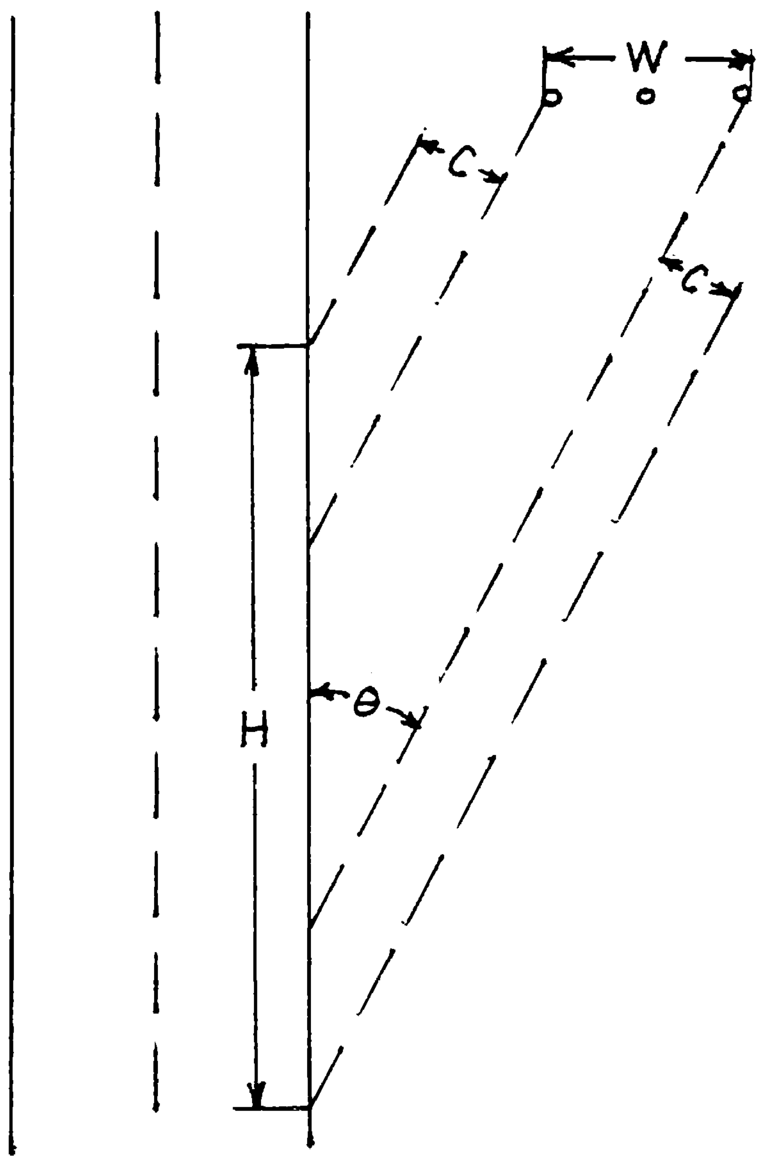

Figure 1 - Computation of Hazard Length

procedure, which is approximately correct for small angles of θ (less than 20 degrees), is necessary because some cars may pass between widely spaced posts without impact. Because highway signs are usually at least 8 feet above ground, cars may easily pass under them.

The near edge of the sign is assumed to be placed 10 feet outside the shoulder or 20 feet from the edge of pavement. These are typical placement locations for roadside signs.

Figure 2 shows the equation developed to determine the probability of a sign being impacted over its presumed service life of 10 years. A certain proportion of vehicles leaving the roadway will avoid hitting the sign but will roll over or strike other objects. These accidents should not be included because it is desired to predict only sign-related accidents. For signs which are typically 20 feet away from the shoulder, about 25 percent will "get-away" as suggested by Perchonak, 1978 (Reference 8). Strictly speaking, the latter study applies to vehicles which leave the roadway and are not involved in any collision. Here, they are assumed to be involved in non-sign accidents. In addition, an additional 25 percent of multi-vehicle accidents result in vehicles leaving the roadway (Huelke and Gilkes, 1967, Reference 9). Equation 2 is developed recognizing that each mile of two-lane highway has 10,560 feet of roadside (right and left).

The foregoing analysis treats signs as independent roadside objects at least 800 feet apart. It is not good practice to place such signs closer. Greater spacing is desirable because drivers cannot readily understand the sign messages with closely spaced signs. Therefore, the "continuous barrier effect" of closely spaced utility poles, as suggested by Zegeer, does not apply here.

Inserting the foregoing information into Equations 1 and 2, it is now possible to determine the probability of a sign being hit during its service

Let:

H = Hazard length in feet (From Figure 1)

S = Single vehicle accident rate (Number of accidents per 100 million vehicle - miles of travel)

G = Proportion of vehicles that "get-away" i.e., leave the roadway near a sign but avoid hitting it.

A = Average daily traffic (thousands of vehicles)

M = Added factor for multivehicle run-off-road accidents (1.25)

p = Probability of sign being impacted over 10 years.

Then:

$$p = HSAM\ (1-G)\ (3.46 \times 10^{-6}) \quad \text{(Equation 2)}$$

Note: To derive equation 2, for ADT = 1,000:

a: $365 \times 10 \times 1{,}000 \times S \div 10^8$ = single vehicle accidents per mile of highway in 10 years.

b: $H \div 10{,}560$ = proportion of 1 mile of roadside (both sides) occupied by the "hazard".

Multiplying a x b above = probability of sign being hit, i.e.:

$$365 \times 10 \times 1000 \times \frac{S}{10^8} \times \frac{H}{10{,}560} = 0.00000346SH$$

which translates to Equation 2 when factors M and A are included and simplifying exponential notation is employed.

Figure 2 - Computation of Sign Impact Probability

life. For probabilities greater than 1, the sign will likely be hit more than once in 10 years. Readers who doubt such high probabilities should consult their local state highway department's traffic or maintenance engineers who usually have "horror stories" of specific sign locations that have been impacted several times in a single year.

For benefit-cost analyses, the sign impact probabilities may be computed for the following suggested values: sign widths of 1 foot (single post), 6, 12, 18, 30 and 42 feet: ADT values of 100, 1000 and 10,000 vehicles per day for 2-lane highways: single vehicle accident rates of 50, 100, 200 and 400 accidents per 100 million vehicle-miles of travel. Other variables, such as curvature and roadside development, result in combinations of variables numbering in the thousands. Therefore, a better procedure is to develop a program for a microcomputer or programmable calculator that may be employed for each specific signing situation.

3.1.2 Single Vehicle Accident Rates

Desirably, the single vehicle accident rate to be employed for any analysis should be the rate for the highway under consideration. As an alternative, the following single vehicle accident rates may be used for two-lane rural highways (Reference 51) single vehicle rates are 32 percent of the total rates.

Number of businesses per mile:	0	10	20	30	40	50
Total accident rate:	210	280	350	420	490	560
Single vehicle accident rate:	70	90	120	140	160	190

For sharp curves, the accident rates are greater yet, as shown by Raff (Reference 10) for two-lane roads, and a curve factor has been computed based on the tangent accident rate which has a curve factor of unity:

Curvature	Accident Rate	Curve Factor
Tangent	230	1.0
0-2.9 degrees	160	0.7
3-5.9 degrees	250	1.1
6-9.9 degrees	280	1.2
10 degrees or more	350	1.5

These curve factors may be multiplied by the single vehicle accident rates to account for the higher rates for sharp curves. In addition, Perchonak (Reference 8) has shown that the outsides or outside of a curve has 2.67 times as many run-off-road accidents as the insides of curves. To account for this difference, centrifugal force (C.F.) factors have been computed and are as follows:

Outsides of Curves: 1.4

Insides of Curves: 0.5

The C.F. factor is also multiplied by the single vehicle accident rate and by the curve factor.

3.1.3 Benefit-Cost Example: Break-Away Signs

An example of application of the foregoing procedure to benefit-cost analysis follows. Given a two-lane highway with considerable roadside development i.e., 40 businesses per mile and ADT of 6,000 vehicles, should a proposed large destination sign with four posts 18 feet apart be made break-away when installed on the outside of a 7 degree curve?

From Eq. 1 $$H = \frac{18}{\text{Tan } 15^0} + \frac{12}{\text{Sin } 15^0} = 113 \text{ feet}$$

From Eq. 2 $$P = (113)(269)(6)(1.25)(0.75)(3.46\times10^{-6}) = 0.59$$

NOTE: In Eq. 2, S = (160)(1.2)(1.4) = 269

Therefore, a sign on the outside of such a curve has a 59 percent chance of being hit once in 10 years. If such a sign can be made break-away for an additional \$100 in initial costs and \$100 in repair costs and if net accident costs are \$6,000, the benefit-cost ratio is 18, i.e., $\frac{(6,000 \times .59)}{200}$, for a 10 year service life and no interest. With interest at 10% annually, the benefit-cost ratio on a present worth basis is about 12, i.e., $\frac{(3725 \times .59)}{162}$,

where:

Initial Cost:	\$100 now, present worth: \$100
Repair Cost:	\$100 in 5 years, present worth: \$62
Accident Savings:	\$6,000 in 5 years, present worth: \$3,725

Note that the accident, if it occurs, is assumed to take place in 5 years (half the service life). "Net accident costs" are the difference between cost estimates of a nonbreak-away accident of \$6,500 and a break-away accident of \$500. Recommended accident costs (Miller, et al, Reference 11) in 1980 dollars range from \$2,291 for a low severity (MAIS category 1 injury accident) to \$10,306 for moderate severity (category 3) to \$261,581 for severe (category 5).

Clearly, such a sign installation should be made break-away. Indeed, even if the break-away costs are 10 times as great (i.e., \$1000 initial costs and \$1000 sign repair costs), the break-away features yields a benefit-cost ratio with interest which is greater than unity.

The foregoing procedures, with minor modifications, may be applied to four and six-lane divided and undivided rural and surburban highways that do not have full control of access.

3.2 Other Roadside Obstacles

Desirably, roadsides should be clear of obstructions and have flat slopes of 4:1 and preferably 6:1. For roadside safety activities in connection with resurfacing, rehabilitation and reconstruction (RRR) work on existing highways, primarily two-lane rural roads, the choices are often limited to: removal of trees; relocation of utility poles, signs and mailboxes; and protection of fixed objects by guardrail. The key question is whether any of these options is cost-effective.

Required first is the probability of impacting any roadside object. Several studies have obtained information on the number and severity of accidents involving roadside objects but (apart from utility pole accidents, which are beyond the scope of this analysis) have not obtained comparable inventory data on the number of such objects along the roadside or the space they occupy. Therefore, indirect means are required to obtain such probabilities.

As shown under the preceding section, single vehicle accident rates may be estimated for two-lane rural highways with various levels of roadside business, curvature and inside/outside of curve. As an alternative, locally obtained rates may be used for the highway under consideration. The next step is to apportion the roadside object as part of the highway roadside.

3.2.1 Hazard Length

For isolated objects such as trees, luminaires and mailboxes, the method shown in Figure 1 may be used directly to compute hazard length, taking "W", the object width, as one or two feet. For linear obstacles parallel to the roadside, such as guardrail, lines of closely spaced trees, bridge rail, underpasses, abutments and ditches, the hazard length is computed as follows:

$$H = L + \frac{2C}{\sin \theta} \qquad \text{(Equation 3)}$$

where H = Hazard length along highway in feet
L = Length of linear obstacle parallel to highway in feet
C = Car width in feet (usually 6 feet)
θ = Departure angle of car in degrees (usually 15 feet)

3.2.2 Impact Probability

Given the hazard length, H, the section on single vehicle accident rates, Figure 2 and Equation 2 may be used to compute the probability of the object being impacted. Roadside objects tend to be placed at varying distances from the edge of the pavement and, therefore, in Equation 2, the "G" factor or proportion of vehicles that "get away", i.e., leave the pavement but do not hit the object will vary as shown below (Perchonak, Reference 8):

Distance of Object From Edge of Pavement Feet	"G" Factor
1	.17
5	.20
10	.21
15	.23
20	.25
30	.30
50	.33

3.2.3 Accident Severity

Once the impact probability is determined (Equation 2) to complete the benefit-cost analysis, it is necessary to determine the relative severity of each type of collision with a roadside object. Cirillo (Reference 12) has shown that guardrails protecting overpasses, underpasses, piers, abutments and sign posts experience about half the severity in terms of cost per accident compared to that experienced by these same objects not protected by guardrails. It is reasonable to expect that the relative severity of other fixed objects such as trees and luminaire supports will also have the same severity ratio. Therefore, if the costs of accidents for the highway under consideration are known, those impacting guardrails may be multiplied by 0.67; those impacting fixed objects not protected by guardrails may be multiplied by 1.33.

If costs for the highway under consideration are not known, Miller, T. R., et al, 1984, (Reference 11) show direct cost data by McFarland and Rollins, 1982, for rural single vehicle accidents involving fixed objects of $850 for each property damage only (PDO) accident and $4,000 for each injury accident (1980 dollars). Indirect costs bring the total for each PDO to about $1,000. The indirect costs are about one-third of the direct costs for the less severe and moderate accidents and equal to or greater than the direct costs for the more severe accident groups. A rough average may be taken as 50% of direct costs for indirect costs bringing the total for each injury accident to $6,000. If the injury and PDO accidents are equal in number, a typical situation, the overall average is $3,500 per accident in 1980 dollars and $4,200 when the inflation rate has increased 20% (1985 dollars).

3.2.4 <u>Benefit-Cost Example: Trees</u>

An example of application of the above procedure follows. Given a two-lane highway with little roadside development (i.e., 1 business per mile, a level roadside, and ADT of 3,000 vehicles) should a line of closely spaced trees, 300 feet long on a tangent and 20 feet from the edge of pavement be left in place, removed or protected by a guardrail? Assume that tree removal costs are $500 and guardrail costs $20 per linear foot, life of guardrail is 20 years, and ignore interest.

From Eq. 3 $H = 300 + \frac{12}{\sin 15} = 346$ feet

From Eq. 2 $P = (346)(1.0)(72)(3)(1.25)(.75)(3.46 \times 10^{-6}) = 0.24$

Therefore, there is a 24 percent chance that the line of trees will be hit once in 10 years or 48 percent in 20 years. The average accident costs over 20 years will be (0.48)(4,200) = 2016 and 1.33 x 2016 = $2,681 if not protected by a guardrail and .67 x 2016 = $1,351 if protected by a guardrail. Assume 50 feet of guardrail will require repair for each accident at a cost of $500; i.e., 0.48 x 500 = $240. The costs will then be as follows over 20 years.

	Accident Costs	Tree Removal	Guardrail	Total
Trees left in Place	$2,681	0	0	$2,681
Trees Removed	0	$500	0	$500
Trees Protected by Guardrail	$1,351	0	$6,240	$7,591

Clearly, the best alternative is to remove the trees. If local sentiment precludes such an option, protection of car occupants by a guardrail is not cost-effective. The trees should be left in place. If the ADT is only 18,000 vehicles per day, however, it is cost-effective to protect the trees by guardrail, compared to leaving them in place without a guardrail. If the ADT is less than 500 vehicles per day, it is not even cost-effective to remove the trees even if local sentiment approves. They should simply be left in place.

If the trees are not closely spaced, the above procedure may be used by assigning a tributary length to each tree and adding these values: The tributary length is the diameter of the tree plus $\frac{12}{\sin \theta}$.

The procedure developed in this report for estimating accident probability of roadside features has been based on available accident research findings combined with judicious analysis. It should be of assistance to those officials undertaking benefit-cost analyses of safety improvements of roadside features in connection with RRR projects. The benefit-cost procedure has been programmed for a IBM PC computer.

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February 1994

Conceptual Plan for an Interactive Highway Safety Design Model

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

FOREWORD

This report, FHWA-RD-93-122, contains a conceptional plan for an interactive highway safety design model (IHSDM). The IHSDM is envisioned as a geometric design tool to assist engineers in evaluating the safety of alternative highway designs. The IHSDM will enhance the consideration of safety, as well as other social, economic, and environmental factors, when developing highway projects. The conceptional plan was developed with input from numerous individuals with backgrounds in highway engineering, research, statistics, human factors, and traffic operations. It should be noted the IHSDM is still evolving in the sense that specific details of the model are still being developed.

Sufficient copies of this report are being distributed to provide a minimum of one copy to each Region and Division office and State highway agency. Direct distribution is being made to the Division offices. Additional copies for the public are available from the National Technical Information Service (NTIS), Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. A small charge will be imposed by NTIS.

Lyle Saxton
Director, Office of Safety and
Traffic Operations Research and
Development

NOTICE

Technical Report Documentation Page

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16. Abstract

This report presents a conceptual plan for an interactive highway safety design (IHSD) model under consideration for development by FHWA. This report combines elements of three separate plans for the IHSD model that were developed independently by different contractors. The report also includes elements of a plan for roadside safety models developed recently for FHWA.

The IHSD model is intended as a tool that could be used by a designer or design reviewer to assess the safety effects of specific highway geometric design decisions. The model would be interactive in that it would allow the designer to make changes in the geometric design and evaluate the safety effects of those changes as part of a single software package. A key element of the IHSD model would be an accident predictive model incorporating statistical relationships between geometric design elements and safety. Separate submodels would be provided for roadway sections, intersections, interchange ramps and speed-change lanes, and roadside areas. The IHSD model would also include modules for design policy review, design consistency review, benefit-cost analyses, driver vehicle/dynamics simulation, and graphical displays of roadway geometrics. The report includes a research plan for the development of the IHSD model.

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Computer-Aided Design	Roadside Safety	
Intersections	Design Consistency	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

CONTENTS

CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Background

There has never been a formalized process for incorporating highway safety considerations into the highway geometric design process. Traffic operational effects of geometric design decisions can be evaluated with the *Highway Capacity Manual*[1] and related software, analytical models and computer programs are available to assess the effects of projects on air pollution and noise, but there is no comparable approach to highway safety considerations.[1] Instead, highway safety considerations are incorporated through application of geometric design policies, through engineering judgments by designers and design reviewers, and through highway agency experience with similar projects. There are fundamental problems with this approach because the judgments of experts may not agree and because particular project sites may have specific characteristics that make experience at other sites inapplicable. Tradeoffs between safety and other design considerations such as traffic operations, air pollution, noise, or historic preservation are difficult to make when the safety impacts are not well quantified.

The implementation and development of an Interactive Highway Safety Design (IHSD) model will move the highway design process toward the ultimate goal of "quality" design. Conceptually, quality is achieved at the junction of accepted, safe, and efficient designs (see figure 1). "Accepted" designs meet established criteria/standards specifications, such as the policies of the American Association of State Highway and Transportation Officials (AASHTO).[2] "Safe" designs ensure that tolerable thresholds of the driver, vehicle, or roadway performance are not exceeded. "Efficient" designs provide operational levels of service commensurate with a roadway's functional classification and access control. Quality is increased and ultimately achieved when compatibility among these three attributes is attained for each individual design consideration.

Figure 1 calls attention to the point that the safety aspects of a highway design cannot be considered alone. Consideration of safety must be coordinated with consideration of other key design issues including traffic operations, environmental effects, right-of-way needs, and construction costs. The development of an IHSD model provides an opportunity to change the way that safety is considered in the highway design process. If safety considerations can be made as explicit as traffic operational or environmental analyses, then better, safer, and more cost-effective designs will result.

There is a substantial body of research on the relationships between geometric design and accident experience. The results of this research have been abstracted and summarized, but have never been synthesized, codified, or put into a consistent form to allow engineers to easily apply these results in the design process. Research studies have addressed different highway types and different parts of the highway system, but the results are not available in consistent form for comparative purposes.

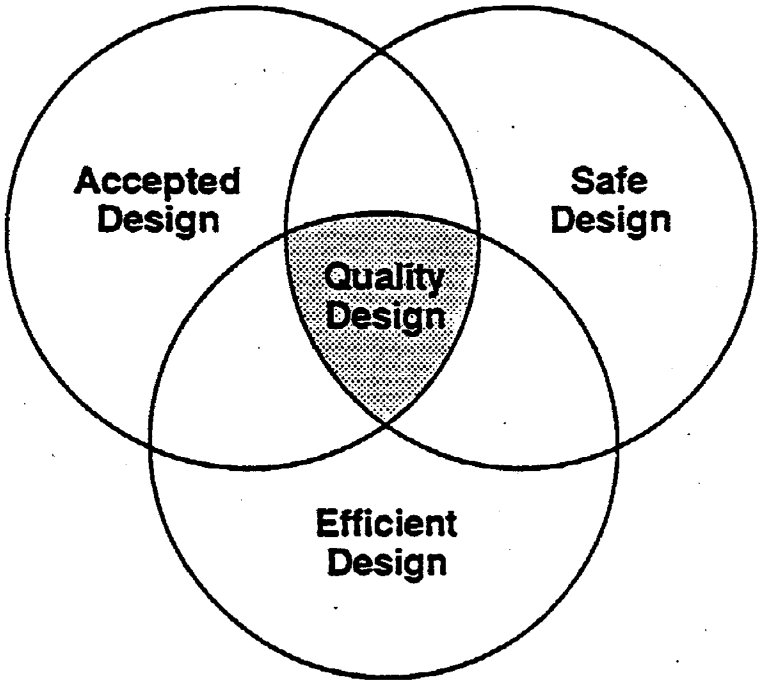


Figure 1. Compatibility of design considerations.

Even various research projects that have addressed the same issue have used different safety measures of effectiveness to quantify the safety implications of that issue.

Because of these concerns, the Federal Highway Administration (FHWA) has recognized a need to develop a model for evaluating the expected accident experience associated with different geometric design configurations and to incorporate that model in an interactive computer program. This program will allow designers to optimize their design from a safety viewpoint and will provide the necessary inputs on safety for cost-effectiveness analyses of the tradeoffs between safety and the other design considerations described above. The program will also provide the capability for highway designers to ensure that their design is in compliance with established design policies and design consistency guidelines. The development of this model and an interactive computer program to apply it will require research over a multiyear period.

This report provides a conceptual plan for development of the IHSD model. The plan provides a "road map" for model development that addresses the recommended organization and structure of the model, the appropriate role for the model in the design process, and the future research needed to develop the model. This plan consolidates the recommendations made in separate plans originally developed for FHWA in three independent efforts.[3,4,5] The plan also incorporates recommendations for roadside safety research from another report recently prepared for FHWA.[6] This consolidated plan has been reviewed and improved in response to comments from an expert panel including the authors of the four reports mentioned above and invited experts in the fields of geometric design, highway safety, human factors engineering, and statistics.[3,4,5,6]

IHSD Model Objectives

The objectives of developing and implementing the IHSD model are to:

- Improve the ability of designers to consider safety in the highway design process.
- Provide improved quantitative relationships between geometric design elements and accidents for use by designers.
- Automate the consideration of safety in the highway design process so that safety considerations can be incorporated more efficiently and more consistently than has been possible in the past.

The conceptual plan presented in this report is intended to show how these objectives can be achieved.

User Community

The primary user community for the IHSD model comprises highway designers in State highway agencies. However, other potential users include local highway agencies, consulting firms, and FHWA. The IHSD model could be employed by highway engineers, both in the development of designs for highway improvement projects and in the design review process. For example, the IHSD model could be used by internal design reviewers within a highway agency and by external reviewers, such as FHWA. This approach would enable both designers and design reviewers to be working from the same knowledge base concerning relationships between accidents and geometrics.

The Challenge in IHSD Model Development

The development of an IHSD model will be one of the most difficult challenges ever undertaken in traffic safety research. However, the potential payoff in terms of the number of highway projects for which safety can be improved is also very large.

Past research has taken a piecemeal approach to the development of relationships between accidents and geometrics. Improved accident data bases such as the FHWA Highway Safety Information System (HSIS) present some hope of developing better safety relationships at lower cost than has been possible in the past.

However, only an integrated approach like that recommended in this plan provides a chance of developing reliable safety relationships.

Key features of this plan that are essential to the success of the IHSD model development are:

- Use of consistent accident definitions in safety research.
- Strong and effective management of research by FHWA.
- Coordination by a central data quality assurance contractor.
- Formation of expert panels of geometric designers and researchers to guide the model development.
- Formal validation of safety research.
- Peer review of all safety research results by recognized experts.
- Development of user-friendly software that is designed for effective use in the operating environment of a highway agency.
- Complete testing of software by potential users.

The development of quantitative accident predictive relationships for the IHSD model is one of the largest accident research undertakings ever proposed. The required time, level of effort, and funding level to develop an IHSD model have not been determined in detail, but they are substantial and should not be underestimated.

Organization of This Conceptual Plan

The remainder of this conceptual plan for the IHSD model is organized as described below.

Section II presents an overview of the conceptual plan for the IHSD model as a whole. This overview addresses both the accident predictive model and other elements of the model such as the design policy review module, the design consistency review module, and the benefit-cost module.

Section III presents an overview of the conceptual plan for the accident predictive portion of the IHSD model that includes guidelines for model development, model structure (including a preliminary flow diagram), geometric and traffic control features to be incorporated in the model, safety measures of effectiveness, and issues to be resolved.

Section IV presents a discussion of the submodels of the accident predictive model that address roadway section accidents, intersection accidents, interchange ramp and speed-change lane accidents, and roadside accidents for specific geometric alternatives.

Section V presents a conceptual plan for other elements of the IHSD model including the design policy review module, the design consistency module, the benefit-cost module, the vehicle dynamics model, and the graphics package.

Section VI summarizes the research needs for development of the IHSD model, including a flow diagram for the recommended research program.

Section VII discusses computer requirements for the IHSD model.

Appendix A presents a table of relationships between accident rate and traffic volume developed by the California Department of Transportation (Caltrans) for use in their accident surveillance system. This appendix provides an example of how safety relationships can be organized for a variety of roadway, intersection, and ramp types.

Appendix B presents research problem statements that describe the research needed to develop the IHSD model.

II. OVERVIEW OF INTERACTIVE HIGHWAY SAFETY DESIGN MODEL

This report presents a conceptual plan for development of an IHSD model to improve the ability of engineers to consider safety in highway design decisions.

The IHSD model is intended as a tool to enable designers to evaluate the relative safety of various geometric for specific highway improvement projects. Thus, the IHSD model will be a site-specific, project-specific safety analysis tool. The potential users of the model are geometric designers assigned to evaluate geometric alternatives for a specific projects and internal or external design reviewers assigned to review and evaluate the proposed design.

The IHSD model can be used to evaluate one site or one project at a time and is not intended to perform the functions of an accident surveillance system or a statewide safety management system. The model is not intended to identify high-accident locations from systemwide data or to evaluate the increased effectiveness of accident countermeasures that might be expected at such locations. Instead, the model is intended to include an evaluation tool that can predict safety under typical or average conditions on the highway system.

The frequency and severity of traffic accidents are known to vary widely over the highway system, even between locations that are nominally very similar; accident frequency and severity can also vary widely over time at a given location. These variations are often difficult to explain and are certainly difficult to predict. No model can be expected to predict the number or severity of accidents that will occur at any particular location in any particular year. However, research results indicate that some geometric features (sharper curves, narrower lanes and shoulders, congested intersections) are associated with higher accident rates, and it is reasonable to expect that predictions of the expected long-term accident experience associated with particular alternative geometric features will be of assistance to designers in choosing among those alternatives. The intent of the model is to assist designers in deciding, under typical or average conditions, which of several geometric alternatives can be expected to have the best safety performance.

The IHSD model will also have the capability to assist designers by directing their attention to particular portions of the design that have the highest accident rates or severities, have inconsistencies between particular geometric features that could violate driver expectancy, or are not in compliance with accepted design policies. This should assist designers in improving the safety performance of particular geometric alternatives.

The scope of the IHSD model as recommended in this report is limited to safety analyses and does not include other types of analyses, such as operational or environmental analyses, that might be conducted as part of the design process. However, it is recommended that the IHSD model be developed so that operational or environmental analysis software could be incorporated at a later date and called from within the IHSD model if this capability is desired by users.

The IHSD model will consist of six separate modules or programs. These are:

- An accident predictive model to estimate the expected number and severity of accidents for different geometric design alternatives for specific highway projects including both new construction and improvements to existing highways.
- A design policy review module to identify and flag aspects of the design that do not comply with established AASHTO or State and local design policies.
- A design consistency review module to identify and flag aspects of the design that violate design consistency and driver expectancy rules.
- A benefit-cost module to evaluate the cost-effectiveness of proposed geometric design modifications intended to improve safety.
- A driver/vehicle dynamics model capable of simulating vehicle operation as influenced by roadway geometry, driver preferences and performance limitations, and vehicle performance limitations.
- A graphics package to display the geometric design features of any alternative under consideration in plan view, in profile view, or as a view of the roadway from the driver's perspective.

An overview of each of these six modules is presented below.

Accident Predictive Model

The accident predictive model will be an interactive program that can be used by highway design engineers to estimate the safety performance of specific geometric design alternatives for highway improvement projects. The program will enable the user to determine the expected accident experience for any specific geometric configuration, interactively make changes in the geometric design, and then reevaluate the effects of those changes on accident experience. This will enable highway designers to optimize their designs from a safety standpoint.

Most of this conceptual plan focuses on the development of the accident predictive model, since this will present the most challenging research and development problems. Section III of this report summarizes the organization and structure of the accident predictive model. Section IV presents a plan for specific submodels of the accident predictive model to address roadway sections, intersections, ramps and speed-change lanes, and roadside areas. Section VI addresses many of the research issues in development of an accident predictive model. In particular, this section stresses the importance of validation of the accident predictive model.

Design Policy Review Module

Discussions with State highway agency design engineers during the development of this conceptual plan concluded that it was unreasonable to expect that the accident predictive portion of the IHSD model would be capable of addressing all geometric design elements of interest. For this reason, it is recommended that the IHSD model include two other programs: a design policy review module and a design consistency review module.

The design policy review module would be intended to identify and flag elements of the design that do not comply with established AASHTO or State and local design policies. This module would assist designers in evaluating design elements that are not directly addressed by the accident predictive model. For example, if the accident predictive model did not include a safety effect for the amount of superelevation on a horizontal curve or the curb return radius at an intersection, overall safety of the design could still be assured by comparing these geometric elements to established design policies. However, design policies alone cannot be used to optimize safety cost-effectiveness as quantitative accident predictions can.

The identification of a design element as not in compliance with established design policies does not necessarily mean that the design should be changed. Exceptions to policies are often granted when it appears that full compliance with established design policies would not be cost-effective. However, a design policy review module as part of the IHSD model would provide a means for assuring that such decisions are made explicitly and are well documented. The design policy review module is addressed in more detail in section V of this report.

Design Consistency Review Module

The design consistency review module is intended to identify and flag elements of the design that violate design consistency and driver expectancy. Such inconsistencies often arise from changes in cross-section between adjacent roadway sections or from poor transitions between tangent and horizontal curves.

Development of a design consistency review module will require design consistency to be transformed from a generalized concept to a specific concept to which quantitative definitions and procedures can be applied. A current FHWA research contract is examining this issue and further research may be required.

The design consistency review module will include a simplified procedure for evaluating the lateral accelerations generated by passenger cars and trucks when traversing the design. These procedures will identify and flag any geometric elements that generate lateral accelerations that are large enough to involve risk of vehicle skidding or rollover. Designers can then evaluate the need for changes in the design to reduce lateral acceleration (e.g., increased radius of curvature). Such problems can, if necessary, be studied in more detail with the driver/vehicle dynamics model discussed below.

Benefit-Cost Module

A benefit-cost module will be provided to determine the cost-effectiveness of additional expenditures whose specific purpose is to improve the safety of a highway improvement project. Thus, the benefit-cost program could be used to determine if an incremental increase in construction cost could be justified on the basis of accident reduction alone. No attempt would be made to incorporate other types of benefits, such as traffic operational benefits or environmental benefits, in the program. Consideration of nonsafety benefits would make the benefit-cost program much more complex. Furthermore, other computer programs already exist to evaluate traffic operational and environmental effects, at least for some types of projects.

Driver/Vehicle Dynamics Model

The driver/vehicle dynamics model is intended as a tool for designers to evaluate and compare the adequacy of alternative geometric designs to accommodate a range of vehicle types including passenger cars, single-unit trucks, and combination trucks. The model should be capable of simulating vehicle operation as influenced by roadway geometry, driver preferences and limitations, and vehicle performance limitations. Driver behavior, including path following and speed selection, is an important element in evaluation of vehicle dynamics for specific geometric alternatives. However, existing vehicle dynamics models do not consider driver behavior other than rudimentary path following. Therefore, development of a driver/vehicle dynamics model, incorporating a realistic driver model, is recommended.

Graphics Package

The IHSD model should include a graphics package capable of displaying the geometric design features of any alternative under consideration in plan view, in profile view, or as a view of the roadway from the driver's perspective.

III. OVERVIEW OF IHSD ACCIDENT PREDICTIVE MODEL

This section of the report presents guidelines for development of the accident predictive portion of the IHSD model, including the structure of the model (illustrated by a flow diagram), the portions of the highway system to be addressed, the geometric features to be addressed for each portion of the highway system, and the safety measures of effectiveness that will be used.

Guidelines for Accident Predictive Model Development

The following guidelines have been developed for the accident predictive model:

- The primary function of the IHSD model is as a tool that can be used by a designer to estimate the safety performance of various geometric alternatives (line, grade, and cross-section) for a highway project.

- The IHSD model should be an interactive computer software package; i.e., within the same software package, the designer should be able to make changes in the geometrics and evaluate the safety effects of those changes.

- The IHSD model should be built in modular fashion to implement a safety assessment analysis process for comparing design alternatives. A modular structure will allow updated or revised accident predictive relationships to be incorporated in the IHSD model as they are developed.

- The IHSD model should be based on valid research findings concerning the relationships between geometric features and safety. Where valid relationships do not currently exist, they should be developed in future research in a form suitable for incorporation in the model. The plan presented in this report takes the optimistic view that, with improved safety data bases and analysis techniques, it will be possible to develop valid statistical relationships that quantify the incremental effects of geometric features on safety. However, it should be recognized that major improvements in the quality and completeness of accident data may be required to make improved statistical relationships feasible.

- Safety relationships in the IHSD model must not only address the safety effects of geometric features but, for completeness, must also incorporate the effects of traffic volumes and traffic control.

- The safety relationships in the IHSD model will be most effective if accident rates, severity distributions, and accident type distributions are related to the geometric features and traffic control elements having a causative effect on those accidents, rather than the features at the immediate site where the accident occurs. For example, a rear-end collision at the end of a queue on the approach to the signalized intersection should be attributed to the intersection and not to the roadway section on which the approach is located.

- The predictive model should make a careful distinction between on-roadway and roadside accidents. The cause of on-roadway accidents is directly related to geometric, driver, and vehicle factors on the roadway. The cause of roadside accidents is also related to geometric, driver, and vehicle factors on the roadway, but roadside design features are a severity-increasing feature in roadside accidents.

- The previous points call attention to the general need to make a careful distinction between causative and severity-increasing factors in selecting candidate geometric and traffic variables for use in accident predictive models. For example, the percentage of trucks in the traffic stream is not a causative factor for head-on collisions on rural two-lane undivided highways, but it certainly could be a severity-increasing factor. Predictive models for accident rate should focus on causative factors, while severity-increasing factors should be employed in predicting the severity distribution.

- The predictive model should be validated using a validation data set that is independent of the data used to develop the model. In addition, the model should be validated using an approach that is completely different from the approach that is used in developing the model.

Levels of Detail in Accident Prediction

It is envisioned that the accident predictive portion of the IHSD model would be developed at two levels of detail:

- **Level 1** analysis would be intended for location studies and would focus on comparing the safety performance of alternative alignments. Some cross-section variables would be set to default values and the roadside would be represented by a generalized rating (e.g., 1 to 7 scale) such as that used by Zegeer et al.[7]

- **Level 2** analysis would require complete data on the roadway alignment, roadway cross-section, and roadside design for each geometric alternative under consideration. This level of analysis would be intended primarily for detailed design of geometric alternatives for a given alignment, but could also be applied to comparison of alternative alignments for which full geometric details were available.

The level 1 analysis would apply primarily to projects involving new facilities or projects involving facility reconstruction in which a change in alignment (e.g., flattening a horizontal curve) was being considered. The level 2 analysis would be potentially applicable to development of either a preliminary or final design for any project.

Current State highway agency practices generally require determination of geometrics for all roadway design elements and most roadside design elements in the preliminary design phase. Thus, most geometric design decisions are made before the development of the final plans, specifications, and estimates (PS&E) package begins. Thus, both the level 1 and level 2 analyses would generally be applied in the preliminary design phase. However, level 2 analysis could also be employed in making any necessary revisions to a preliminary design during the final design process.

Since level 1 analysis should require only simple geometric input (e.g., centerline alignment, centerline profile, typical cross-section), input procedures for geometric data should be included directly in the IHSD model. Level 2 analysis will require the geometric design of each alternative to be specified in greater detail. Therefore, it is recommended that the level 2 analysis capabilities be developed to interface directly with a computer-aided design and drafting (CADD) system. The design for each geometric alternative would be developed in a CADD environment and then imported into the IHSD model for analysis. Alternatively, the IHSD model could become an analysis capability included in the CADD system. In either case, the designer would return from the IHSD model to the CADD environment to make any desired changes in the alternative designs and then return to the IHSD model again for subsequent analyses.

Model Structure

The accident predictive portion of the IHSD model will be intended to estimate the expected accident experience for any given geometric design alternative for any particular site. The model will include submodels for four distinct portions of the highway system. These are: roadways between intersections; intersections; interchange ramps; and roadside areas. Separate accident rate and/or severity estimates will be developed for each of these four portions of the highway system and summed together. Accidents should be assigned to one of these four submodels based on the location of the first harmful event in the accident and the relationship of that first harmful event to specific geometric features. For example, the intersection submodel should be based on accidents in which the first harmful event occurred at an intersection or in which the first harmful event was related to the backup of traffic from an intersection.

The recommended conceptual structure for the model is illustrated in figure 2. The submodels for these four portions of the highway system will be highly interrelated since, for example, the accident experience on the roadside depends not only on the roadside geometrics and obstacles, but also on the geometrics and traffic

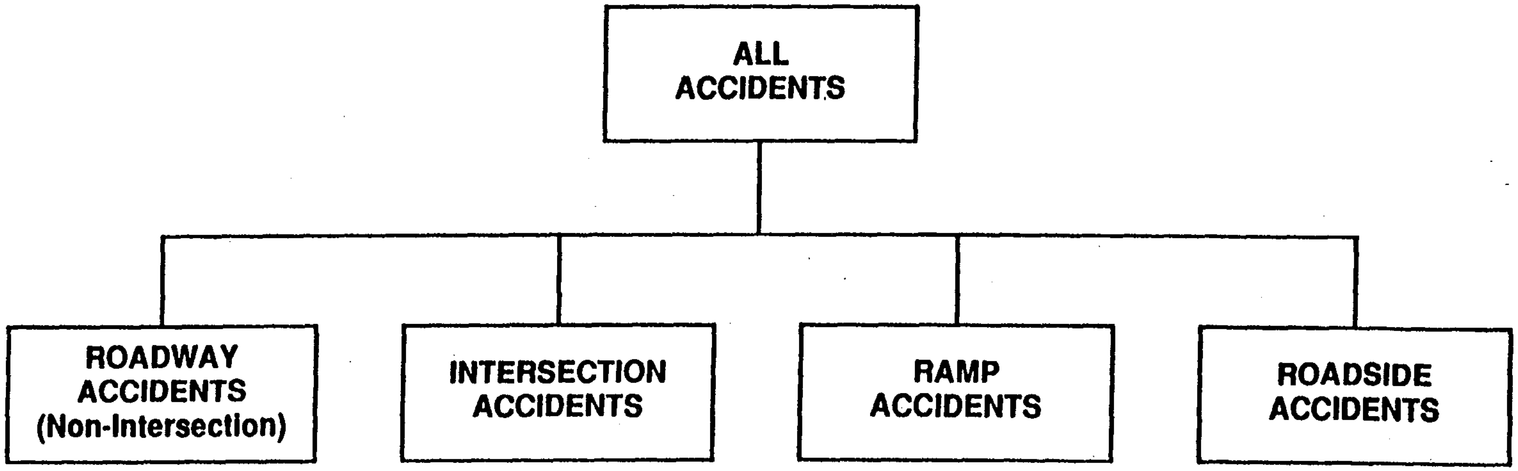


Figure 2. Accident predictive model structure—portions of the highway system represented by individual submodels.

volumes on the roadway which determine how many vehicles are likely to run off the road at a given location. Ramp accident rates may depend on entering traffic speeds which are a function of conditions on the mainline roadway. Thus, output data from one submodel may be used as input data to others. Each submodel will also need to be further subdivided into models applicable to freeways, two-lane roadways, multilane divided and undivided roadways, etc., in both urban and rural environments. The specific definitions that will be used for each portion of the roadway system are presented in section IV of this report.

In accordance with the model structure shown in figure 2, the number of accidents (by severity level) for any project would be the sum of the number of accidents for each individual roadway segment, intersection, ramp, and roadside area that makes up a specific project. All roadways would be segmented into relatively homogeneous subsections for accident estimation purposes. Each intersection and interchange ramp would be treated separately. And, each roadway segment, intersection, and interchange ramp would have one or more roadside areas whose accident experience would need to be estimated.

A preliminary flow diagram for the accident predictive model is presented in figure 3. This flow diagram illustrates how the IHSD model would operate sequentially to develop predictions of both the on-roadway and roadside accidents for a given highway project. Each accident prediction submodel shown in figure 3 is addressed in more detail in section IV of this report.

Geometric and Traffic Control Features to be Incorporated in the Model

The accident predictive model will potentially need to incorporate the safety effects of all geometric design features for roadways, intersections, ramps, and roadsides for which design alternatives need to be considered in the design process. This is a very large list, as illustrated in figure 4. The figure shows the geometric features that would be most desirable to incorporate in the model.

The figure also shows traffic characteristics and traffic control data that are potentially needed for each submodel and safety measures of effectiveness that are potentially applicable. Each of these aspects of the model is discussed below.

Safety Effects of Geometric Features

The safety effects of some of the features listed in figure 4 have been established (at least for some highway types), while others clearly need to be addressed in future research before they could be incorporated in the model. A number of the key sources in the literature are reviewed in the compendium of relationships between safety and geometric design elements currently being prepared for FHWA.[8]

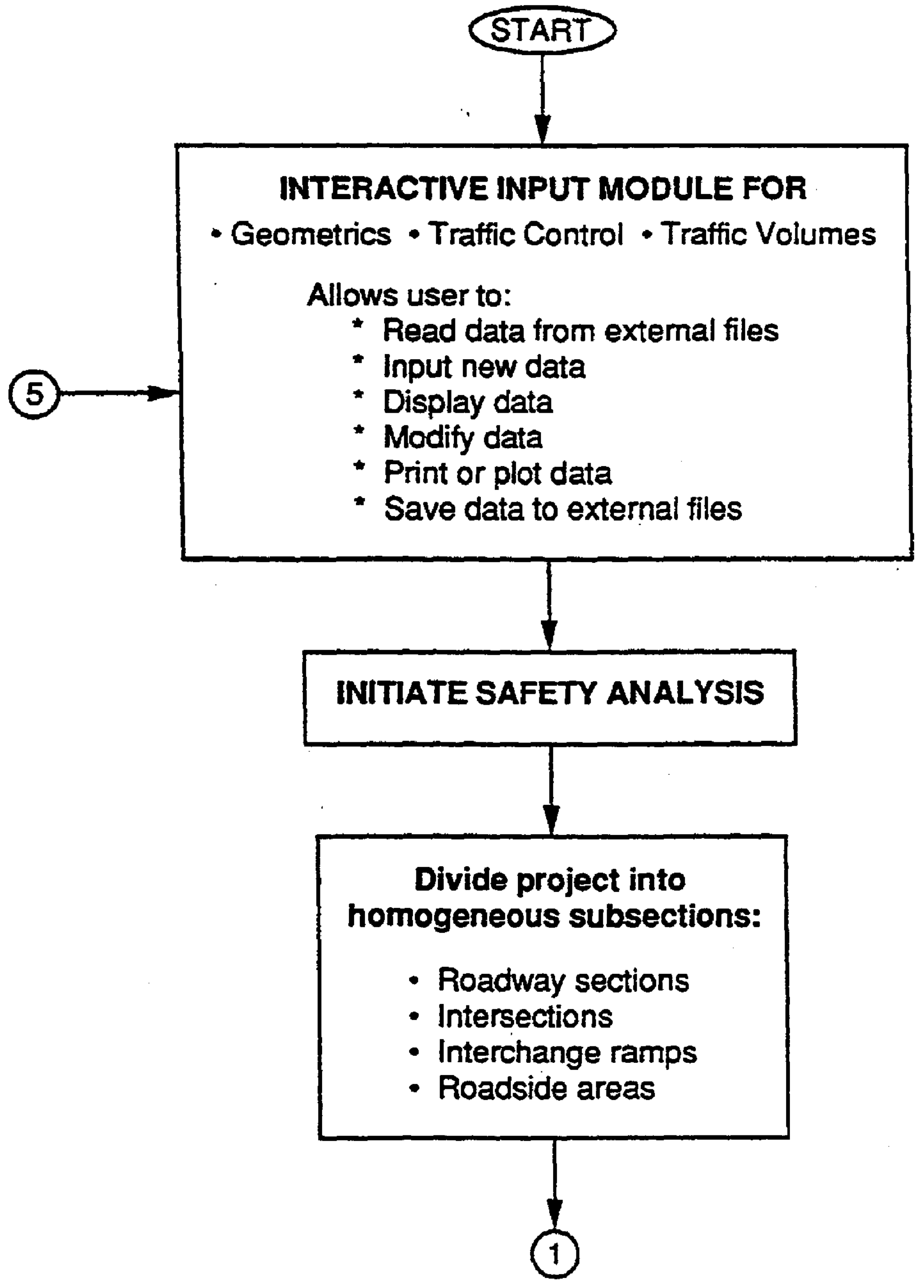


Figure 3. Preliminary flow diagram for the accident predictive model.

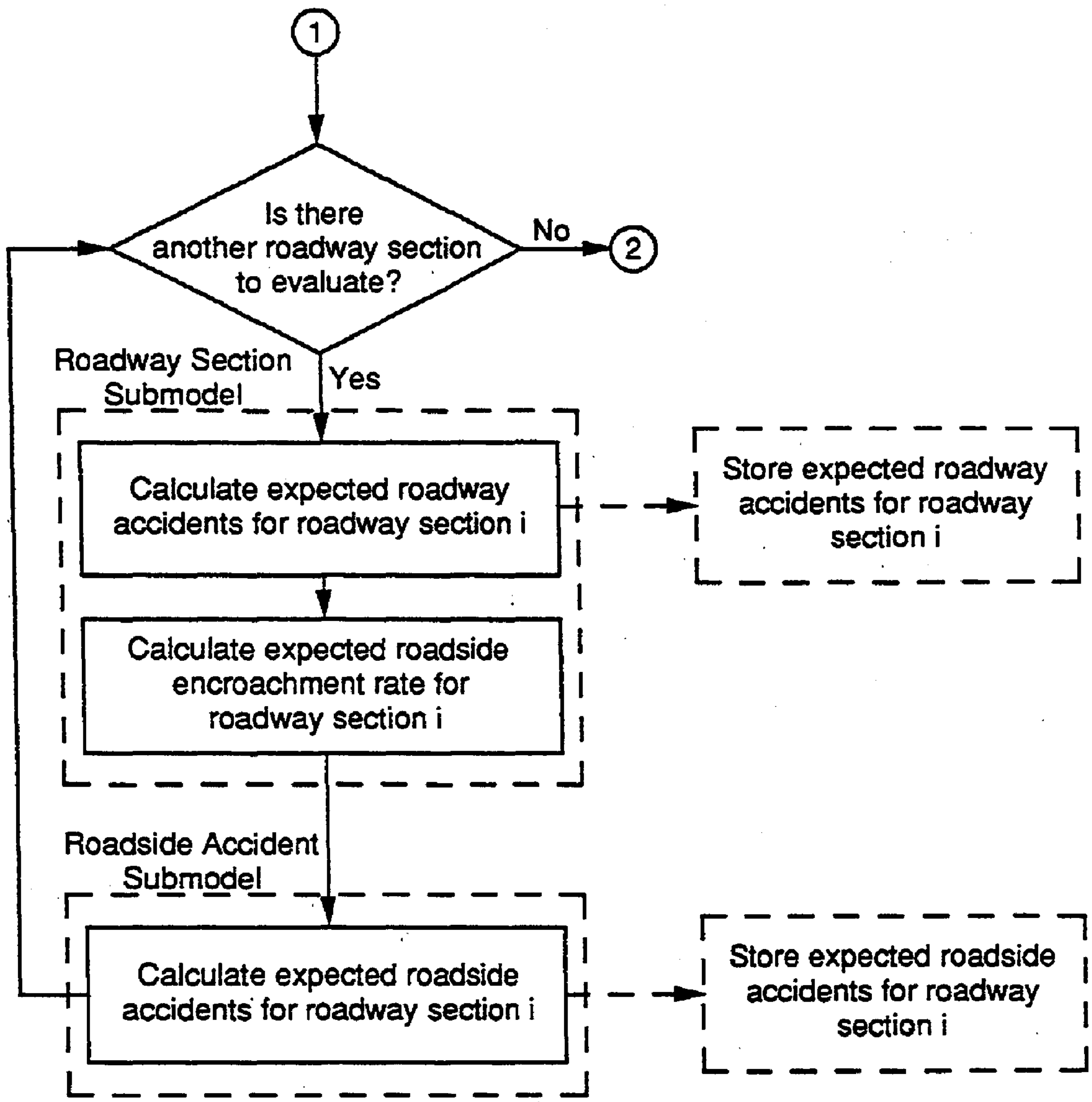


Figure 3. Preliminary flow diagram for the accident predictive model (continued).

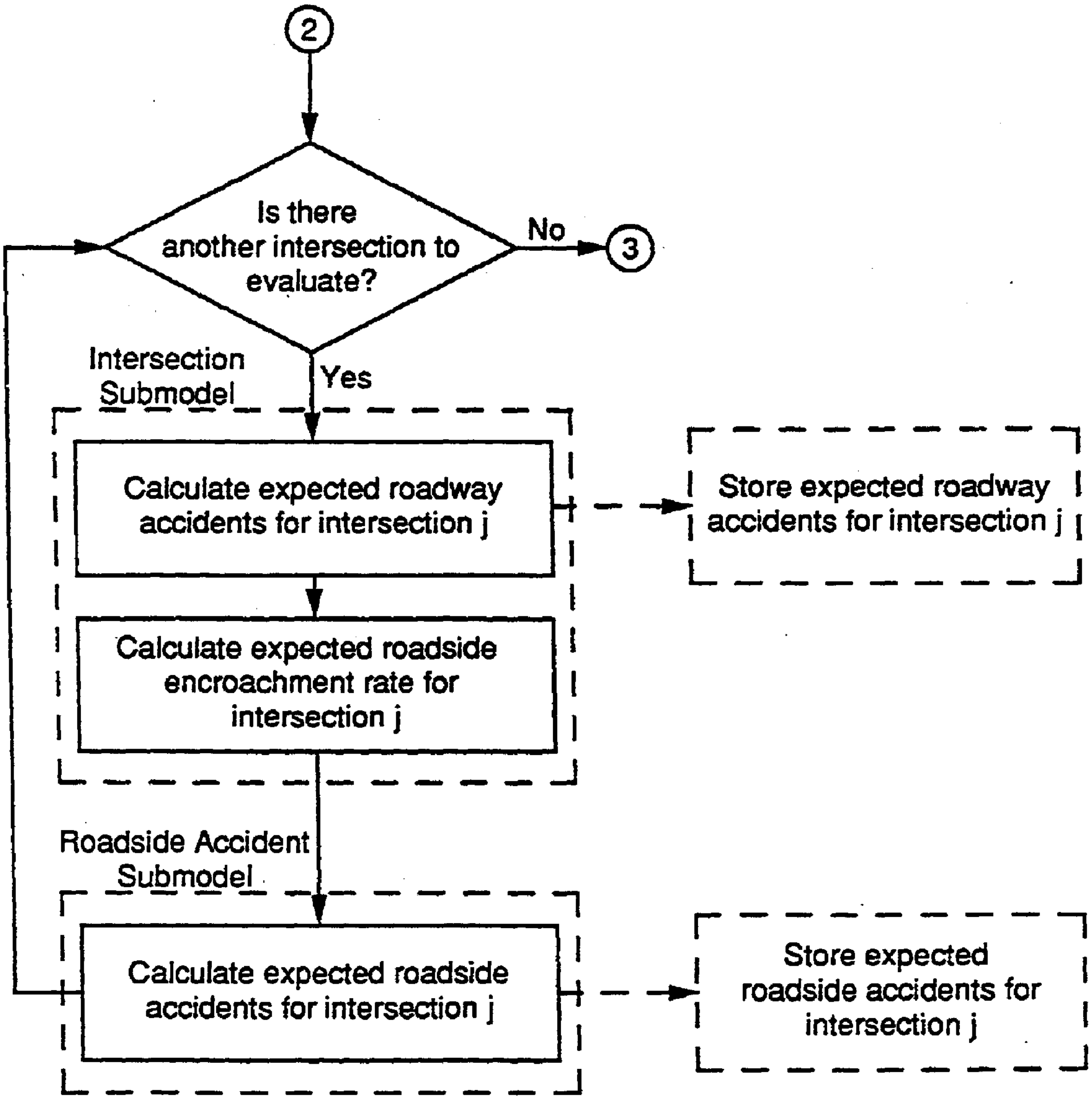


Figure 3. Preliminary flow diagram for the accident predictive model (continued).

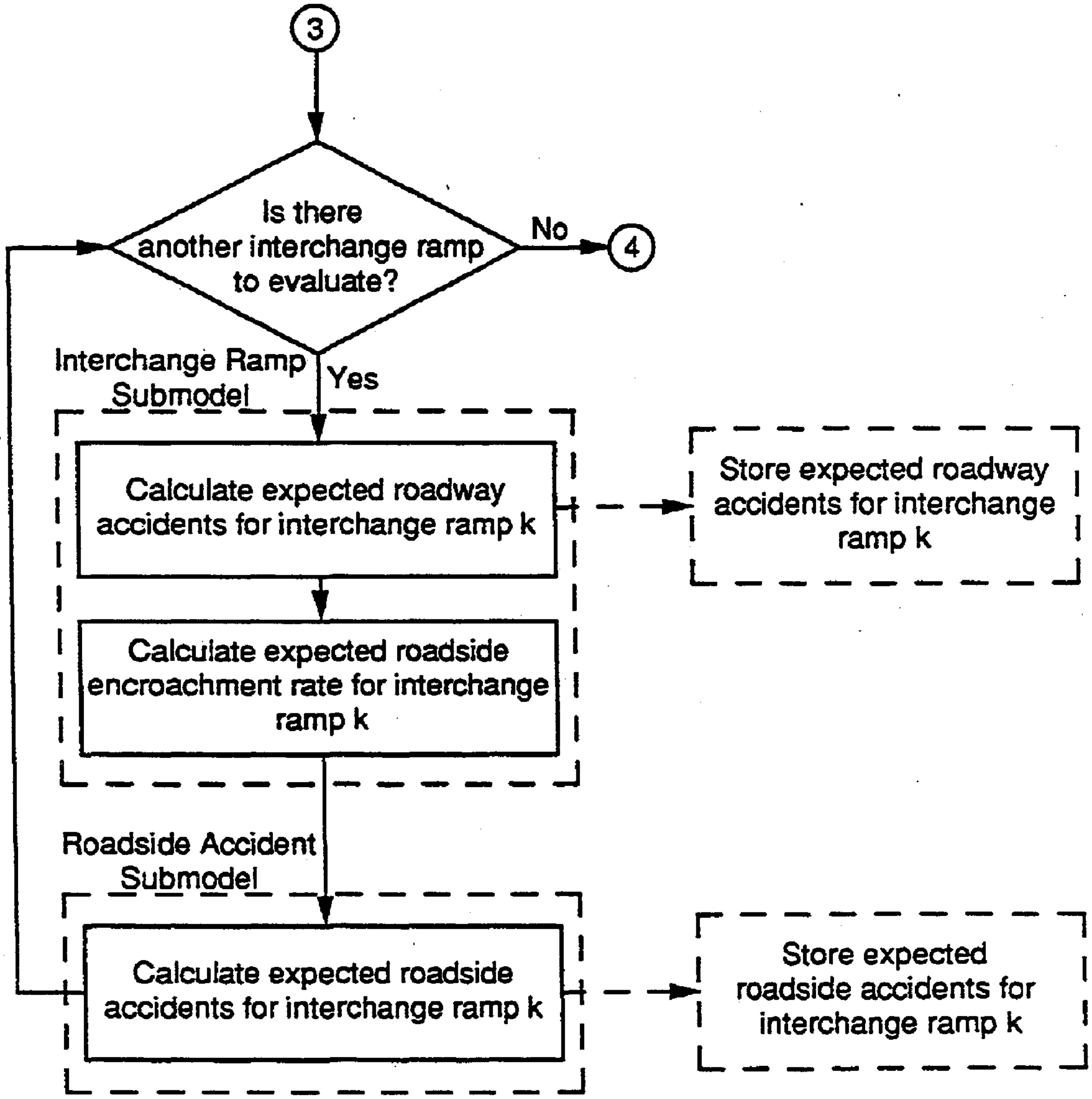


Figure 3. Preliminary flow diagram for the accident predictive model (continued).

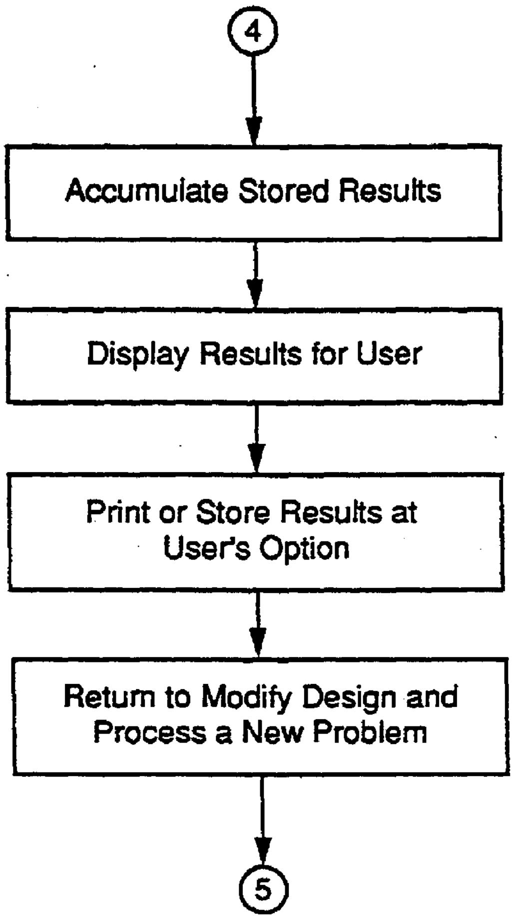


Figure 3. Preliminary flow diagram for the accident predictive model (continued).

ALL ACCIDENTS

- ROADWAY ACCIDENTS (Non-Intersection)
- INTERSECTION ACCIDENTS
- RAMP ACCIDENTS
- ROADSIDE ACCIDENTS

	ROADWAY ACCIDENTS (Non-Intersection)	INTERSECTION ACCIDENTS	RAMP ACCIDENTS	ROADSIDE ACCIDENTS
Geometric and Physical Features	Number of Lanes Divided/Undivided Access Control Urban/Suburban/Rural Horizontal Curves Percent Grade Vertical Curves/SSD Lane Width Presence of Shoulder Shoulder Type Shoulder Width Presence of Curbs Curb Offset Presence of Median Median Type Median Width Driveway Density Driveway Features (Median Openings, Turn Lanes) Bridges Bridge Width Auxiliary Lanes (TWLTL, Passing or Climbing Lanes) Special Features (e.g., Turnouts) Taper Lengths	Number of Approaches Approach Alignment (Skewed/Offset) Number of Lanes Per Approach Special Lanes (Right Turn/ Left Turn/Shared/Exclusive) Urban/Suburban/Rural Approach Widths Divided/Undivided Approaches Corner Sight Distance/Safe Approach Speed	Ramp Type: • Freeway/Freeway • Fwy/Art Off-Ramp • Fwy/Art On-Ramp • Arterial/Arterial Ramp Configuration: • Diamond • Parclo Loop • Full Loop • Directional • Button Hook • Slip Ramp Length Urban/Suburban/Rural Horizontal Curves Length and Type of Speed-Change Lanes	Barriers: • Guardrail • Bridge Rail • Concrete Barriers Embarkment Slopes • Fill Slope • Cut Slope Ditch Design Continuous Obstacles: • Retaining Wall, Fence, etc. • Classify by Side of Road, Distance from Road, and Severity Point Obstacles: • Trees, Signs, Mailboxes, Culverts, etc. • Classify by Side of Road, Distance from Road, and Severity Roadway Curvature
Traffic Characteristics and Traffic Control Features	Traffic Volume Percent Trucks Design or Posted Speed Operating Speed Passing/No-Passing Zones	Entering Traffic Volumes Percent Left Turns Percent Right Turns Percent Trucks Approach Speed Traffic Control (Signalized/ Two-Way Stop/Four-Way Stop/ Yield/No Control) Signal Phasing Signal Timing Clearance Intervals	Traffic Volumes Percent Trucks Advisory Speed Design Speed Operating Speed	Traffic Volume Percent Trucks Encroachment Rate
Safety MOEs	Accident Rate Per Million Veh-Mi Accidents Per Mi Per Year Severity Distribution Accident/Collision Types etc.	Accident Rate Per Million Entering Vehicles Accidents Per Year Severity Distribution Accident/Collision Types etc.	Accident Rate Per Million Vehicles Accidents Per Year Severity Distribution Accident/Collision Types etc.	Accident Rate Per Million Veh-Mi Accidents Per Mi Per Year Severity Distribution Accident/Collision Types etc.

Figure 4. Candidate geometric and traffic features and safety MOE's.

A review of the literature makes clear that existing safety relationships are based on a variety of measures of effectiveness and functional forms that are not consistent with one another and would be very difficult to use together. Therefore, this plan recommends that new safety relationships be developed for use in the IHSD accident predictive model. This new research must be carefully coordinated to assure consistency between the safety relationships developed for different parts of the roadway system. These new safety relationships should be developed using consistent definitions of accident types which are presented in section IV of this report. The research needed to develop these relationships is described in section VI and appendix B of this report.

Traffic Characteristics and Traffic Control Features

The basic inputs to the accident predictive model will include traffic volumes and traffic characteristics on the roadways and intersections of interest, and traffic control features that are present.

Traffic volumes are important not only as an exposure measure, but also because accident rates for roadways and intersections may themselves be a function of traffic volumes. At intersections, turning volumes (percent left and right turns) are, in effect, exposure measures for accidents involving those movements. Traffic characteristics such as percent trucks may also have quantifiable effects on safety at some locations.

Traffic control will need to be considered as well. For example, the type of traffic control present at an intersection (signal, four-way STOP, two-way STOP, YIELD, or no control) may be the single best predictor of accident experience other than traffic volume. Speed conditions will be important in many situations so the model will need to incorporate posted speeds, design speeds, or operating speeds. Other traffic control features that have unique effects (e.g., passing/no-passing zones) will also need to be incorporated.

Safety Measures of Effectiveness

A key issue in planning the accident predictive model is how the safety of a highway should be determined or defined. Our recommended approach to the development of an IHSD model is to make the accident predictive model as quantitative as possible. It would be most desirable to provide safety estimates in terms of familiar measures of effectiveness (MOE's) such as accident rate and severity levels. However, we recognize that the model can be only as precise as the research data that support it. Thus, the MOE's finally adopted will depend on the completeness and precision of current and future research, including further research to be performed for FHWA in support of the model development. Less quantitative concepts may need to be considered in some situations, particularly in the location study (or level 1 analysis) stage. For example, the model could be used to define various "levels of safety" analogous to the levels of service used in traffic operational analysis. Figure 5

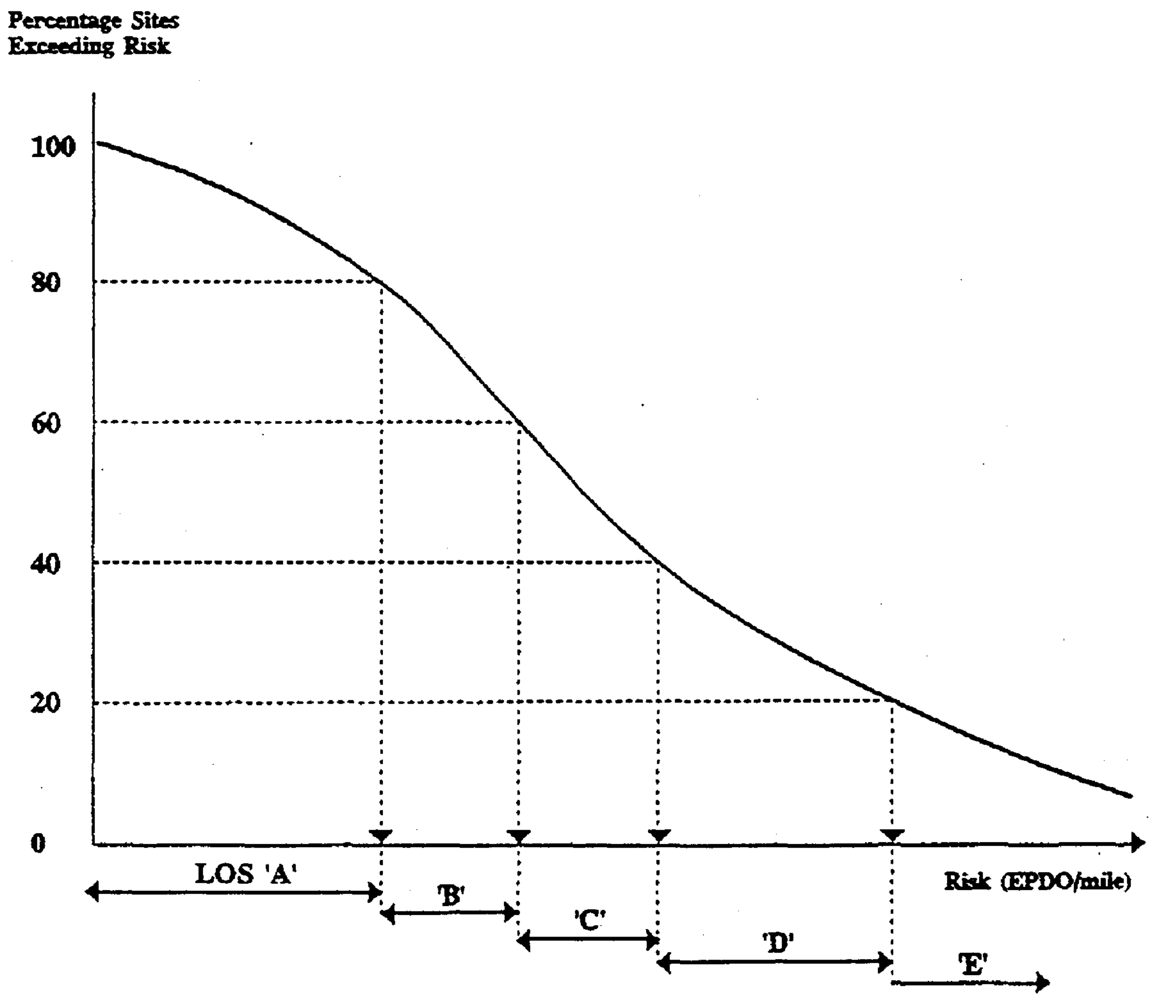


Figure 5. Candidate method of defining level of safety for specific roadway types.

illustrates how such a "level of safety" concept could be implemented, based on the statewide or areawide distribution of accident risk for a specific roadway type as represented by equivalent-property-damage-only (EPDO) accidents per mile. Nevertheless, our plan presented in this report is directed toward the development of an accident predictive model for making quantitative safety estimates, with qualitative MOE's being used only to simplify and summarize the presentation of the model predictions.

There is no single MOE for safety performance in highway design analogous to level of service as a measure of traffic operational performance. Figure 4 shows the safety measures of effectiveness that have typically been used in the past and that could potentially be incorporated in each submodel. The safety MOE's shown in figure 4 are those that are applicable to individual portions of the highway system (roadway sections, intersections, etc.). There is also a need, however, for an MOE to describe the overall safety performance of an entire project. Alternative safety MOE's for an entire project include the expected annual:

- Total number of accidents.
- Number of accidents weighted by severity (i.e., a severity index).
- Number of severe accidents [e.g., consider fatal and injury accidents only, given the under reporting problems inherent in property-damage-only (PDO) accidents, or include only PDO tow-away accidents].
- Accident experience expressed in dollar terms, based on accident cost data currently in use by FHWA. (This form is most appropriate for input to benefit-cost models, but may be less accepted by users than the other forms.)

Our recommendation is that the IHSD model should predict the expected total number of accidents for a project, with a breakdown by severity level. It must be recognized, however, that because of the well-known problem of underreporting of less severe accidents, the model predictions for fatal and injury accidents are likely to be more accurate than the predictions for property-damage-only (PDO) accidents.

The IHSD model would be intended to interactively display changes in the selected safety measure(s) for different geometric design alternatives. These measures can be calculated directly from the typical accident rate and severity measures for individual portions of the highway system shown in figure 4. Thus, the IHSD model should be structured to estimate both accident frequency or rate measures and accident severity measures for each design alternative. Both are needed to get a complete picture of the safety performance of a design alternative. It will also be desirable to estimate the distribution of particular accident types as well, since some alternative design features that reduce accidents may address one particular type of accident. The model should also be capable of providing separate estimates of the number of accidents involving a vehicle leaving the roadway as the basis for evaluating the severity increasing/reducing effects of roadside features.

Although the expected annual number of accidents will be the primary safety MOE for the IHSD model, the accident numbers will be determined from predictive relationships expressed in terms of the following measures:

Roadway Sections

- Accident rate per million veh-mi.
- Accident rate per mi per year.

Intersections

- Accident rate per million entering vehicles.

Interchange Ramps

- Accident rate per million veh-mi.
- Accident rate per million vehicles traversing the ramp.

It should be noted that accident rates per million veh-mi and accident rates per mi per year are compatible and one can be directly converted into the other if the length and traffic volume of a site is known.

In addition to the safety measures of effectiveness for the project as a whole, the IHSD model should be able to provide a breakdown of the expected accident experience for each particular roadway section, intersection, interchange ramp, and roadside area that constitutes the project. This should assist designers in identifying specific geometric features for which concentrations of accidents are likely and for which the expected accident experience might be reduced through redesign. To assist designers in interpreting the accident predictions for individual roadway sections or intersections, the model output might include not only the expected annual number of accidents, but also the probability of zero accidents in any given year. This probability can be computed directly from the expected number of accidents based on the assumption that accidents follow a Poisson distribution.

The output of the accident prediction model should include not only expected values for annual accident frequencies but also standard deviations or confidence intervals corresponding to those expected values. Standard deviations or confidence intervals indicate the uncertainty in the predicted values which should be taken into account by designers in interpreting the predictions provided by the model.

In summary, the safety measures of effectiveness provided by the model should include:

- Expected annual number of accidents within the specified limits of a highway improvement project.
- Distribution of those accidents by severity level (fatal/injury/PDO).
- Expected distribution of those accidents by accident type.
- Predicted numbers of accidents for specific roadway segments, intersections, interchange ramps, and roadside areas, including the probability of zero accidents in any given year for particular roadway segments, intersections, or ramps.
- Standard deviations or confidence intervals for predicted accident estimates.

IV. DESCRIPTION OF ACCIDENT SUBMODELS

This section describes each of the accident submodels that will be incorporated in the IHSD accident predictive model, including the roadway section, intersection, interchange ramp, and roadside submodels.

Roadway Section Accident Submodel

The roadway section accident submodel has two objectives:

- To estimate the expected annual number of on-roadway accidents for a specific roadway section.

- To estimate the expected annual number of roadside encroachments for a specific roadway section as input to the roadside accident submodel.

The estimation of roadway accident experience is discussed in detail in this section. The estimation of roadside encroachments is discussed in general terms in this section and is discussed in more detail in the section on the roadside accident submodel.

Definition of Roadway Section Accidents

Roadway section accidents are defined as accidents in which the first harmful event occurs on the roadway and is not related to an intersection or an interchange ramp. On-roadway accidents are defined as those in which the first harmful event occurs on the roadway. For purposes of this definition, the roadway includes both the traveled way and shoulders. The definition of roadway section accidents includes:

- Single-vehicle noncollision accidents that occur in the roadway, such as:
  - overturning in the roadway.
  - other miscellaneous noncollision accidents.

- Single-vehicle collision accidents that occur on the roadway, such as:
  - collision with a parked vehicle.
  - collision with a nonmotorist (pedestrian, bicycle, or animal).
  - collision with a fixed object in the traveled way or shoulder (a limited category that includes collisions with overhead signs or structures).
  - other collisions (e.g., debris in roadway).

- All multiple-vehicle collision accidents [except for collisions that involve a motor vehicle leaving one roadway and colliding with a vehicle on another (nonintersecting) roadway, which are usually classified as a single-vehicle run-off-road accidents].

Note that the definition of on-roadway accidents excludes all accidents in which the first harmful event is a vehicle leaving the roadway. Such run-off-road accidents will be addressed by the roadside accident submodel.

Predictive Relationships for Roadway Section Accidents

The roadway section accident submodel will be based on an accident predictive model or models. This model will have the following general form:

$$AR_i = f\ (\text{geometrics, traffic control, traffic volumes}) \qquad (1)$$

where AR_i = expected accident rate for roadway section i (accidents per million veh-mi)

Predictive models or tabulations of average values would also be needed for the accident severity distribution and the accident type distribution for particular roadway types.

The following discussion presents alternative approaches for predicting roadside accidents based on two general forms for accident predictive models. The forms for predictive relationships shown below make use of adjustment factors for specific geometric and traffic control elements that are combined either by multiplication or addition. These adjustment factors can be either linear or nonlinear and their values could be determined from predictive equations or presented in tabular form. Where valid statistical analyses indicate that there are interactions between two or more model parameters, combined adjustment factors for those parameters could be developed. The remainder of this section presents the conceptual model for roadway section accidents; the accident research issues inherent in developing such a model are discussed in section VI of this report.

The roadway section accident submodel could utilize an accident rate predictive equation of the following general form:

$$AR_i = AR_B\ f_{CS}\ f_{HC}\ f_L \qquad (2)$$

or

$$AR_i = AR_B + f_{CS} + f_{HC} + f_L \qquad (3)$$

where AR_B = basic tangent section accident rate for appropriate roadway type and ADT (accidents per million veh-mi).

f_{CS} = safety adjustment factor for effects of cross-sectional elements such as lane width, shoulder width, shoulder type, etc.

f_{HC} = safety adjustment factor for horizontal curves based on radius of curve, length of curve, superelevation, etc.

f_L = safety adjustment factor for other geometric and traffic control elements that can vary longitudinally along the highway including grades, auxiliary lanes, speed limits, passing/no-passing zones, driveway densities, etc.

Note that if a multiplicative approach like equation (2) is used, the adjustment factors have a nominal value of 1.00. Adjustment factors with values less than 1.00 correspond to design features that have lower accident rates than the base condition; values greater than 1.00 correspond to design features that have higher accident rates than the base condition. By contrast, with an additive approach, the adjustment factors have a nominal value of 0.00 and the adjustment factors would be either positive or negative depending upon whether a particular design feature is associated with higher or lower accident rate than the base condition.

The basic tangent section accident rates represent the average accident rate for a tangent roadway section considering only the effects of ADT and roadway type. These basic rates would be determined from statistical relationships between accident rate and ADT for tangent sections on individual roadway types. These relationships could have various forms such as:

$$AR_B = c_1 + c_2\ ADT \quad (4)$$

$$AR_B = c_1 + c_2\ /\ ADT \quad (5)$$

$$AR_B = c_1 + c_2\ ADT + c_3\ ADT^2 \quad (6)$$

where c_1, c_2, c_3 = regression coefficients

ADT = average daily traffic volume (veh/day)

Note that the form of the relationship between accident rate and traffic volume is not necessarily linear. The specific form of the accident rate-ADT relationship could differ between roadway types and would be selected based on the best fit to data for that roadway type. It is expected that the basic section accident rates would include typical levels of bicycle and pedestrian accidents, as well as typical frequencies of accident types that bear no obvious relationship to the roadway geometrics (e.g., a fire in a vehicle).

Along with the basic accident rates, data analysis could establish the typical accident severity distribution and accident type distribution for particular roadway types. These distributions could be incorporated in the IHSD model for specific roadway types. Our current recommendation is that the accident severity distribution and accident type distribution might not need to be expressed as a function of traffic volume or geometric variables other than the basic roadway type, but this issue needs to be addressed in research.

A typical list of roadway types for which accident rate-ADT relationships might be required to cover the full range of highway conditions of interest is as follows:

- Urban freeways.
- Rural freeways.
- Rural multilane divided highways.
- Rural multilane undivided highways.
- Rural two-lane highways.
- Urban arterial streets.
- Other functional classifications.

It might also be necessary to stratify roadway types by ADT level, terrain, etc. Separate safety relationships would be needed for each roadway type unless an analysis found no statistically significant differences between the relationships for similar roadway types. In this case, it would be justified to combine the accident rate-ADT relationships for these roadway types.

Appendix A presents examples of some basic accident rate-ADT relationships developed by the California Department of Transportation (Caltrans) for their State highway system.[9] These relationships are used in Caltrans accident surveillance system to determine expected accident rates for specific roadway types. The actual accident experience of particular roadway sections is then compared to these expected values to determine whether the roadway section should be considered a high-accident location. These relationships are not used by Caltrans to predict the safety consequences of design decisions. Nevertheless, they illustrate the first step in the process of characterizing the safety performance of an agency's highway system as a basis for design decisions.

The values of the individual safety adjustment factors could be determined from relationships of the following form:

$$f_{CS} = f_{LW}\ f_{SH} \tag{7}$$

or

$$f_{CS} = f_{LW} + f_{SH} \tag{8}$$

where: f_{CS} = safety adjustment factor for the effects of cross-sectional elements

f_{LW} = safety adjustment factor for the effect of lane width

f_{SH} = safety adjustment factor for the effect of shoulder type and width

Equations similar in form to equations (7) and (8) could be developed for the horizontal curve factor (f_{HC}) and the longitudinal factor (f_L).

The multiplicative approach to adjustment factors may be preferable to the additive approach because it might allow individual highway agencies to periodically update the basic roadway section accident rates (AR_B) from their own data, but continue to use the adjustment factors based on national data. For example, table 1 presents hypothetical values of f_{CS} in equations (2) and (7) for paved shoulders based on application of an accident predictive model for rural two-lane highways developed by Zegeer et al.[7] (Table 1 is based on the assumptions that the ADT is 1,000 veh/day, that the site is located in rolling terrain with a roadside hazard rating of 5, and that accidents "related" to the highway cross-section constitute 50 percent of all accidents.)

Table 1. Relative accident rates for combinations of lane width and shoulder width.

Lane width (ft)	Shoulder width (ft)				
	8	6	4	2	0
12	1.00	1.06	1.13	1.30	1.48
11	1.06	1.17	1.26	1.43	1.61
10	1.11	1.24	1.37	1.50	1.74
9	—	1.35	1.52	1.70	1.87
8	—	—	1.63	1.85	2.11

A variety of modeling approaches and statistical techniques are potentially applicable to the determination of the values of the adjustment factors. Model forms could include linear, exponential, log-linear, logistic, probit, polynomial, and discrete models. Statistical techniques for quantifying the coefficients of these models could include ordinary least squares, weighted least squares, modified minimum Chi-squared, and maximum likelihood. For any given case, the most appropriate modeling approach and statistical technique should be selected through exploratory analysis of sample data sets.

This plan does not attempt to identify the statistical techniques that are best suited to the development of accident predictive models for specific portions of the roadway system and specific geometric elements. Such plans are being developed in two current FHWA contracts entitled, "Experimental Plans for Accident Studies of Highway Design Elements."[10,11] Development of experimental plans for accident prediction for at-grade intersections and for prediction of roadside encroachments is currently underway in those two contracts.

Once the expected accident rate (AR_i) for a particular roadway section is determined, the expected annual number of accidents can be determined as:

$$N_i = (AR_i \; L_i \; ADT_i) \times 365 \times 10^{-6} \quad (9)$$

where:

N_i = expected annual number of accidents for roadway section i

L_i = length of roadway section i (mi)

ADT_i = average daily traffic volume for roadway section i (veh/day)

The expected annual number of accidents (N_i) can then be broken down into severity levels or accident types by multiplying by the appropriate percentages from the accident severity and type distributions for the appropriate roadway section type or from predictive models for the accident severity distribution.

Prediction of Roadway Section Encroachment Rates

The recommended method for predicting roadside accidents is through use of a roadway accident submodel developed from encroachment and accident severity data. This approach is discussed in greater detail in the later section on that submodel, but it will suffice to say here that this model functions by: (1) estimating the roadside encroachment rate (the annual number of roadside encroachments), the distribution of roadside encroachment angles, and the potential severity of the roadside features that may be encountered by an errant vehicle at a particular location; and (2) using those estimates to predict the expected number of fatal and injury accidents on the roadside for that location.

The roadway section accident rate submodel will estimate the roadside encroachment rate for each roadway section as input to the roadside accident submodel. The existing roadside models essentially treat the encroachment rate as a constant for any section of roadway, because no better information is available. However, the authors recommend that the encroachment rate should be a function of the geometrics of the roadway section; for example, one would expect the encroachment rate to be higher on a horizontal curve than on a tangent section. Such relationships would need to be developed through observation or modeling in future research, because only limited relationships of this type are available in the current state of the art.

Most previous attempts to predict roadside accident rates have addressed single-vehicle run-off-road accidents resulting from single-vehicle encroachments. However, roadside encroachments also occur in multiple-vehicle collisions when a vehicle leaves the roadway after colliding with another vehicle. The IHSD model should recognize that roadside design can be a severity-increasing factor in such accidents. We recommend that roadside research develop a measure of the percentage of vehicles involved in multiple-vehicle collisions that leave the roadway subsequent to the collision. For example, the encroachment rate for a roadway section could be estimated as:

$$E_i = ESV_i + N_i \; PMV_r \; NVEH_r \; PROR_r \qquad \textbf{(10)}$$

where

E_i = expected annual number of roadside encroachments for roadway section i

ESV_i = expected annual number of single-vehicle encroachments

N_i = expected annual number of accidents for roadway section i

PMV_r = proportion of total accidents represented by multiple vehicle collisions for roadway type r

$NVEH_r$ = average number of vehicles involved per multiple-vehicle collision for roadway type r

$PROR_r$ = probability that a vehicle involved in a multiple-vehicle collision will leave the roadway for roadway type r

The section of this report on the roadway accident submodel addresses how the encroachment rate (E_i) would be used in the prediction of the expected annual number of roadside accidents.

Intersection Accident Submodel

The intersection accident submodel has two objectives:

- To estimate the expected annual number of on-roadway accidents related to specific intersections.
- To estimate the expected annual number of roadside encroachments for a specific intersection as input to the roadside accident submodel.

Each of these objectives is addressed below.

Definition of Intersection Accidents

Intersection accidents are defined as accidents in which the first harmful event occurs on a roadway section, or ramp and is related to a specific intersection. This would include the following types of on-roadway accidents:

- Multiple-vehicle collisions between vehicles traveling straight ahead or making turning maneuvers within the intersection.

- Multiple-vehicle collisions on the intersection approaches involving vehicles stopped or slowing due to operational conditions within the intersection.

- Single-vehicle noncollision accidents within the limits of the intersection (e.g., overturning in the roadway, etc.)

- Single-vehicle collision accidents within the limits of the intersection or related to the intersection, such as:

  — collision with a nonmotorist (pedestrian, bicycle, animal, etc.).

  — collision with a fixed object in the traveled way (a limited category that includes collisions with overhead signs, mast arms, or structures).

  — other collisions (e.g., debris in the roadway within the intersection).

This definition addresses what accident analysts typically designate as "intersection-related" accidents rather than "at-intersection" accidents. Intersection-related accidents include not only accidents that fall within the curbline limits of the intersection, but also accidents on any approach to the intersection whose cause is related to the operation of the intersection. For example, a rear-end collision at the end of a queue of vehicles backed up from a signal should be attributed to the signalized intersection even if it occurred several hundred feet from the intersection. The definition of on-roadway accidents would be the same for intersections as for roadway sections, including accidents that occur on both the traveled way and shoulders.

It should be understood that the definition of an "intersection-related" accident does *not* incorporate a specific approach length that is considered to be related to the intersection. Any accident that is caused by or related to the operation of the intersection is considered to be an "intersection-related" accident, no matter how far from the intersection it occurs. Naturally, "intersection-related" accidents would be expected to occur over a greater distance from the intersection on a high-volume, congested approach than on a low-volume, uncongested approach. In addition to the "intersection-related" accident experience, accidents that are not related to the operation of the intersection would be expected to occur on each approach; such accidents would be predicted by the roadway section model rather than the intersection model.

Predictive Relationships for Intersection Accidents

Predictive relationships for intersection accidents would need to be developed along similar lines to the predictive relationships for roadway section accidents. Intersection types would be classified based on:

- Area type (urban/rural).

- Number and arrangement of intersection legs: .

    - 3-leg (T intersection).
    - 3-leg (Y intersection).
    - 4-leg (normal).
    - 4-leg (offset or skewed).
    - multileg.

- Traffic control type:

    - traffic signal.
    - all-way STOP.
    - two-way STOP.
    - YIELD control.
    - no control.

Basic intersection accident rates (equivalent to AR_B) could be developed for each intersection type using regression equations like equations (3), (4), or (5). The basic intersection accidents would be expressed in terms of accidents per million entering vehicles. The appendix presents examples of some basic accident rate-traffic volume relationships developed by Caltrans; these estimated are used in accident surveillance.

Adjustment factors would need to be developed for cross-sectional features on each approach such as number of lanes, lane widths, right- and left-turn lanes, medians, etc. A realistic model for signalized intersections also needs to incorporate the operation of the signal (phasing, cycle length, etc.) and the congestion levels present at the intersection.

Prediction of Intersection Encroachment Rates

Roadside encroachments at intersections involve vehicles leaving one of the intersecting roadway sections. However, the roadside encroachment rate on intersection approaches may be higher than on roadway sections between intersections. For example, some vehicles might run off the road to avoid a rear-end or sideswipe collision with vehicles queued on the intersection approach. Thus, the intersection submodel will estimate the component of the roadside encroachment rate for intersection approaches that is over and above the roadside encroachment rate for normal roadway sections.

Interchange Ramp Accident Submodel

The interchange ramp accident submodel has two objectives:

- To estimate the expected annual number of on-roadway accidents related to a specific interchange ramp.

- To estimate the expected annual number of roadside encroachments for a specific interchange ramp as input to the roadside accident submodel.

Each of these objectives is addressed below.

Definition of Interchange Ramp Accidents

For purposes of the IHSD model, an interchange ramp is defined as a roadway whose function is (1) to connect two access-controlled freeway sections; or (2) to connect an access-controlled freeway section with a roadway section without access control. Connections between ramps and mainline freeway sections typically operate in free-flow fashion and usually incorporate a speed-change lane (acceleration or deceleration lane). Connections between ramps and roads without access control (e.g., the arterial crossroad at a freeway-arterial interchange) may have either free-flow operation (i.e., with a speed-change lane) or interrupted flow operation (i.e., with a STOP sign or signal, as on a diamond interchange ramp).

The interchange ramp accident submodel will incorporate separate predictive models for:

- The ramp proper.

- One or more speed-change lanes.

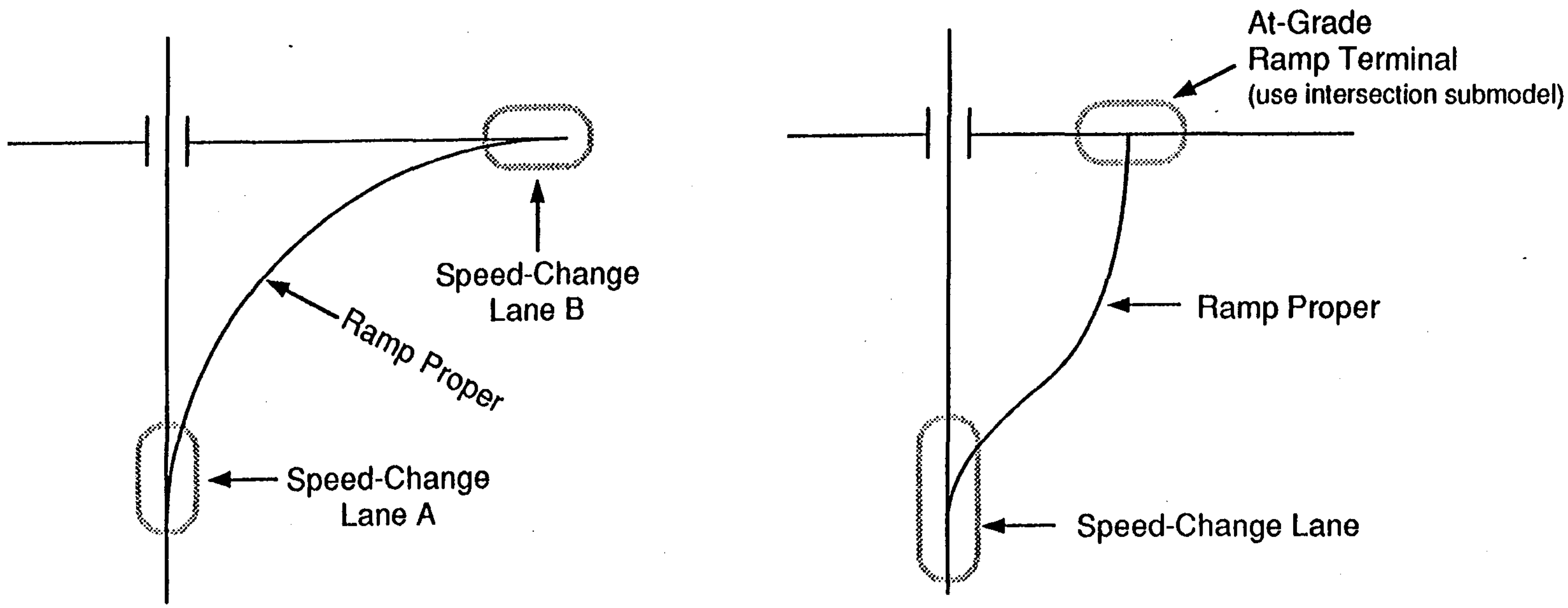
Ramp terminals with interrupted flow (i.e., with STOP signs or traffic signals) will be addressed with the intersection submodel rather than the ramp submodel (see example in figure 6). Special provisions will need to be made for handling:

- Junctions within ramps (e.g., major forks or merges of directional ramps).

- Collector-distributor roads.

- Speed-change lanes that form a weaving area between two ramps.

- Ramps in arterial/arterial or low-speed arterial/collector or arterial/local interchanges.



(a) Ramp with free-flow connections at both ends.

(b) Ramp with interrupted flow at one end.

Figure 6. Examples of accident prediction submodels used for various interchange areas.

Interchange ramp accidents are defined as all accidents in which the first harmful event occurs on the roadway within the ramp proper or a speed-change lane and all accidents on adjacent roadway sections in which the first harmful event is related to the presence of the ramp. In other words, if the presence of the ramp elevates the accident rate of the mainline freeway above the normal roadway section accident rate, this effect will be accounted for by the ramp submodel. Interchange ramp accidents include:

- Single-vehicle (collision or noncollision) accidents that occur on the roadway of the ramp proper or the speed-change lane.
- Multiple-vehicle collisions that occur on the roadway of the ramp proper or the speed-change lane.
- Multiple-vehicle accidents that occur on adjacent roadway sections because of the presence of the ramp.

Predictive Models for Interchange Ramp Accidents

Separate predictive models are needed for ramp accidents and speed-change lane accidents. An analogous predictive approach to that represented by equations (1) through (9) can be used for both. This approach involves estimation of a basic accident rate (equivalent to AR_B) for the ramp or speed-change lane, which can then be modified by appropriate adjustment factors.

In the ramp model, the basic accident rate would be determined as a function of traffic volume and ramp type. Ramp type would be defined by:

- Area type (urban/rural).
- Type of operation:
  - on-ramp.
  - off-ramp.
- Ramp configuration:
  - diamond.
  - cloverleaf loop.
  - parclo loop.
  - directional.
  - buttonhook.
  - slip ramp to one-way frontage road.
  - scissors ramp to two-way frontage road.

An early set of models of this type were developed for Caltrans by Lundy.[12] The appendix presents a more recent set of Caltrans accident rate estimates for ramps.[9] Adjustment factors would need to be provided for ramp cross-section and alignment elements.

In the speed-change lane model, the basic accident rate would be determined as a function of traffic volume and speed-change lane type (acceleration lane/deceleration lane). Adjustment factors would need to be provided for speed-change lane length and width.

Prediction of Interchange Ramp Encroachment Rates

Encroachment rate predictions for the ramp proper would be developed in a manner similar to roadway section encroachment rates. For speed-change lanes, roadside encroachment rates in the vicinity of the speed-change lane and the gore areas of freeway off-ramps may be higher than the normal encroachment rates for roadway sections. The speed-change lane model will incorporate procedures for predicting the excess encroachment rates over and above the basic roadway section encroachment rate.

Roadside Accident Submodel

The purpose of the roadside accident submodel of the IHSD model is to estimate the annual number of accidents by severity level in which the first harmful event is a vehicle leaving the roadway. The severity-increasing effects of roadside design on vehicles that leave the roadway after a multiple-vehicle collision should also be considered. Generalized safety predictions based on a roadside rating system like the 1-to-7 scale used by Zegeer, et al., could suffice for application of the IHSD model in a level 1 analysis.[7] However, a model that addresses the safety effects of specific roadside design features is needed for level 2 analyses.

It should be recognized that roadside features are, strictly speaking, severity-increasing rather than causative factors in run-off-road accidents. The cause of a roadside accident is the vehicle, driver, or roadway factor (or combination of factors) that caused the vehicle to leave the roadway and encroach on the roadside. The consequences of a vehicle leaving the roadway depend on the roadside design. At a site with good roadside design—flat slopes and no roadside obstacles—a roadside encroachment may result in no personal injury or property damage and, thus, no reportable accident may result. The same encroachment at a location with poor roadside design—steep slopes or unforgiving fixed objects—could result in a very severe accident. Thus, accident data cannot be relied upon to establish encroachment rates because some encroachments result in reportable accidents and others do not. Furthermore, many roadside accidents that should be reported are not.

A suitable modeling approach for predicting roadside accident experience has been developed over the years in a series of National Cooperative Highway Research Program (NCHRP), FHWA, and AASHTO publications. These are:

- *NCHRP Report 77*, "Development of Design Criteria for Safer Luminaire Supports."[13]
- *NCHRP Report 148*, "Roadside Safety Improvement Programs for Freeways—A Cost-Effectiveness Priority Approach."[14]
- The 1988 AASHTO *Roadside Design Guide*.[15]
- Development and subsequent improvements to the Benefit to Cost Analysis Program (BCAP).[16,17,18]
- Research currently underway in NCHRP Project 22-8, "Evaluation of Performance Level Selection Criteria for Bridge Railings."[19]
- Research currently underway in NCHRP Project 22-9, "Improved Procedures for Cost-Effectiveness Analysis of Roadside Safety Features."[20]

The roadside safety model included in the AASHTO *Roadside Design Guide*, based on *NCHRP Report 77*, and *NCHRP Report 148*, was known as the ROADSIDE model.[15,13,14] This model has been provided to users in the form of a microcomputer program that can be used to compare roadside accident rates and severities of different roadside designs. The subsequent projects have developed, and are refining, an improved roadside safety model known as the Benefit to Cost Analysis Program (BCAP).[16,17,18,19,20]

The general approach to roadside safety estimation used in all of these models is represented by the equation:

$$E_a = V\ P(E)\ P(C|E)\ P(I|C) \tag{11}$$

where E_a = expected number of fatal plus nonfatal injury accidents per year within a roadway section of length L.

V = vehicle exposure; number of vehicles per year passing through the roadway section L.

$P(E)$ = probability that a vehicle will encroach on the roadside within section L; the proportion of vehicles passing through section L that would be expected to encroach on the roadside. This probability is a function of the length L and the geometric design of the roadway.

$P(C|E)$ = probability of a collision, given that an encroachment has occurred; the proportion of all encroachments that result in collisions with a roadside obstacle. This probability is a function of the encroachment angle, the encroachment distance, the lateral placement of the roadside obstacle, and the size of the obstacle.

$P(I|C)$ = probability of an injury (fatal or nonfatal) given that a collision has occurred; the proportion of all collisions that result in an injury. This probability is a characteristic that can be estimated from accident data for each type of roadside obstacle.

A key step in the application of the roadside safety model is the estimation of the roadside encroachment rate, expressed as roadside encroachments per vehicle-mile, which serves as the basis for determining P(E) in equation (11). Past research, including data collected by Hutchinson and Kennedy and by Cooper, has been used for this purpose.[21,22] However, none of the existing data sources is considered satisfactory because these existing data sources fail to distinguish adequately between intentional and unintentional encroachments; thus, the available data may overstate the rate of unintentional encroachments. New encroachment data are needed for reliable roadside modeling. Particular attention should be paid to the variation of roadside encroachment rates as a function of roadway features such as horizontal curvature.

Figure 7 illustrates a plan view of the hazard envelope used in the estimation of the probability of a collision given an encroachment [P(C|E)]. The determination of P(C|E) requires data on the distribution of encroachment angles (ϕ in figure 7) and encroachment distances as well as the size and placement of particular roadside obstacles.

The distance from the edge of the travel lane to a particular roadside hazard is designated by distance A in figure 7. The probability of lateral encroachment distance (X) for errant vehicles for a specific vehicle mix is expressed in the model as a function of design speed. A collision between an errant vehicle and a roadside hazard is possible only if $X \geq A$ and only if the vehicle leaves the road within the interval A-D in figure 7 appropriate for its encroachment angle (ϕ). Care must be taken in applying the roadside hazard model to determine the relative positions of the roadside obstacles. One roadside obstacle may have a reduced probability of being struck if it is partially or completely behind another obstacle along the path of an errant vehicle.

Finally, the model incorporates the probability of an injury given that a collision occurs [P(I|C)] based on estimates of the actual severities of collisions with particular types of objects. Thus, the value of P(I|C) varies with object type.

The roadside hazard model can be applied to collisions with continuous features like guardrail, concrete barriers, retaining walls, or bridge rail. The logic is

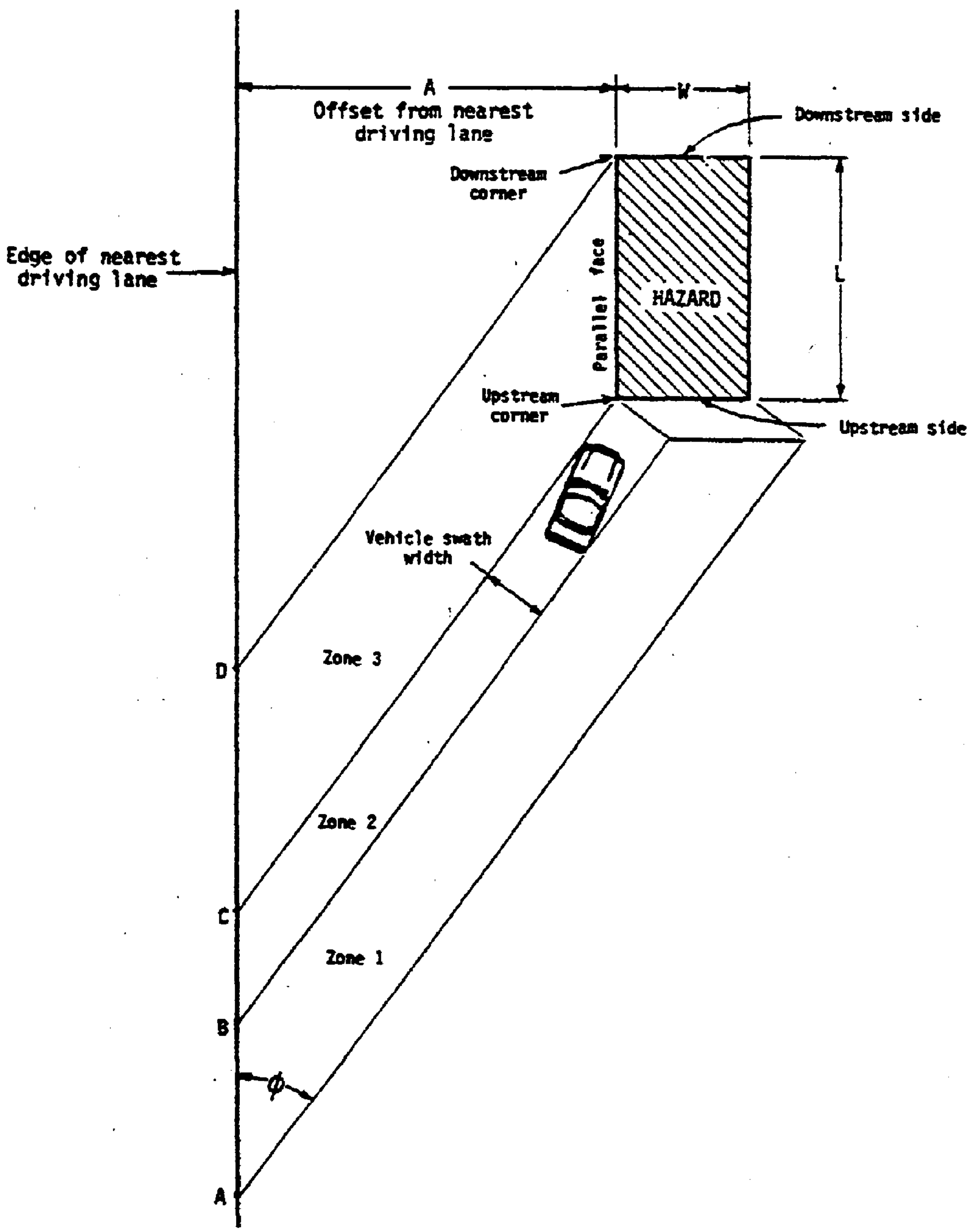


Figure 7. Hazard model for roadside encroachments.

similar to the logic for a point object, except that the P(C | E) increases with the longitudinal extent of the obstacle. In the limiting case, where the continuous obstacle extends for the entire length of the roadway section being analyzed P(C | E) can be determined directly from the probability of a particular encroachment distance.

The same logic can also be applied to roadside accidents involving sideslopes where no obstacles are present. The value of P(C | E) can be determined directly from the encroachment distance probabilities based on the distance from the traveled way to the beginning of the slope. The value of P(I | C) increases with the steepness of the slope (i.e., injuries are more likely on 3:1 slopes than on 4:1 slopes, and are more likely on 4:1 slopes than on 6:1 slopes).

The existing versions of the roadside hazard model address only estimates for fatal and injury accidents. If PDO accidents are included in the IHSD model, P(I | C) would need to be replaced with P(A | C), the probability of a reportable accident given a collision, and values for of P(A | C) would need to be developed for specific hazard types.

The roadside hazard model was developed for roadway sections and has never been applied to intersections. However, with two modifications, the roadside hazard model can be adapted to intersections. First, as discussed in the intersection accident submodel, the roadside encroachment rates may be higher on intersection approaches than on normal roadway sections. Second, many roadside hazards on intersection approaches may have the potential for being struck from different directions by errant vehicles for different intersection legs. Thus, each intersection leg will need to be individually addressed by the model, considering all roadside hazards that could potentially be struck.

The existing roadside hazard model should be directly applicable to interchange ramps and speed-change lanes except that the encroachment rates may be higher and the distribution of encroachment angles could be different.

A plan for further development of the roadside hazard model has been developed for FHWA.[6] This plan addresses further improvement to the roadside hazard model that will result from NCHRP Projects 22-8 and 22-9.[19,20] Execution of the FHWA plan is recommended as part of the IHSD model development. Validation of the roadside hazard model is an important part of this plan.

Preliminary Evaluation of State Data Files

A preliminary analysis of the Minnesota and Utah HSIS files has been conducted to determine the practicality of the accident definitions presented in this conceptual plan. The primary emphasis in this preliminary analysis was placed on distinguishing between accidents that are related to roadway sections, intersections, interchange ramps and speed-change lanes, and roadside areas. The Minnesota and Utah files were selected for this purpose because they appear to have the most complete geometric data of any of the HSIS files. It was determined that the accident definitions presented here can be implemented as specified in this plan, but care in interpretation of the data are needed.

The existing data files were generally adequate in distinguishing between roadway section and intersection accidents. Both the Minnesota and Utah files contain variables identifying at-intersection accidents (accidents that occur within the intersection boundaries as defined by the curblines) and intersection-related accidents (accidents that occur on an intersection approach, but are related to the operation of the intersection). While only limited photolog checks of specific accident reports have been conducted, the Minnesota and Utah intersection accident data appear credible, with one exception. A few intersection-related accidents were found in the Minnesota data for fully access-controlled freeways. These appear to be accidents that were related to the operation of ramp terminals and should be classified as ramp accidents.

The ability to distinguish accidents related to interchange ramps and speed-change lanes in the HSIS files has not been verified. The Minnesota files contain an interchange code that is not fully explained in the HSIS documentation. However, it appears that this code can be used to identify ramp accidents. It is not clear whether speed-change lane accidents can reliably distinguished in any State data base without the review of hard copy accident reports.

Both the Minnesota and Utah HSIS accident files contain accident codes that purport to distinguish between on-roadway accidents and run-off-road accidents. However, a preliminary analysis found an unusually low percentage of single vehicle run-off-road accidents in Minnesota on rural freeways and two-lane highways (18 percent, in comparison to over 30 percent which is common in other States). This same problem was present, to a lesser extent in the Utah data. Review of the data for "object struck" from both States indicated that many of the accidents coded as single-vehicle on-roadway accidents actually involved a vehicle leaving the traveled way and shoulder and encroaching on the roadside. For example, it is (by definition) impossible for a vehicle to strike a guardrail, bridge rail, median barrier, utility pole, or embankment unless that vehicle leaves the roadway. The only fixed-object collisions that are generally possible on the roadway are collisions with overpass structures, overhead mast arms used to support traffic control devices, and overhanging branches of trees.

This review provided convincing evidence that the classification of accidents as on-roadway or off-roadway that is performed by investigating officers and/or accident encoders cannot always be relied upon. On the other hand, it was found to be possible to use the reported data for "object struck" codes, together with the on-roadway/off-roadway code, to make a reasonable determination of which accidents involved a vehicle leaving the roadway.

Based on the conclusions of this preliminary evaluation of accident data files, we are reasonably confident that the HSIS files (and other similar State files) are suitable for use in the development of accident predictive relationships. More investigation is needed of the ability to identify ramp and speed-change lane accidents. Because of the potential for problems like the difficulty of distinguishing between on-roadway and off-roadway accidents, the authors have recommended that the IHSD model development team include a central data quality assurance contractor with responsibility to evaluate the adequacy of all data files used in the model development and to apply the recommended accident definitions in a consistent manner.

V. OTHER ELEMENTS OF THE INTERACTIVE HIGHWAY SAFETY DESIGN MODEL

This section presents a conceptual plan for the three elements of the IHSD model other than the accident predictive model. These are: the design policy review module; the design consistency review module; the benefit-cost module; the driver/vehicle dynamics module; and the graphics package.

Design Policy Review Module

The design policy review module is intended to identify and flag elements of the design that do not comply with established AASHTO or State and local design policies. This module would assist designers in evaluating design elements that are not directly addressed by the accident predictive module. Design elements that can be effectively reviewed by this module include:

- Stopping sight distance at vertical and horizontal curves.
- Decision sight distance for avoidance maneuvers on specific road types.
- Passing sight distance for two-lane highways.
- Horizontal curve design:
    - radius.
    - superelevation.
    - superelevation transitions (runoff/runout).
    - pavement widening on curves.
    - curves on turning roadways.
    - high-speed vs. low-speed design.
- Vertical curve design:
    - length of crest vertical curves.
    - length of sag vertical curve.
- Lane width.
- Width of turning roadways.
- Percent grade (maximum/minimum).
- Climbing lanes (are warrants met?).
- Drainage (check for flat spots).
- Pavement cross-slope for normal crown section.
- Shoulder cross-slope.
- Difference in cross-slope between adjacent lanes.
- Difference in cross-slope between traveled way and shoulder.
- Shoulder width.
- Roadside slopes (foreslope/backslope).
- Roadside clear zone width.
- Curb design.
- Median width.

- Ramps:
  - design speed relative to mainline design speed.
  - pavement width.
  - shoulder width.
- Speed-change lanes:
  - length.
  - width.
  - taper lengths.
  - weaving length and number of lanes.
- Horizontal curves at intersections:
  - radius.
  - superelevation.
- Channelizing islands:
  - size.
- Curb return radii.
- Cul-de-sac/turnaround radii.
- Turning lanes.
- Intersection sight distance.

The design policy review module appears to be essential to automating the consideration of safety in the highway design process because it is unlikely that all of the design elements listed above can be addressed by valid statistical relationships in the accident predictive model. In order to conduct this review the user would need to provide the design speed and functional classification of each roadway section as input.

The design policy review module would compare each of these design elements to the established criteria in AASHTO or State and local design policies and identify any discrepancies. The identification of a design element as not in compliance with established design policies does not necessarily indicate that the design should be changed. Exceptions to design policies are often granted when it appears that full compliance with the policy would not be cost effective. However, a design policy review module as part of the IHSD model would provide a means for assuring that such decisions are made explicitly and are well documented.

The design policy review module would be limited to geometric elements of the design. For example, the consideration of drainage in the design policy review would be limited to identifying flat spots in the roadway that might drain poorly. It would not check the hydraulic or hydrologic aspects of drainage design.

The design policy review module will require the development of computer logic to evaluate compliance with AASHTO and/or State and local design policies. Design policy review modules may become a more common part of CADD systems in the future. If comprehensive design policy review modules are generally available as part of future CADD systems, it might not be necessary to develop one as part of the IHSD model. However, use of the design policy review module in the CADD system, even if it was not included in the IHSD model, would still have an important role in ensuring the safety of proposed geometric designs.

Design Consistency Review Module

The design consistency review module would be intended to identify and flag elements of the design that violate design consistency and driver expectancy guidelines. A design consistency review module would go beyond determining whether a design complies with established design policies to determining whether it meets the expectations of drivers. Development of a design consistency review module would require design consistency to be transformed from a generalized concept to specific concept with quantitative definitions and procedures that can be applied. A current FHWA research contract is examining this issue, and future research may be required.

Aspects of a highway design that are candidates for evaluation in a design consistency review module include:

- Changes in cross-section between adjacent roadway sections:
  - compatibility between adjacent cross-sections (lane widths, shoulder widths, shoulder types, curb lines, etc.).
  - adequacy of transition design.
- Consistency of horizontal alignment:
  - consistency of radii of adjacent horizontal curves.
  - sharp curve after gentle curve.
  - sharp curve after long tangent.
  - reverse curves.
  - broken-back curves.
  - adequacy of transitions.
- Consistency of vertical alignment:
  - consistency of K-values for vertical curves.
- Coordination between horizontal and vertical alignment.
- Interchanges:
  - interchange patterns/configuration.
  - coordination of lane balance and basic number of lanes.
  - right-hand vs. left-hand exits.

- Access control measures:

    - at-grade exit/entrance combinations.
    - continuous left-turn lane configuration.
    - U-turn provisions.
    - left-turn lanes.

As in the design policy review module, identification of a design element as inconsistent would not necessarily require that element to be changed. The program would merely flag that design element for review and possible improvement.

In choosing design elements to be included in the design consistency review module, it is recommended that priority be given to inclusion of those geometric elements for which highway agencies most frequently lose tort liability cases. This approach could give the design consistency module an important role in minimizing the tort liability exposure of highway agencies.

It is recommended that the design consistency review model, at least in its initial form, should be based on expert opinion. A panel of experienced designers, traffic safety engineers, and human factors specialists would be established to formulate design consistency guidelines. The design consistency review module in this form would be functionally an expert system, although this does not necessarily mean that it would be programmed using an expert systems shell. More quantitative design consistency concepts could be introduced at a later date, when research to develop and validate those concepts is complete. For example, current FHWA research is developing the concepts of driver workload and operating speed reduction as measures of design consistency.[23] Driver workload is defined as the time rate at which drivers must perform a given amount of mental information processing or specific driving tasks; thus, driver workload increases with geometric complexity. Operating speed reduction is a measure of driver response to complex geometrics; thus, speed reductions may represent a surrogate measure for accident potential on horizontal curves.

The design consistency module should include a procedure to calculate, for each horizontal curve, the speed at which a selected vehicle type (probably a large truck) would skid or roll over, based on a point mass representation of the vehicle. This procedure would warn the user if the margin of safety between the skidding or rollover speed and the design speed of the curve appears to be too small. The vehicle operating speed used in this analysis would be estimated from the design speed of the horizontal curve itself and the design speed of the geometric element(s) upstream of the curve. The design consistency module could identify and flag for the designer those geometric elements that might be in need to redesign to reduce their lateral acceleration demands.

The driver/vehicle dynamics model (see below) would provide the designer with a more sophisticated (and more accurate) method of making such determinations and could be used for indepth investigation of critical situations identified by the design consistency module. The simplified procedures in the design consistency module would not be adequate to evaluate compound horizontal curves or transitions between tangents and curves. However, the design consistency program could advise users of situations in which application of the vehicle dynamics model might be desirable.

Benefit-Cost Module

The benefit-cost module will provide a capability for the IHSD model to determine the cost effectiveness of any proposed change in a design, involving an additional increment of construction cost, that is proposed specifically to improve safety. The benefit-cost module would assess whether this additional expenditure can be justified economically on the basis of accident reduction alone. No attempt will be made to incorporate other types of benefits, such as traffic operational or environmental benefits, in the program. Consideration of nonsafety benefits would make the benefit cost program much more complex. Other computer programs already exist to evaluate traffic operational and environmental effects, at least for some types of projects.

The benefit-cost module would operate in conjunction with the accident predictive model. The IHSD model user would first evaluate one geometric alternative using the interactive features of the IHSD program. This first design alternative would be assigned a name (for example, ALT1) by the IHSD program user and the predicted safety performance of that alternative would be stored in a file at the user's request. Then, the user would modify the original design to create a second geometric alternative. That second geometric alternative would be assigned a name (say, ALT2) by the program user and its safety performance would also be stored in a file at the users request.

In the benefit-cost module, the user would select two or more geometric alternatives by name for analysis (in this case, ALT1 and ALT2). The user would then be asked to enter the estimated construction cost for each alternative. To keep the IHSD model from becoming too complex, the authors recommend that the user estimate the construction cost from some source other than the IHSD program. However, if the IHSD model was fully integrated with a highway agency's CADD system, it should be possible to develop a construction cost estimate directly from construction quantities and unit costs generated in the CADD system.

The safety benefit-cost ratio for any proposed improvement would be calculated as:

$$B/C = \frac{\sum_{i} (N_{i1} - N_{i2}) AC_i}{(CC_2 - CC_1) CRF} \quad \textbf{(12)}$$

where: N_{ij} = expected annual number of accidents of accident severity level i for design alternative j.

AC_i = accident cost ($) for accident severity level i.

CC_j = estimated construction cost ($) for design alternative j.

CRF = capital recovery factor for n years at x% interest

n = service life of proposed improvement (years).

x% = minimum attractive rate of return (interest rate).

The results would be displayed for the user or printed at the user's option.

A proposed change from design alternative ALT1 to ALT2 would be justified on the basis of safety alone if the value of B/C calculated using equation (12) is 1.0 or greater. The benefit-cost module should flag any comparison requested by the user for which the annual accident frequencies predicted for the two alternatives are not statistically significantly different from one another. Benefit-cost comparisons between alternatives that differ so little in the expected number of accidents may be inappropriate. It would also be desirable to display the range of possible benefit-cost ratios based on the confidence intervals for accident rate of the design alternatives being compared.

It is recommended that the benefit-cost module include the capability to consider the effects of other nonsafety benefits and costs that can be quantified in monetary terms, but the IHSD model will not provide a method to quantify benefits or costs other than safety. However, if the user has these data available from external sources, a method to incorporate them in the benefit-cost module will be provided.

Equation (13) presents a modified version of equation (12) that incorporates consideration in the benefit-cost analysis of other annual benefits (OAB), other capital costs (OCC), and other annualized costs (OAC):

$$B/C = \frac{\left[\sum_i (N_{i1} - N_{i2})\ AC_i\right] + OAB}{(CC_2 - CC_1)\ CRF + (OCC)CRF + OAC} \tag{13}$$

where:

OAB = other (nonsafety) annual benefits ($).
OCC = other capital costs ($).
OAC = other annualized costs ($).

In addition, to reduce the reliance on accident cost data in the economic analysis, the benefit-cost module should permit estimation of the annualized construction cost per accident reduced. The annualized cost per accident would be computed as:

$$\text{Cost per accident reduced} = \frac{(CC_2 - CC_i)\ CRF}{\sum_i (N_{i1} - N_{i2})} \tag{14}$$

where the parameters in equation (14) are the same as those in equation (12). Equation (14) has more limited application than equation (12). For example, equation (14) provides no method for the user to determine whether the additional construction cost is justified on the basis of safety, except by the exercise of the user's judgment concerning whether the cost per accident reduced is reasonable. Equation (14) is also not sensitive to the relative severity of the accidents reduced. Equation (14) is strictly a safety analysis technique; there is no appropriate method to include nonsafety benefits.

Driver/Vehicle Dynamics Model

The IHSD model should include a driver/vehicle dynamics model capable of simulating vehicle operation as influenced by roadway geometry, driver preferences and performance limitations, and vehicle performance limitations. This model would provide an indication of the loss-of-control potential for specific vehicle types traversing the geometric alternatives being considered by the designer. The driver/vehicle dynamics model would provide IHSD model users with a tool that is more accurate than the procedures in the design consistency module (based on the point mass representation of the vehicle) that could be applied to the analysis of horizontal curves flagged by the design consistency module, compound horizontal curves, and transitions between curves and tangents.

The driver/vehicle dynamics model should be capable of running a vehicle through the geometrics of any given design alternative and generating plots of (1) vehicle speed, (2) the lateral position of the vehicle (relative to the centerlines, lane lines, and edgelines), and (3) the lateral accelerations experienced by the vehicle.

Color should be used to highlight these plots. For example, the lateral position plot could be colored yellow if any portion of the vehicle approached within 0.3 m (1 ft) of a centerline, lane line, or edge line, and could be colored red if any portion of the vehicle crossed the centerline, lane line, or edge line. The lateral acceleration plot could be colored yellow when the vehicle approached within a specified margin of safety of its skidding or rollover point and could be colored red if a skid or rollover occurred.

There are a number of existing vehicle dynamics models, including HVOSM, Phase-4, ADVS, and VDNL. However, these existing vehicle dynamics models include, at best, only a rudimentary driver model. Typically, a vehicle dynamics model includes a driver path following algorithm to simulate the driver's steering input, but vehicle dynamics models typically use user-specified vehicle speed and acceleration/deceleration rates, rather than trying to model driver speed selection.

Realistic driver behavior must be included in any vehicle dynamics model to make it a useful part of the IHSD model. It is for this reason that we have named the required model a *driver*/vehicle dynamics model, rather than simply a vehicle dynamics model, as its predecessors have been known. Research should be conducted to develop an improved driver model that includes not only driver path following, but also driver speed selection based on realistic driver reactions to the highway geometrics and to traffic control devices such as advisory speed signing. It may be necessary to include a user-selected driver aggressiveness factor or to make a safety-conservative choice and pre-select a relatively aggressive driver. The revised driver model should be developed from existing driver speed-selection logic in traffic operational simulation models, from new driver research, or from some combination of the two. A specific plan for this research should be developed. This plan should recommend the appropriate applications of specific data collection approaches, such as field data collection and driving simulators in this research.

The driver/vehicle dynamics model should allow the user to select a passenger car, a single-unit truck, or an articulated combination truck, as the vehicle to be simulated. The model should have the capability to simulate all vehicle characteristics that are potentially related to steering and path following, tire/pavement friction, and rollover potential. For example, truck suspension characteristics must be considered in determining both truck offtracking and rollover potential. External factors that influence vehicle dynamics include driver steering inputs (path following), driver speed selection and acceleration/deceleration preferences, and pavement surface friction. The driver path following model should be based on the path deviations that would be expected of a normal driver following a horizontal curve. However, consideration should also be given to including an option for the model to simulate the larger path deviations that might be representative of an impaired driver or the total lack of path following that might result from a driver falling asleep.

The development of the driver/vehicle dynamics model will require research on driver control, path following, and speed selection. There is a general lack of driver models that take into account such important factors as perception, psychomotor control, cognition, decision making, and risk perception. A better understanding is needed of the kinds of information drivers require to keep themselves on the roadway, how drivers use this information, and how drivers translate the available information into decision/control responses.[24]

Consideration should also be given to how the presence of other traffic on the road affects vehicle guidance and control. It seems likely that the presence of other traffic on the road, in the same or the opposing direction, would help drivers in guiding their vehicles, but this effect has not been modeled.

The driver/vehicle dynamics model could be developed by modification of one or more existing vehicle dynamics models to incorporate the new driver model. However, recent advances in modeling technology, such as AUTOSIM, have made it possible to develop a new model with the same or less effort than modifying an existing model. Therefore, the development of a new model is recommended.

The driver/vehicle dynamics model will also have utility in research to evaluate the consequences of vehicles running off the road at particular locations, angles, and speeds. To be completely useful for this purpose, the vehicle dynamics model would need to be integrated with an impact model (e.g., based on finite element analysis). With such a combination, researchers could generate some of the data needed to improve the roadside submodel of the accident predictive model. However, the use of the driver/vehicle dynamics model for such applications is considered to be strictly a research activity that has application in the IHSD model development. There is no need to make the capability for roadside modeling available to IHSD model users; the driver/vehicle dynamics model should be available as a stand-alone model for sophisticated users who can find other applications for it. In other words, the roadside portion of the IHSD model may be developed using some outputs from the vehicle dynamics model, but the IHSD model would not provide users with the capability to apply the vehicle dynamics model for roadside modeling.

Graphics Package

The IHSD model should include a graphics package that allows designers to review the geometrics of each design alternative before assessing its safety performance and to review the geometrics again following the safety assessment as part of deciding what geometric changes might be appropriate to improve safety. The graphics package should include the capability to generate screen displays of a:

- Plan view of the roadway geometrics centered on any station (i.e., location) selected by the user.
- Profile view of the roadway geometrics centered on any station selected by the user.

- Plan view in the upper half of the screen and a profile view in the lower half of the screen centered on any station selected by the user.

- View of the roadway geometrics from the driver's perspective or an elevated perspective, looking in either direction of travel from any station selected by the user.

For the plan and profile views, the user should be able to select the range of stations to be included in the display and, thus, the scale of the plan or profile.

The geometric data needed to predict safety performance in a level 1 analysis can be entered and modified through an interactive data entry module within the IHSD model. This interactive data entry module should also include the capability to store and retrieve files of geometric data for specific design alternatives. In such a level 1 analysis, the graphics package will provide the means for the user to display the data as it entered and confirm its accuracy. Geometric data for a level 2 analysis will be entered and modified through a CADD system. The graphics package in the IHSD model should have the capability to display a design alternative imported from a CADD system. However, modification of the design for a level 2 analysis should be accomplished in the CADD system and not in the IHSD model.

Figure 8 illustrates a plan view of a basic section alignment that might be generated as part of a level 1 analysis. The display would show horizontal alignment and lane and shoulder widths. A more detailed display of a plan view, such as might be generated for a level 2 analysis is shown in figure 9. The display for a plan view could potentially include not only horizontal curvature and lane and shoulder widths, but also pavement markings, traffic control devices, special lanes, intersection details, and roadside features. The displays included in both figures 8 and 9 should include marks that indicate the centerline stations.

Figure 10 illustrates a centerline profile of the roadway such as might be generated by the graphics package. This view shows the grades and vertical curves along the roadway centerline. The horizontal scale shows the stations along the roadway centerline, and the vertical scale shows the elevation. The profile display could also be developed to include the capability to display pavement edge profiles.

Figure 11 shows a view from the driver's perspective including the level of detail that would typically be available in a level 1 analysis. Figure 12 shows added details that could be available in a level 2 analysis.

The driver's perspective display planned for the IHSD model would provide a static view of the roadway. However, static views could be displayed in sequence to create a dynamic view equivalent to what the driver would see while traveling down the road. Addition of this capability is considered to have a lower priority than other aspects of the IHSD model.

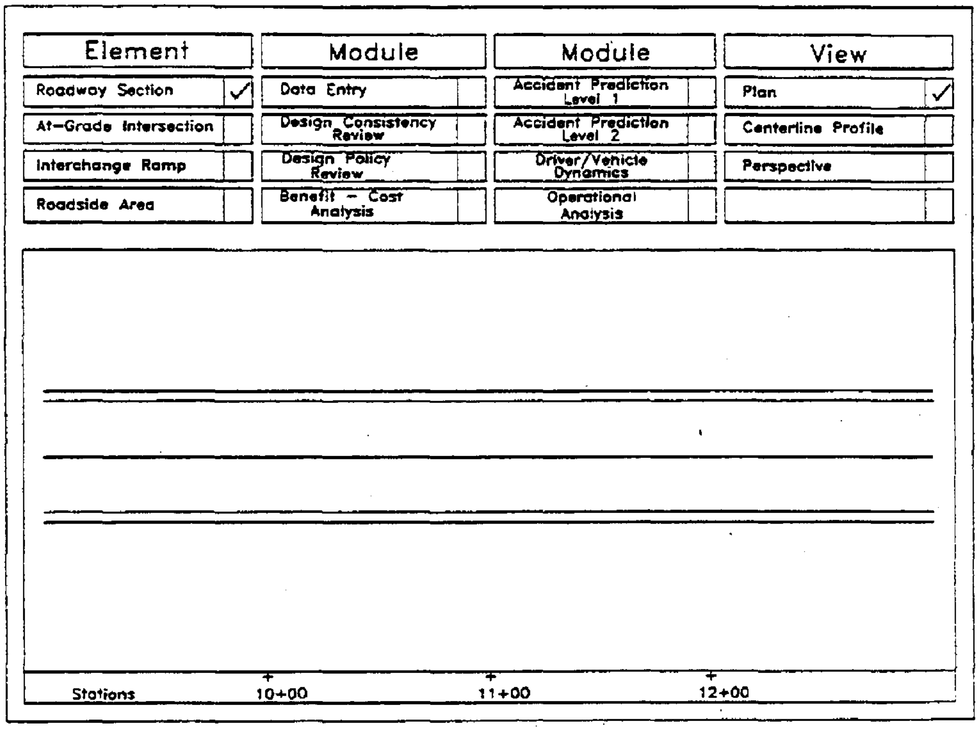


Figure 8. Screen display of plan view for level 1 analysis.

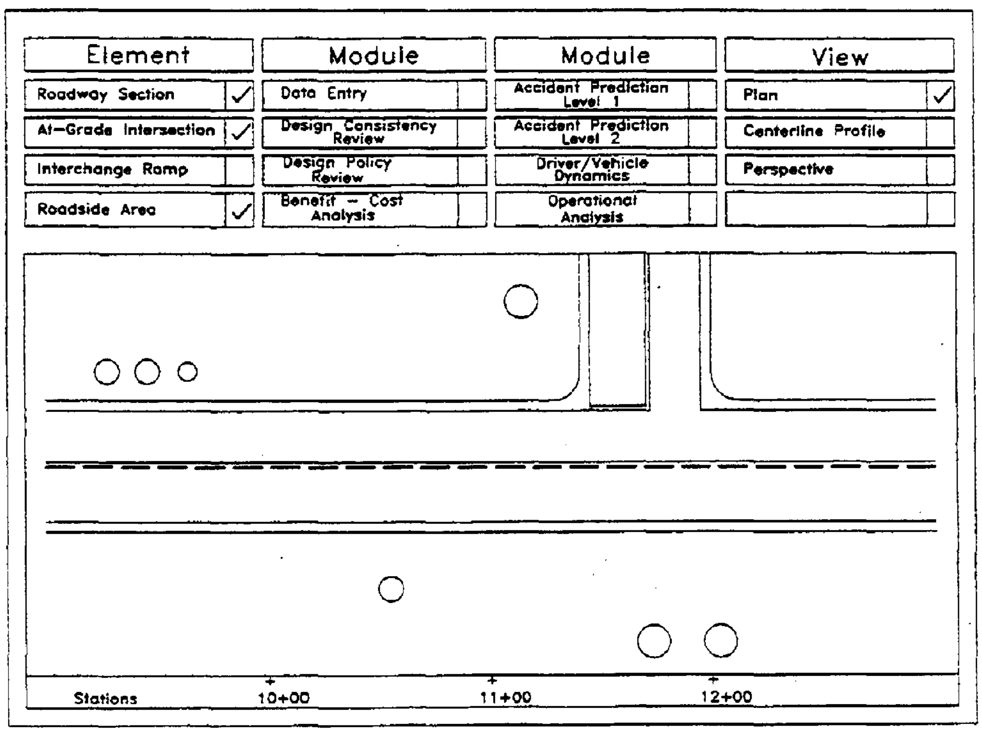


Figure 9. Screen display of plan view for level 2 analysis.

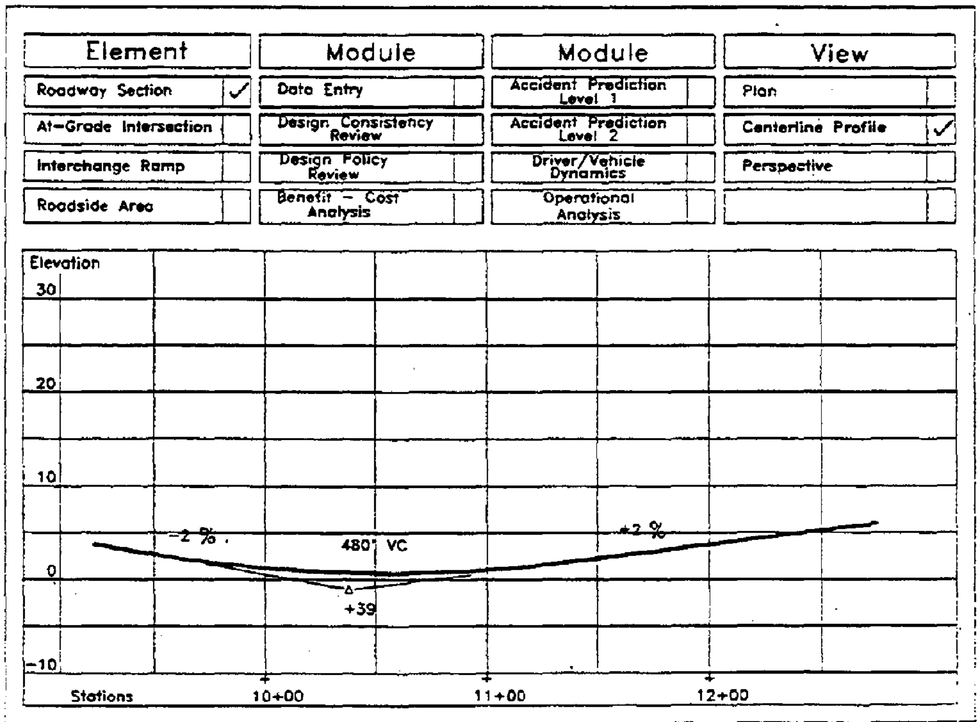


Figure 10. Screen display of centerline profile display.

A number of highway agencies have existing graphics packages that have been developed for use in conjunction with their CADD systems. Such existing packages should be reviewed to determine if one or more of them might be appropriate for use with the IHSD model.

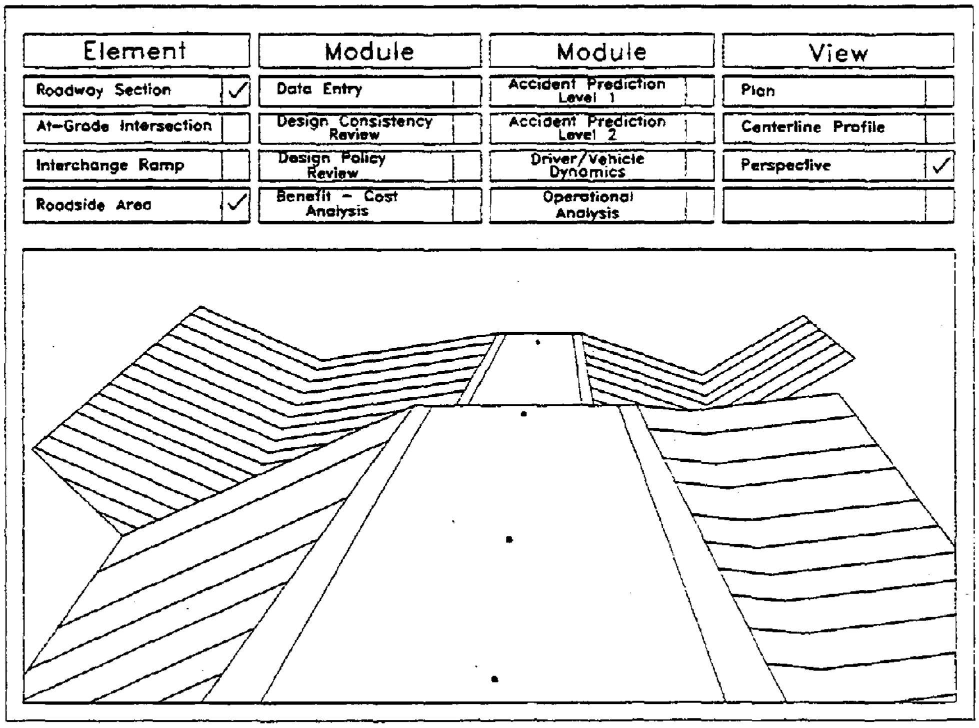


Figure 11. Screen display of perspective view for level 1 analysis.

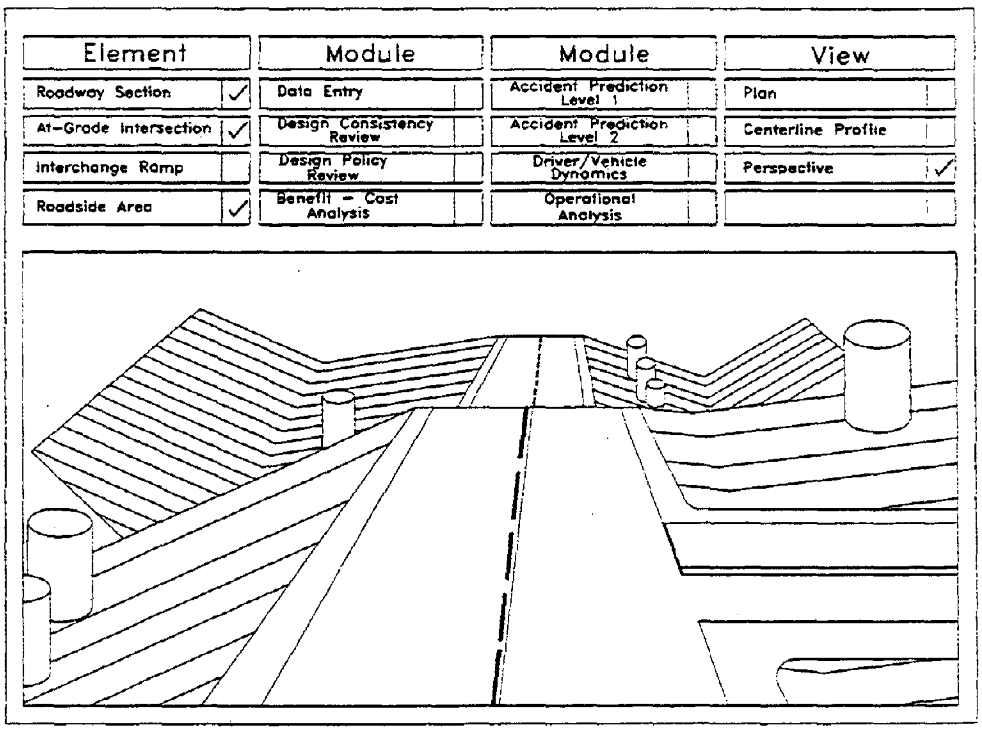


Figure 12. Screen display of perspective view for level 2 analysis.

VI. RESEARCH NEEDS

This section summarizes the research and development needs for development of the IHSD model. The authors of this plan feel strongly that a usable IHSD model must be based on the results of new safety research, performed in accordance with the guidelines presented in this plan. The key to this new research is use of consistent accident definitions, such as those presented in this report, and the use of improved data bases such as the HSIS. Existing safety relationships in the literature are simply too fragmented and inconsistent to even consider the possibility that they could be used together in a coherent model.

The following discussion identifies the drawbacks of existing safety research and documents the need for, and the recommended approach to, the development of new safety relationships. The section concludes with a summary of 22 research problem statements that address the research required to develop the IHSD model. These research problem statements are presented in full in appendix B.

Need for New Safety Relationships

The plan for the accident predictive model, as presented in sections III and IV of this report, is based on the development of relationships between accidents and geometric features in the forms suggested in equations (1) through (9). It is possible that the IHSD model could be developed by adapting existing safety relationships in the literature, particularly for some roadway types. Several potentially useful relationships are available in the literature. For example, Zegeer et al. developed the following safety predictive relationship for rural two-lane highways:[7]

$$AO/M/Y = 0.0019\ (ADT)^{0.8824}\ (0.8786)^{W}\ (0.9192)^{PA}\ (0.9316)^{UP}\ (1.2365)^{H}\ (0.8822)^{TER1}\ (1.3221)^{TER2} \qquad (15)$$

where: AO/M/Y = accident rate per mi per year for accident types related to cross-section elements (single-vehicle plus opposite direction head-on, opposite direction sideswipe, and same-direction sideswipe accidents)

ADT = average daily traffic volume (veh/day)

W = lane width (ft)

PA = average paved shoulder width (ft)

UP = average unpaved shoulder width (ft)

H = roadside hazard rating (1 to 7 scale)

TER1 = 1 if level terrain; 0 otherwise

TER2 = 1 if mountainous terrain; 0 otherwise

There are, however, several major problems with developing the IHSD models based on existing safety relationships. These include:

- Only a few roadway types such as freeways and two-lane highways have been modeled.

- The existing models are not comprehensive; i.e., they do not include all geometric variables that are potentially of interest to the designer.

- Existing models use varying safety MOE's that are not always compatible. This makes it difficult to combine results from different studies.

- Existing models have not been based on the accident classifications presented in section IV, which make a careful distinction between on-roadway and roadside accidents and use a different modeling approach for each. Equation (15) is one of the few models that includes consideration of the roadside. However, while the roadside variable in equation (15) might be appropriate for level 1 analysis, the roadside hazard rating is too general for use in level 2 analysis.

Existing models have been limited by the difficulty of developing models that incorporate the incremental effects of geometric features on accidents. These difficulties arise because the safety effects of many geometric features are small and are highly correlated with one another. For example, Cleveland found that safety models could only be based on "bundles" on interrelated geometric variables (i.e., combined effects of lane width, shoulder width, roadside design, etc.), but that the interactions between the variables in the "bundle" could not be isolated.[25] It is possible that, in the development of the IHSD model, the interactions between highly correlated ("bundled") variables may need to be postulated.

In order for the IHSD model to be feasible, it will be necessary to demonstrate or postulate the incremental effects of specific geometric features. There are several reasons to believe that an effort to develop predictive relationships for the IHSD model can be more successful than some previous efforts:

- Better safety data bases are available now than ever before. Past accident research has often been based on accident data bases of limited size that had to be laboriously assembled for one particular research study. Many States have now developed accident records systems that can link together accident, geometric, and traffic volume data. Several such data bases have been assembled in the FHWA HSIS, which could be an excellent tool to develop relationships for the IHSD model.

- The conceptual plan for the IHSD model is based on careful distinction between on-roadway and roadside accidents and classification of on-roadway accidents as related to specific roadway sections, intersections, or interchange ramps. Application of these definitions should create a more consistent data base.

- An integrated approach to development of the IHSD models will use a uniform set of safety MOE's, which should reduce the incompatibility problems inherent in previous research. If several contractors are involved in developing different elements of the IHSD model, it is essential that there be overall guidance to coordinate their efforts.

Development of New Safety Relationships

The development of reliable, valid safety relationships for the accident predictive models will require a major research undertaking that is carefully planned and carefully executed. The following guidelines are recommended to ensure that this major effort produces useful results:

- Statistical modeling to develop accident prediction models for specific geometric elements and specific highway and area types should be based on carefully developed experimental plans. These experimental plans should specify the data sources to be used, the sample sizes required, the independent and dependent variables to be considered, the data collection procedures that will be used to obtain any necessary data not included in existing data files, and the statistical modeling approaches to be employed. Particular emphasis should be placed on the use of statistical modeling approaches that are appropriate for the proposed application. These experimental plans should be subject to expert peer review before they are executed.

- The experimental plans for accident predictive models should explicitly address the issues of data quality and statistical reliability. Data quality issues should include not only the accuracy of the accident, geometric, and traffic volume data to be used in modeling, but also the appropriateness of the selected sites. It may not be appropriate to perform statistical modeling using every available site. Instead, there should be a screening process by which certain sites with extremely high accident rates and/or unusual driver populations can be eliminated as outliers; e.g., sites near several large taverns with large concentrations of accidents involving impaired drivers where the effects of geometrics could be overwhelmed by the effects of the impaired drivers. In addition, there should be a protocol that specifies which types of accidents are to be used in statistical modeling. Some accident types that bear no obvious relationship to geometrics should be omitted in the model development efforts and should, instead, be considered as part of the basic roadway section or intersection accident rates.

- The plans for developing safety relationships should be sensitive to the issue of accident migration. Accident migration occurs when the geometrics of one location are improved which reduces accidents at that location but increases accidents at other locations. For example, flattening a horizontal curve may reduce accidents involving impaired drivers at that curve, but those same drivers (because they are impaired) may then have an accident at another location as they proceed down the road. Because of the potential for accident migration, safety relationships may overstate the magnitude of the benefits that can be obtained from geometric improvements.

- The accident predictive models should be developed with post-1986 accident data. Accident rates, and especially severities, have decreased substantially since 1986 as mandatory seat-belt laws have been enacted and seat-belt usage has risen dramatically. Thus, the use of pre-1986 data could be misleading in predicting the safety effects of future geometric improvements. Similarly, careful attention should be paid to the accident severity-reducing effects of air bags in future data as vehicles equipped with air bags become more prevalent.

- Validation of the accident predictive models developed for use in the IHSD model should be a major concern. Many past statistical relationships developed to predict accidents have not been very reliable, and such relationships are not trusted by potential users. Therefore, it is vital to the credibility of the IHSD model that the accident predictive relationships used in the model have been demonstrated to be credible. Validation of these relationships should be performed both with data sets that are independent of the data used to develop the model and, whenever possible, by validation methods that differ from the method by which the model was developed. For example, it may be appropriate to use a driver/vehicle dynamics model to validate relationships developed from accident data or to use accident data to validate a roadside model developed from encroachment data. Each experimental plan for the development of accident predictive models should recommend approaches to the validation process and the expert peer reviewers of those experimental plans should also be asked to recommend validation techniques. Both the predictive models developed and the process used to validate them should be subject to expert peer review after they are complete.

The research problem statements discussed in the next section and presented in appendix B address the research required to develop the IHSD model.

Research Problem Statements

This section describes a series of 22 research problem statements that provide a practical and realistic approach to development of an IHSD model. Twelve of these 22 problem statements deal with the development of the accident predictive model, 8 deal with the other modules of the program, and 2 deal with fitting the various modules together into a working package. Two of the problem statements include demonstration of prototype software that practicing highway engineers in State highway agencies or consulting firms would be invited to test and evaluate. The comments from these practicing highway engineers would be considered in further development or revision of the models.

The plan for future research has been developed to enable it to be executed as part of FHWA's ongoing contract research program. As a practical matter, the plan recognizes that FHWA will probably elect to develop the IHSD model using multiple contractors to perform various parts of the research and development activities. The 22 research problem statements presented here do not necessarily represent 22 separate research contracts; FHWA could choose to break apart or combine these research tasks in whatever way that was felt to be most appropriate. However, if multiple contractors are used, *a key element of the plan would be strong coordination from FHWA and from a central data quality contractor who would evaluate and prepare the data files for analysis by other contractors*. All data analyzed by any contractor developing models for a specific portion of the accident predictive model—intersections, for example—would be provided to that contractor by the data quality contractor after an initial check to determine that the data quality appears acceptable and the data file is compatible with the data files being used by other contractors. The models developed by each contractor would be subject to peer review by recognized experts. This peer review would be organized by the data quality assurance contractor.

The 22 research problem statements recommended for development of the IHSD model are as follows:

<u>Accident Predictive Model</u>

#1 Data Quality Assurance and Coordination

#2 Experimental Plan for Predictive Models for Roadway Sections

#3 Development of Predictive Models for Roadway Sections

#4 Experimental Plan for Predictive Models for Intersections

#5 Development of Predictive Models for Intersections

#6 Preliminary Demonstration of the IHSD Model

#7 Experimental Plan for Predictive Models for Ramps and Speed-Change Lanes

#8 Development of Predictive Models for Ramps and Speed-Change Lanes

#9 Experimental Plan for Predictive Models for Roadside Areas

#10 Development of Predictive Models for Roadside Areas

#11 Validation and Revision of Accident Predictive Models

#12 Software Development to Implement Accident Predictive Models

Other Elements of the IHSD Model

#13 Development of Procedures for Design Policy Review

#14 Development of Procedures for Design Consistency Review

#15 Development of Procedures for Benefit-Cost Analysis

#16 Development of Graphics Package

#17 Software Development to Implement Design Policy and Design Consistency Reviews

#18 Detailed Plan for Development of Driver/Vehicle Dynamics Model

#19 Development of Driver Model for Driver/Vehicle Dynamics Model

#20 Software Development for Driver/Vehicle Dynamics Model

Final Testing and Revision of IHSD Model

#21 User Evaluation of the IHSD model

#22 IHSD model Revisions and Development of Final Implementation Package

Figure 13 presents a flow diagram showing how these research problems fit together into the overall development of the IHSD model. Each of these 22 research problem statements is presented in detail in appendix B of this plan.

No attempt has been made to identify the specific cost or time requirements for completing the work called for under each research problem statement. However, it is

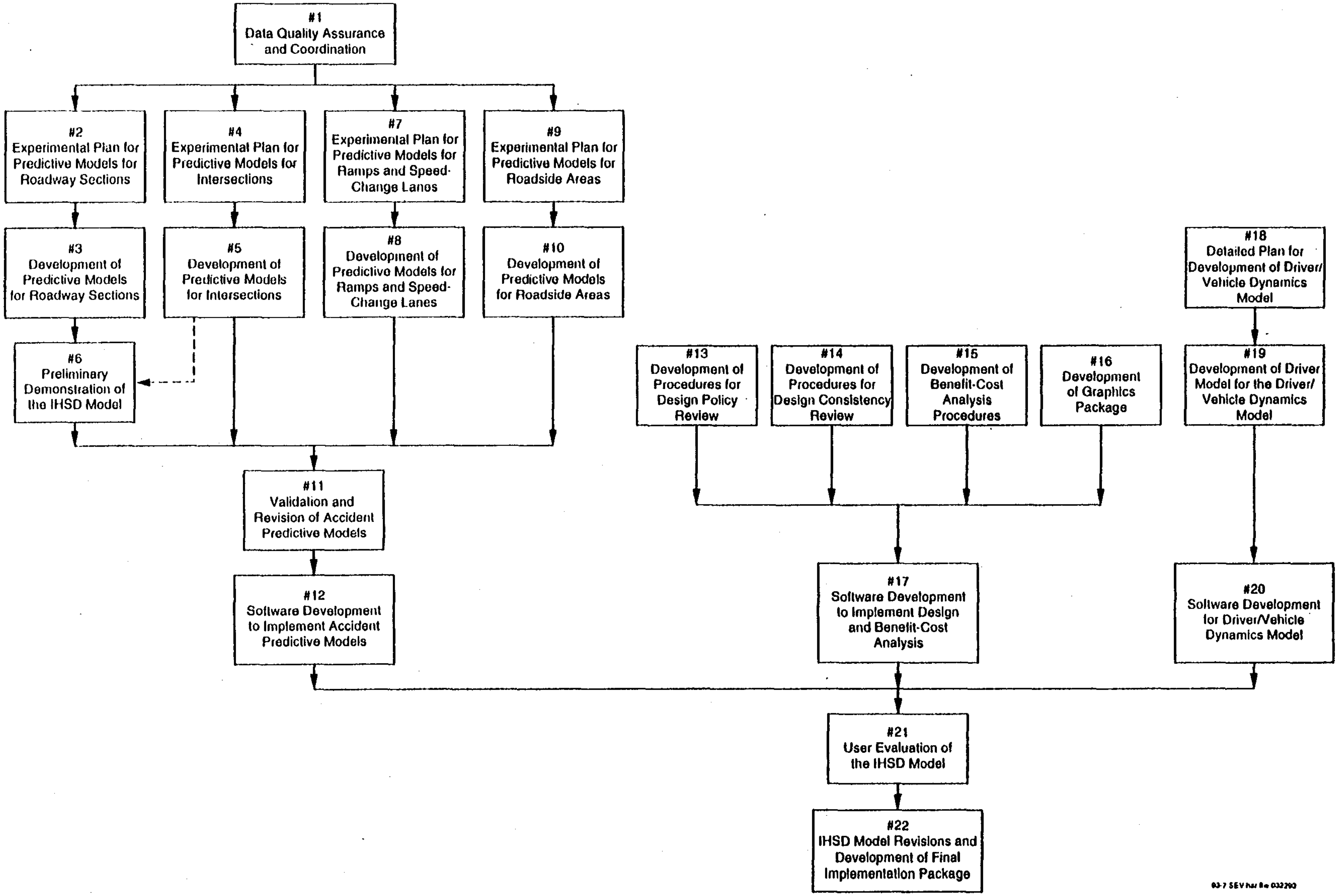


Figure 13. Recommended research program for development of the IHSD model.

expected that the research would require an average of 3 to 5 person-years of effort per problem statement. The general sequencing of the research is indicated by figure 13, but there is flexibility to start some projects earlier than others as funds become available.

Priorities for IHSD Model Development

The expert panel convened during the development of this plan was asked to recommend priorities for development of the IHSD model. This was done by rating priorities for particular issues on a scale from 10 (high priority) to 1 (low priority).

Table 2 presents the priorities recommended for development of the various elements of the IHSD model. The table shows that the highest priority is assigned to the accident predictive model, which received a rating of 9 out of a possible 10 points. Relatively high priorities were also assigned to development of the design consistency review module, the design policy review module, and the interactive data entry module. Lower priorities were generally assigned to the graphics packages, the benefit-cost module, and the driver/vehicle dynamics model.

Table 2. Recommended priorities for development of IHSD model elements.

IHSD Model Element	Priority rating[1]	Maximum rating	Minimum rating
Accident predictive model	9.0	10	5
Design consistency review module	8.0	10	5
Design policy review module	7.7	10	5
Interactive data entry module	7.6	10	2
Graphics package (plan view)	7.0	10	2
Benefit-cost module	6.6	10	3
Graphics package (perspective view)	6.6	10	1
Graphics package (profile view)	6.6	9	2
Driver/vehicle dynamics module	5.7	8	3

[1] Priority ratings were made on a scale from 10 (highest priority) to 1 (lowest priority).

The expert panel was also asked to assign a priority to the incorporation in the IHSD model of a dynamic view from a driver's perspective of a drive through the geometrics for any specific design alternative. This capability was assigned a priority rating of 5.1, lower than any of the other IHSD model elements included in table 2. The general assessment of the expert panel was that such a capability was a desirable, but not a necessary, feature of the IHSD model.

Table 3 presents the priorities that were recommended for the development of the various submodels of the accident predictive model. Development of the accident predictive submodels for roadway sections and roadside areas were assigned the highest priorities, with lower priorities assigned to the submodels for at-grade intersections and interchange ramps and speed-change lanes.

Table 3. Recommended priorities for development of accident predictive submodels.

Accident predictive submodel	Priority rating[1]	Maximum rating	Minimum rating
Roadway sections	9.1	10	7
Roadside areas	8.4	10	5
At-grade intersections	7.3	10	1
Interchange ramps and speed-change lanes	6.1	8	5

[1] Priority ratings were made on a scale from 10 (highest priority) to 1 (lowest priority).

Table 4 presents the priorities that were recommended for development of accident predictive models for specific highway and area types. Rural two-lane highways were assigned the highest priority, because of the vast extent of the rural two-lane highway system and the potential for safety improvements in the design of projects on rural two-lane highways. The lowest priorities were assigned to the development of accident predictive models for freeways because freeways already have very low accident rates and because the geometrics of most freeway projects are already about as good as we know how to make them; thus, there is very little potential to improve the design of freeway projects through the application of an IHSD model. The other highway types were assigned priorities that fall between the rural two-lane highways and urban and rural freeways.

IHSD Model Development Guidelines

The following guidelines for development of the IHSD model are recommended:

- A small portion of the IHSD model should be selected for initial development with the objective of configuring that portion of the model as a working prototype as soon as possible. The prototype version of the model should include selected accident predictive models; e.g., roadway sections and intersections on rural two-lane highways. The inclusion of initial versions of the design consistency review module and the graphics package would also be desirable. The prototype version should be useful both for informing users about the potential applications for the

Table 4. Recommended priorities for development of accident predictive models for specific highway and area types.

Highway and area type	Priority rating[1]	Maximum rating	Minimum rating
Rural two-lane highways	8.7	10	7
Rural multilane undivided nonfreeways	7.7	10	4
Urban multilane undivided arterials	7.1	9	5
Rural multilane divided nonfreeways	6.7	10	4
Urban multilane divided arterials	6.4	10	3
Urban two-lane arterials	5.9	10	1
Urban freeways	5.3	8	2
Rural freeways	4.6	7	1

[1] Priority ratings were made on a scale from 10 (highest priority) to 1 (lowest priority).

IHSD model, learning more about user needs for the model, and developing support for the model in the user community.

- A staged development process may be appropriate for the IHSD model, with several intermediate versions between the prototype version of the model and the final version containing all of the capabilities envisioned in this report.

- Both the prototype and all subsequent versions of the IHSD model should undergo extensive testing before their release to ensure that they are working properly and provide the intended results. Poorly-written computer software can give a model a bad reputation, even when the underlying safety research is sound.

- The IHSD model software should be developed to minimize or prevent misuse of the model. For example, if a user tries to apply the model to a problem for which it was not intended, either a warning should be provided to the user or the model should not analyze the problem at all. For example, the authors envision that the driver/vehicle dynamics model included in the IHSD model would be restricted to certain specific vehicles and certain specific applications. Sophisticated users could obtain the driver/vehicle dynamics model as a stand-alone program and apply it as they wished, but the model should prevent unsophisticated users from possibly misusing the model.

- Before the IHSD model is released to users, a formal plan should be developed for maintaining and updating the model. This plan should indicate what maintenance and updating activities will be undertaken by FHWA and what data can be supplied and updated by users. The

VII. COMPUTER REQUIREMENTS

The computer and software environment in which the IHSD model will run has received preliminary consideration in the development of this conceptual plan. We envision a model that will run on a microcomputer such as an IBM PC or compatible, but would also be transportable to other environments. The computer model could be implemented as either a:

- Stand-alone model on a microcomputer, minicomputer, or mainframe. This may be most appropriate for level 1 analysis (location study), as defined in section III of this plan.
- Software package that could be integrated with highway capacity software, such as the Highway Capacity Software (HCS) system. While it might be too complex to envision a single software package to do both traffic operational and traffic safety analyses, both packages could be developed to share a common input format for geometric and traffic data. This approach has been used in development of the Arterial Analysis Package (AAP) that allows NETSIM, SOAP, and PASSER to share the same input format. This approach may be most appropriate for level 1 analysis (location study).
- Stand-alone model that uses as input, geometric data output from a computer-aided design and drafting (CADD) system such as Intergraph or AUTOCAD. This might allow the safety package to use existing coordinate geometry (COGO) files. This approach is potentially applicable to both level 1 and level 2 analyses.
- Software module that can be integrated into and used interactively with CADD software such as Intergraph or AUTOCAD. This approach is potentially applicable to both level 1 and level 2 analyses.

In all probability, the interactive highway design model may assume several different forms in different stages of its development, first as a stand-alone package and later integrated with other software. In all forms, the package should be interactive; i.e., it should allow the user to change elements of the geometric design and directly determine the safety effects of those changes. No attempt has been made at this time to specify the computer requirements for the IHSD model in greater detail because both computer hardware and CADD system capabilities are likely to improve greatly before any software development for the IHSD model begins.

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table of contents

maintenance and updating plan should include a plan for the funds required to ensure that new research findings can be incorporated in the IHSD model and made available to users as they are developed.

Management of IHSD Model Development

The development of the IHSD model is a major R&D undertaking that requires a nontraditional management approach. It is recommended that FHWA establish two expert panels or steering committees to help guide the IHSD model development effort. The panels would provide expert review of experimental plans and research results and would promote continuity between independent research efforts. One panel would be made up of experienced geometric designers who would be charged with ensuring that the final IHSD model would be a tool of practical utility to designers. The second panel would be composed of researchers charged with ensuring that each research effort conducted as part of the IHSD model development is well coordinated with other research efforts and produces valid results.

These two panels would meet approximately twice per year to review progress on the IHSD model development. Researchers involved in the IHSD model development would make presentations to the panels and participate in discussions about the direction of model development activities. Continuity in membership of these panels over a period of years while the IHSD model was under development would be important. This would probably involve a time commitment too large to expect from volunteers, so the panel members may need to be hired as consultants, perhaps by the central data quality contractor discussed above.

APPENDIX A: BASIC EXPECTED ACCIDENT RATE TABLES DEVELOPED BY CALIFORNIA DEPARTMENT OF TRANSPORTATION

This appendix presents a table of basic expected accident rates and severity distributions for roadway sections, intersections, and ramps developed by the California Department of Transportation.[9] These rates and severity distributions are currently used for accident surveillance in California, but illustrate the form in which basic accident rates could be developed for use in accident predictive models.

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	HIGHWAY TYPE	TERRAIN OR ADT	AHS	AREA	ACC COSTS ($1000) F+I	ALL
H 01	1.65	.45/	4.0	46.3	50.3	CONVENTIONAL 2 LANES OR LESS	FLAT	≤55	RURAL	62.3	32.6
H 02	1.15	.45/	4.2	45.7	49.9	CONVENTIONAL 2 LANES OR LESS	FLAT	>55	RURAL	65.1	33.7
H 03	2.00	.45/	3.0	51.0	54.0	CONVENTIONAL 2 LANES OR LESS	ROLL	≤55	RURAL	48.1	27.1
H 04	1.35	.45/	3.9	48.7	52.6	CONVENTIONAL 2 LANES OR LESS	ROLL	>55	RURAL	59.2	32.3
H 05	2.45	.45/	2.9	54.1	57.0	CONVENTIONAL 2 LANES OR LESS	MTN	≤55	RURAL	45.4	26.9
H 06	1.55	.45/	3.4	51.8	55.2	CONVENTIONAL 2 LANES OR LESS	MTN	>55	RURAL	51.7	29.7
H 07	3.90	.000	1.3	40.6	41.9	CONVENTIONAL 2 LANES OR LESS		<45	SUBURBAN	28.9	13.6
H 08	2.60	.000	2.0	45.0	47.0	CONVENTIONAL 2 LANES OR LESS		45-55	SUBURBAN	35.1	17.8
H 09	2.20	.000	2.2	45.0	47.2	CONVENTIONAL 2 LANES OR LESS		>55	SUBURBAN	37.3	18.9
H 10	4.30	.000	.6	37.3	37.9	CONVENTIONAL 2 LANES OR LESS		<45	URBAN	18.6	8.6
H 11	2.90	.000	1.5	42.3	43.8	CONVENTIONAL 2 LANES OR LESS		≥45	URBAN	28.2	13.8
H 12	1.20	.000	4.3	48.4	52.7	CONVENTIONAL 3 LANES			RURAL	63.6	34.7
H 13	1.60	.000	3.8	50.0	53.8	CONVENTIONAL 3 LANES			SUBURBAN	50.3	28.2
H 14	1.90	.000	3.5	50.0	53.5	CONVENTIONAL 3 LANES			URBAN	44.6	25.1
H 15	.80	.000	5.2	44.8	50.0	EXPRESSWAY 3 LANES OR LESS	FLAT		RURAL	76.9	39.7
H 16	1.00	.000	4.3	50.0	54.3	EXPRESSWAY 3 LANES OR LESS	ROLL		RURAL	62.1	34.9
H 17	1.70	.000	4.3	50.0	54.3	EXPRESSWAY 3 LANES OR LESS	MTN		RURAL	62.1	34.9
H 18	1.50	.000	3.5	39.0	42.5	EXPRESSWAY 3 LANES OR LESS		≤55	SUBURBAN	56.6	25.5
H 19	1.00	.000	3.5	43.1	46.6	EXPRESSWAY 3 LANES OR LESS		>55	SUBURBAN	52.7	25.9
H 20	1.25	.000	2.7	40.2	42.9	EXPRESSWAY 3 LANES OR LESS			URBAN	43.3	20.0
H 21	1.80	.000	2.0	37.0	39.0	UNDIVIDED 4 LANES	FLAT		RURAL	45.6	19.3
H 22	2.70	.000	1.7	41.7	43.4	UNDIVIDED 4 LANES	ROLL/MTN		RURAL	38.4	18.1
H 23	4.50	.000	.9	39.8	40.7	UNDIVIDED 4 LANES		≤55	SUBURBAN	24.1	11.3
H 24	3.90	.000	.9	44.8	45.7	UNDIVIDED 4 LANES		>55	SUBURBAN	22.8	11.8
H 25	6.20	.000	.7	34.9	35.6	UNDIVIDED 4 LANES		<45	URBAN	20.6	8.9
H 26	4.80	.000	.7	36.4	37.1	UNDIVIDED 4 LANES		≥45	URBAN	20.2	9.1
H 27	2.00	.000	2.0	37.0	39.0	UNDIVIDED 5-6 LANES	FLAT		RURAL	45.6	19.3

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	HIGHWAY TYPE	TERRAIN OR ADT	AHS	AREA	ACC COSTS ($1000) F+I	ALL
H 28	3.20	.000	1.7	41.7	43.4	UNDIVIDED 5-6 LANES	ROLL/MTN		RURAL	38.4	18.1
H 29	4.50	.000	.9	39.8	40.7	UNDIVIDED 5-6 LANES		≤55	SUBURBAN	24.1	11.3
H 30	3.90	.000	.9	44.8	45.7	UNDIVIDED 5-6 LANES		>55	SUBURBAN	22.8	11.8
H 31	6.20	.000	.7	34.9	35.6	UNDIVIDED 5-6 LANES		<45	URBAN	20.6	8.9
H 32	4.80	.000	.7	36.4	37.1	UNDIVIDED 5-6 LANES		≥45	URBAN	20.2	9.1
H 33	1.30	.000	2.3	42.4	44.7	DIVIDED 4 LANES	FLAT		RURAL	45.7	21.8
H 34	2.10	.000	1.6	42.4	44.0	DIVIDED 4 LANES	ROLL/MTN		RURAL	36.8	17.6
H 35	3.00	.000	1.0	40.9	41.9	DIVIDED 4 LANES		≤55	SUBURBAN	25.1	12.0
H 36	2.50	.000	1.0	41.2	42.2	DIVIDED 4 LANES		>55	SUBURBAN	25.0	12.0
H 37	4.70	.000	.7	32.8	33.5	DIVIDED 4 LANES		<45	URBAN	21.2	8.8
H 38	3.30	.000	.7	37.9	38.6	DIVIDED 4 LANES		≥45	URBAN	19.8	9.2
H 39	1.30	.000	2.3	42.4	44.7	DIVIDED 5 LANES OR MORE	FLAT		RURAL	45.7	21.8
H 40	2.10	.000	1.6	42.4	44.0	DIVIDED 5 LANES OR MORE	ROLL/MTN		RURAL	36.8	17.6
H 41	3.80	.000	.9	44.5	45.4	DIVIDED 5 LANES OR MORE		≤55	SUBURBAN	22.9	11.8
H 42	2.50	.000	.9	51.7	52.6	DIVIDED 5 LANES OR MORE		>55	SUBURBAN	21.4	12.5
H 43	4.40	.000	.6	40.4	41.0	DIVIDED 5 LANES OR MORE		<45	URBAN	18.0	8.8
H 44	3.30	.000	.6	40.4	41.0	DIVIDED 5 LANES OR MORE		≥45	URBAN	18.0	8.8
H 45	.80	.017	2.8	45.1	47.9	DIV. EXPRESSWAY 4 LNS OR MORE		≤65	RURAL	49.9	25.2
H 46	.60	.007	3.0	45.1	48.1	DIV. EXPRESSWAY 4 LNS OR MORE		>65	RURAL	52.2	26.4
H 47	1.30	.017	2.1	43.0	45.1	DIV. EXPRESSWAY 4 LNS OR MORE		≤65	SUBURBAN	37.3	18.2
H 48	.90	.007	2.1	43.0	45.1	DIV. EXPRESSWAY 4 LNS OR MORE		>65	SUBURBAN	37.3	18.2
H 49	2.15	.000	1.4	42.6	44.0	DIV. EXPRESSWAY 4 LNS OR MORE		≤55	URBAN	27.0	13.3
H 50	1.75	.000	1.4	42.6	44.0	DIV. EXPRESSWAY 4 LNS OR MORE		>55	URBAN	27.0	13.3
H 51	.60	.65/	4.6	47.7	52.3	FREEWAY 4 LANES OR LESS	≤15000	≤65	RURAL	67.3	36.4
H 52	.40	.65/	4.7	47.3	52.0	FREEWAY 4 LANES OR LESS	≤15000	>65	RURAL	68.8	37.0
H 53	.50	.004	4.6	47.4	52.0	FREEWAY 4 LANES OR LESS	>15000	≤65	RURAL	67.6	36.4
H 54	.35	.004	3.2	44.6	47.8	FREEWAY 4 LANES OR LESS	>15000	>65	RURAL	54.9	37.5

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	HIGHWAY TYPE	TERRAIN OR ADT	AHS	AREA	ACC COSTS ($1000) F+I	ALL
H 55	.20	.007	3.4	45.7	49.1	FREEWAY 5-6 LANES			RURAL	56.2	28.9
H 56	.20	.004	2.6	43.5	46.1	FREEWAY 7 LANES OR MORE			RURAL	48.6	23.8
H 57	.70	.65/	1.1	40.8	41.9	FREEWAY 4 LANES OR LESS	≤15000	≤65	SUBURBAN	26.3	12.5
H 58	.45	.65/	2.4	40.8	43.2	FREEWAY 4 LANES OR LESS	≤15000	>65	SUBURBAN	42.1	19.6
H 59	.70	.004	1.1	40.8	41.9	FREEWAY 4 LANES OR LESS	>15000	≤65	SUBURBAN	26.3	12.5
H 60	.45	.004	2.2	42.2	44.4	FREEWAY 4 LANES OR LESS	>15000	>65	SUBURBAN	38.9	18.7
H 61	.25	.007	1.6	40.0	41.6	FREEWAY 5-6 LANES			SUBURBAN	32.9	15.2
H 62	.25	.004	1.1	41.8	42.9	FREEWAY 7 LANES OR MORE			SUBURBAN	26.0	12.6
H 63	.45	.011	1.1	40.6	41.7	FREEWAY 4 LANES OR LESS			URBAN	24.1	11.5
H 64	.35	.006	.8	39.4	40.2	FREEWAY 5-6 LANES			URBAN	20.7	9.8
H 65	.30	.004	.8	39.4	40.2	FREEWAY 7-8 LANES			URBAN	20.7	9.8
H 66	.25	.004	.8	39.4	40.2	FREEWAY 9-10 LANES			URBAN	20.7	9.8
H 67	.25	.004	.8	39.4	40.2	FREEWAY 11 LANES OR MORE			URBAN	20.7	9.8

BASE RATES

HIGHWAY SEGMENTS	ACCIDENTS/MILLION VEHICLE MILES (MVM)
INTERSECTIONS	ACCIDENTS/MILLION VEHICLES (MV) ENTERING THE INTERSECTION
RAMPS	ACCIDENTS/MILLION VEHICLES (MV) TRAVERSING THE RAMP

ADT FACTOR - VALUE TO BE ADDED TO THE BASE RATE. "0.60/" MEANS 0.60 DIVIDED BY ADT IN THOUSANDS; I.E., WITH 5,000 ADT, 0.12 WOULD BE ADDED TO THE BASE RATE. "0.017" MEANS 0.017 TIMES ADT IN THOUSANDS; I.E., WITH 20,000 ADT, ADD 0.34 TO THE BASE RATE.

ACCIDENT COSTS ($1,000)

	F	I	PDO	AVE
R	608	15.2	2.5	28.5
S	551	12.2	2.5	13.7
U	534	10.3	2.5	9.8
AVE	574	11.8	2.5	14.6

BASIC EXPECTED ACCIDENT RATE TABLE FOR INTERSECTIONS

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	INTERSECTION TYPE*	CONTROL TYPE	AREA	ACC COSTS ($1000) F+I	ALL
I 01	.11	.000	2.4	51.6	54.0	F, M AND S	NO CONTROL	RURAL	41.5	23.6
I 02	.40	.000	2.4	44.9	47.3	F, M AND S	STOP & YIELD SIGNS	RURAL	45.3	22.7
I 03	.98	.000	1.2	43.2	44.4	F, M AND S	SIGNALS	RURAL	31.2	15.3
I 04	1.01	.000	2.1	41.7	43.8	F, M AND S	FLASHERS	RURAL	43.6	20.5
I 05	.16	.000	1.1	44.0	45.1	F, M AND S	NO CONTROL	SUBURBAN	25.3	12.8
I 06	.42	.000	1.1	37.5	38.6	F, M AND S	STOP & YIELD SIGNS	SUBURBAN	27.6	12.2
I 07	.77	.000	.4	38.5	38.9	F, M AND S	SIGNALS	SUBURBAN	17.7	8.4
I 08	.82	.000	1.9	33.0	34.9	F, M AND S	FLASHERS	SUBURBAN	41.5	16.1
I 09	.11	.000	.8	38.1	38.9	F, M AND S	NO CONTROL	URBAN	21.1	9.7
I 10	.32	.000	.8	36.5	37.3	F, M AND S	STOP & YIELD SIGNS	URBAN	21.5	9.6
I 11	.54	.000	.4	36.0	36.4	F, M AND S	SIGNALS	URBAN	16.1	7.4
I 12	.54	.000	1.9	29.9	31.8	F, M AND S	FLASHERS	URBAN	41.6	14.9
I 13	.19	.000	1.8	48.1	49.9	T, Y AND Z	NO CONTROL	RURAL	36.6	19.5
I 14	.26	.000	1.8	45.3	47.1	T, Y AND Z	STOP & YIELD SIGNS	RURAL	37.9	19.2
I 15	.49	.000	1.2	40.4	41.6	T, Y AND Z	SIGNALS	RURAL	32.3	14.9
I 16	.79	.000	1.2	40.4	41.6	T, Y AND Z	FLASHERS	RURAL	32.3	14.9
I 17	.16	.000	1.8	48.9	50.7	T, Y AND Z	NO CONTROL	SUBURBAN	31.3	17.1
I 18	.26	.000	1.0	41.9	42.9	T, Y AND Z	STOP & YIELD SIGNS	SUBURBAN	24.8	12.0
I 19	.47	.000	.8	39.0	39.8	T, Y AND Z	SIGNALS	SUBURBAN	23.0	10.7
I 20	.47	.000	.8	39.0	39.8	T, Y AND Z	FLASHERS	SUBURBAN	23.0	10.7
I 21	.13	.000	1.2	40.3	41.5	T, Y AND Z	NO CONTROL	URBAN	25.4	12.0
I 22	.17	.000	1.0	37.1	38.1	T, Y AND Z	STOP & YIELD SIGNS	URBAN	24.0	10.7
I 23	.37	.000	.4	37.8	38.2	T, Y AND Z	SIGNALS	URBAN	15.8	7.6
I 24	.44	.000	.4	37.8	38.2	T, Y AND Z	FLASHERS	URBAN	15.8	7.6

* INTERSECTION TYPES

F - FOUR-LEGGED
M - MULTI-LEGGED
S - OFFSET

T - TEE
Y - WYE
Z - OTHERS

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	RAMP TYPE	RAMP AREAS	ON/ OFF	AREA	ACC COSTS ($1000) F+I	ALL
R 01	.35	.000	1.3	45.0	46.3	FRONTAGE ROAD	1-4	N/A	RURAL	31.8	16.1
R 02	.90	.000	.7	33.6	34.3	FRONTAGE ROAD	1-4	N/A	URBAN	21.0	8.8
R 03	.35	.000	1.3	45.0	46.3	COLLECTOR ROAD	1-4	N/A	RURAL	31.8	16.1
R 04	.40	.000	.7	33.6	34.3	COLLECTOR ROAD	1-4	N/A	URBAN	21.0	8.8
R 05	.80	.000	1.8	36.1	37.9	DIRECT, SEMI-DIR CONN (LT TRN TRAF)	1-4	OFF	RURAL	43.4	18.0
R 06	.80	.000	1.8	41.7	43.5	DIRECT, SEMI-DIR CONN (LT TRN TRAF)	1-4	OFF	URBAN	32.0	15.3
R 07	.60	.000	1.8	44.9	46.7	DIRECT, SEMI-DIR CONN (LT TRN TRAF)	1-4	ON	RURAL	38.0	19.1
R 08	.60	.000	1.8	45.0	46.8	DIRECT, SEMI-DIR-CONN (LT TRN TRAF)	1-4	ON	URBAN	30.4	15.6
R 09	1.55	.000	1.7	38.1	39.8	DIAMOND	1-4	OFF	RURAL	40.5	17.6
R 10	1.65	.000	.5	39.7	40.2	DIAMOND	1-4	OFF	URBAN	16.8	8.3
R 11	.80	.000	1.7	39.7	41.4	DIAMOND	1-4	ON	RURAL	39.5	17.8
R 12	.90	.000	.5	38.6	39.1	DIAMOND	1-4	ON	URBAN	17.0	8.2
R 13	.45	.000	1.3	36.6	37.9	SLIP	1-4	OFF	RURAL	35.5	15.0
R 14	.45	.000	.7	38.3	39.0	SLIP	1-4	OFF	URBAN	19.7	9.2
R 15	.35	.000	1.3	45.4	46.7	SLIP	1-4	ON	RURAL	31.7	16.1
R 16	.35	.000	.7	38.3	39.0	SLIP	1-4	ON	URBAN	19.7	9.2
R 17	.75	.000	1.3	36.6	37.9	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-4	OFF	RURAL	35.5	15.0
R 18	.95	.000	.8	40.0	40.8	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-4	OFF	URBAN	20.6	9.9
R 19	.60	.000	1.3	45.4	46.7	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-4	ON	RURAL	31.7	16.1
R 20	.65	.000	.8	41.2	42.0	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-4	ON	URBAN	20.3	10.0
R 21	1.70	.000	1.3	36.6	37.9	LOOP WITH LEFT TURN	1-4	OFF	RURAL	35.5	15.0
R 22	1.70	.000	.7	35.1	35.8	LOOP WITH LEFT TURN	1-4	OFF	URBAN	20.5	9.0
R 23	1.35	.000	1.3	45.4	46.7	LOOP WITH LEFT TURN	1-4	ON	RURAL	31.7	16.1
R 24	1.05	.000	.7	40.2	40.9	LOOP WITH LEFT TURN	1-4	ON	URBAN	19.3	9.4
R 25	3.55	.000	1.3	42.4	43.7	BUTTONHOOK	1-4	OFF	RURAL	32.8	15.8
R 26	1.60	.000	.7	36.8	37.5	BUTTONHOOK	1-4	OFF	URBAN	20.1	9.1
R 27	.90	.000	1.3	42.4	43.7	BUTTONHOOK	1-4	ON	RURAL	32.8	15.8

BASIC EXPECTED ACCIDENT RATE TABLE FOR RAMPS 04/15/88 PAGE 6

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	RAMP TYPE	RAMP AREAS	ON/' OFF	AREA	ACC COSTS ($1000) F+I	ALL
R 28	.70	.000	.7	38.9	39.6	BUTTONHOOK	1-4	ON	URBAN	19.6	9.3
R 29	1.55	.000	1.3	36.6	37.9	SCISSORS	1-4	OFF	RURAL	35.5	15.0
R 30	1.10	.000	.7	38.1	38.8	SCISSORS	1-4	OFF	URBAN	19.7	9.2
R 31	.85	.000	1.3	45.4	46.7	SCISSORS	1-4	ON	RURAL	31.7	16.1
R 32	.60	.000	.7	36.8	37.5	SCISSORS	1-4	ON	URBAN	20.1	9.1
R 33	.35	.000	1.3	36.6	37.9	SPLIT	1-4	OFF	RURAL	35.5	15.0
R 34	.30	.000	1.0	41.7	42.7	SPLIT	1-4	OFF	URBAN	22.6	11.1
R 35	.25	.000	1.3	45.4	46.7	SPLIT	1-4	ON	RURAL	31.7	16.1
R 36	.25	.000	1.0	38.6	39.6	SPLIT	1-4	ON	URBAN	23.5	10.8
R 37	1.25	.000	1.3	36.6	37.9	LOOP WITHOUT LEFT TURN	1-4	OFF	RURAL	35.5	15.0
R 38	1.25	.000	.7	37.1	37.8	LOOP WITHOUT LEFT TURN	1-4	OFF	URBAN	20.0	9.1
R 39	.85	.000	1.3	45.4	46.7	LOOP WITHOUT LEFT TURN	1-4	ON	RURAL	31.7	16.1
R 40	.75	.000	.7	42.2	42.9	LOOP WITHOUT LEFT TURN	1-4	ON	URBAN	18.8	9.5
R 41	.85	.000	1.3	45.0	46.3	TWO-WAY RAMP SEGMENT	1-4	N/A	RURAL	31.8	16.1
R 42	.85	.000	.7	31.3	32.0	TWO-WAY RAMP SEGMENT	1-4	N/A	URBAN	21.8	8.7
R 43	1.25	.000	1.3	36.6	37.9	REST AREA, VISTA PT, TRK SCALE	1-4	OFF	RURAL	35.5	15.0
R 44	1.10	.000	.7	31.3	32.0	REST AREA, VISTA PT, TRK SCALE	1-4	OFF	URBAN	21.8	8.7
R 45	.35	.000	1.3	45.4	46.7	REST AREA, VISTA PT, TRK SCALE	1-4	ON	RURAL	31.7	16.1
R 46	.35	.000	.7	31.3	32.0	REST AREA, VISTA PT, TRK SCALE	1-4	ON	URBAN	21.8	8.7
R 47	1.20	.000	1.3	36.6	37.9	OTHER	1-4	OFF	RURAL	35.5	15.0
R 48	1.20	.000	.7	34.4	35.1	OTHER	1-4	OFF	URBAN	20.7	8.9
R 49	.95	.000	1.3	45.4	46.7	OTHER	1-4	ON	RURAL	31.7	16.1
R 50	.95	.000	.7	34.4	35.1	OTHER	1-4	ON	URBAN	20.7	8.9
R 51	1.05	.000	1.3	45.0	46.3	OTHER	1-4	N/A	RURAL	31.8	16.1
R 52	1.05	.000	.7	31.3	32.0	OTHER	1-4	N/A	URBAN	21.8	8.7
R 53	.85	.000	1.3	36.6	37.9	DIAMOND	1-3	OFF	RURAL	35.5	15.0
R 54	.95	.000	.7	40.0	40.7	DIAMOND	1-3	OFF	URBAN	19.3	9.3

RATE GROUP	BASE RATE	+ ADT FACTOR	PCT FAT	PCT INJ	PCT F+I	RAMP TYPE	RAMP AREAS	ON/ OFF	AREA	ACC COSTS ($1000) F+I	ALL
R 55	.65	.000	1.3	45.4	46.7	DIAMOND	1-3	ON	RURAL	31.7	16.1
R 56	.50	.000	.7	40.0	40.7	DIAMOND	1-3	ON	URBAN	19.3	9.3
R 57	.20	.000	1.3	36.6	37.9	SLIP	1-3	OFF	RURAL	35.5	15.0
R 58	.20	.000	.7	31.3	32.0	SLIP	1-3	OFF	URBAN	21.8	8.7
R 59	.20	.000	1.3	45.4	46.7	SLIP	1-3	ON	RURAL	31.7	16.1
R 60	.20	.000	.7	31.3	32.0	SLIP	1-3	ON	URBAN	21.8	8.7
R 61	.60	.000	1.3	36.6	37.9	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-3	OFF	RURAL	35.5	15.0
R 62	.60	.000	1.2	43.3	44.5	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-3	OFF	URBAN	24.4	12.3
R 63	.40	.000	1.3	45.4	46.7	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-3	ON	RURAL	31.7	16.1
R 64	.50	.000	1.2	43.4	44.6	DIRECT, SEMI-DIR CONN (RT TRN TRAF)	1-3	ON	URBAN	24.4	12.3
R 65	1.65	.000	1.3	36.6	37.9	LOOP WITH LEFT TURN	1-3	OFF	RURAL	35.5	15.0
R 66	1.65	.000	.7	31.3	32.0	LOOP WITH LEFT TURN	1-3	OFF	URBAN	21.8	8.7
R 67	.90	.000	1.3	45.4	46.7	LOOP WITH LEFT TURN	1-3	ON	RURAL	31.7	16.1
R 68	.90	.000	.7	31.3	32.0	LOOP WITH LEFT TURN	1-3	ON	URBAN	21.8	8.7
R 69	1.50	.000	1.3	36.6	37.9	LOOP WITHOUT LEFT TURN	1-3	OFF	RURAL	35.5	15.0
R 70	1.10	.000	.7	32.9	33.6	LOOP WITHOUT LEFT TURN	1-3	OFF	URBAN	21.2	8.8
R 71	.90	.000	1.3	45.4	46.7	LOOP WITHOUT LEFT TURN	1-3	ON	RURAL	31.7	16.1
R 72	.70	.000	.7	41.1	41.8	LOOP WITHOUT LEFT TURN	1-3	ON	URBAN	19.1	9.4
R 73	.85	.000	1.3	45.0	46.3	TWO-WAY RAMP SEGMENT	1-3	N/A	RURAL	31.8	16.1
R 74	.85	.000	.7	31.3	32.0	TWO-WAY RAMP SEGMENT	1-3	N/A	URBAN	21.8	8.7
R 75	.80	.000	1.3	36.6	37.9	OTHER	1-3	OFF	RURAL	35.5	15.0
R 76	.80	.000	.7	31.3	32.0	OTHER	1-3	OFF	URBAN	21.8	8.7
R 77	.55	.000	1.3	45.4	46.7	OTHER	1-3	ON	RURAL	31.7	16.1
R 78	.55	.000	.7	31.3	32.0	OTHER	1-3	ON	URBAN	21.8	8.7
R 79	.55	.000	1.3	45.0	46.3	OTHER	1-3	N/A	RURAL	31.8	16.1
R 80	.55	.000	.7	31.3	32.0	OTHER	1-3	N/A	URBAN	21.8	8.7

APPENDIX B: RECOMMENDED RESEARCH PROGRAM FOR DEVELOPMENT OF THE IHSD MODEL

Research Problem Statement 1

Title: Data Quality Assurance and Coordination

Description of Problem

Past research in the development of statistical relationships between accident experience and highway geometric design variables has been based on data bases of varying quality and on a variety of statistical approaches and measures of effectiveness. Thus, the results of past research do not lend themselves to being used together in a coordinated fashion to predict the safety effects of geometric changes.

The problem of incompatibility that has arisen in past research results can be partially addressed by rigorous application of the accident definitions and classifications presented in this conceptual plan for determining the safety measures of effectiveness for the IHSD model. However, to ensure that every contractor working on the IHSD model applies these definitions properly, it is recommended that a single contractor have the responsibility for preparing the data bases for analysis. Candidate data bases would include the five State data bases of accident, geometric, and traffic volume data (Illinois, Maine, Michigan, Minnesota, and Utah) in the FHWA HSIS, as well as similar data bases maintained by other States, including California and Washington.

A key activity in preparing these data bases for analysis is a careful review and assessment of the quality of the information in each data base for each dependent variable and independent variable to be used in developing predictive models. This review should be conducted for all portions of the data base that will be used in predictive modeling including the data on roadway sections, intersections, ramps and speed-change lanes, and roadside areas. A review of this type has been conducted for roadway section data in the Minnesota and Utah HSIS files as part of the development of this conceptual plan. Several data quality problems were found in those data bases, particularly problems related to the distinction between on-roadway and off-roadway accidents. Appropriate methods for resolving these data quality problems have been developed for roadway sections in the Minnesota and Utah files. In other cases, it might be determined that data quality problems cannot be resolved and that particular data files should not be used. Such data quality problems must be investigated and resolved by a single contractor to ensure that other contractors involved in IHSD model development are starting with consistent data bases. However, those other contractors developing portions of the IHSD model should also be alert throughout the model development effort for possible data quality problems.

It should be recognized that even the best accident data currently available have limitations with respect to data quality and completeness that may limit the accuracy of the statistical relationships developed. This plan takes the optimistic view that improved geometric and traffic volume files, such as those in the HSIS files, that can be linked to accident data bases, will lead to improvements in the statistical relationships that can be developed. However, it must be recognized that even in the best available files, the quality and completeness of the available data are still less than desirable. This makes validation of the resulting accident predictive models particularly important (see Research Problem Statement 11).

The data quality assurance contractor should also have a key role in verifying that the predictive models developed by different contractors for different portions of the highway system (roadway sections, intersection, ramps and speed-change lanes, and roadside areas) are consistent with one another and are based on correct interpretation of the data files provided for analysis. This should be accomplished by obtaining expert peer review of all experimental plans for development of accident predictive models and of all safety relationships developed for the IHSD model.

The data quality assurance contractor should also be responsible for organizing two expert panels or steering committees to guide the IHSD model development effort. One panel would be made up of experienced geometric designers who would be charged with ensuring that the final ISHD model would be a tool of practical utility to designers. The second panel would be composed of researchers charged with ensuring that each research effort conducted as part of the IHSD model development is well coordinated with other research efforts and produces valid results. This second panel should include experienced researchers in the fields of geometric design, highway safety, statistical analysis of accident data, and human factors. These panels would meet approximately twice per year to review the progress of IHSD model development and to recommend future model development activities.

Research Objectives

The objectives of the research activity under this problem statement would be to:

- Assess the quality of each data file considered for use in development of the IHSD model.
- Develop consistent methods for resolving any data quality problems found in these data bases.
- Prepare data files in a consistent format for provision to other researchers.
- Assist other researchers in using these files in the manner intended.

- Review results generated by other researchers to ensure that they are consistent with one another and based on correct interpretation of the data files provided for analysis.

- Organize expert panels or steering committees of geometric designers and researchers to guide the IHSD model development.

Specific Tasks to be Performed

The specific tasks to be performed as part of this activity are as follows:

- Obtain copies of the HSIS data files for Illinois, Maine, Michigan, Minnesota, and Utah and the similar files for other States, including California and Washington.

- Evaluate each file to assess the quality of the data used to distinguish between accidents that occur on or are related to roadway sections, intersections, ramps and speed-change lanes, and roadside areas. Develop consistent methods for resolving any data quality problems encountered.

- Assess the quality of data in each file for the candidate dependent and independent variables that may be considered in developing predictive models for roadway sections, intersection, ramps and speed-change lanes, and roadside areas.

- Recommend which data files should and should not be used for specific purposes in development of the IHSD models, based on data quality. Data quality should be judged on the basis of:

  - completeness of variables included in the data files.

  - accuracy and reasonableness of the data, as verified by examining accident rates for different highway types and one-way and multiway distributions of specific variables.

  - appropriateness of data file for multiple uses in IHSD model development. Preference should be given to data files that are appropriate for roadway section, intersection, ramp/ speed-change lane, and roadside modeling.

- Prepare the data files needed for the performance of Research Problem Statements 2 through 10, incorporating a consistent definition of which accidents should be attributable to roadway sections, intersections, ramps and speed-change lanes, and roadside areas. Prepare written guidelines for the use of each data file in development of the IHSD model.

- Provide advice and/or assistance to researchers using the data files.
- Arrange for peer review of predictive models generated from the data files by other researchers to determine that they are valid and based on proper interpretation of the data files.
- Organize expert panels of geometric designers and researchers to guide the IHSD model development effort.

Research Problem Statement 2

Title: Experimental Plan for Predictive Models for Roadway Sections

Description of Problem

The IHSD model should include separate submodels containing predictive relationships for estimating the safety performance of roadway sections, intersections, ramps and speed-change lanes, and roadside areas. This problem statement addresses the development of predictive models for roadway sections.

Predictive relationships based on a valid statistical analysis results are needed for use in estimating the safety performance of roadway sections. Previous attempts to develop such relationships have yielded inconsistent results because of poor data quality, limited sample sizes, varied modeling approaches, and confounding of intersection and roadside effects with roadway section effects. An experimental plan should be developed to ensure that these problems are remedied in the development of safety relationships for the IHSD model.

Research Objective

The research objective under this problem statement would be to:

- Prepare an experimental plan for development of statistical predictive relationships for roadway sections that represent the effect of roadway geometrics and traffic volumes on accident experience (i.e., accident rate, accident severity, accident type distribution).

The predictive relationships must be developed based on the accident definitions presented in this conceptual plan, so that the relationships will be compatible with the other portions of the IHSD model. The data used in modeling must be of sufficient quality for use in this effort, as verified in the manner described in Research Problem Statement 1.

Specific Tasks to be Performed

The experimental plan developed for roadway sections should specify the following activities:

- Obtain data files from at least two States containing accident, geometric, and traffic volume data of sufficient quality for use in use in modeling of roadway section accident experience.

- Develop statistical models of the effects of geometric design and traffic variables on accident experience using several candidate functional forms and/or statistical techniques.

- Examine State-to-State differences between the models developed. Determine the most generally applicable models obtained and/or the best method of accounting for or adjusting for these differences.

- Select the best predictive model(s) for use in the IHSD model. The best model(s) will probably be those with a functional form or modeling approach that works satisfactorily for the data from more than one State, even if the numerical values obtained from different States differ to some extent.

- Validate the predictive model(s) using data that are independent of the data used in their development. In addition, model validation by methods other than statistical analysis of accident data should be considered.

The dependent variables that should be used as measures of effectiveness in this modeling activity should be:

- Accident rate (per million vehicle-miles).

- Accident severity distribution.

- Accident type distribution.

The independent variables that should be considered, at a minimum, include:

- Number of through lanes.
- Divided/undivided.
- Access control.
- Urban/suburban/rural.
- Lane width.
- Presence of shoulder.
- Shoulder type.
- Shoulder width.
- Median type.
- Horizontal curves:
  - degree of curve.
  - length of curve.
- Percent grade.
- Driveway density.
- Type of development.
- Average daily traffic volume.
- Percent trucks.
- Design or posted speed.
- Operating speed.

Other candidate independent variables that could be considered are listed in figure 4 in the main text of this report. However, it is unlikely that all of these variables have safety effects that can be accurately determined. For example, vertical curve geometry and stopping sight distance have very subtle effects that have never been adequately modeled. It must be recognized that determination of the effects of some geometric variables may be beyond the capability of even the most complete data bases and the best statistical techniques.

The list of independent variables presented above includes the ADT of the roadway section to represent the general level of traffic volume on the facility. In addition, it would be desirable to find a method to include congestion effects in the predictive model through the use of variables such as peak hour traffic volumes, peak V/C ratio, and/or a measure of the daily duration of congestion.

It appears that the best available data files contain sufficient geometric variables for modeling of roadway section accident experience without the need for supplementary field data collection. However, if questions about the data arise, it may be desirable to verify some geometric data elements for specific roadway sections in the field or from photologs.

A preliminary evaluation of the Minnesota and Utah HSIS files as part of the preparation of this conceptual plan has concluded that they are sufficiently complete for use in modeling roadway section accident experience. The Utah file includes data on the location and geometrics of horizontal curves, while the Minnesota file does not.

Recommended approaches for the development of predictive models for roadway sections have been presented in the conceptual plan for the IHSD model in Chapter IV of this report. Guidelines for the development of new safety relationships from accident data have been presented in Chapter VI. In particular, the guidelines state that the sites used in modeling should be carefully reviewed to identify and eliminate outliers that may have particularly high accident experience because of unusual driving populations (e.g., the presence of a few large taverns resulting in a high incidence of driving while intoxicated).

Research Problem Statement 3

Title: Development of Predictive Models for Roadway Sections

Description of Problem

Accident predictive models for roadway sections should be developed in accordance with the experimental plan developed in Research Problem Statement 2.

Research Objectives

The preliminary research objectives are identified in Research Problem Statement 2. These may be revised in the experimental plan.

Specific Tasks to be Performed

The specific tasks to be performed will be determined in the development of the experimental plan. A preliminary discussion of the tasks to be performed is presented in Research Problem Statement 2.

Research Problem Statement 4

Title: Experimental Plan for Predictive Models for Intersections

Description of Problem

The IHSD model should include separate submodels containing predictive relationships for estimating the safety performance of roadway sections, intersections, ramps and speed-change lanes, and roadside areas. This problem statement addresses the development of predictive models for intersections.

Predictive relationships based on a valid statistical analysis results are needed for use in estimating the safety performance of at-grade intersections. Only very limited attempts have been made in the past to develop safety predictive models for intersections. Improved modeling approaches are need for use in the IHSD model. An experimental plan should be prepared that specifies how these predictive models for intersection accidents should be developed.

Research Objective

The research objective under this problem statement would be to:

- Prepare an experimental plan for development of statistical predictive relationships for intersections that represent the effect of intersection geometrics and traffic volumes and characteristics on accident experience (i.e., accident rate, accident severity distribution, accident type distribution).

The predictive relationships must be developed based on the accident definitions presented in this conceptual plan, so that the relationships will be compatible with the other portions of the IHSD model. The data used in modeling must be of sufficient quality for use in this effort, as verified in the manner described in Research Problem Statement 1.

Specific Tasks to be Performed

The experimental plan developed for at-grade intersections should specify the following activities:

- Obtain data files from at least two States containing accident, geometric, and traffic volume data of sufficient quality for use in use in modeling intersection accidents.

- Supplement these data files with additional intersection geometric variables collected in the field or from photologs.

- Develop statistical models of the effects of geometric design and traffic variables on accident experience using several candidate functional forms and/or statistical techniques.

- Examine State-to-State differences between the models developed. Determine the most generally applicable models obtained and/or the best method of accounting for or adjusting for these differences.

- Select the best predictive model(s) for use in the IHSD model. The best model(s) will probably be those with a functional form or modeling approach that works satisfactorily for the data from more than one State, even if the numerical values obtained from different States differ to some extent.

- Validate the predictive model(s) using data that are independent of the data used in their development. In addition, model validation by methods other than statistical analysis of accident data should be considered.

The dependent variables that should be used as measures of effectiveness in this modeling activity should be:

- Accident rate (per million entering vehicles).

- Accident severity distribution.

- Accident type distribution.

The independent variables that should be considered include:

- Entering traffic volumes.
- Type of traffic control (signalized/two-way STOP/two-way STOP with flashing beacon/four-way STOP/four-way STOP with flashing beacon/ no control).
- Number of approaches.
- Approach alignment (horizontal/vertical alignment).
- Number of lanes on each approach.
- Special lanes (right-turn/left-turn/shared/exclusive).
- Urban/suburban/rural.
- Approach widths.
- Divided/undivided approaches.
- Percent left turns.
- Percent right turns.
- Percent trucks.

- Approach speed.
- Signal phasing/timing.
- Stopping sight distance.
- Intersection sight distance.

Several of these variables including approach alignment, special lanes, and signal phasing are not typically included in existing computerized State data files. Supplementary data collection in the field or from photologs may be required to obtain these data.

Some candidate variables, such as curb return radii have very subtle effects that are difficult to quantify. It must be recognized that determination of the effects of some variables may be beyond the capability of even the most complete data bases and the best statistical techniques.

In addition to the entering traffic volumes expressed as ADT values, it would be desirable to include measures of congestion such as the peak hour traffic volumes, peak V/C ratios, and/or daily duration of congestion.

Predictive models for intersection accidents should produce estimates both for "at-intersection" accidents (i.e., accidents that occur within the curbline limits of the intersection) and for other "intersection-related" accidents (i.e., accidents that occur on the intersection approaches but are caused by or related to the operation of the intersection. This definition does *not* incorporate a specific approach length that is considered to be related to the intersection. Any accident that is caused by or related to the operation of the intersection is considered to be an "intersection-related" accident, no matter how far from the intersection it occurs. Naturally, "intersection-related accidents would be expected to occur over a greater distance from the intersection on a high-volume, congested approach than on a low-volume, uncongested approach. In addition to the "intersection-related" accident experience, accidents that are not related to the intersection would be expected to occur on each approach; such accidents would be predicted by the roadway section model rather than the intersection model.

The most promising data bases for the development of predictive models for intersections appear to be the Maine and Minnesota HSIS files and the file maintained by Caltrans. However, these files need to be fully investigated.

Recommended approaches for the development of predictive models for roadway sections have been presented in the conceptual plan for the IHSD model.

Research Problem Statement 5

Title: Development of Predictive Models for Intersections

Description of Problem

Accident predictive models for at-grade intersections should be developed in accordance with the experimental plan developed in Research Problem Statement 4.

Research Objectives

The preliminary research objectives are identified in Research Problem Statement 4. These may be revised in the experimental plan.

Specific Tasks to be Performed

The specific tasks to be performed will be determined in the development of the experimental plan. A preliminary discussion of the tasks to be performed is presented in Research Problem Statement 4.

Research Problem Statement 6

Title: Preliminary Demonstration of the IHSD model

Description of Problem

A demonstration of the IHSD model is recommended as early as possible in the development process. A prototype version of the IHSD accident predictive model should be developed to demonstrate the capabilities of the model. This will be useful to test concepts in the model and to demonstrate the model to potential users, including highway agencies, consulting firms, and researchers.

It is recommended that a prototype version of the accident predictive portion of the IHSD model be developed including the safety relationships developed for roadway sections and at-grade intersections. In other words, this prototype could be developed at the conclusion of the work described in Research Problem Statement 5. It is recommended that safety relationships for ramps and speed-change lanes not be included in the demonstration version; this would be an unnecessary complication that is not essential to the demonstration of the model capabilities. Roadside accidents could be addressed with a generalized roadside rating system or with the existing version of the ROADSIDE model without waiting for the necessary improvements described in Research Problem Statements 9 and 10. The prototype version of the IHSD model should be capable of performing a level 1 analysis, as defined in section III of this plan, and should be capable of illustrating how a level 2 analysis would be performed. Based on the priorities established by an expert panel (see table 2 in this report), accident predictive models for rural two-lane highways would appear to be most appropriate for the prototype version of the IHSD model.

Any operational problems with the IHSD model identified during development of the prototype version or identified by its users should be fully evaluated in subsequent development of the model.

Research Objectives

The objectives for development of a preliminary demonstration version of the IHSD model are as follows:

- Test concepts for potential use in the final version of the IHSD model.
- Test user interfaces (input formats, screen displays, printout formats, etc.) for future software development.
- Obtain user comments on the applicability and practicality of the IHSD model.

The development of a prototype version of the IHSD model should be an excellent means of gaining user support for future development of the model.

Specific Tasks to be Performed

Specific tasks to be performed under this research problem statement are as follows:

- Develop computer software for a prototype of the IHSD accident predictive model.
- Test the prototype version of the accident predictive model by applying it to a series of realistic design problems.
- Test the prototype version of the accident predictive model by asking potential users to exercise it and provide comments.
- Prepare a report with recommendations for future development of the IHSD model.

Research Problem Statement 7

Title: Experimental Plan for Predictive Models for Ramps and Speed-Change Lanes

Description of Problem

The IHSD model should include separate submodels containing predictive relationships for estimating the safety performance of roadway sections, intersections, ramps and speed-change lanes, and roadside areas. This problem statement addresses the development of predictive models for ramps and speed-change lanes.

Predictive relationships based on a valid statistical analysis results are needed for use in estimating the safety performance of interchange ramps and speed-change lanes. There has been only limited safety research concerning ramps and speed-change lanes and none that is appropriate for direct application in the IHSD model. The first step in the development of such predictive relationships should be the preparation of an experimental plan.

Research Objective

The research objective under this problem statement would be to:

- Prepare an experimental plan for development of statistical predictive relationships for ramps and speed-change lanes that represent the effect of roadway geometrics and traffic volumes and characteristics on accident experience (i.e., accident rate, accident severity distribution, accident type distribution).

The predictive relationships must be developed based on the accident definitions presented in this conceptual plan, so that the relationships will be compatible with the other portions of the IHSD model. The data used in modeling must be of sufficient quality for use in this effort, as verified in the manner described in Research Problem Statement 1.

Specific Tasks to be Performed

The experimental plan developed for interchange ramps and speed-change lanes should specify the following activities:

- Obtain data files from at least two States containing accident, geometric, and traffic volume data of sufficient quality for use in use in modeling ramp and speed-change lane accidents.

- Supplement these data files with additional geometric variables collected in the field or from photologs.

- Develop statistical models of the effects of geometric design and traffic variables on accident experience using several candidate functional forms and/or statistical techniques.

- Examine state-to-state differences between the models developed. Determine the most generally applicable models obtained and/or the best method of accounting for or adjusting for these differences.

- Select the best predictive model(s) for use in the IHSD model. The best model(s) will probably be those with a functional form or modeling approach that works satisfactorily for the data from more than one State, even if the numerical values obtained from different States differ to some extent.

- Validate the predictive model(s) using data that are independent of the data used in their development. In addition, model validation by methods other than statistical analysis of accident data should be considered.

The dependent variables that should be used as measures of effectiveness in this modeling activity should be:

- Accident rate (per million vehicles traversing the ramp or speed-change lane).

- Accident severity distribution.

- Accident type distribution.

The independent variables that should be considered include:

- Ramp type:
  - freeway/freeway.
  - freeway/arterial off-ramp.
  - freeway/arterial on-ramp.
  - arterial/arterial.
- Ramp configuration:
  - diamond.
  - parclo loop.
  - full loop.
  - directional.
  - buttonhook.
  - slip.
- Ramp length.

- Number of lanes on ramp.
- Urban/suburban/rural.
- Horizontal curves.
- Type of speed-change lane.
- Length of speed-change lane.
- Traffic volume traversing ramp.
- Percent trucks.
- Advisory speed.
- Design speed.
- Operating speed.

Many of these variables are not typically included in computerized State data files and supplementary data collection in the field or from photologs will probably be required. For example, existing ramp files do not typically contain geometric data on speed-change lanes or horizontal curves.

In addition to the ADT traversing the ramp, it would be desirable to include variables, such as peak hour volumes, representing the level and duration of congestion on the ramp. However, congestion measures are much more difficult to define for ramps than for roadway sections or intersections because congestion is usually controlled more by ramp terminal operations than by the capacity of the ramp proper.

The most promising data file for analysis of ramps and speed-change lanes is the ramp file maintained by the Caltrans. However, this file has not yet been fully investigated.

Recommended approaches for the development of predictive models for roadway sections have been presented in the conceptual plan for the IHSD model.

Research Problem Statement 8

Title: Development of Predictive Models for Ramps and Speed-Change Lanes

Description of Problem

Accident predictive models for interchange ramps and speed-change lanes should be developed in accordance with the experimental plan developed in Research Problem Statement 7.

Research Objectives

The preliminary research objectives are identified in Research Problem Statement 7. These may be revised in the experimental plan.

Specific Tasks to be Performed

The specific tasks to be performed will be determined in the development of the experimental plan. A preliminary discussion of the tasks to be performed is presented in Research Problem Statement 7.

Research Problem Statement 9

Title: Experimental Plan for Predictive Models for Roadside Areas

Description of Problem

Modeling of roadside accidents must be approached in a very different way than modeling of on-roadway accidents. Many roadside accidents are not reported because, if the roadside design is good, a vehicle leaving the roadway may not suffer consequences serious enough to create a reportable accident. In addition, many roadside accidents involve only a single vehicle; reporting levels are generally lower for single-vehicle accidents than for multiple-vehicle accidents.

The most widely used model for predicting roadside accidents has been developed in a sequence of past and present research efforts that has been carried on over a period of more than 20 years.[14,15,16] The model is currently being improved in NCHRP Projects 22-8 and 22-9.[17,18] A recent FHWA report has recommended a plan for collection of roadside safety data to further improve the roadside accident prediction model; execution of this plan would begin with the improved version of the model that is developed in NCHRP Project 22-9.[6]

The roadside data collection plan developed for FHWA recommends five specific studies that should be conducted to improve the roadside safety model.[6] These are:

- Validation of encroachment frequency/rate (Study 1).
- Determination of encroachment frequency/rate adjustment factors (Study 2).
- Determination of the effect of roadside conditions on impact probability and severity (Study 3).
- Determination of distributions of impact conditions (Study 4).
- Development of relationships between impact conditions, performance limits, and injury probability and severity (Study 5).

Detailed descriptions of the work needed to address each of these problems are presented in the FHWA report, including estimates of the required time and cost to accomplish this work.

A detailed experimental plan should be developed to indicate which portions of this FHWA plan must be accomplished to create an roadside accident predictive model that is acceptable for use in the IHSD model. The development of this experimental plan should include pilot studies to test the recommended data collection activities and, where appropriate, to choose between alternative research approaches.

The experimental plan to be developed should address predictive models for use in both level 1 and level 2 analyses. Level 1 analyses should be based on safety relationships incorporating the generalized roadside rating scheme (i.e., 1 to 7 scale) developed by Zegeer et al. and/or the concepts in the existing ROADSIDE model.[7] Level 2 analyses should be based on a revised version of the ROADSIDE model developed in accordance with the research approach described above.

Research Objectives

The research objectives to be addressed in the experimental plan should include:

- Develop a simplified approach for predicting roadside accidents that can be employed in level 1 analyses.

- Obtain new data on encroachment rates for freeways, multilane nonfreeways, and two-lane highways and new data on accident severities associated with roadside collisions in accordance with the plan developed for FHWA.[6]

- Develop a revised version of the roadside safety model based on new data concerning encroachments and accident severities.

Specific Tasks to be Performed

The experimental plan developed for interchange ramps and speed-change lanes should specify the following activities:

- Adapt either the generalized roadside rating scheme (i.e., 1 to 7 scale) developed by Zegeer et al. and/or the concepts in the existing roadside safety model discussed above to provide a simplified model for predicting roadside accidents that can be employed in level 1 analyses.[7]

- Improve the existing roadside safety model using the data collection approaches recommended in an FHWA plan to obtain a model appropriate for application to detailed roadside design issues in level 2 analyses in the IHSD model.

- Validate the roadside safety model using data that are independent of the data used in its development. In addition, model validation by methods other than probabilistic modeling based on encroachment and accident severity data should be considered.

Research Problem Statement 10

Title: Development of Predictive Models for Roadside Areas

Description of Problem

Accident predictive models for roadside areas will be developed in accordance with the experimental plan developed in Research Problem Statement 9.

Research Objectives

The preliminary research objectives are identified in Research Problem Statement 9. These may be revised in the experimental plan.

Specific Tasks to be Performed

The specific tasks to be performed will be determined in the development of the experimental plan. A preliminary discussion of the tasks to be performed is presented in Research Problem Statement 9.

Research Problem Statement 11

Title: Validation and Revision of Accident Predictive Models

Description of Problem

A major emphasis has been placed on model validation efforts throughout the description of Research Problem Statements 2 through 10. These validation efforts focus on the individual pieces of the accident predictive model.

When the work under Research Problem Statements 2 through 10 is complete, a major effort is needed to validate the accident predictive portion of the IHSD model as a whole, and make any necessary revisions. This will require that the accident predictive model be assembled as a whole and that its overall predictions be compared to the actual safety performance of specific sites or highway types. *This comparison should be made using safety data other than the data used in the model development.* For example, the data used in validation of the accident predictive models could consist of either portions of the data bases used in development that are specifically held aside for validation purposes or could consist of a later year of data from the same State(s). A key issue to be addressed in this validation effort is the accuracy of accident prediction for the combined on-roadway and roadside portions of the model.

One possible validation methodology might be a case study approach. A case study analysis could address accidents associated with various classes of highway to determine which geometric features would have been most effective in preventing or reducing the severity of an accident. One might, for example, analyze a sample of 150 to 200 accident reports from a wide variety of locations on rural highway curves. There will be a variety of accident causes discernable from the accident reports (including the narrative description): driving too fast with loss of control, falling asleep, improper passing, rear-end collisions because of large speed differentials, etc. In some cases, follow-up interviews with the investigating officer or the involved parties might be necessary to clarify accident causation. Each of the accident types identified above is affected differently by the various geometric features. A case study analysis would determine which features have the greatest safety impacts and which types of geometric or traffic control improvements (increasing curve radii, widening lanes, adding rumble strips, improving signing and delineation, clearing roadsides, etc.) might be most effective. If the case study analysis confirms the importance of the same geometric features as the quantitative statistical relationships, this will confirm the validity of those relationships. If the case study analysis indicates the importance of different geometric features than the quantitative statistical relationships, this may indicate that the statistical relationships are not valid because of the inherent limitations in the quality and completeness of the available accident data. Consideration should then be given to acquiring better accident data and/or using alternative statistical modeling techniques.

While the validation work under Research Problem Statement 11 may be performed using a simple, computerized version of the accident predictive model developed for testing purposes, this activity is intended as a validation of the accuracy of the predictive model and *not* as a test of a user-oriented software package. It is recommended that any necessary changes to the predictive model be made before the major software development effort begins.

Research Objectives

The objectives of the research under this problem statement are to:

- Validate the predictive relationships developed for the accident predictive portion of the IHSD model.

- Make appropriate revisions to improve the predictive ability of these relationships.

Specific Tasks to be Performed

The specific tasks to be performed in the research under this problem statement are:

- Assemble the accident predictive models for roadway sections, at-grade intersections, ramps and speed-change lanes and roadside areas into a combined predictive model.

- Validate the combined predictive models against actual safety performance data other than the data that was used in the model development.

- Assess the predictive ability of the combined accident predictive model.

- Make any necessary adjustments to the submodels for specific portions of the highway system (roadway sections, intersections, ramps and speed-change lanes, and roadside areas) to improve their respective predictive abilities and the predictive ability of the combined model.

- Prepare the accident predictive model in final form for use in software development in Research Problem Statement 12.

Research Problem Statement 12

Title: Software Development to Implement Accident Predictive Models

Description of Problem

Once the accident predictive procedures for use in the IHSD model have been finalized, as described in Research Problem Statement 11, the primary software development for implementing these procedures will begin. This work is intended to developed a high-quality, professional software package that applies the accident predictive procedures. Section III of this plan presents a preliminary flow diagram for the accident predictive portion of the model. This software development work could be performed independently or could be combined with the software development activity for the design policy review, design consistency review, and benefit-cost analyses described in Research Problem Statement 17.

No determination has yet been made as to whether the software for the IHSD model should be developed as a stand-alone package or as an integral part of a highway agency's CADD software. Such a decision would be premature at this time, given the rapid developments of computer hardware and software currently underway. However, it is clear that the software for level 2 analyses using the accident prediction model must be capable of interfacing with a CADD system.

Human factors experts on human-computer intersection should be involved in the software development from its inception to help determine software requirements based on user needs.

Research Objectives

The objectives of the research under this problem statement are to:

- Develop high-quality, professional software for the accident predictive portion of the IHSD model.

- Conduct an Alpha test of the software to the point that it is ready for application and assessment by users.

It should be noted that an Alpha test is an inhouse test of a software package by its development team, in contrast to a Beta test which is a test performed by knowledgeable outsiders.

Specific Tasks to be Performed

The specific tasks to be performed under this research problem statement are:

- Develop a final software development plan for the accident predictive portion of the IHSD model.
- Execute the plan and develop high-quality, professional software for the accident predictive portion of the IHSD model.
- Conduct an Alpha test of the software and make appropriate revisions to remove bugs and identify improvements to make the software more user friendly.
- Prepare the software in final form for combination with the accident predictive model component of the model and for Beta testing by potential users.
- Develop a draft users manual for the software.

Research Problem Statement 13

Title: Development of Procedures for Design Policy Review

Description of Problem

Not all highway design decisions can be addressed with a formal accident predictive model like that developed under Research Problem Statements 1 through 12. Therefore, the IHSD model should provide the user with other approaches to review the adequacy of specific design alternatives. One appropriate approach to supplement the accident predictive model is the inclusion in the IHSD model of a module intended to review a specific design alternative to identify and "flag" any design elements that do not comply with accepted design policies such as the AASHTO Green Book and applicable State or local highway agency design policies. Section V of this plan presents a candidate list of geometric design elements that could be addressed in the design policy review.

The identification of a design element as not in compliance with established design policies does not necessarily mean that the design should be changed. Exceptions to policies are often granted when it appears that full compliance with established design policies would not be cost effective. However, a design policy review module as part of the IHSD model would provide a means for ensuring that such decisions are made explicitly and are well documented.

A specific approach for this design policy review should be developed as part of the recommended research.

Research Objectives

The objective of the recommended research under this problem statement is to:

- Develop an automated method for identifying specific design features that do not comply with AASHTO, or specific State or local highway agency, design policies.

Specific Tasks to be Performed

The specific tasks to be performed as part of this research are:

- Identify specific design elements and design policies that should be included in the design policy review module.

- Provide a method for highway agencies to supplement any AASHTO numerical values or procedures with numerical values or procedures based on State or local highway agency design policies.

- Develop a procedure to implement the design policy review as part of the IHSD model. This procedure should be specified in sufficient detail to permit the development of design policy review software as described in Research Problem Statement 17.

Research Problem Statement 14

Title: Development of Procedures for Design Consistency Review

Description of Problem

Not all highway design decisions can be addressed with a formal accident predictive model like that developed under Research Problem Statements 1 through 12. Therefore, the IHSD model should provide the user with other approaches to review the adequacy of specific design alternatives. One appropriate approach to supplement the accident predictive model is the inclusion in the IHSD model of a module intended to review a specific design alternative to identify and "flag" any design elements that are inconsistent with driver expectancy. Such inconsistencies often arise from differences in geometrics between adjacent roadway elements (e.g., inappropriate cross-section transitions between adjacent roadway sections or between tangents and horizontal curves). Section V of this plan presents a tentative list of geometric design elements that could be addressed in the design consistency review.

The identification of a design element as inconsistent with adjacent sections does not necessarily mean that the design should be changed. It may not be cost effective to eliminate all design inconsistencies. For example, signing can be used in some cases to change driver expectancy and make an apparently inconsistent design more consistent. However, a design consistency review module as part of the IHSD model would provide a means of ensuring that such decisions are made explicitly and are well documented.

A specific approach for this design consistency review should be developed as part of the recommended research. In order to use an automated approach to design consistency review, design consistency must be transformed from a generalized concept to a specific concept to which quantitative definitions and procedures can be applied. Initial development of design consistency review procedures should be based on expert opinion. A panel of experienced geometric designers, traffic safety engineers, and human factors specialists should be established to formulate design consistency guidelines. Other design consistency concepts that are more quantitative, including those from current FHWA design consistency research, should be introduced at a later date.

The design consistency module should include a procedure to calculate, for each horizontal curve, the speed at which a specified vehicle types (probably a large truck) would skid or roll over, based on a point mass representation of the vehicle. This procedure would warn the user if the margin of safety between the skidding or rollover speed and the design speed of the curve appears to be too small. The vehicle operating speed used in this analysis would be estimated from the design speed of the horizontal curve itself and the design speed of the geometric element(s) upstream of the curve. The driver/vehicle dynamics model (see Research Problem

Statements 18 through 20) could be applied where a more sophisticated analysis tool is needed.

Research Objectives

The objective of the recommended research under this problem statement is to:

- Develop an automated method for identifying specific features of a design that are not inconsistent with driver expectancy.

Specific Tasks to be Performed

The specific tasks to be performed as part of this research are:

- Develop quantitative definitions of consistent and inconsistent design practices that implement valid research concerning design expectancy.

- Develop a procedure to implement a design consistency review as part of the IHSD model. This procedure should be specified in sufficient detail to permit the development of design consistency review software as described in Research Problem Statement 17.

Research Problem Statement 15

Title: Development of Procedures for Benefit-Cost Analysis

Description of Problem

The IHSD model should include benefit-cost procedures to allow users to determine whether a proposed design modification that involves an additional expenditure in construction cost is economically justified on the basis of improved safety. The benefit-cost procedures would not address nonsafety benefits such as traffic operational or environmental benefits. However, the benefit-cost module should include the capability for the user to supply data on monetary benefits and costs not related to safety if the user has such data available from other sources. A recommended method for computing the benefit-cost ratio and the annualized cost per accident reduced for a proposed design modification is presented in section V of this plan.

Research Objectives

The objectives of the research under this problem statement are to:

- Develop a procedure for benefit-cost analysis that can be used to determine whether proposed design modifications that increase construction costs are justified on the basis of safety. The procedure should determine values for the safety benefit-cost ratio and the annualized cost per accident reduced.

Specific Tasks to be Performed

The specific tasks to be performed as part of this research are:

- Develop a procedure to implement benefit-cost analysis as part of the IHSD model. This procedure should be specified in sufficient detail to permit the development of benefit-cost analysis software as described in Research Problem Statement 17.

Research Problem Statement 16

Title: Development of a Graphics Package

Description of Problem

The IHSD model should include a graphics package that allows designers to review the geometrics of each design alternative before assessing its safety performance and to review the geometrics again following the safety assessment as part of deciding what geometric changes might be appropriate to improve safety. The graphics package should include the capability to generate the following screen displays selected by the user:

- Plan view of the roadway geometrics centered on any station (i.e., location).
- Profile view of the roadway geometrics centered on any station.
- Plan view in the upper half of the screen and a profile view in the lower half of the screen centered on any station.
- View of the roadway geometrics from the driver's perspective or an elevated perspective, looking in either direction of travel from any station.

A number of highway agencies have developed graphics packages for use with their CADD systems that have some or all of the capabilities described above. Such existing packages should be reviewed to determine if one or more of them might be appropriate for use with the IHSD model.

Research Objectives

The objectives of the research under this problem statement are to:

- Develop detailed plans for a graphics package to generate screen displays of the geometrics of design alternatives including plan views, centerline profiles and perspective views.

Specific Tasks to be Performed

The specific tasks to be performed as part of this research are:

- Develop detailed plans for a graphics package to generate screen displays of the geometrics of design alternatives including plan views, centerline profiles and perspective views. This plan should be developed in sufficient detail to permit the subsequent development of the graphics package in Research Problem Statement 17.

Research Problem Statement 17

Title: Software Development to Implement Design Policy Review, Design Consistency Review, Benefit-Cost Analysis, and the Graphics Package

Description of Problem

Once the design policy review, design consistency review, and benefit-cost analysis procedures and the plans for the graphics package for use in the IHSD model have been finalized, as described in Research Problem Statements 13 through 16, the primary software development for implementing these procedures will begin. This work is intended to develop a high-quality, professional software package that applies each of the design review procedures and can graphically create and display the geometric features for each design alternative. Separate modules for design policy compliance review, design consistency review, and benefit-cost analysis are envisioned so that the IHSD model user can choose to perform any of these reviews or all of them. This software development work could be performed independently or could be combined with the software development activity for the accident predictive module described in Research Problem Statement 12.

No determination has yet been made as to whether the software for the IHSD model should be developed as a stand-alone package or as an integral part of a highway agency's CADD software. Such a decision would be premature at this time, given the rapid developments of computer hardware and software currently underway. However, the potential benefits of integrating the design review modules directly with a highway agency's CADD software package are obvious.

Human factors experts on human-computer interaction should be involved in the software development from its inception to help determine software requirements based on user needs.

Research Objectives

The objectives of the research under this problem statement are to:

- Develop high-quality, professional software for the design policy review, design consistency review, benefit-cost analysis modules of the IHSD model, and the graphics package.

- Conduct an Alpha test of the software to the point that it is ready for application and assessment by users.

It should be noted that an Alpha test is an inhouse test of a software package by its development team, in contrast to a Beta test which is a test performed by knowledgeable outsiders.

Specific Tasks to be Performed

The specific tasks to be performed under this research problem statement are:

- Prepare a final software development plan for the design policy compliance review, design consistency review, and benefit-cost analysis modules of the IHSD model and the graphics package.

- Execute the plan and develop high-quality, professional software for the design review portion of the IHSD model.

- Conduct an Alpha test of the software and make appropriate revisions to remove bugs and identify improvements to make the software more user friendly.

- Prepare the software in final form for combination with the accident predictive model component of the model and for Beta testing by potential users.

- Develop a draft users manual for the software.

Research Problem Statement 18

Title: Detailed Plan for Development of a Driver/Vehicle Dynamics Model

Description of Problem

The IHSD model should include a driver/vehicle dynamics model capable of simulating vehicle operation as influenced by roadway geometry, driver preferences and performance limitations, and vehicle performance limitations. This dynamics model would provide an indication of the loss-of-control potential for specific vehicle types traversing the geometric alternatives being considered by the designer. The driver/vehicle dynamics model would provide IHSD model users with a tool that is more accurate than the procedures in the design consistency module (based on the point mass representation of the vehicle) that could be applied to the analysis of horizontal curves flagged by the design consistency module, compound horizontal curves, and transitions between curves and tangents.

The driver/vehicle dynamics model should be capable of running a vehicle through the geometrics of any given design alternative and generating plots of (1) the lateral position of the vehicle (relative to centerlines, lane lines, and edgelines), and (2) the lateral accelerations experienced by the vehicle. Color should be used to highlight these plots. For example, the lateral position plot could be colored yellow if any portion of the vehicle approached within 0.3 m (1 ft) of a centerline, lane line, or edge line, and could be colored red if any portion of the vehicle crossed the centerline, lane line, or edge line. The lateral acceleration plot could be colored yellow when the vehicle approached within a specified margin of safety of its skidding or rollover point and could be colored red if a skid or rollover occurred.

Realistic driver behavior must be included in any vehicle dynamics model to make it a useful part of the IHSD model. It is for this reason that we have named the required model a *driver*/vehicle dynamics model, rather than simply a vehicle dynamics model, as its predecessors have been known. Research should be conducted to develop an improved driver model that includes not only driver path following, but also driver speed selection based on realistic driver reactions to the highway geometrics and to traffic control devices such as advisory speed signing. It may be necessary to include a user-selected driver aggressiveness factor or to make a safety-conservative choice and pre-select a relatively aggressive driver. The revised driver model should be developed from existing driver speed-selection logic in traffic operational simulation models, from new driver research, or from some combination of the two. A specific plan for this research should be developed; this plan should recommend the appropriate applications of specific data collection approaches, such as field data collection and driving simulators in this research.

The driver/vehicle dynamics model should allow the user to select a passenger car, a single-unit truck, or an articulated combination truck, as the vehicle to be simulated. Consideration should be given to including an option for the model to simulate the larger path deviations that might be representative of an impaired driver or the total lack of path following that might result from a driver falling asleep.

Because of recent advances in the technology for generating the equations of motion for vehicle dynamics models, the development of a new model is recommended, because this should be at least as efficient as developing a new model.

Research Objectives

The objectives of the research under this problem statement are to:

- Prepare a detailed experimental plan for development of a driver/vehicle dynamics model.

Specific Tasks to be Performed

The specific issues to be addressed in preparation of the experimental plan for the driver/vehicle dynamics model are:

- The approach to be used for developing the vehicle dynamics portion of the model.

- The types of vehicles to be considered and the determination of the specific characteristics of those vehicles needed as input data.

- The driver research needed for development of the driver portion of the model, including decisions as to the research approaches to be employed (i.e., field studies, driving simulation, etc.).

- A plan for the interface by which the driver/vehicle dynamics model will obtain input data on the geometrics of specific design alternatives.

- The types of output data to be provided and how those outputs will be displayed to the user.

Research Problem Statement 19

Title: Development of Driver Model for the Driver/Vehicle Dynamics Model

Description of Problem

The plan for development of the driver model that is developed in the work under Research Problem Statement 18 will be executed in the work performed under Research Problem Statement 19.

Research Objectives

The objective of the research under this problem statement is to develop the driver portion for the driver/vehicle dynamics model. This will require research on driver path following and driver speed selection as influenced by roadway geometrics and traffic control devices. The research plan developed under Research Problem Statement 18 will indicate the types of data collection activities to be undertaken as part of this research (e.g., field data collection, driving simulation, etc.).

Specific Tasks to be Performed

The specific tasks to be performed will be determined in the development of the experimental plan in Research Problem Statement 18.

Research Problem Statement 20

Title: Software Development for Driver/Vehicle Dynamics Model

Specific Tasks to be Performed

Once the plan for the driver/vehicle dynamics model is developed and the necessary research leading to a new driver model is complete, the primary software development for the driver/vehicle dynamics model can begin. This work is intended to develop a high-quality, professional software package that can simulate a specific vehicle traveling through the geometrics of a specific design alternative. The model will incorporate realistic vehicle operations as influenced by roadway geometry, driver preferences and performance limitations, and vehicle performance limitations. The driver/vehicle dynamics model should be capable of operating both as a stand-alone model and as part of the IHSD model.

Research Objectives

The objectives of the research under this problem statement are to:

- Develop a high-quality, professional software package for the driver/vehicle dynamics model.
- Conduct Alpha and Beta tests of the software to the point that it is ready for application by users.

It should be noted that an Alpha test is an inhouse test of a software package by its development team, in contrast to a Beta test which is a test performed by knowledgeable outsiders.

Specific Tasks to be Performed

The specific tasks to be performed under this research problem statement are:

- Prepare a final software development plan for the driver/vehicle dynamics model.
- Execute the plan and develop high-quality, professional software for the model.
- Conduct an Alpha test of the software and make appropriate revisions to the model to remove bugs and identify improvements to make the software more user friendly.

- Conduct a Beta test of the software by potential users as a stand-alone model and make appropriate revisions.

- Prepare the software for a Beta test as part of the IHSD model as a whole (i.e., linked to the accident predictive model and the design and benefit-cost analysis modules).

- Develop a draft users manual for the software.

Research Problem Statement 21

Title: User Evaluation of the IHSD Model

Statement of Problem

Once the initial development and testing of the software for the IHSD model is complete, there is a need for a thorough evaluation, or Beta test, by potential users. A Beta test of software is conducted in final or near final form, before the software is released for general use. Beta testing is conducted by knowledgeable outsiders after complete debugging of the software by its developers, although some unsuspected bugs may be uncovered during the test.

The users selected for participation in this test should be highway design engineers in State or local highway agencies and/or design consulting firms. The users selected for the Beta test should be both computer literate and experienced in the highway design process. Their evaluation will be essential both for determining whether the software is user friendly and whether the software can be used effectively in the highway design process. There is still an opportunity for further revisions to the software based on the results of the Beta test before the software is released for general use.

The user evaluation should address all aspects of the software including the accident predictive module, the design policy review module, and the design consistency review module.

Research Objectives

The objectives of the research under this problem statement are to conduct a user evaluation in order to:

- Identify any remaining bugs in the IHSD software.
- Assess the user friendliness of the IHSD software.
- Assess the practicality of incorporating the IHSD software in the existing highway design process.

Revisions to the IHSD model software can still be made as part of the work described in Research Problem Statement 22.

Specific Tasks to be Performed

The specific tasks to be performed under this research problem statement are as follows:

- Identify a group of highway design engineers in State and local highway agencies and/or design consulting firms who are willing to participate in evaluation of the IHSD model software.
- Provide a copy of the software developed under Research Problem Statements 12, 17, and 20 to each evaluator along with a copy of the draft users manual.
- Provide each evaluator with a form on which to evaluate the software and provide comments concerning the need for further revisions to the software and the users manual.
- Compile the evaluation results and prepare specific recommendations concerning the need for revisions to the IHSD model software and users manual.

Research Problem Statement 22

Title: IHSD Model Revisions and Development of Final Implementation Package

Statement of Problem

Following the user evaluation of the model, the recommendations concerning further revisions to the IHSD model software and users manual that were developed under Research Problem Statement 21 must be implemented. This will be accomplished under Research Problem Statement 22 and a final implementation package for distribution to users will be prepared.

Research Objectives

The objectives of the research under this problem statement is to:

- Make revisions to the IHSD model software and users manual in accordance with the recommendations developed under Research Problem Statement 14.

- Prepare a final implementation package containing the software and documentation for distribution to users.

Specific Tasks to be Performed

The specific tasks to be performed under this research problem statement correspond directly to the objectives stated above. These tasks are to:

- Make revisions to the IHSD model software and users manual in accordance with the recommendations developed under Research Problem Statement 14.

- Prepare a final implementation package containing the software and documentation for distribution to users.

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THE CONDUCT OF SOCIO-ECONOMIC IMPACT ASSESSMENTS: A MANUAL FOR STATE HIGHWAY PERSONNEL

Vol. I. The Impact Assessment Process

January 1983

User's Guide

Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D.C. 20590

FOREWORD

This two-volume user's guide is designed for State highway personnel responsible for assessing the potential impacts of highway projects and reporting the results in environmental documents. It focuses on site-specific assessment activities performed in conjunction with Class I major actions and Class III environmental assessments.

The Manual was developed by J.A. Reyes Associates, Inc. Stan Jorgensen, Joel Ticatch, Linda Kobrin, and John Sheridan were the principal authors. Technical inputs and guidance were provided by Ron Giguere, FHWA project manager; Joan Bossert, Environmental Research Consultants, Ltd., Denver, Colorado; Dale Hilliard, Maryland State Department of Transportation; and Carl Miller, Oklahoma Department of Transportation. Doug Willier and Kathy Osen performed research assignments on the project; Lin Webster and Nan Boova produced the final copy. Mr. Jorgensen and Mr. Ticatch served as project director and principal investigator, respectively.

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16. Abstract

This Manual is designed to assist State highway personnel to assess the socio-economic impacts of new highway construction and major improvements. It presents procedures and tools intended to simplify the conduct of thorough, systematic assessments. Seven major impacts are covered, and techniques for examining the attitudes and perceptions of local residents and leaders receive special emphasis.

Volume I discusses the primary components of assessment: (1) definition of information requirements, (2) location of sources and collection of data, and (3) analysis and presentation of findings. A variety of figures and tables are used to guide the reader through these activities.

This is the first of two volumes comprising the Manual. Volume II contains "Resource Materials" (Report No. FHWA - RD - 83 -).

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CONTENTS

Volume I. The Impact Assessment Process

FIGURES

FIGURES (continued)

TABLES

CONTENTS

Volume II. Resource Materials

Page

FIGURES

TABLES

INTRODUCTION

Since 1972, environmental impact assessments have been a required part of the planning process for all major highway projects supported by Federal Aid highway funds. In that year, the Federal Highway Administration (FHWA) published initial guidelines for implementing the transportation component of the National Environmental Policy Act (NEPA) of 1969. Over the past 10 years, these guidelines have been elaborated by FHWA (most notably in the Process Guidelines published in 1974) and adopted by many States.

Existing Federal and State guidelines provide general criteria and standards on (1) what impacts to look for when performing an assessment, and (2) the information to be assembled, analyzed, and presented in environmental documents which show assessment results. Road construction and improvement projects are normally planned and implemented at the State level. Therefore, State highway agency personnel are normally responsible for applying existing guidelines in the performance of assessments.

PURPOSE

This Manual is designed to be used by State highway personnel who are responsible for assessing the potential impacts of new highway projects and reporting the results in environmental documents. It focuses on the systematic assessment of site-specific displacement and proximity effects, and the use of findings to plan projects which stimulate positive socio-economic development and minimize adverse effects.

The Manual provides a set of checklists, procedures, and analytic techniques which State practitioners may use to:

- Define the information required to investigate impacts in study areas subject to displacement and proximity effects,
- Locate and collect this information, and
- Organize the information in formats which profile the areas subject to impacts and provide a basis for analyzing and documenting assessment findings.

The emphasis on performance of these basic activities is intended to simplify the assessment process, make it more cost-effective, and improve the quality of results.

COVERAGE

The Manual covers the assessment of social and economic impacts. Physical impacts, which are also examined in the environmental assessment process, are not covered.

The three social impacts examined are:

- Impacts on the accessibility of intra-community and outside destination points to community residents,
- Impacts on community and neighborhood cohesion, and
- Impacts on local residents caused by the displacement and forced relocation of households, local businesses, and community institutions within the right-of-way (ROW).

The four economic impacts examined are:

- Impacts on employment, income, and business activity caused by ROW acquisition and changes in accessibility,
- Impacts on residential activity, including changes in the cost and availability of existing housing, and the need for and rate of new construction in the study area,
- Fiscal impacts on local governments, including highway-induced changes in the local tax base and revenues, and in expenditures required to provide local government services, and
- Impacts on local land use and development plans.*

The Manual also covers techniques for profiling the attitudes and perceptions of local leaders, interest groups, businesspersons, and residents. Data of

*The categorization of social and economic impacts used here and throughout the Manual was developed by Skidmore, Owings and Merrill and presented in the Environmental Assessment Notebook Series (Washington: U.S. Department of Transportation, 1975). This work was a pioneering effort to codify the FHWA's guidelines and systemize the assessment activities needed to satisfy the established requirements.

special interest in this area include:

- The attitudes of respondents toward the proposed project,
- Their preferences on route location and design features, and
- Their perceptions concerning possible effects of the project on the social and economic life of affected communities.

The Manual provides guidance on the identification, collection, and presentation of data needed to explore the seven impact areas listed above, and to profile the attitudes and perceptions of potentially affected populations.

Assessment activities are normally conducted in two stages, referred to in the Manual as preliminary and detailed assessment. In preliminary assessment, practitioners identify concentrations of local residents and economic activities subject to project impacts and screen for indicators of special sensitivity to negative impacts. In detailed assessment, practitioners conduct an in-depth examination of the corridors defined by alternative alignments to determine the scope, magnitude, and duration of possible impacts.

ORGANIZATION

The Manual consists of two volumes. Volume I focuses on the three major steps in the assessment process: (1) identification of information requirements, (2) collection of data, and (3) presentation of findings. Volume II provides resource materials which can be used, as needed, to support the assessment and documentation activities described in the first volume.

The materials presented are designed for use with different types of highway projects in a variety of settings. Hence, users are free to select and use those sections of the Manual which satisfy their special needs.

Volume I: The Impact Assessment Process. The opening section of Volume I, The Context of Socio-Economic Impact Assessment, provides information which can be used to classify highway construction and improvement projects. It specifies the assessment activities and documentation requirements associated with each project category, and shows how these activities fit into the overall project planning process.

This section also discusses the seven major socio-economic impact areas examined in the assessment process. It covers the types of impacts to look for in each of these areas, and the information needed to screen for potential impacts and estimate their scope, magnitude, and duration. The discussion concludes with a description of information needed to profile the attitudes of affected populations towards the project and their perceptions concerning its possible effects.

The three main sections of Volume I focus on the mechanics of the assessment process. Part 1, Information Requirements, specifies the data needed to (1) define local study areas, (2) assess potential socio-economic impacts, and (3) profile public attitudes and perceptions. Core information requirements for completing both preliminary and detailed assessment activities are presented in a series of data fields. These fields are a checklist of the information potentially needed to conduct assessment under each of the impact areas treated in the Manual.

Part 2, Data Collection, examines the use of (1) maps, (2) records, and (3) surveys to collect socio-economic data. It identifies and discusses 9 map types, 21 record sources, and 7 survey techniques which are potential sources of the information requirements specified in Part 1.

A set of matrices is used to correlate individual data elements specified in the Part 1 data fields with the sources of these data. Since data collection activities are normally conducted by topic (e.g., population), rather than by type of impact (e.g., cohesion), the data/source matrices in Part 2 are organized in nine topical categories:

- Land use
- Community facilities
- Population
- Housing
- Business activity
- Employment
- Agriculture
- Local government finance
- Attitudes and perceptions

Part 2 concludes with a discussion of the trade-offs involved in using maps, records, and surveys as data sources. These sources are evaluated using the following criteria: (1) information available, (2) geographic units covered, (3) currency of data, (4) resources required to collect the data, and (5) reliability and validity of the data.

Part 3, Display and Analysis of Data, focuses on the use of (1) maps, (2) tables, (3) graphics, and (4) narrative formats to organize and present assessment data. These formats are used both to identify potentially adverse impacts and to present findings which meet Federal and State documentation requirements. Numerous examples are provided on the use of maps and mapping techniques, statistical and analytic tables, graphs, and narrative summaries for these purposes. Most of the examples are excerpted from environmental documents prepared by State highway agencies.

In summary, Volume I presents checklists, matrices, and procedures which can be used to complete the following assessment activities:

ACTIVITY	CONTENTS OF MANUAL	PERTINENT DISPLAYS
Define information requirements.	Part 1 specifies potential information requirements for each impact area.	Data fields are presented in Figures 3 - 11.
Locate sources and collect data.	Part 2 links individual data elements with their sources.	Topical matrices are presented in Figures 13 - 21.
Analyze and present findings.	Part 3 shows organizing mechanisms commonly used by practitioners to identify and estimate impacts and document findings.	Sample maps, tables, graphs, and narratives for organizing data are presented in Figures 22 - 59 and Tables 1 - 28.

Volume II: Resource Materials. Volume II provides backup materials -- detailed information on available data sources, sampling approaches, and analytic tools -- which may be used, as needed, to support the assessment activities described in Volume I.

Part 1, Information Sources, consists of an alphabetical listing and critical evaluation of the 9 map and 21 record sources covered in the Manual. The map sources which receive individual treatment are:

- Aerial photographs
- Census maps
- Comprehensive plan maps
- Land use maps
- Plat maps
- Soil maps
- Statewide highway maps
- USGS topographic maps
- Zoning maps

The record sources examined are:

- Agricultural statistics
- Annual operating budgets
- Building permit files
- Business directories
- Business licenses
- Capital Improvement Programs
- Census reports *
- Classified ads
- Community facility registers
- Comprehensive plans
- Criss-cross area directories
- Employment statistics
- Farm record cards
- Health facilities directories
- Library facilities directories
- Multiple listing services
- Population statistics
- Property assessment records
- Public property inventories
- School directories
- Zoning ordinances

Part 2, Survey Techniques, provides a listing and critical evaluation of the seven survey techniques covered in the Manual. These are:

- Windshield surveys
- Walk-through reconnaissance
- Purposive surveys of area elites
- Mini-surveys of area residents and businesses
- Surveys of local facility managers
- Surveys of area residents and businesses
- Trip activity surveys

The description and evaluation of these survey approaches are followed by a series of questions and response categories which can be used to collect data using each technique.

Part 3, Sampling Procedures, describes state-of-the-art sampling methodologies. It focuses on the utility and limitations of different sampling plans in solving problems encountered in generating reliable survey results, while minimizing the cost of data collection.

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*Census reports covered include:
- Block Statistics
- County Business Patterns
- Current Business Reports
- Economic Census Reports
- Tract Reports
- Urban Transportation Planning Package

Part 4, Analytic Techniques, describes state-of-the-art analytic methodologies which can be applied in the assessment process. Each methodology is discussed in terms of its particular utility in identifying significant relationships among available socio-economic data and developing reliable measures of potential effects.

Volume II may be used in conjunction with Volume I, or read independently as a compendium of sources and techniques. The relationship between activities covered in the two volumes is shown below:

ACTIVITY	VOLUME I	VOLUME II
Define information requirements.	Part 1 specifies potential information requirements for each impact area.	
Locate sources and collect data.	Part 2 links individual data elements with their sources.	Part 1 examines the utility of specific map and record sources. Part 2 evaluates individual survey techniques, and includes questions and sample response categories. Part 3 provides technical coverage of random and non-random sampling methodologies.
Analyze and present findings.	Part 3 shows organizing mechanisms commonly used by practitioners to identify and estimate impacts and document findings.	Part 4 covers advanced analytic techniques.

* * * * *

The Manual is predicated on the belief that assessment activities can frequently be simplified, and the results improved, when practitioners concentrate on a limited number of clearly stated data requirements and widely available information sources. In this context, the information requirements covered serve as a checklist of the core socio-economic data needed to conduct impact assessments. The sources identified are those most commonly available. The presentational formats offered are those widely used in current documentation.

Assessment activities and documentation required to meet Federal and State guidelines vary depending on the type of highway project proposed and the status of the project in the planning process.

Chapter 1 describes the project classification typology currently used by Federal and State agencies. It provides examples of each project type and descriptions of the environmental impact assessment activities and documentation required for each. Figure 1 summarizes these requirements for Class I, II and III projects.

The required assessment activities are then correlated with the stages in the overall highway planning process when they are normally completed, and with the decision points where the results are used to help determine the future evolution of the project. Figure 2 provides a summary schematic of the relationship between the planning and environmental assessment processes.

Chapter 2 describes the three social and four economic impact areas that are normally examined during the assessment process and addressed in formal environmental documents. This description covers the dimensions of each impact area which should be examined, and the kind of data required to complete the assessment and document findings.

The public attitudes and perceptions about a proposed project which should be examined and documented in the course of impact assessment are also discussed in terms of what information is needed and its utility in meeting the the goals of the assessment process.

This opening section provides a framework for the three major parts of Volume I which treat (1) information requirements, (2) sources, and (3) presentational formats for organizing and documenting findings.

Chapter 1. ASSESSMENT REQUIREMENTS BY PROJECT TYPE AND STAGE IN THE PLANNING PROCESS

The levels of effort and information required to examine and document the social and economic impacts of a Federally-funded highway project are determined by FHWA's classification of the project and the stage in the planning process during which assessment is conducted.*

1.1 REQUIREMENTS BY PROJECT TYPE

Projects are classified as Class I, II, or III based on their scope, complexity, resource utilization, and their foreseeable impacts on the area where they are built. Class I and Class III actions are considered to be major, and require exploration of impacts and documentation of findings. Class II actions are regarded as minor, and are usually excluded from formal assessment requirements. Figure 1 (p.10) shows the assessment activities and documentation required for each of the three project types.

1.1.1 Class I Major Actions

Class I major actions involve the taking of an extensive amount of ROW. They are expected to have significant impacts on the physical environment, and on social and economic life in the area where they are built. For example, major actions may alter accessibility and land use patterns; stimulate, direct, or limit economic development; and disrupt social ties in local communities and neighborhoods. Actions in this category include:

- Any new controlled access freeway;
- Any highway project of 4 or more lanes at a new location; and
- Any major highway development where construction involves a large amount of demolition, displacement of individuals or businesses, or disruption of local traffic patterns.

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*The classification scheme used by the Department of Transportation is adapted from Council on Environmental Quality (CEQ) regulations for implementing the procedural provisions of the National Environmental Policy Act of 1969.

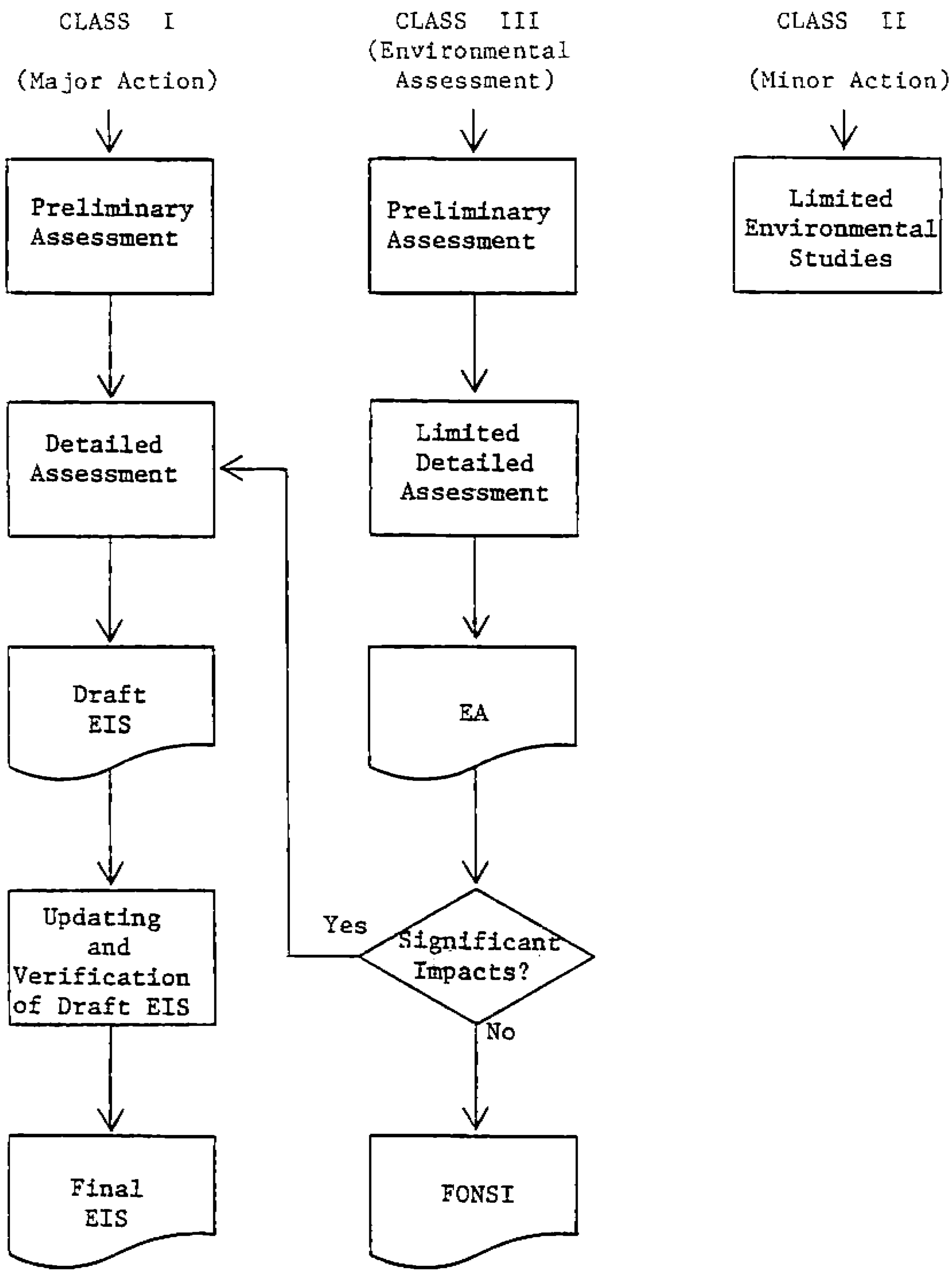

Figure 1. FHWA environmental classification of highway projects.

Class I actions require a detailed environmental study of alternative route locations and of the preferred route. Environmental studies are conducted in two stages. In the first stage, referred to throughout this Manual as preliminary assessment, planners screen for potential negative social and economic impacts. That is, they identify concentrations of residents and economic activity subject to negative impacts and screen for indicators of special sensitivity to these impacts. In the second stage, referred to here as detailed assessment, alternative routes are thoroughly evaluated to determine the scope, magnitude, and duration of possible impacts in the corridors defined by each ROW. During both preliminary and detailed assessment, planners are encouraged to disseminate information about the proposed project and solicit the views of potentially affected parties in the study area.

The findings of environmental studies are documented in the draft environmental impact statement (DEIS). The DEIS provides a profile of the study area, describes alternative routes being considered, and analyzes and compares the anticipated social, economic, and physical effects of each.* It also discusses procedures that could be implemented to mitigate impacts. This draft document thus addresses all of the environmental issues and is meant to satisfy as many of the requirements of the final environmental impact statement (FEIS) as possible at the time of preparation.

Following preparation and dissemination of the DEIS, a route-location public hearing is held.** At the hearing, interested parties are invited to give testimony regarding the proposed route locations and the possible impacts of each on their community. Comments made at the hearing, and by review agencies, along with the findings of preliminary and detailed assessment and other public input, are used to select a preferred route.

The FEIS, which is based on updated information from the DEIS, identifies the preferred alternative, and discusses why it was selected over the other routes

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*Based on CEQ's 1980 re-evaluation of guidelines for preparing environmental documentation, a preferred route may be specified in the DEIS.

**The CEQ re-evaluation also authorizes combined location-design hearings.

considered. Possible negative impacts of the preferred alternative are described and procedures to mitigate harms associated with these negative impacts are identified. The FEIS also incorporates comments received on the draft document and summarizes the results of the public participation process.

Data developed during socio-economic impact assessments, and through public participation, generally appear in the sections of the FEIS described below.*

- Alternative Routes. Here the results of social and economic assessment activities are used to compare alternative routes. Subsections on each of the routes discuss key indicators in the seven impact areas investigated and public perceptions and preferences concerning each alternative. The preferred route is highlighted in this section.

- Affected Environment. In this section, aggregate socio-economic data, collected during preliminary assessment, are used to profile the study area. This profile shows the existing conditions against which all impacts are considered.

- Environmental Consequences. This section contains detailed data on the results of all impact assessment activities, including those covered in this Manual. For each impact area, it shows what data were collected and applied to make determinations regarding the incidence and magnitude of the impact. Subsections on social impacts are: accessibility, cohesion, and displacement. Economic impacts are covered in subsections on: employment, income, and business activity; residential activity; fiscal impacts; and local land use and development plans.

- Public Participation. This section describes efforts made through public meetings and hearings, surveys, and the use of other techniques to determine citizens' attitudes toward the project, their preferences on route location and design features, and their perceptions of possible negative effects.

The preferred route must then be approved by FHWA -- based on the contents of the FEIS -- before the proposed project can enter the design stage.

This generally marks the end of the formal assessment process. However, additional studies may be undertaken and completed when special circumstances make this necessary. Examples are: instances when significant changes occur in the area subject to impact during the time lapse between the completion of the

*These sections also contain the findings of physical impact assessments which are not addressed in this Manual.

assessment and the beginning of construction which require an update of existing information; cases where the preferred route is significantly altered; and instances where other new data about the project and its ROW requirements become available which suggest that its socio-economic impacts will be different from those expected.

1.1.2 Class II Minor Actions

Class II minor actions normally require very little right-of-way and are not expected, individually or cumulatively, to have a significant effect on the environment. Examples of Class II actions are:

- Improvement of an existing highway by resurfacing, restoration, widening by less than one lane width, adding shoulders or auxiliary lanes for localized purposes, or correcting substandard curves and intersections;
- Highway safety or traffic improvement projects, including the correction or improvement of a hazardous location, elimination of a roadside obstacle, and the placement of highway signs, pavement markings, or traffic control devices; and
- Reconstruction or modification of an existing bridge on essentially the same alignment or location, including widening by less than a single travel lane, and adding shoulders, safety lanes, or walkways.

Minor actions are usually considered categorical exclusions. They do not require formal environmental assessment, public hearings or documentation, although limited studies may be conducted.

This classification is not applicable, however, when the proposed action requires acquisition of more than minor amounts of ROW or causes citizen conflict. When these exceptions occur, the project is usually designated a Class III action.

1.1.3 Class III Environmental Assessments

Class III environmental assessments are those for which the expected significance of impacts on the environment is not clearly established. They differ from Class I actions in that the length of the new facility is often shorter, and the ROW used follows that of an existing roadway for at least part of its length. Projects in this category include:

- Expansion or realignment of an existing facility, and
- Reconstruction of a multi-lane bridge or interchange area.

Actions in this class require at least a limited environmental study and the preparation of an Environmental Assessment (EA) document. If the EA identifies potentially significant impacts, route alternatives must be studied in greater depth and an EIS must be prepared. Otherwise, a finding of no significant impact (FONSI) is issued by FHWA, marking the completion of the route location assessment process.

The EA is similar to the EIS in terms of issues covered. However, the EA is developed earlier in the assessment process. It contains data used during preliminary assessment -- and, in some cases, limited detailed data on alternative routes -- to describe the study area and identify potential social and economic impacts. It need not, however, recommend a preferred route since none of those being considered may have significant negative impact on the environment.

As stated earlier, this Manual has been developed for users conducting assessments for Class I major actions that require preparation of EISs. However, the assessment procedures covered -- particularly those described in the sections on preliminary assessment -- can also be used as a guideline for development of EAs for Class III environmental assessments, and for minor actions.

1.2 REQUIREMENTS BY STAGE IN THE PLANNING PROCESS

FHWA guidelines stress identification of potential social, economic, and physical effects of proposed Class I major actions as early in the highway development process as possible. The sequence of assessment activities is reflected in the flowchart in Figure 2 (p.15) which shows socio-economic impact assessment requirements at each stage in the highway planning process.

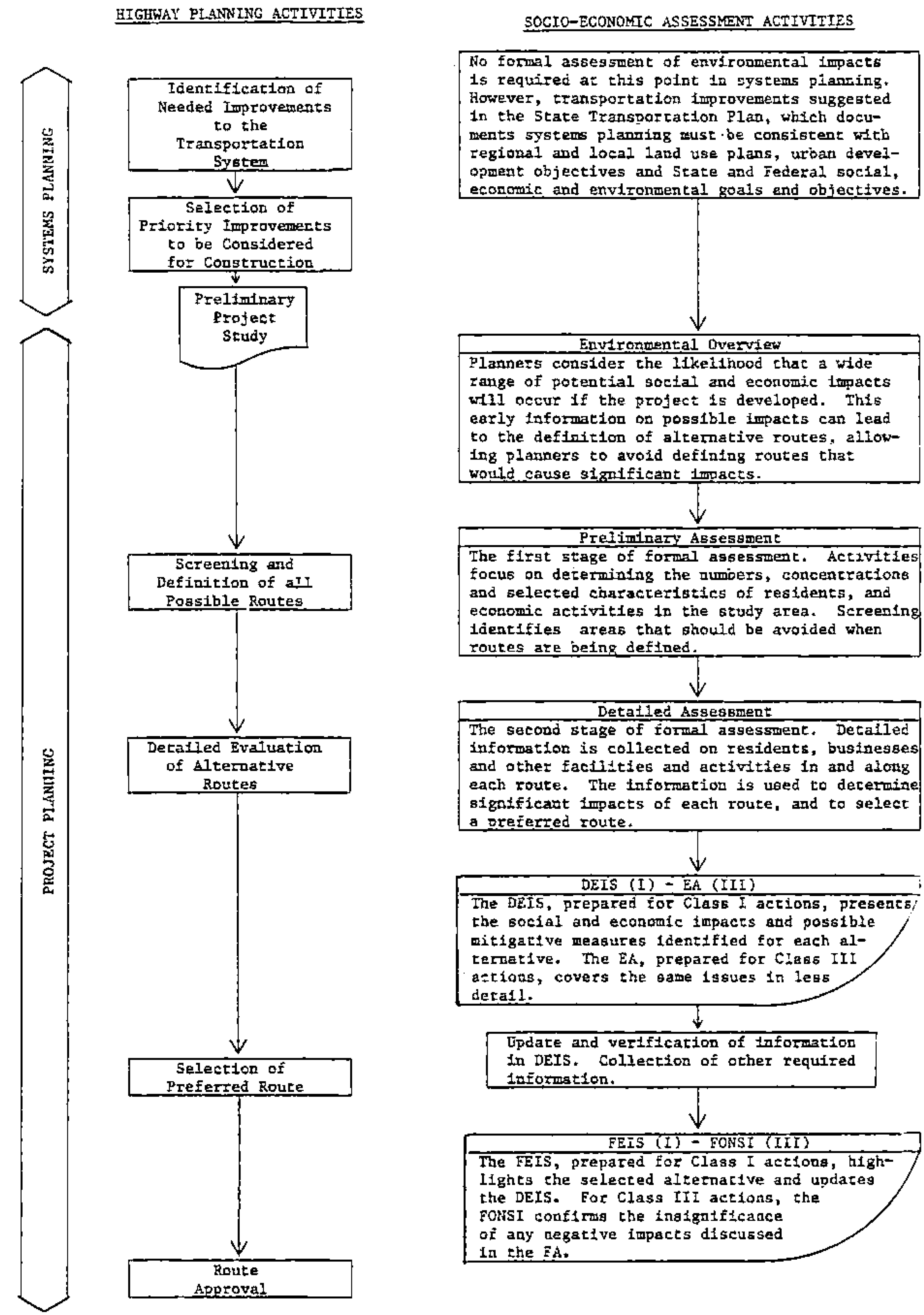

Figure 2. Socio-economic assessment by stage in the highway planning process.

Information and opinion survey activities also change according to the stage in the planning process. During preliminary assessment, the focus is on general preferences regarding the project and its value to the community. Preferences among alternative routes and perceptions concerning the potential effects of each are central during detailed assessment. Preferences regarding design features, possible relocation areas, and housing units may also be solicited and recorded during detailed assessment.

Chapter 2. ASSESSMENT REQUIREMENTS BY IMPACT AREA

This chapter describes the three major social impacts and four major economic impacts which should be examined in completing environmental impact assessments. It also describes the assessment of public attitudes and perceptions on whether to continue the project, where it should be located, what effects it will have, and which design features should be incorporated to minimize unavoidable negative impacts.

This discussion of the types and interplay of impacts is intended to provide a basis for undertaking the three major steps in the assessment process: (1) identification of the data required to investigate potential impacts, (2) location and collection of this information, and (3) organization of the data into formats which show the scope and interaction of positive and negative effects.

2.1 ASSESSMENT OF SOCIAL IMPACTS

Social impact assessment focuses on the possible impacts of highway projects on residents in affected areas. These include persons subject to displacement, encroachment, air and noise pollution, and other negative proximity effects. As noted in the Introduction, the social impact assessment activities described in this Manual focus on three areas of inquiry:

- Accessibility. Will the road restrict or deny local residents' access to important destinations within and outside their local community?
- Cohesion. Will the road disrupt the stability and cohesiveness of existing communities and neighborhoods?
- Displacement. How many homes, local businesses, and community institutions will be taken? Where are they located? Who lives in or uses them? And what is required to ensure that residents are relocated in suitable alternative housing, and that existing service levels are maintained?

The following subsections describe the impacts examined in these three areas.*

*See the list of references at the end of this chapter for the titles of publications which summarize the results of empirical studies of the impact of new highway facilities on accessibility, cohesion and displacement.

2.1.1 Accessibility

Highways are built to relieve congestion, reduce travel time and transportation costs, and improve access to destination points. Any proposed highway project entering the project planning stage must meet these criteria. The identification of beneficial effects of the proposed road on area-wide accessibility is initiated in the systems planning stage, and continues throughout the planning process.

New roads can offer similar benefits to local residents, improving their access to employment opportunities, shopping areas, recreational facilities, and other destinations. Road improvements may also allow local agencies to reduce costs and increase efficiency in providing services. For example, improved access may allow local government agencies to improve their educational and public health services, expand library services, and improve the delivery of fire and police protection services.

While the general rule is that new highways increase access, this is not always true at the local level. If communities and neighborhoods are segmented or abutted on by a new facility, the new road may make it harder for local residents to get to important destination points.

A road that passes through a local area can create barriers that disrupt free movement between interdependent parts of vital, integrated communities. Local stores, service centers, and civic institutions may also be displaced by the ROW, or may close due to changes in economic activity caused by the road. This, in turn, can make it more difficult for local residents to secure the goods and services they need.

Determining the gains and losses in accessibility -- and particularly the potential accessibility problems created at the local level -- is an important aspect of impact assessment.

2.1.2 Cohesion

It is both Federal Highway Administration and State highway agency policy to avoid severance of cohesive communities and neighborhoods when new roads are built. If local communities are segmented or encroached upon by a new facility, care is taken to minimize impacts which might disrupt or erode community and neighborhood cohesion.

While cohesion is highly valued, it is a complex, elusive concept, and it is difficult to develop direct measures of its most important dimensions. On one level, it can be said that new roads tend to increase the cohesiveness of both the economic activity and social life in the areas where they are built. They improve access, stimulate interactions, and bring people closer to each other by reducing travel times and costs. As in considering impacts on accessibility, however, such area-wide, quantifiable benefits do not always reflect what is happening at the local level. This is true, in part, because the meaning of the concept changes at the community and neighborhood level.

At the local level, cohesion is associated with strong identification with place, neighbors, and local institutions. High levels of mutual attraction between local residents are also indicators, as are shared perceptions of, and attitudes towards, common objects. Behavioral indicators of a cohesive social life at the local level include participation in local civic and neighborhood activities, use of common facilities, frequent socializing and mutual support activities.

A new highway can have permanent negative effects on social cohesion in the community through which it runs. A road that segments or encroaches on local residential areas often displaces homes and the people who live in them. The road may also displace local institutions which provide a focus for interaction among residents, or disrupt their service areas. Displacement or denial of access to retail stores and other local sources of goods and support services can also disrupt the cohesiveness of local community life.

The new road may create barriers which discourage or hinder contacts among the residents who remain, and disrupt interactions between residents and the local institutions and organizations on which they depend. This will occur when a highway facility displaces or disrupts access to key local institutions such as schools, churches, and social centers.

Other effects such as noise, increased traffic, and air pollution may drive people inside, reducing interactions among neighbors and isolating residents from each other. Additional long-term negative effects on the cohesiveness of local residents may result from changes in spatial relations and land-use patterns in the impacted area. These may alter the scale and character of the affected community, and cause residents to withdraw from their surroundings, becoming increasingly isolated and alienated.

Impacts on the social cohesion of affected neighborhoods are, perhaps, the most difficult to specify and measure. The procedures followed are similar to those followed in examining the other impacts treated here. The dimensions of the issue which pertain to the particular project and study area under consideration must be determined, and the data required to examine each of these must be specified. These data must then be located, collected, and organized to speak to the issue: How will the project affect the cohesiveness of affected local communities?

2.1.3 Displacement

The taking of residences, local businesses and community institutions, and the forced relocation of residents and businesses are the most direct, tangible effects of new highway construction. Displacement effects are not always negative, of course. There are instances where families and businesspersons who are forced to relocate are able to use the equity in their displaced homes and businesses and their relocation payments -- sometimes supplemented by additional capital from savings or loans -- to improve their circumstances. That is, residents may go from being renters to homeowners, move to larger, better maintained homes in nicer neighborhoods, and improve the quality of their surroundings.

While some displaced residents and businesspersons find opportunities in relocation, and are prepared to take advantage of them, others will find relocation difficult. People can become very attached to their homes. This attachment often extends to their immediate surroundings: their yards; relatives, neighbors, and friends in the area; local shops and other activity centers; and the general scale, feel, and location of their homes and neighborhoods.

The severance of attachments of this kind can cause serious disturbances among displaced persons.

Severance effects can be compounded when displaced families -- either because of physical constraints or for economic reasons -- are unable to relocate their households in surroundings similar to those from which they have been separated. However, even if the physical characteristics of new housing and neighborhoods are, in fact, an improvement, this cannot always compensate for the loss of connection with a home and neighborhood to which a family has become attached over time.

It is not surprising, therefore, that some relocated families have reported that they feel disoriented and isolated in their new settings and have expressed the desire to return to their old homes and neighborhoods. These feelings are often strongest immediately following the move, and diminish over time as individuals adjust to their new surroundings. Because the effects can be so extreme, it is necessary to identify possible displacement impacts early in the planning cycle, and to specify how many residences and individuals will be affected by each alternative route during detailed assessment.

2.2 ASSESSMENT OF ECONOMIC IMPACTS

Economic impact assessment focuses on the possible effects of highway projects on individual businesses and on the local economy. As indicated in the Introduction, economic impact assessment activities described in this Manual focus on four areas of inquiry:

- Employment, income, and business activity. How many businesses will the road displace? What impacts will those near the ROW suffer? Will the new road draw local consumers and workers to outside market areas? Can the local economy sustain the resulting business, customer, and income losses?

- Residential activity. How much will the housing stock be reduced? Can the remaining stock absorb displaced residents? Will the road affect future patterns of residential settlement and housing construction?

- Fiscal impacts. How will local government budgets be affected by the loss of taxable properties, displaced public facilities, and reductions in property values of land near the road?

- Land use and development plans. How will the changes caused by the road conflict with local land use and development plans?

The subsections which follow describe the impacts to be examined in these four areas.*

2.2.1 Employment, Income, and Business Activity

New highway construction and major improvements usually stimulate economic activity in the regional market area through which they pass. The purchases of materials and labor required during facility construction are the initial sources of increased economic activity, provided that they come from area sources.

The improved access provided by a new facility, which results from reduced travel time and transportation costs, also stimulates the local economy. It often means quicker and cheaper access to resources, the opening of wider markets for goods produced in the area, and access to more customers for retail marketers. These changes can reduce production costs and increase sales in the immediate and outlying trade areas. Existing businesses, especially those with high transportation costs such as heavy industry and agricultural producers, will often benefit. New businesses may also move in to take advantage of expanding markets.

Jobs are created by the initial surge of activity, and by the induced growth new roads often stimulate in affected areas. New jobs, in turn, can mean an influx of new residents, increased activity in the housing market, and new consumers who stimulate the local economy. This sort of growth is a secondary, or indirect, impact of highway construction.

If undeveloped or depressed areas are made more accessible by the new facility, there is a likelihood of positive impacts on a large scale. Improved

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*The list of references at the conclusion of this chapter includes publications which summarize empirical studies of the impact of new highway facilities on employment, income and business activity, residential activity, local government finances, and land use.

accessibility may result in the development of outlying areas or the redevelopment of urban acreage.

While the general effect of a new road is to stimulate economic activity, the area in and near the ROW may be subject to serious negative impacts. Local businesses must often bear these effects. It is the special responsibility of economic impact assessments to focus on the effects of the proposed facility on local business activities and individual businesses subject to displacement and negative proximity effects.

Displacement. The displacement and forced relocation of businesses in the ROW is the most tangible negative economic impact that a highway project can have on a local economy. Displaced businesspersons may feel they will be unable to operate outside their established location and close down; or they may choose to reestablish operations at a new location. Regardless of whether these businesses liquidate or relocate in other parts of the region, displacement usually means a reduction in employment opportunities, services for residents, and revenues for local governments. Any losses in jobs, services, and revenues will, of course, have negative multiplier effects similar to those of the positive impacts. For these reasons, planners try to avoid the displacement of businesses, especially those that employ study area residents and those upon which local residents are dependent.

Construction Impacts. During construction, businesses near the ROW may lose customers and sales revenues due to detours, heavy truck traffic, and other access problems. Other effects, such as noise and dust, may also reduce revenues. These losses can shut down a business since construction often takes up to a year or more.

Proximity Effects. Once the highway facility is complete, nearby businesses may suffer from noise and air pollution, safety hazards, and other negative proximity effects. The completed facility can also cause reductions in local street traffic and create access problems for some businesses by introducing limited-access roads, or by eliminating on-street parking, turn lanes, etc.

These proximity effects can make it difficult or unpleasant for customers to patronize neighborhood establishments and force them to use other shopping areas. Resulting reductions in sales and revenues are likely to be as permanent as the proximity effects. Affected businesses may be forced to lay off employees and, in some instances, to close down. While States are not responsible for mitigating patronage problems, they try to minimize all proximity effects through route selection.

Indirect Impacts. Reductions in patronage of local establishments can also be caused by area-wide accessibility changes that (1) make it easy for consumers and workers to get to other market areas, and (2) induce the inflow of new businesses that capture demand previously met by existing establishments. These changes may result in the weakening of existing businesses, another round of shutdowns, and elimination of incentives for normal growth.

Agricultural Impacts. New construction which passes through agricultural areas may also cause negative effects. Prime and unique farmland is protected by Section 4(f) provisions, but in some cases, displacement of acreage for the ROW may be unavoidable.* Depending on the ROW location, the loss of land -- and productivity -- may be compounded by segmentation of remaining parcels. Segmentation can restrict access to the land and increase the cost of production.

The increased cost of farming these isolated parcels may cause farmers to leave them idle, which further reduces the total number of tillable acres. Additional acreage may be lost if the new facility induces development on agricultural land at interchanges and along the ROW.

Multiplier Effects. If the negative effects discussed above are substantial, they will have a ripple effect throughout the local economy. Losses felt by businesses in and near the ROW, combined with indirect effects, can lead to higher levels of unemployment, reduced demand, lower revenues and a downward spiraling economy. When market areas become depressed, they are frequently subject to population losses which make recovery difficult.

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*See Department of Transportation Act of 1966, Section 4(f); Title 49, U.S.C. Section 1653(f); Title 23, U.S.C. Section 138.

The impacts on local businesses will be magnified if the new facility bypasses a small town and its local economy, or improves the access of local populations to a major market area that provides job opportunities, and goods and services that are unavailable in the locality.

As indicated by the discussion above, this impact area is broad and multidimensional, and the effects to be explored are both direct and indirect, immediate and long-term. Explanation of impacts on employment, income and business activity requires the collection of data which can be used to profile economic activity across the area.

2.2.2 Residential Activity

Assessment in this area is concerned with changes in the housing stock, in the availability and cost of housing, and in local residential settlement patterns that, in turn, alter trends in residential construction.

A new highway facility can stimulate the local housing market by creating new demand for housing. If the facility provides improved access between the area subject to proximity effects and other regional locations -- especially major employment centers -- the study area may become a more desirable place for workers and other potential residents to live. Over time, housing can be further stimulated by the multiplier effects of increased area-wide business activity, i.e., some of the work force attracted to impacted areas by new job opportunities will be drawn from outside the region and require new housing.

These highway-induced demands for housing will first absorb the available units. If the existing stock is insufficient to meet demand, there will be new residential construction in the area. The building of new homes will create jobs and increase demand for other resources in the construction sector of the economy. Then, through an additional series of multiplier effects, the induced residential construction will stimulate business activity throughout the economy.

A new facility can also influence residential development by creating attractive investment opportunities. If a highway provides access to a previously isolated area where undeveloped land is available, or to blighted areas, investors may attempt to capitalize on improved access to these areas by turning them into residential communities.

In the years following any initial residential influx, the consumer demands of the area's new population will stimulate additional business start-ups, more jobs, and another round of economic growth.

Economic growth and other stimulants to residential activity, however, are not always desirable. Some localities will oppose a new road for the very reason that, in the long run, the highway is expected to cause artificially high levels of residential inflow, new construction and uncontrolled economic growth. In the short run, the highway project may also disrupt the equilibrium between housing supply and demand and, therefore, the existing pattern of residential activity.

Reduction in the Local Housing Stock. The most immediate and tangible impact on residential activity occurs when route location necessitates displacement of dwelling units situated on land required for the ROW. The residential housing stock is reduced by the number of dwellings taken; and at the same time, demand for the remaining stock increases as displaced families look for new homes. If displacement is substantial, i.e., if the number of dwelling units taken is high relative to the total number of units in the study area, this pressure on the market may raise the costs of available housing for local residents. It can also cause overcrowding.

Shortages of Relocation Housing. The existing housing stock in the local area may be inadequate to meet the housing needs of displaced families. The likelihood of inadequate housing has increased in recent years due to a growing nationwide housing shortage and abnormally high housing costs. When comparable housing is available to relocatees, the costs may place it out of the range they can afford. A displaced family, then, will become eligible for the benefits of housing of last resort, an FHWA program which provides special relocation assistance in unusual circumstances.*

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*See the Uniform Relocation Assistance and Real Property Policies Act of 1970, Title 42, U.S.C. Section 4601-4655 (P.L. 91-646). This Act has been implemented through the Federal Aid Highway Program Manual, Volume 7.

These impacts will be compounded in urban areas if highway facilities are routed through the more deteriorated parts of a city. Displaced dwellings will tend to be old and dilapidated, housing the poor, the aged, and ethnic minorities. When displaced, these people will seek low-cost housing, which has become increasingly scarce in cities due to slum clearance, enforcement of housing codes, and the higher cost of inner-city housing. In summary, the the housing market may not respond to the demands of these relocatees.

When comparable replacement housing is inadequate or unavailable, Federal law requires that housing be built to meet the needs of those being displaced. Construction of new dwellings is infrequent, however, occurring only when a project causes high levels of displacement usually associated with urban expressways. Subsidized housing lessens the negative impact on residential activity, but it is not considered a satisfactory solution.

Undesirable Residential Construction. While increases in population and induced residential construction brought about by the highway may be good for the local economy, they may not be in keeping with local development plans. The planning goals of towns that attempt to limit and control growth for aesthetic reasons, or to preserve the character of the locality, can be negatively affected by an externally induced surge of residential construction. Even in areas where no plans to limit development exist, an unforeseen population increase can cause overcrowding and deterioration of the quality of life in the community (see Section 2.2.4 below). The influx can also overload local public facilities, reducing the quality of life in the study area.

Examination of impacts on residential activity requires knowledge of the housing market in the impacted area and of local development plans and trends. The practitioner must also have the ability to forecast the effects of the proposed facility on the local economy.

2.2.3 Fiscal Impacts

When a new highway facility provides improved access, land near the facility -- where accessibility gains are concentrated -- tends to increase in value. The travel time and cost savings associated with affected parcels is, in effect, capitalized in the value of real estate. As properties increase in value over time, they will generate additional tax revenues for local governments. Enhanced accessibility may also lead to other increases in tax revenues. The new sources of tax dollars are businesses and residences that come into the area, previously unused parcels that may be developed, and already improved land that may be subject to more intensive uses.

While new businesses, residences and other types of development will increase the tax revenues of local governments, they will also make offsetting demands on local services, the main source of local governments' expenditures. Tax revenues from new commercial and industrial development will normally exceed expenditures for increases in public service provision. But in the area of residential development this is not always the case, since an influx of new residents can bring about large increases in the demand for public services, e.g., education, the most costly public service.

In the long run, tax revenues that accrue to the local government from highway-induced increases in property values and new development usually outweigh -- or at least offset -- negative tax effects. In the short run, however, negative effects which occur before any tax benefits are realized can have negative impacts on local government finances.

Tax Base Losses. The amount of taxable land in the study area is reduced when privately owned land is acquired by the State for the highway's ROW. Reductions in the tax base lead, in turn, to a reduction in property tax revenues.

Reductions in the tax base should also cause an offsetting reduction in government expenditures because homes and businesses taken for the ROW no longer make use of publicly financed services. However, because only the incremental costs, and not the fixed costs, of service provision are usually affected by these reductions in demand, there will be little or no effect on the overall cost of public service provision. The major exception is when displacement takes a large number of homes and businesses.

In summary, if a significant percentage of a locality's tax base is eliminated, the resultant revenue losses can destabilize the local budgets. No compensation is provided to local governments which would lessen the impact of losses in tax revenues.

Reductions in Property Values. Because revenues from property taxes are a major source of funds for local government operations, reductions in property values will cause reductions in local revenues. While most land near the proposed facility is likely to increase in value as a result of increased accessibility and development potential, land directly abutting on the facility is likely to drop in value. Decreases in property values are attributable primarily to negative spillover effects, such as noise and air pollution, heavy traffic, or safety hazards. These negative effects interfere with residential areas more than commercial ones; therefore, residential property is most vulnerable to devaluation. To avoid a drastic devaluation, residential property is sometimes rezoned for commercial use. Some decreases in property values, however, can be expected regardless of land use.

Similar reductions can result when a new facility restricts access to certain parcels of land. Affected parcels include those far from exit and entry points, e.g., those between the interchanges of limited-access routes.

Examination of impacts on local government finance requires information on sources and uses of tax revenues for the affected governments. This information, combined with knowledge of potential effects of the proposed project, provides a basis for tracing positive and negative tax base impacts.

2.2.4 Local Land Use and Development Plans

Transportation is a major determinant of land development patterns. Thus a new highway facility or major improvement can have a pivotal effect on the future development and uses of land in the area where it is built. When a proposed project is studied during systems planning, efforts are made to ensure that it will be consistent with regional land use and growth plans. In fact, planners often incorporate plans for new road construction into regional comprehensive plans, making the new roads an integral part of planned development projects. In these cases in particular, and usually in all cases, a new road can be expected to be compatible with regional development plans.

At the local level, this is not always true. Assessments in this area, then, must focus on the relationship between existing plans at the community level and the anticipated impacts of proposed highway projects.

Local government agencies -- counties, municipalities, towns and townships -- generally engage in the development and implementation of some form of land use planning. The purpose of this planning activity can be to stimulate growth and direct it in such a way as to secure the associated benefits and avoid undesirable effects. In other instances, the goal may be to limit economic growth, to maintain the residential character of a community, or to preserve the desired aesthetic relationship between structures in the area and their setting.

A new highway facility can further community plans for growth and development by inducing changes in the area that are consistent with planning goals and objectives. Changes such as the attraction of new business, induced increases in residential construction, and more intensive land use are often considered positive by localities. This might be the case if highway-induced effects stimulate the maximum economic development possible without causing overcrowding and reductions in the quality of life.

In some study areas, the same changes will be incompatible with local development plans. Highway effects which planners may see as undesirable for residential communities include the intensification of land use, the attraction of commerce and industry, and an increased rate of population inflow. For example, in stable local communities, the highway-induced attraction of local consumers to more distant markets, or the attraction of new and larger stores to compete with existing ones, may destroy the local economic balance.

Often the changes induced by a highway will be only partially consistent with future plans. The goals of a locality desiring economic growth may also include preservation of open spaces and parks. If a facility that promises to stimulate economic activity must be routed through these areas, then community plans are both positively and negatively affected. In these cases, a trade-off analysis will be required to determine whether the beneficial impacts outweigh the harmful ones.

2.3 ASSESSMENT OF PUBLIC ATTITUDES AND PERCEPTIONS

It is the policy of both the FHWA and State highway agencies that information on the attitudes and perceptions of citizens in affected areas should be collected and incorporated into the decisionmaking process at each stage in the assessment process. Based on past experience, a project is unlikely to be built if a significant number of citizens in the affected area have strong negative attitudes and perceptions concerning the proposed project. Therefore, it is essential at each stage in the planning process to determine (1) what information about public attitudes and perceptions should be available to decisionmakers at the time, (2) whom the information is to be collected from, and (3) how to collect the data.

Major decisions where public input is critical include decisions on whether the project should be constructed, where the new facility should be located, and what design features to include. Information is commonly collected from public officials, heads of local institutions and other local leaders, businesspersons, residents, and potentially displaced families.

Respondent surveys are the most common means of data collection. However, attitudes and perceptions can also be extracted from records of public hearings, newspaper articles, and other written sources.* Examination of analogous cases can also provide useful information on who can be expected to support and oppose the project, and why they will adopt the positions they take.

Information on perceptions of effects and the importance assigned to each can serve several purposes. It shows the reasoning behind expressed attitudes and preferences. It can also alert assessment teams to possible negative impacts which should be examined in detail using data from maps, records, and other sources. Perceptual data can also reveal citizen misconceptions which should be addressed in public meetings and in other communications developed by State highway agencies to inform the public about the project.

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*A staple here is local planning documents and zoning ordinances which express community goals in the areas of new development, preservation and the limits of desirable growth.

Descriptive data on the socio-economic characteristics of respondents are typically collected along with data on attitudes and perceptions. Analysis of findings is then used to correlate attitudes and perceptions with socio-economic characteristics and specify what segments of the community will resist the planned development.

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Part 1. INFORMATION REQUIREMENTS

Part 1 is devoted to (1) specification of the core data required to conduct socio-economic impact assessments, and (2) discussion of how these data are used to explore and anticipate potential impacts and develop measurements of their magnitude, intensity, and duration.

Chapters 3 - 6 focus, respectively, on the data elements needed during preliminary and detailed assessment to:

- *Define the study areas,*
- *Identify and assess potential social impacts,*
- *Identify and assess potential economic impacts, and*
- *Identify and profile the attitudes and perceptions of persons living and working in the areas subject to impact.*

Each chapter contains a set of data fields showing the information elements required to perform the indicated activity. These fields, taken together, provide a comprehensive inventory of assessment data. Practitioners may wish to use the data specified in these fields to construct their own, project-specific list of information requirements.

The narrative sections of each chapter discuss the use of these data (1) to profile the impacted area, (2) to screen for potential negative effects, and (3) to develop measures of their magnitude, intensity, and duration.

Chapter 3. DATA REQUIRED TO DEFINE THE STUDY AREA

Socio-economic impact assessment begins with the development of spatial boundaries for the area where impacts will be investigated. In this Manual, the area subject to impacts from all feasible route alternatives, which is defined at the beginning of preliminary assessment, is referred to as the macro-scale study area. The areas defined by each alternative ROW examined in detailed assessment, and the corridors along the ROWS where proximity effects may occur, are referred to as micro-scale study areas.

The following sections discuss data requirements for defining study areas during preliminary and detailed assessment. Figure 3 (below) shows the additional data -- beyond the project-specific and transportation-related data on hand when assessment begins -- which is typically required to define macro and micro study areas.

****
LAND USE
****

Aggregate Data on Land Use
- Topographic features*
- Boundaries
  - community
  - neighborhood
  - political
- Land use by activity

****
COMMUNITY FACILITIES
****

Aggregate Data on Community Facilities**
- Number
- Type
- Location

****
POPULATION
****

Population Concentrations
- Population centers

****
HOUSING
****

Concentrations of Residential Structures
- Locations
- Types of housing

****
EMPLOYMENT
****

Major Employment Area
- Number
- Type
- Location

****
BUSINESS
****

Concentrations of Businesses***
- Number
- Type
- Location
- Number of tenants

****
AGRICULTURE
****

Aggregate Data on Agriculture
- Prime and unique farmlands
- Farms
  - number
  - location

*Includes natural and manmade features.
**Includes police stations, fire and rescue facilities, health care facilities, schools, libraries, religious facilities, social/cultural facilities and recreational facilities.
***Includes shopping centers, industrial parks and office buildings.

Figure 3. Data used to define the study area.

3.1 DEFINING THE MACRO STUDY AREA IN PRELIMINARY ASSESSMENT

The first task in the preliminary assessment phase is to gather information needed to define the macro-scale study area. Practitioners use data on the proposed project, which is usually already available to them, to get a clear idea of the project and its scope. The dimensions of the proposed improvement or new construction, the location of terminal points, and the project's length and approximate width are identified. Information on the project's purpose also often helps planners to clarify the boundaries of the study area. If data are available at this stage on total acres of ROW to be used, the possible locations and acreage requirements of major interchanges, and feasible route alternatives, this information should also be examined. To put project information in a spatial context, information on existing maps of the area is examined. These maps show the terrain of the area, and the existence of natural and manmade corridors and barriers which help frame and delineate the study area. They also provide information on the roadway network now serving the area.

Data on existing public transportation systems and overall traffic statistics for the area are also useful in defining boundaries. Other useful map information includes concentrations of housing and business activity, the location of major public and private facilities, and existing recreation areas and open space.

In defining the study area, it is also valuable to explore the relationship between the spatial area subject to potential impacts and the smallest units of aggregate data on population, housing, and business activity found in standard statistical sources. Examples of units for which aggregate data are available are census tracts and blocks, counties, and townships.

Information on political jurisdictions which bound and segment the potential study area, and on the boundaries of affected regional and local planning areas, is also highly useful. This information not only helps to define study area boundaries; it also indicates possible sources of information which can be used to explore project impacts.

When the study area for preliminary assessment has been defined, it is typically shown in spatial terms on a base map against a backdrop of selected natural and manmade features.

3.2 DEFINING MICRO STUDY AREAS IN DETAILED ASSESSMENT

In detailed assessment, the initial problem normally is to subdivide the macro study area into segments which correspond to areas subject to the displacement and proximity effects of each alternative route under consideration. These corridors, or micro-scale study areas, are defined initially by overlaying the proposed ROWs on base maps developed in preliminary assessment.

Information on the proposed facility should be reexamined in relation to the features of the areas through which each alternative route passes. Special attention should be paid to any new, more exact information on entry and exit points, possible design features, and ROW requirements which emerge as alternative routes are specified. For example, study areas often should be extended around major interchanges, since the magnitude of impacts is typically greatest at these points and their ramifications are more far-reaching. Other design features, such as vertical alignment and the use of frontage roads, will also affect the size of the study area.

In defining micro study areas, it is useful to look again at what is known about population, housing, and business concentrations; the location of key facilities; and the configuration and use of the existing transportation network. This information takes on added significance when the locations of possible ROWs have been defined. The same is true for information on political jurisdictions and planning area boundaries.

It is also useful to reexamine the spatial units covered by available statistical sources to see how they match up with the boundaries of study areas developed during detailed assessment. Maps and records data which provide more detail on the boundaries of local service areas -- e.g., school districts -- and areas served by local shopping centers may also be useful in refining study area boundaries. These more detailed sources can be secured from local agencies.

In summary, the information used to define the areas subject to detailed assessment is similar to, but more detailed than, that used in determining the area examined in preliminary assessment. The fact that the locations of alternative ROWs have been defined provides new information and gives new significance to existing data.

Chapter 4. DATA REQUIRED TO ASSESS SOCIAL IMPACTS

The factual data required to profile the study area and screen for social impacts, specified by impact area, are presented in the following sections. Discussions on using this information are also presented by impact area.

See Chapter 6 for a discussion of data on attitudes and perceptions used in social impact assessment.

4.1 ACCESSIBILITY

The following subsections discuss the data required to assess the impact of proposed projects on accessibility during preliminary and detailed assessment. Figure 4 (p. 39) specifies the data elements used to complete and document the assessment process.

4.1.1 Data Used in Preliminary Assessment

Screening for possible impacts on access to important destinations begins with a review of data on the proposed project. This will include its end points, size, projected average daily traffic (ADT), and general ROW requirements.

The existing transportation network in the macro study area must be examined. This will include a look at traffic statistics showing ADT by route, if the information is available. If these data distinguish between local and through traffic, or contain other detail on origins and destinations, type of vehicle used, trips during commuter hours, etc., this information should be examined for what it says about local travel patterns. Statistics on travel to work, generally available in census publications, should also be consulted. Estimates of the impact of the proposed facility on ADT for existing roadways should also be taken into consideration.

The next step is to look at existing information on the total number and concentrations of residences in the macro study area. Neighborhoods should also be identified. These data should be supplemented by information on the number

PRELIMINARY ASSESSMENT

****
LAND USE
****

Aggregate Data on Land Use
  Total land area
  Topographic features *
  Boundaries
    community
    neighborhood
    political
  Land use by activity

****
COMMUNITY FACILITIES
****

Aggregate Data on Community Facilities **
  Number
  Type
  Location

****
POPULATION
****

Aggregate Population Data
  Population density
    persons per acre
    persons per household
  Total population
    by age
    by race/ethnicity
    by marital status
    by household relationships
    by occupation
    by family income
    by number of automobiles
  Population trends & projections
    total population
    by age
    by race/ethnicity
    by income
Population Concentrations
  Over 65
  Ethnic minorities
  Religious minorities
  Low-income families
  Female-headed households
  Foreign-born
  Non-English speaking

****
HOUSING
****

Aggregate Housing Data
  Total housing units
Concentrations of Residential Structures
  Location
  Types of housing
  Condition of housing
  Approximate number of units

****
EMPLOYMENT
****

Aggregate Employment Data
  Total persons in labor force
  Total persons employed
    by industry
    by occupation
  Unemployment rate
    total unemployed
Major Employment Areas
  Number
  Type
  Location
  Approximate number of employees
  Residential concentrations
  Modes of travel to work

****
BUSINESS
****

Concentrations of Businesses ***
  Number
  Type
  Location
  Number of tenants

DETAILED ASSESSMENT

****
COMMUNITY FACILITIES
****

Data on Individual Facilities
  Service area
  Usage
    enrollment/membership
    total capacity
    usage/capacity ratio
  Population served
    by age
    by race/ethnicity
    by income level
    by neighborhood of residence
    by mode of travel
  Facility-to-population standard

****
POPULATION
****

Data on Individual Households
  Number of licensed drivers
  Number of vehicles owned
  Proximity to destination points
    place of employment
    shopping areas
    community facilities
  Predominant mode of travel
Trip Activity of Individuals
  Characteristics of tripmakers
    age
    sex
    race/ethnicity
    occupation
    income
    disabilities
  Individual trips ****
    mode of travel
    origin/destination
    route followed
    travel time
    cost
    purpose
    importance

****
EMPLOYMENT
****

Data on Individual Employees
  Place of employment
  Location of residence
  Mode of travel to work
  Route followed
  Cost

****
BUSINESS
****

Data on Individual Businesses
  Service area
  Clientele served
    by age
    by race
    by ethnicity
      by income level
      by residential area
      by mode of travel

*Includes natural and manmade features.
**Includes police stations, fire and rescue facilities, health care facilities, schools, libraries, religious facilities, social/cultural facilities and recreational facilities.
***Includes shopping centers, industrial parks and office buildings.
****Includes trips to employment areas, community facilities, shopping areas, recreation and other important destinations.

Figure 4. Data used to assess impacts on accessibility.

and location of major work places, shopping centers, schools, recreation areas, and other facilities used by the people living in the area.

Additional data on population characteristics are collected and used to screen for concentrations of residents who have limited mobility and may suffer from any disruption of normal trip patterns. Key indicators of the population at risk here are number of households without cars; number of elderly persons and school-aged children; low-income families; handicapped individuals; and concentrations of minority-group members and foreign-born residents. Physically disabled persons and people with low incomes have fewer travel options available to them and are more likely to rely on pedestrian routes, making them particularly vulnerable to the negative impacts of physical barriers, increased traffic and faster travel speeds. An understanding of the access-related gains and losses of populations with limited mobility is particularly important, given the sensitivity of these citizens to changes in access to critical destinations.

Information should also be collected on the location of public facilities, retail outlets, office buildings, and other work and recreation areas which play a significant role in the lives of local residents. These data are used to see the relationship between residences and key destination points in the local area.

4.1.2 Data Used in Detailed Assessment

In detailed assessments of alternative routes, the initial task is to regroup data collected in preliminary assessment to reflect the micro study areas defined by proposed alternatives. Once this is done, the information can be used to estimate the potential impacts of each route, and to compare routes to determine which will have the minimum negative impacts on accessibility.

If a proposed route passes through areas with a significant residential population, more detailed information on the trip activities of local residents may be required. Information of interest here includes origin and destination points, trip frequency and purpose, arrival and departure times, and modes of travel. These data are generally not available in records or map sources.

They can, however, be collected using on-site observation, interviews, or trip diaries.

Information on trip generators within the local community, e.g., local stores, service centers, and public facilities, is also used to determine key trips, modes of access, and destination points. Data collection here focuses on service areas, number of persons using the facility and its services, where these people live, and how they get to the facility. Records maintained by local organizations in the impacted areas are normally the sources of these data.

4.2 COHESION

The following subsections discuss data required to assess the impact of proposed projects on the cohesiveness of affected communities and neighborhoods during preliminary and detailed assessment. Figure 5 (p.42) specifies the data elements used to complete and document this assessment.

4.2.1 Data Used in Preliminary Assessment

During preliminary assessment, it is the responsibility of impact analysts to (1) identify the communities and neighborhoods in the areas which are subject to highway effects, and (2) screen for communities with high levels of cohesion, and populations particularly sensitive to project-related disruptions of their daily activities.

The assessment begins with a review of information on population clusters and community boundaries in the macro study area. Information on the existing transportation network, and on natural and manmade barriers, is also examined. The relationships of these features to population concentrations are noted. The boundaries of local political units should also be taken into account.

The next step is to take a closer look at the characteristics of homes and residents in the community(ies) identified in the study areas. This closer look should serve to identify groups of residents with characteristics which are used as indirect, or proxy, indicators of high levels of cohesiveness, and to screen for indicators of special sensitivity to the disruptive effects of a

PRELIMINARY ASSESSMENT

****
LAND USE
****

Aggregate Data on Land Use
- Total land area
- Topographic features*
- Boundaries
  - community
  - neighborhood
  - political
- Land use by activity

****
COMMUNITY FACILITIES
****

Aggregate Data on Community Facilities**
- Number
- Type
- Location

****
POPULATION
****

Aggregate Population Data
- Population density
  - persons per acre
  - persons per household
  - persons per room
- Total population
  - by age
  - by race/ethnicity
  - by marital status
  - by household relationships
  - by occupation
  - by family income
  - by number of automobiles
- Population trends & projections
  - total population
  - by age
  - by race/ethnicity
  - by income

Population Concentrations
- Over 65
- Ethnic minorities
- Religious minorities
- Low-income families
- Female-headed households
- Foreign-born
- Non-English speaking

****
HOUSING
****

Aggregate Housing Data
- Total housing units
  - by type
  - by tenure
  - by units per structure
  - by age of structure
  - by rooms per unit
  - by persons per room
  - by condition
  - number without plumbing facilities
  - number without kitchen facilities
  - owner-occupied by value
  - renter-occupied by monthly rent

Concentrations of Residential Structures
- Housing types
- Condition of housing
- Approximate number of units

****
EMPLOYMENT
****

Aggregate Employment Data
- Total persons in labor force
- Total persons employed
  - by industry
  - by occupation
- Unemployment rate
  - total unemployed

****
BUSINESS
****

Concentrations of Businesses***
- Number
- Type
- Location

DETAILED ASSESSMENT

****
COMMUNITY FACILITIES
****

Data on Individual Facilities
- Service area
- Usage
  - enrollment/membership
  - total capacity
  - usage capacity ratio
- Population served
  - by age
  - by race/ethnicity
  - by income level
  - by neighborhood of residence
  - by mode of travel
- Facility-to-population standard

****
POPULATION
****

Data on Individual Households
- Residence
  - tenure of residence
  - time at current residence
  - time in area
- Composition of household
  - number of persons
  - relationship of residents
  - by sex
  - by age
  - by race/ethnicity
  - by educational background
- Number handicapped
- Number in school
- Employment of each resident
  - number employed by occupation
  - number unemployed by occupation
- Household income
- Number of licensed drivers
- Number of vehicles owned
- Proximity to destination points
  - place of work
  - shopping areas
  - community facilities
- Predominant mode of travel
- Social interaction
  - frequency of social contact with neighborhood residents
  - participation in local organizations and activities
  - frequency of mutual support activities

*Includes natural and manmade features.

**Includes police stations, fire and rescue facilities, health care facilities, schools, libraries, religious facilities, social/cultural facilities and recreational facilities.

***Includes shopping centers, industrial parks and office buildings.

Figure 5. Data used to assess impacts on cohesion.

new road. These include:

- Areas where a high percentage of residents have lived at the same address for periods of five years, ten years or longer. Stability and low turnover rates are associated with strong neighborhood ties, resistance to change, and high levels of intergenerational cultural transmission.

- Areas marked by concentrations of residential housing units with shared characteristics. Variables of particular interest here are type and market value of housing, owner-occupancy rates, and ratios of persons-per-room and rooms-per-dwelling-unit. The assumption here is that people occupying similar dwelling units also share other psychological and behavioral characteristics. Discontinuities in these same housing characteristics are viewed as indicators of neighborhood boundaries and transitional areas.

- Neighborhoods with concentrations of racial and ethnic minorities, foreign-born residents, and persons with strong cultural or religious ties. These are indicators of high levels of dependence on the group for both emotional and economic support.

- Areas with concentrations of persons over 65, children under 18, single-parent or female-headed households, and persons who do not have access to automobiles. These indicators of vulnerability to the disruption of normal daily activities suggest limited mobility and possible access problems.

4.2.2 Data Used in Detailed Assessment

In detailed assessment, the information on community boundaries, residential clusters, and the characteristics of residents is reordered and used to make comparisons between micro study areas affected by each route alternative. Sometimes the units of statistical data on housing and population characteristics do not match up with the spatial units of the study areas, and comparisons of key indicators cannot be made using standard statistical sources. In these instances, there may be a need to supplement statistical data with information collected by State and local sources.

Survey techniques -- on-site observations, interviews, trip diaries, etc. -- can also be used in detailed assessments to collect information on behavioral indicators of cohesion. These include the nature and frequency of interactions among residents, and between residents and local institutions. Survey approaches used here are often modifications of traditional origin-destination surveys which are adapted to make the residence the radiant point in recording trip activities and social interactions. Respondents may also be asked to rate or rank the importance of trip types and interactions. Map overlays are often used here to show the routes which residents frequently travel -- by car, bicycle, or on foot -- in order to reach intra-community and outside destination points.

Another approach is to record observations on frequency and time of use for local facilities. Other variables commonly collected are the home address, mode of travel, and demographic characteristics of users.

Survey questionnaires directed at local residents can also be used to generate direct measures of identification with place and attitudes toward possible displacement. Often, perceptual data concerning the proposed project's impact on community life are also collected.

In assessing negative impacts on cohesion by route alternative, close attention should also be paid to the results of the assessment of displacement effects. This includes data on the displacement of residents, community facilities and open space.

4.3 DISPLACEMENT

The following subsections discuss the data required to identify the potential displacement effects of a proposed project. Figure 6 (p. 45) specifies the data used to complete and document the assessment process.

4.3.1 Data Used in Preliminary Assessment

To explore displacement effects during preliminary assessment, it is essential to review existing information on the size of the facility, the possible routes where it may be located, and the number of acres which must be taken to construct the facility. The number and types of dwelling units possibly affected, and their distribution across the study area, is also essential information here. Information on areas with high concentrations of residences can be used to block out zones in the study areas where displacement will be most severe if land is taken to build a road.

****
LAND USE
****

Total land area
Topographic features*
Land use by activity
Land use trends
  land use by activity

****
POPULATION
****

Aggregate Population Data
  Population density
    persons per acre
    persons per household
    persons per room
  Total population
    by age
    by race/ethnicity
    by marital status
    by household relationships
    by occupation
    by family income
    by number of automobiles
  Population trends & projections
    total population
    by age
    by race/ethnicity
    by income
Population Concentrations
  Over 65
  Ethnic minorities
  Religious minorities
  Low-income families
  Female-headed households
  Foreign-born
  Non-English speaking

****
HOUSING
****

Aggregate Housing Data
  Total housing units
    by type
    by tenure
    by units per structure
    by age of structure
    by rooms per unit
    by persons per room
    by condition
    number without plumbing facilities
    number without kitchen facilities
    owner-occupied by value
    renter-occupied by monthly rent
  Vacancy rate
    normal
    actual
  Housing trends & projections
    total housing units
    by type
    by tenure
    vacancy rate
    value of owner-occupied units
    monthly rent on rented units

DETAILED ASSESSMENT

****
POPULATION
****

Data on Individual Households
  Residence
    tenure of residence
    time at current residence
    time in area
  Composition of household
    number of persons
    relationship of residents
    by sex
    by age
    by race/ethnicity
    by educational background
  Number handicapped
  Number in school
  Employment of each resident
    number employed by occupation
    number unemployed by occupation
  Household income
  Number of licensed drivers
  Number of vehicles owned
  Proximity to destination points
    place of work
    shopping areas
    community facilities
  Predominant mode of travel

****
HOUSING
****

Data on Available Housing Units
  Location
  Type
  Size
  Tenure
  Condition
  Cost
Data on Individual Dwelling Units
  Location
  Owner
  Tenure
  Structure
    type
    number of units
    year built
    condition
  Unit
    type
    number of floors
    number of rooms
    condition
    value of owner-occupied units
    monthly rent on rented units
  Description of surrounding area
    land uses
    vacant lots, dwellings
    conditions

*Includes natural and manmade features.

Figure 6. Data used to assess displacement impacts.

Information on dwelling units should be accompanied by data on the total residential population at risk, and its distribution across the study area. It is also valuable to identify concentrations of residents with characteristics that indicate a special sensitivity to negative displacement effects.

One indicator of special importance is the length of time residents have lived at their current address. Attachment is viewed here as a function of time, and it is assumed that long established residents will have more trouble adjusting to a move then relative newcomers. Other indicators of attachment to place are a high incidence of owner-occupied and single-family detached homes. The rationale here is that people who own their homes and live in detached housing move less often than renters and apartment dwellers.

Other key indicators of sensitivity to displacement are:

- A high incidence of elderly and disabled residents. These people tend to find adjustment to new surroundings more difficult. They may be dependent on the assistance of relatives or neighbors living nearby to get to places, to carry groceries and other goods home for them, and to provide other important support functions. The same problems apply to families without automobiles.

- The presence of significant numbers of low-income families. These families are least able to take advantage of the opportunities for upward mobility that relocation provides for some displaced residents. They will also find it more difficult to secure equivalent replacement housing without increasing their housing costs.

- Concentrations of ethnic and religious minorities, and foreign-born and non-English speaking residents. These residents may be more dependent on supportive relationships with relatives and friends in the immediate neighborhood, and less likely to have the mobility required to sustain these ties if they are forced to move to a new location.

The incidence of substandard housing is also a factor to be considered. However, the idea that it is less damaging to take substandard housing should be tempered by the fact that the people living in this kind of housing are often least able to take advantage of the opportunities offered by relocation. They will also often have the greatest difficulties in adjusting to new surroundings, developing new social ties, and gaining access to critical destination points in the area where they are relocated.

4.3.2 Data Used in Detailed Assessment

After alternative routes have been defined, the focus of displacement studies shifts to the residential structures and individual dwelling units in each proposed ROW. The information collected on these dwelling units, and the people living in them, is similar to the aggregate data collected from statistical sources in preliminary assessment. Now, however, it is necessary to get this information for the individual homes that would be taken, and the residents who would be displaced, by each alternative route.

Engineering data and base maps are used to define the possible ROWs in spatial terms. If these ROWs can be matched up with the parcels covered in local records sources, e.g., tax assessors' records, these sources can be used to secure some of the necessary data on homes and residents. Drive-through or walk-through surveys are also used to check and supplement data in records sources. Additional information collected in this way may include the incidence of vacant homes and houses for sale on the affected blocks; selected characteristics of the neighborhood; and estimates of the market value of homes in the proposed ROWs.

On-site surveys can also be used to record observations on the characteristics of individuals living in the potentially displaced residences and in the surrounding neighborhood. This information will necessarily be incomplete because the residents themselves, who could provide these data, are usually not interviewed. However, local realtors, community leaders, and other knowledgeable individuals may be called upon to supplement information collected through observations.

In order to better understand the impacts of displacement and relocation, it is necessary to look beyond the ROWs to evaluate possible relocation sites nearby. Here the items of particular interest are residential land use in the area; number, type and condition of dwelling units; and the number of unoccupied dwellings and vacant lots. Data showing changes in housing units -- e.g., trends in the issuance of construction permits, changes in the amount of the housing stock and in residential zoning -- are also valuable indicators. Local records and expert judgments of local realtors and developers may be used to secure this information.

In some instances, survey approaches are used during detailed assessment to collect information from a sample of residents on their feelings of attachment to their homes and neighborhoods, and their attitudes towards possible displacement. This information, which is discussed in more detail in Section 4.2.2 on cohesion, provides indicators of sensitivity to negative displacement effects and possible resistance to relocation.

Chapter 5. DATA REQUIRED TO ASSESS ECONOMIC IMPACTS

The factual data required to profile the study area and screen for economic impacts are presented and discussed in the following sections. The discussions on how these data can be used, and the data fields which specify individual data elements, are organized by impact area.

See Chapter 6 for a discussion of data on attitudes and perceptions used in economic impact assessment.

5.1 EMPLOYMENT, INCOME AND BUSINESS ACTIVITY

Figure 7 (p. 49) provides a listing of the core data required for the preliminary and detailed assessment of impacts on employment, income and business activity. The subsections which follow provide a discussion of how these data are used to screen for potential impacts and to develop measures of their scope, magnitude and duration.

5.1.1 Data Used in Preliminary Assessment

Displacement Effects. In screening for potential displacement effects, data on the number, size, and location of shopping centers, industrial parks, and other commercial clusters should be examined. This information is used to identify concentrations of businesses in the study area that should be avoided, if possible, when defining alternative routes. If a proposed route alternative passes through a business-intensive area, a more careful assessment will be required to determine the severity of displacement and proximity effects.

Construction Impacts and Proximity Effects. Aggregate statistics on types, sizes, revenues, and ownership of study area businesses are also collected here. They are used to determine whether a high percentage of businesses are sensitive to disruption of normal activities brought about by construction and proximity effects. Sensitive businesses include those that are service-oriented, small and owner-operated.

PRELIMINARY ASSESSMENT

****
LAND USE
****

Aggregate Data on Land Use
  Land use by activity
  Zoning restrictions
  Average market value of property
    by type
Undeveloped Land
  Location
  Size
  Topography
  Zoning restrictions
  Utility system
  Market value
Scheduled Development Projects
  Location
  Land use activity
  Description
  Estimated development cost

****
EMPLOYMENT
****

Aggregate Employment Data
  Total persons in labor force
    by age
    by race/ethnicity
  Total persons employed
    by industry
    by occupation
  Job openings by type
  Average wage by occupation
  Unemployment rate
    total unemployed
    by industry
    by occupation
Major Employment Areas
  Number
  Type
  Location
  Approximate number of employees
  Residential concentrations of
    employees
  Modes of travel to work

****
BUSINESS
****

Aggregate Data on Businesses
  Total number of businesses
    by type
    by legal form of organization
    revenues by type
    number owner-operated
  Business trends
    total number of businesses
    revenues by type of business
Concentrations of Businesses*
  Number
  Type
  Location
  General description
  Number of tenants

****
AGRICULTURE
****

Aggregate Data on Agriculture
  Total acres
    by land use**
    by crop
    average productivity
    average revenues
  Prime & unique farmland
  Farms
    number
    location
    average acres

DETAILED ASSESSMENT

****
POPULATION
****

Data on Individual Households
  Proximity to destination points
    place of employment
    shopping areas
Trip Activity of Individuals
  Individual trips
    mode of travel
    origin/destination
    route followed
    travel time
    cost
    purpose

****
EMPLOYMENT
****

Data on Individual Employees
  Place of employment
  Length of service w/current employer
  Location of residence
  Mode of travel to work
  Route followed
  Cost

****
BUSINESS
****

Data on Individual Businesses
  Type
  Legal form of organization
  Location
    years at current location
    years in area
  Street frontage
  Structure
    age
    size
    condition
    special features
    location of entrance
  Finances
    annual gross revenues
    total monthly expenses
    monthly payroll
    revenue trends
    sales trends
  Number of employees
    by labor category
    by age
    by sex
    by race/ethnicity
    by residential area
    by mode of travel to work
  Service area
  Clientele served
    by age
    by race/ethnicity
    by income level
    by residential area
    by mode of travel

****
AGRICULTURE
****

Data on Individual Farms
  Total acres
    by land use**
    cropland by crops grown
  General description
    years in operation
    tenure
    type of operation***
    seasonal or year-round
      operation
Operational Data by Land
Use and Crop
  Cost per acre
  Yield per acre
  Revenue per acre

*Includes shopping centers, industrial parks and office buildings.
**Includes croplands, pasturelands, orchards, and forests.
***Includes dairy, livestock, and orchard.

Figure 7. Data used to assess impacts on employment, income and business activity.

Indirect Impacts. Examination of the potential indirect impacts of the proposed facility requires the collection of data on the regional market area of which the study area is a part. Fairly detailed data on shopping centers and industrial areas are collected to develop an inventory of business activity in the market area. The locations of these commercial areas are examined to identify those that would be made more accessible by the proposed facility. The numbers and types of businesses operating in these areas are compared with those in the local area to determine whether the regional market area is likely to attract local consumers.

Data on employment in the local area, and in the market area, are also collected and compared to assess indirect impacts. The types of jobs available, income levels, and employment and unemployment rates provide a picture of the two labor markets, and indicate the ability of each market to attract and absorb new employeees.

Available data on the mobility of the local population are also used here to determine whether people can take advantage of new shopping and employment opportunities. These data include the number and geographic concentrations of autoless households, elderly persons, and those with handicaps -- all indicators of limited mobility. Other useful information in this area describes ADT on existing roadways and traffic projections based on changes in the network.

Determining the likelihood that new businesses will be drawn into the local area to compete with existing ones will probably require the judgments of business experts. Data on vacant and undeveloped land, and local zoning, are also used to determine the feasibility of business influx.

Agricultural Impacts. Screening for agricultural impacts is required when there are operating farms in the area subject to impacts. Data on the locations of farmland and numbers of farms are used to identify possible displacement and segmentation of farm parcels. To get an indication of the productive value of lost farmland, aggregate data on the types of crops grown, the average productivity per acre, and operating revenues of farms in the area are collected.

Basic data used to screen for development pressure on agricultural land are: the topography around farm areas, the configuration of the current roadway network, and distances between farms and developed areas. Land use patterns, zoning regulations, real estate values, and existing development trends are other indicators of the possible intensity of development pressure.

Aggregate data on the productivity and revenues generated by farmlands are also used here as indicators of the profitability of farming in the area. This, in turn, indicates the likelihood that farmers will resist pressure to convert their land.

Multiplier Effects. Multiplier effects occur anytime a significant change takes place in an integrated market setting. Screening identifies potential employment, income and business activity effects which will, in turn, cause ripple effects throughout the local economy.

5.1.2 Data Used in Detailed Assessment

Displacement. At this stage, the names, types, locations, sizes, and facade conditions of individual businesses located along each of the proposed ROWs are collected. These data identify the total number of businesses that will be displaced by each route alternative. They also show the percentages of these businesses that are local, service-oriented, small, and in poor physical condition.

Land uses and physical conditions in the area where businesses operate, and observable characteristics of the physical plant, are also collected. Information of this kind on businesses in the alternative ROWs indicates standards that any relocation area should meet. It will also serve to identify the important physical operating requirements of businesses which may potentially be relocated. Information is also collected on the jobs provided by the business. Additional data on the addresses and modes of travel used by current employees can show the likelihood that these people will be able to travel to a new work location. These data can be used by relocation officers to develop conceptual relocation plans.

Construction Impacts. Businesses subject to construction impacts are identified along each ROW. Data on street frontage and the placement of business entrances are collected to help determine whether construction activities will directly affect businesses close to the ROWs. The magnitude of construction impacts is indicated by information on the extent and duration of construction activities associated with each route.

If information on traffic-diversion plans becomes available during detailed assessment, it can be used to specify in more detail the intensity of construction impacts which will interfere with normal business activity.

Proximity Effects. Proximity effects are normally experienced by the same businesses that are subject to construction impacts. To assess proximity effects on these businesses, detailed information on the location and design features of the proposed alternatives is examined. Expert judgment is often required to predict how the alternatives might reduce access and cause safety hazards in getting to these businesses. Other indicators of proximity effects are data on expected levels of air and noise pollution associated with each route.

Indirect Impacts. In detailed assessment of indirect impacts of alternative routes, data on centers of business activity in the market area -- collected during preliminary assessment -- are combined with newly available data on changes in access. Information on highway-induced changes in access includes expected alterations of frequently traveled routes between the locality and regional attractions, changes in travel times to desired destination points, and projections of changes in ADT associated with each of the routes.

Survey data from local employees and consumers can also be used to assess indirect impacts. Satisfaction with current employment, perceptions of employment opportunities that would be made available by the proposed facility, and expected behavior regarding employment if the facility is constructed are indicators of worker attraction to new job opportunities. Data can be collected from local consumers on satisfaction with local shopping opportunities, and on attraction to other shopping areas that will be made more accessible by the proposed routes.

Agricultural Impacts. Detailed assessment of agricultural impacts requires data on individual farms subject to displacement and development pressure. The layout, acreage, and land uses of farms are used to determine acreage that will be taken, and parcels that will be segmented and isolated, by each route.

Additional data on each of the affected farms are then required to determine the severity of these effects on the livelihood of farmers and the productivity of farmlands. Data used here include tenure, ownership, and operating conditions; internal operations, especially transportation; and costs and revenues over time. Farmers' perceptions of the proposed route, ROW takings, and the possible isolation of productive parcels should be used to verify and supplement impact determination made from statistical information.

Data on the productivity and profitability of affected farms are also used to assess the likelihood that farmers will respond to development pressure by selling their farms. To add detail to the assessment of anticipated development pressure, data on land values, mortgage rates and capital costs of development -- examined in preliminary assessment -- are usually updated. Data on assessment rates and ratios for developed land and other costs of development are used to estimate the general climate for large-scale investment.

If possible, farmers and developers themselves should be questioned about their attitudes toward development of farmland; they will often provide data on special circumstances that would otherwise be unavailable to investigators.

Multiplier Effects. Estimates of multiplier effects are developed using much of the data collected in the detailed assessment of impacts on employment, income and business activity. The data are used to make judgments about the magnitude and direction of direct effects. Selected items are used to calculate local employment and income multipliers, which indicate the number of times each direct effect -- such as income reductions resulting from layoffs, or reduced business revenues caused by proximity effects -- will be felt throughout the economy. The minimum data required to calculate the multipliers are total area employment, area employment in basic industries, total area wage-and-salary income, and area wage-and-salary income in basic industries.

5.2 RESIDENTIAL ACTIVITY

Figure 8 (below) provides a listing of the data required for the preliminary and detailed assessment of impacts on residential activity. The subsections which follow provide a discussion of how these data are used to identify and measure potential impacts.

PRELIMINARY ASSESSMENT

****
LAND USE
****

- Aggregate Data on Land Use
  - Total land area
  - Land use by activity
  - Zoning restrictions
- Planned Land Use
  - Growth and development plan
    - projected land use
    - expected levels of development
- Undeveloped land
  - Location
  - Size
  - Topography
  - Zoning restrictions
  - Utility system
  - Market value

****
POPULATION
****

- Aggregate Population Data
  - Population density
    - per acre
    - persons per household
    - persons per room
  - Total population
    - distribution by age
    - distribution by race/ethnicity
    - distribution by household relationships
    - distribution by family income
- Population Concentrations
  - Population centers

****
HOUSING
****

- Aggregate Housing Data
  - Total housing units
    - by type
    - by tenure
    - by units per structure
    - by age of structure
    - by rooms per unit
    - by persons per room
    - by condition
    - number without plumbing facilities
    - number without kitchen facilities
    - owner-occupied units by value
    - rented units by monthly rent
  - Vacancy rate
    - normal
    - actual
  - Housing trends & projections
    - total housing units
    - by type
    - by tenure
    - vacancy rate
    - value of owner-occupied units
    - monthly rent on rented units
- Concentrations of Residential Structures
  - Location
  - Housing types
  - Condition of housing
  - Approximate number of units

DETAILED ASSESSMENT

****
POPULATION
****

- Data on Individual Households
  - Residence
    - tenure of residence
    - time at current residence
    - time in area
  - Composition of household
    - number of persons
    - relationship of residents
    - by sex
    - by age
    - by race/ethnicity
    - by educational background
  - Number handicapped
  - Number in school
  - Employment of each resident
    - number employed by occupation
    - number unemployed by occupation
  - Household income
  - Number of licensed drivers
  - Number of vehicles owned
  - Proximity to destination points
    - place of work
    - shopping areas
    - community facilities
  - Predominant mode of travel

****
HOUSING
****

- Data on Individual Dwelling Units
  - Location
  - Type
  - Size
  - Tenure
  - Structure
    - type
    - number of units
    - year built
    - condition
  - Unit
    - type
    - number of floors
    - number of rooms
    - condition
    - value of owner-occupied units
    - monthly rent on rented units
  - Description of surrounding area
    - land uses
    - vacant lots, dwellings
    - condition
- Data on Available Housing Units
  - Location
  - Type
  - Size
  - Tenure
  - Condition
  - Cost
- Housing Construction Trends
  - Construction permits issued
  - Housing starts
  - Number of units completed
  - Number of units demolished
  - Net change in housing stock

Figure 8. Data used to assess impacts on residential activity.

5.2.1 Data Used in Preliminary Assessment

Reduction in the Local Housing Stock. The reduction in the local housing stock caused by the proposed facility depends on the number of residential structures to be demolished or relocated when land is cleared for the ROW. Data used during preliminary assessment to estimate the number and types of dwellings to be taken are described in Section 4.3 on residential displacement. That section also discusses data used to identify residential areas where reductions in the housing stock caused by placement of a road would be the most severe.

Shortages of Replacement Housing. Data used in preliminary assessment to determine whether there will be a shortage of replacement housing for persons forced to relocate include characteristics of potentially displaced dwellings and households, and the supply and availability of existing housing. Data on displaced dwellings and households, discussed in more detail under residential displacement (see Section 4.3), give an initial indication of replacement housing needs. Aggregate data on the existing housing market -- including the number and types of houses, market values, monthly rental and vacancy rates -- are indicators of the availability of housing in the study area.

Data on replacement housing needs should be compared with data on the housing market to determine whether the existing stock can absorb relocatees. However, estimates of replacement housing needs are very crude at this stage, and any determinations regarding the adequacy of replacement housing should be used with caution.

Undesirable Residential Construction. The projected level of induced construction -- a major indicator of the likelihood of undesirable residential construction that will be caused by the proposed facility -- is very difficult to estimate. Induced residential construction is an indirect impact, and while practitioners can examine contributing factors, such as increased demand for housing and the feasibility of development, they can only guess what the cumulative effect will be.

During preliminary assessment, data on expected changes in traffic volume and patterns, and other indicators of increased access between the local area and other areas in the region -- discussed in the section on accessibility (see Section 4.1) -- identify possible sources of increases in local housing demand. Another indicator of new housing demand is expert judgment regarding the likelihood that highway-induced increases in business activity will create job opportunities for new residents of the area.

Projected increases in housing demand are examined in conjunction with data on the need for, and feasibility of, new construction. Data on the housing stock discussed above can be used to estimate shortfalls in available housing to meet new demand which, in turn, indicates the need for new housing. Information on zoning in the study area, the availability of undeveloped land, capital costs of development, and the availability of mortgage money help to characterize the climate for investment in housing.

Judgments regarding projected levels of residential construction made from these data must be compared to local plans for development and growth to determine the desirability of potential residential construction. Data used to determine local plans are discussed in Section 5.4, on land use and development plans.

5.2.2 Data Used in Detailed Assessment

Reductions in the Local Housing Stock. Once the feasible routes are identified, a count is made of the residential structures potentially displaced by each route. Data required to identify and characterize these reductions in the local housing stock include the size, type, tenure and condition of the dwelling units, and their relation to the larger structures of which they are a part. The information can be compared with aggregate data on existing housing sizes, types, tenure, and condition to determine the percentage of the total stock being removed.

Shortages of Replacement Housing. Data on individual dwellings potentially displaced by each route are also used to assess whether there is adequate replacement housing for displaced residents. The types, locations, tenure, conditions, and other features of these dwellings that characterize the potential relocatees' current living situation are indicators of replacement housing needs. Other information available through observation of the area surrounding potentially displaced homes indicates the characteristics of (1) families who may be relocated, and (2) the neighborhoods in which they live. All of these factors contribute to the identification of replacement needs. Surveys can be used to collect more detailed data on potentially displaced residents. Information typically collected on household members includes number, age, sex, employment status, occupation, income, and significant financial obligations of family members; length of residence in neighborhood and home; availability of vehicles; and important destinations and modes of access. Surveys can also collect data on residents' opinions regarding the adequacy of their current home and neighborhood, the value they place on ties to neighborhood, friends, relatives and ethnic groups, and the importance of maintaining these ties.

Assessment of the availability of housing in the study area, at this stage, requires the updating of data on the housing stock collected during preliminary assessment. This information should be supplemented by time-series data showing trends in the volume of housing stock and annual construction permits issued; annual net changes in housing stock by type, tenure and conditions; and market values and rental costs. Projections for these indicators which have been developed by local planning agencies should be collected as well.

Depending on how soon relocation is expected to occur, vacancy rates -- the key indicator of available housing -- can be further specified by examining newspaper advertisements and checking multiple-listing services. Building permits and records of housing start-ups, along with applications for zoning of new residential subdivisions, are used to refine estimates of new housing that will be available at the time of relocation. In addition, the expert judgments of area realtors can be solicited to verify data in record sources.

Using the data collected on replacement housing requirements and available dwellings, practitioners can identify shortages of relocation housing in areas near each route.

Undesirable Residential Construction. Some additional data become available during detailed assessment which may be used to predict the likelihood and extent of undesirable residential construction. Data on changes in area-wide access can more accurately predict accessibility gains once feasible routes are defined. Findings are used to refine estimates regarding the attractiveness of the locality to residents, and the residential influx and construction which may follow project completion. Additional data, used to assess the likelihood that businesses will be attracted to the area and bring jobs and new residents, are discussed under indirect impacts in Section 5.1.

5.3 FISCAL IMPACTS

The following subsections discuss the data required to assess the impact of a proposed project on local government finances during preliminary and detailed assessments. Figure 9 specifies the data elements used to complete and document the assessment process.

PRELIMINARY ASSESSMENT

****
LAND USE
****

Aggregate Data on Land Use
  Land use by activity
  Average market value of property by type
  Land use trends
    land use
    average market value of property by type

****
LOCAL GOVERNMENT FINANCE
****

Aggregate Assessment & Tax Data
  Total tax base
  by property type
  Assessment
    average assessed value of property
      tax rate by property type
    assessment ratio by property type
      frequency of reassessment
  Property tax revenue
  Tax assessment & revenue trends
    average assessed value of property by type
    tax revenues

DETAILED ASSESSMENT

****
LAND USE
****

Data on Individual Parcels
  Number
  Size
  Land use activity
  Improvements
  Estimated value of land and structures

****
LOCAL GOVERNMENT FINANCE
****

Data on Individual Parcels
  Assessed value
  Assessment ratio
  Tax rate
  Annual property tax

Figure 9. Data used to assess fiscal impacts.

5.3.1 Data Used in Preliminary Assessment

Tax Base Losses. Crude approximations of tax base losses can be made prior to the development of alternative routes. Engineering data are used to develop an estimate of acreage to be taken for the ROW. Data on land uses in the study area are collected and used as a basis for estimating how much of the affected land is devoted to various taxable land uses. Average assessed values and tax rates per acre for each taxable use are then used to (1) estimate the tax revenues generated by property to be taken by the ROW, and (2) forecast the first year reduction in revenues associated with these properties.

Information on the total taxable property base in the study area, by land use if available, is used to determine the percentage reduction in the tax base that ROW acquisition can cause. Similar estimates can be made for lost tax revenues using data on total revenues from property and other local taxes.

Reductions in Property Values. Decreases in property values are usually estimated later in the assessment process, when routes have been defined and more is known about land uses near the alternative routes. Information on the proposed facility available at this stage can, however, be used to judge the magnitude of potential proximity effects which may cause decreases in property values.

5.3.2 Data Used in Detailed Assessment

Tax Base Losses. More reliable estimates of tax base losses can be made when route alternatives have been defined. All property and improvements to be taken by each alternative ROW must be identified. Property assessment files are used here to identify individual parcels of undeveloped and vacant land in each ROW. Tax exempt properties need not be included. The additional data used to identify potentially displaced homes and businesses are discussed in Section 5.2.2 on residential displacement and Section 5.1.2 on employment, income and business activity.

If parcel-by-parcel information is not available, the tax value of displaced land and improvements can be estimated using data on average assessed values for the various property uses. Alternatively, market values of comparable real estate in the area may be used in conjunction with data on the ratio of assessed to market values. Another less accurate, but simpler, method uses estimates of the costs of ROW acquisition -- available from ROW officers --

and the ratio of acquisition costs, or market values, to assessed values. Tax rates, by property use, are then used to translate tax base losses into first year revenue losses.

These estimation procedures should be supplemented by observing locations in the study area where property values deviate significantly from average values. For example, the average assessed value of homes in slum areas will be significantly below the mean for the area. The judgments of tax assessors are often used to make these adjustments.

If parcel-by-parcel information is available, assessed values and annual taxes on potentially displaced parcels are collected. If annual taxes are unavailable, tax rates are again required to estimate first-year tax revenue losses.

First year losses can be compared to data on the total tax base and annual property tax revenues to determine the relative magnitude of these losses.

Tax revenue losses over time are difficult to determine, but can be approximated using data collected during detailed assessment on:

- Trends and projections concerning market value of various property types,
- Trends in assessment and tax rates, and
- Frequency of reassessment.

Future property values can be projected using aggregate time-series data. The expertise of area realtors may also prove useful. Trends in assessment rates and frequency of assessment, available at assessors' offices, are indicators of the time lag that can be expected in the adjustment of assessed values to reflect changing market values.

Decreases in Property Values. Parcels along each ROW that are subject to decreases in property values resulting from negative proximity effects can be identified once alternative routes have been developed. While residences and businesses within this range have already been identified in Sections 5.1.2 and 5.2.2, information on other land uses and improvements must be obtained from observation or property assessment files.

Data used to determine the magnitude of proximity effects, such as limited access, safety hazards, and pollution, are also identified in Section 5.1.2. Limited data are available estimate the magnitude of expected decreases in property values. Decreases in value depend primarily on peoples' perceptions of the negative effects of living or doing business near the facility.

Knowing the land uses of affected parcels helps practitioners to estimate the magnitude of decreases since some uses are historically subject to greater decreases than others. Analogous cases can also be used. Planners cannot rely on these, however, because circumstances in every situation are different. Area realtors and tax assessors are often used to examine available information and make qualitative judgments.

Data on frequency of reassessment and trends in assessment rates as compared to market values can also be used to estimate how quickly changes in property values will be reflected in assessment values.

Property values may be affected by design features which are specified during detailed assessment. For example, if a noise barrier is to be erected, expected reductions in residential value may not occur, or will be less than anticipated. The only way to quantify the impact of these changes or additions to design features is to reinterview experts.

5.4 LOCAL LAND USE AND DEVELOPMENT PLANS

The following subsections discuss the data required to assess the impact of a proposed project on local land use and development plans during preliminary and detailed assessments. Figure 10 (p. 62) specifies the data elements used to complete the assessment process.

5.4.1 Data Used in Preliminary Assessment

Information on community plans for future growth and development is required during preliminary assessment to screen for negative impacts. The goals and objectives, and general strategies for achieving them, found in local planning agency documents are the basic data used. There will often be additional

PRELIMINARY ASSESSMENT

******** LAND USE ********	Planned land use Goals and objectives land use transportation	Strategies Growth and development plan projected land use targeted levels of development
Aggregate Data on Land Use	Importance and urgency of planning goals	

DETAILED ASSESSMENT

All data collected during preliminary and detailed assessment are used to assess impacts on local land use and development plans.

Figure 10. Data used to assess impacts on local land use and development plans.

information on current problems and short- and long-term recommendations in the areas of transportation planning, land use, and community character. Some communities will supplement conceptual plans and policy statements with statistical data on the current situation, and future goals in the areas of land use, zoning, development, population density, etc., to be achieved by actions taken under the plans. Data available in planning documents and through interviews with local planners, elected officials at all levels, and civic leaders, are used to determine policies and strategies for future development.

To determine whether the proposed project will further these plans or conflict with them, data on the potential impacts of the project are required -- in both social and economic areas. This includes virtually all data used during preliminary assessment to identify potential impacts. Here, however, the information is used for the special purpose of determining whether the identified changes caused by the proposed project are consistent, or in conflict, with the short- and long-term planning goals and programs of the area.

Initial assessment is normally confined to determining the overall compatibility between future plans and the construction of a new highway facility or improvement. This is because data on the highway facility and its impacts -- especially the induced effects -- are limited.

5.4.2 Data Used In Detailed Assessment

The detailed assessment of the social and economic impacts of alternative routes provides data which can be used to further assessment in this area. While no new data on land use plans are available, the new and more accurate data on changes caused by the routes can be (1) examined in relation to planning documents, land use plans, and other materials, and (2) considered by planners and other local officials who are qualified to assess the compatibility of each route with community plans.

In many instances, however, the assessment of the project's compatibility with planning goals and objectives will be subject to interpretation and judgment, particularly when the secondary, or induced, effects of the project are at issue. Planning goals and development policies which have not been tied to site-specific proposals are often so broadly stated that it is impossible to address the issues of consistency or conflict except on a case-by-case basis. Additionally, many changes caused by the road cannot be accurately determined. And, as mentioned earlier, many projects will have points of agreement and conflict. Highway practitioners often have to rely on the expert judgments of local planners and other public officials to clarify questions on the impacts of each route on land use and development plans.

It should be noted here that the design features of the proposed route which become known during detailed assessment may have an effect on the compatibility of the proposed project with future plans. Also, local ordinances designed to implement development plans, planning-related regulatory measures such as zoning changes, the designation of special development sectors, and development incentives may be used to minimize adverse impacts on land use and development caused by the selected route. These determinations are often best made by area elites who have been involved in project planning.

Chapter 6. DATA ON PUBLIC ATTITUDES AND PERCEPTIONS REQUIRED TO COMPLETE ASSESSMENTS

The data which can be used to profile attitudes and perceptions concerning the proposed project and its effects are discussed in the following sections. Figure 11 (pp. 65-66) specifies the data elements commonly collected during preliminary and detailed assessments.

6.1 DATA USED IN PRELIMINARY ASSESSMENT

During preliminary assessment, information is commonly collected on the attitudes of local leaders toward the proposed highway project and their expert opinions on existing conditions in the area. This information is often supplemented by data collected from small samples of residents. The key questions here are:

- Is the improvement or new construction needed?
- Will it benefit the area?
- When should it be built?

The question of where the road should be located can also be explored at this point. Answers to this question are used to evaluate the routes deemed feasible by highway engineers.

During preliminary assessment, it is also useful to obtain information from local leaders and residents on what impacts they expect the new facility to have on their communities and neighborhoods. These perceptions can be used to (1) alert practitioners to possible negative impacts that should be examined closely, (2) prepare highway spokesmen for public hearings, and (3) identify and clear up negative perceptions which are based on misconceptions about the proposed project.

Respondents can also be asked which of a series of possible design features should be incorporated into any new facility that passes through the area.

****
PROJECT DATA
****

Preferences Concerning Whether the Road Should be Built
  Desirability of area: with and without facility
  Need for the Facility
  Value to the community
  When the project should be implemented
Perceptions of the Opinions of Others Concerning the Proposed Project
  Residents
  Businesspersons
  Elites
  Area organizations
Opinions Concerning the Impact of the Proposed Project
  Impact on the community
  Impact on the individual
Perception of Ways in Which the Proposed Project would Benefit the Respondent
  Nature of benefits
  Degree of benefits
Perception of Ways in Which the Proposed Project Would Harm the Respondent
  Nature of harm
  Degree of harm
Route Location
  Rating/ranking importance of specified factors in route selection
  Preferences on potential route locations
    strength of preference
    reason for preference

****
DESIGN FEATURES
****

Preference Among Design Features
  Desirability of incorporating a series of design features into the facility

****
ACCESSIBILITY
****

Perceptions of Transportation System
  Adequacy of access to destination points
  Accessibility problems
  Need for a new road
Transportation-Related Community Concerns, Problems and Goals
  Rating convenience of access
    convenience of access to a series of pre-specified places
    general convenience rating for the neighborhood/study area
    convenience by mode of transportation
  Importance of access to specified facilities
    rating the importance of access to list of facilities
    ranking the three most important facilities
  Perception of impacts of project on accessibility

****
COHESION
****

Degree of Cohesiveness of Identifiable Communities/Neighborhoods
Recent Changes in Cohesiveness of Communities/Neighborhoods
Impact of Proposed Project on Cohesion
Ranking of Communities
  Cohesion and integration
  Level of organization
  Participation in local activities
Measures of Current Levels of Cohesion
  Degree of attachment to neighborhood
  Degree of satisfaction with neighborhood
    desire to remain in neighborhood
    rating specificed characteristics of the neighborhood
    rating of services
    perceptions of emotional disposition of neighbors
    judgments on best/worst features
    rating neighborhood against others in area
  Perceived stability of neighborhood
    identification of changes
    perceptions on degree of change

****
DISPLACEMENT
****

Area Residents
  Perception of displacement impacts
  Identification with place
  Rating and ranking of neighborhood features
  Attitude toward possible relocation

****
BUSINESS ACTIVITY
****

Opinions on Current Levels of Business Activity
Opinions Concerning Trends in Business Activity
Optimal Locations for New Businesses
Effect of Proposed Project on Business Activity
  Perceived positive effects
    magnitude of effects
  Perceived negative effects
    magnitude of effects
Effect of Proposed Project on Employment
Perceptions of Consumers in the Study Area
  Satisfaction with local retail opportunities
  Satisfaction with access to retail outlets
  Retail opportunities inaccessible due to inadequate transportation
  Retail outlets to be made available by proposed project
  Expected use of retail outlets to be made available by project

****
RESIDENTIAL ACTIVITY
****

Perception of Impact of Project on Residential Activity
  Highway-induced residential development
    likelihood that increased business activity and access will attract new residents to area
    likelihood that new housing will be constructed to meet new residential demand

****
LAND USE
****

Opinions on Community Goals & Development Plans
  Rating the importance of development goals
  Impact of project on community goals and development plans
  Expected changes in specific uses
    compatibilities
    incompatibilities

****
AGRICULTURE
****

Effect of Proposed Project on Agricultural Productivity
  On conversion of farmland to other uses
Attitudes of Area Farm Owners
  On development of farm land
    all farms
    own farm

****
LOCAL GOVERNMENT FINANCE
****

Perception of Financial Health of Local Government
  Perception of project impact on local government finances
    property values
    sources of revenues
    expenditures

Figure 11. Data used to assess attitudes and perceptions.

****
PROJECT DATA
****

Preferences Concerning Route Alternatives
- Rating the routes
  - reasons for rating
- Specifying best and worst routes
- Perceived effects of best and worst route
- Expected reaction if least preferred routes is selected
- Most disruptive route
  - reasons why most disruptive
- Least disruptive route
  - reasons why least disruptive
- Problems with each alternative
- Indirect methods for collecting data on preferences
  - perceived differences between routes in achiving specified effects
  - degree of difference
- Rating the desirability of possible effects and the likelihood of each route producing each effect
- Perception of impact of route options on respondent

Perception of Route Favored by Others
- Area residents
- Local businessmen
- State and local government officials
- Other groups

Changes in Attitude Towards the Project Over Time
- Direction of change
- Reasons for change

****
DESIGN FEATURES
****

Preferences Among Design Features
- Preferences on alignment
  - grade level
  - supports
  - use of areas under and beside facility
- Preferences on access-related design features
  - on and off ramps
  - crossovers
  - service roads
  - median

Perceptions of Negative Impacts that Need Special Efforts to Mitigate Harm

****
ACCESSIBILITY
****

Impacts of Route Alternatives on Accessibility

Local Resident Perceptions
- Impacts of alternative routes or access to destinations
- Rating importance of access to specified facilities
- Ranking of most important destinations

Special Accessibility Problems

Preferences on Design Features Related to Accessibility
- Expected changes in local facility use caused by proposed route
- Expected negative effects of project on service provision
  - temporary, during construction
  - permanent, following project completion
- Suggestions for minimizing harm
  - during construction
  - over life of facilities
- Expected changes resulting from the project
  - service area
  - geographic distribution of users
  - means of access
  - characteristics of users

****
COHESION
****

Perception of Impacts of Each Route on Local Institutions
- Membership
- Facility usage
- Effectiveness of service delivery
- Future plans
- Availability of alternative services
- Impact of facility displacement on local cohesion

Rating of Neighborhood Features
- Degree of attachment to neighborhood
- Feelings towards neighbors
- Satisfaction with neighborhood.
- Value of community level interactions

Perceptions of Changes in Cohesion
- Nature of change
- Degree of change
- Attitude toward change

Desire to Remain at Current Location
- Future plans

Perceptions of Negative Effects of Alternative Routes on Cohesion
- Identification of effects
- Intensity of feeling about effects
- Likelihood that alternative will cause each effect

****
DISPLACEMENT
****

Importance of Current Features
- Dwelling
- Location
- Neighborhood

Importance of Features at Any New Location
- Having current neighbors close
- Maintaining ethnic or religious ties
- Having relatives, currently in same neighborhood, close by

****
BUSINESS ACTIVITY
****

Assessment of Current Location by Business Owners
- Advantages/disadvantages

Problems Facing Neighborhood Businesses

Factors Affecting Volume of Business
- Clientele
  - sources
  - income range
  - ethnicity
  - mode of access
- Traffic dependence
- Street frontage
- Effect of project on individual businesses
  - during construction
  - permanent
- Adaptability to negative construction and access effects
- Likelihood of business closure
- Effect of knowledge about proposed facility on decisions about current establishment
  - maintenance
  - possible relocation
- Proximity effects of alternative routes
  - air and noise pollution
- Business owner plans
  - if in ROW
  - if proximate to ROW

****
RESIDENTIAL ACTIVITY
****

Expected Decreases in Property Values Due To Proximity Effects
- Possible mitigative measures
- Availability of housing to meet needs of potential relocatees
  - adequacy of replacement housing for potential relocatees

****
LAND USE
****

Perceived Effects of Alternative Routes
- Compatibility of alternative routes with goals and development plans
- Importance of perceived positive and negative effects
- Mitigating adverse impacts
  - design features
  - planning assistance and regulatory measures

****
AGRICULTURE
****

Perception of Proximity Effects by Route Alternative
- Farm land conversion to other uses
- Changes caused by segmentation
  - number of segmented acres
  - travel time/distance to segmented parcels
  - effect on productivity
  - effect on costs
  - ability to maintain operations

****
LOCAL GOVERNMENT FINANCE
****

Effects of Various Design Features on Value of Property Near the ROW
- Perceptions on decreases in tax base due to proximity effects

Figure 11. Data used to assess attitudes and perceptions (continued).

6.2 DATA USED IN DETAILED ASSESSMENT

In detailed assessment of alternative routes, survey activities focus on the preferences of local residents concerning the route alternatives being examined. The objective here is to identify the route most acceptable to the public. Respondents may be asked to rate or rank the alternatives, and provide other information useful in a comparison of proposed routes. This can include measures regarding the strength of resident preferences, i.e., support for and opposition to each route. It also may include the reasons which residents give for their stated preferences, i.e., their perception of positive and negative effects associated with expressed preferences.

Information on design preferences is often collected at this stage. This inquiry is generally more focused than the approach used in preliminary assessment, since preferred routes have now been defined and design features can be considered in terms of discrete route alignments.

Graphic representations of the proposed ROWs for each alternative, and their relation to selected landmarks in the area, are used to help respondents visualize the route alternatives on which they are being asked to comment. Also, questions on the design features which respondents are asked to consider are often accompanied by drawings of each feature.

Part 2. DATA COLLECTION

Part 2 focuses on sources of socio-economic impact data.

Chapter 7 identifies individual maps, records, and survey techniques used to collect the information elements specified in the data fields (Figures 3-11) in Part 1. Each potential data source is described, and its utility for meeting requirements of preliminary and detailed assessment is discussed.

Chapter 8 presents matrices for each of the following topical categories:

Land Use	*Employment*
Community facilities	*Agriculture*
Population	*Local government finance*
Housing	*Attitudes and perceptions*
Business activity	

These matrices correlate data requirements, found in the data fields of Part 1, with the information sources and survey techniques discussed in Chapter 7. The matrices show -- data element by data element -- which information requirements can be found in which sources.

Chapter 9 provides a discussion of trade-off considerations which arise when information and survey sources are selected. The relative strengths and limitations of maps, records, and surveys are discussed in terms of:

- *The information available from each potential source,*
- *Geographic units covered and how they match up with typical study areas in preliminary and detailed assessment,*
- *The currency of data in published sources,*
- *The resources required to collect the data by purchase or by manual and automated retrieval procedures, and*
- *The reliability and validity of the data.*

The materials in these chapters are designed for use in conjunction with the following sections in Volume II:

- *Part 1, Information Sources,*
- *Part 2, Survey Techniques, and*
- *Part 3, Sampling Procedures.*

Chapter 7. SOURCES OF ASSESSMENT DATA

Data required to conduct socio-economic impact assessments are collected from:

- Maps,
- Records, or
- Surveys.

Generally, a combination of these sources is used to gather the required data.

This chapter identifies individual maps, records, and surveys which may be used to collect the data elements specified in Part 1. Maps and records are organized by type of source -- nationwide, State, or local. Surveys are categorized by collection technique -- observation or questionnaire -- and by sampling methodology -- random or non-random.

Source synopses in this chapter indicate the ability of each map, record, and survey covered to provide the general information normally used to complete preliminary assessment, or the more localized, ROW-specific data needed during detailed assessment. Each source and technique is correlated, in Chapter 8, with specific information requirements identified in Part 1.

Page references in this chapter may be used to access the technical descriptions of individual maps, records, and surveys presented in Volume II, Parts 1 and 2. Part 3 of that volume contains a detailed discussion of sampling procedures used when surveys are conducted.

7.1 MAP SOURCES

Maps and aerial photographs used in socio-economic impact assessment identify land use and topographic information. They show natural land features, transportation systems, boundaries, community facilities, residential and business areas, and farmlands. They usually show existing land use, and may also indicate planned usage.

Maps are commonly available from (1) nationwide, (2) State, and (3) local sources. Private cartographic and aerial photography firms -- primarily at the local level -- also prepare maps which may be of use in impact assessment. Many of these firms will custom-prepare maps which meet users' specialized needs. Practitioners should be aware, however, that most of the required cartographic data are readily available from existing map sources, and purchase of specialized services is generally unnecessary.

Maps from nationwide sources provide moderately detailed, standardized cartographic information. They are particularly useful in preliminary assessment to locate the study area and identify its major topographic features. These maps are also indispensable sources of data for study areas not covered by local mapping agencies.

While nationwide maps show only existing land use, some locally produced maps identify projected land use as well. Local maps generally provide more detailed information than nationwide maps, although this is not always the case. Among the most valuable local maps are plats, or real property maps. Plat maps, which are normally used in detailed assessment, enable practitioners to spatially identify individual parcels of land.

Statewide maps, like local maps, vary widely in the information they show. Most provide extensive coverage of the State transportation network. One type of map available from State sources is used to identify prime and unique farmlands.

Many nationwide and State maps are organized by quadrangles. These are the geographic subdivisions of States or counties which are reported on a single map sheet. Quadrangles are normally identified by geographic coordinates or major landmarks. In contrast, local maps usually cover counties, municipalities, planning districts, or neighborhoods. Plats are typically organized by county section, block, and lot.

Although maps vary in their currency, local maps tend to be more up-to-date than those from nationwide sources. To increase the likelihood that cartographic data are generally reliable, practitioners ought to examine information from different map sources. Inconsistencies in data can usually be reconciled by consulting records or conducting observations in the affected places. Special attention should be given to newly developed areas, since they are least likely to be accurately represented on maps.

Practitioners having difficulty locating particular map information are encouraged to contact the National Cartographic Information Center (NCIC). NCIC operates a nationwide information system which directs users to appropriate public or private sources of cartographic data. The system may be accessed by writing:

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, Virginia 22092

7.1.1 Nationwide Maps

Maps available from nationwide sources include:

- United States Geological Survey (USGS) topographic maps,
- Aerial photos, and
- Census maps.

These maps are principally used in preliminary assessment, but also may be consulted in detailed assessment.

USGS topographic maps (Volume II, p. 12) provide moderately detailed coverage of an area. They show natural and manmade features, and community and jurisdictional boundaries. Topographic maps of rural areas identify individual buildings; in metropolitan areas they show all major community features. USGS topographic maps are revised periodically using aerial photographic and field verification techniques.

Aerial photos (Volume II, p. 9) provide pictures of the physical features shown on topographic maps. Altitudes at which photographs are taken vary, as do the geographic areas covered. However, photos are taken frequently and for a wide variety of purposes; thus chances are good that photographs meeting practitioners' needs will be readily available. Aerial photos compiled by the USGS are available from the NCIC.

Census maps (Volume II, p. 19) do not, for the most part, indicate topographic features. Rather, they are used to extract population and housing data from U.S. Census reports. First, the geographic area under investigation is located on a tract outline map (for tract data) or Metropolitan Vicinity Map (for block statistics). Then, when the applicable tract or block numbers have been identified on these maps, the pertinent information may be located in the corresponding reports.

7.1.2 State Maps

Maps available from State sources are:

- Statewide highway maps, and
- Soil maps.

Like nationwide maps, State maps are mainly used in preliminary assessment.

Statewide highway maps (Volume II, p. 11) present many of the same kinds of data as USGS topographic maps, although the extent of coverage varies by State. Because these maps give indepth coverage of the existing transportation network, they are especially valuable in highway planning. Highway maps are usually updated as the State's road system changes.

Soil maps (Volume II, p. 11), available from the State Soil Conservation Service, identify soil characteristics across each county. Practitioners use these maps to identify areas -- e.g., prime and unique farmland -- that should be avoided when highway locations are selected.

7.1.3 Local Maps

The following maps, available from local sources, are frequently consulted in impact assessment:

- Land use maps,
- Comprehensive plan maps,
- Zoning maps, and
- Plat maps.

The first three of these maps are primarily consulted in preliminary assessment. Plat maps are used almost exclusively in detailed assessment.

Land use maps (Volume II, p. 10) identify usage patterns across a community. They show residential, commercial, industrial, agricultural, and other land uses, but may or may not present additional topographic data. Although most land use maps identify current patterns of usage, some maps -- notably comprehensive plan maps (Volume II, p. 10) -- also show land uses planned for the community. Thus examination of comprehensive plan maps will show the expected locations of future residential, commercial, and industrial growth. Planned facilities and other projected development projects are also shown.

Zoning maps (Volume II, p. 36), where used, identify the geographic location of zones in the community. These maps, read in conjunction with zoning texts, enable practitioners to identify those development requirements sanctioned in each zone. In this way, projections about housing density, quality of neighborhoods, etc., may be made in areas where development is planned or in progress.

Individually owned parcels of land in the community are identified on a plat map (Volume II, p. 10). Lot dimensions, utility and access easements, and other information are shown either on the map or on companion documents. Plat maps are normally available from the local property management or assessment office.

7.2 RECORDS SOURCES

Records used in socio-economic impact assessment provide demographic and economic information about the residents, businesses, and community facilities in the study area. They identify the uses to which land and buildings are put, and they give important information on social, economic, and land use trends. Most of the factual data used to profile the macro study area in preliminary assessment are available in records. Records also provide much of the information on micro study areas, although a sizable amount of the data required in detailed assessment must come from surveys.

Records, like maps, are available from (1) nationwide, (2) State, and (3) local sources. The nationwide sources provide aggregate data, whereas the local sources often contain disaggregate information. State sources generally contain aggregate data, although they also include disaggregate information on selected community facilities.

Most records covered in this Manual are compiled by government agencies. Several private sources of potentially useful data are also identified. Private groups produce business and residential directories, maintain lists of properties for sale or lease, and update local population statistics. The privately produced records identified in this Manual are generally as reliable as public records and should not be overlooked when available.

Among the different sources of records, local sources give practitioners access to the broadest range of information. Information available in local sources include data on land use, community facilities and services, population, housing, business, employment, agriculture, and local government finance. Nationwide records, in contrast, provide population, housing, business, and employment statistics. Topics addressed by State sources include community facilities and services, employment, and agriculture. Nationwide and State sources are primarily consulted in preliminary assessment, while local records are most widely used in detailed assessment.

Most records provide geographic coverage at the county or municipal level. There are some important exceptions, however. For instance, many of the population and housing data in nationwide sources are available for census tracts and blocks. Property assessment records, farm records cards, community facilities registers, and other State and local files also contain information on individually owned or operated property units.

Nationwide sources are less likely than other records to be current. The nationwide records presented in Section 7.2.1 (below) are completely updated only once every five years (for business and employment data) or ten years (for population and housing data).* Most State and local sources, in contrast, are revised annually or even more frequently. Some sources, such as

*Many statistics presented in nationwide sources are revised during interim periods, but only for large geographic areas, i.e., States or counties. Nevertheless, large-area statistics are often used as proxy indicators of growth trends in small areas. See Section 9.3 below.

local comprehensive plans or zoning ordinances, are updated less frequently or on an irregular basis. However, in these cases currency can be ensured if all amendments to the documents are examined. Another way to assess currency is to interview agency officials responsible for compiling records. Frequently, these officials will be cognizant of important changes which have occurred since the sources were compiled.

Practitioners may judge the general reliability of records data by (1) comparing similar information in several different records, (2) looking for consistencies in trends over time, and (3) spot-checking the records using mini-surveys and other survey techniques.

7.2.1 Nationwide Sources

Highway practitioners regularly consult the following reports compiled by the U.S. Bureau of the Census:

- Tract Reports,
- Block Statistics,
- Urban Transportation Planning Package (UTPP),
- Economic Census Reports,
- County Business Patterns, and
- Current Business Reports.

The first three reports contain population and housing data used mainly in preliminary assessment, but often studied in detailed assessment as well. The latter three reports present economic data, and are primarily consulted in preliminary assessment. Practitioners may find that other Census reports also contain useful information.

The information presented in Census reports is generally more detailed than data in other records. Also, whereas many records are compiled from sample data, Census reports are based largely on complete-count information. Consequently, practitioners frequently begin their assessment activities by examining Census reports, even when these data are not current.

Tract Reports (Volume II, p. 21) and Block Statistics (Volume II, p. 24) are compiled following each decennial census. They present population and housing data for extremely small geographic areas. These data are extracted by (1) identifying the study area on a Census map, and (2) locating the corresponding tract or block numbers in the appropriate report.

Tract data in the 1980 decennial census are available in printed reports, on microfiche, or on summary tape files (STFs) 1-4. Block data are reported on microfiche and on STF 1.* Summary tape files provide practitioners with several important advantages: (1) they include greater subject and geographic detail than other types of Census reports, and (2) they enable users to manipulate data to serve specific needs. The major disadvantage of STFs is that computer hardware is required.

The UTPP (Volume II, p. 25) is a computer-software program prepared especially for highway planners. It generates population and housing data on (1) residents of census tracts and block groups, (2) workers in these areas, and (3) traffic flows between key residential and employment centers.

Economic census data are generally available in printed reports or on summary tapes. Economic Census Reports (Vol II, p. 26), which are compiled every five years, provide detailed information on the following subjects: (1) retail trade, (2) wholesale trade, (3) service industries, (4) construction industries, (5) manufacturers, and (6) mineral industries. County Business Patterns (Vol. II, p. 26) presents information on businesses and employment by industry; it is updated annually. Current Business Reports (Vol II, p. 28) covers business activities in selected states, SMSAs, and cities; it is issued monthly.

The Census Bureau maintains a sizable public liaison staff. Specialists on this staff (1) assist users in identifying and locating suitable data, (2) direct them to public and private organizations which print out tabulations from

*In non-tracted or non-blocked areas, Census data are reported for small geographic jurisdictions called enumeration districts. Following the 1980 census, enumeration district data were reported on microfiche and on STFs 1 and 3.

summary tapes, and (3) respond to general inquiries. These specialists may be contacted at:

Data User Services Division
Bureau of the Census
Washington, D.C. 20233

Census Bureau regional offices are also staffed by Data User Services specialists.

7.2.2 State Sources

Records available from State sources include:

- Agriculture statistics,
- Employment statistics,
- Health facilities directories,
- Library facilities directories, and
- School directories.

These sources are mainly used in preliminary assessment.

Information reported in State Agriculture Statistics Bulletins (Volume II, p. 15) vary by State. However, most States report information aggregated at the county level on (1) total farm acreage, (2) acreage by crop, (3) productivity per acre, and (4) costs and revenues per acre. Agriculture statistics are updated annually. State employment statistics (Volume II, p. 31), issued monthly, indicate current unemployment rates and provide data on employment trends by industry. Data are typically aggregated for counties, cities, and labor market areas.

Three documents available from State agencies are commonly used to identify community facilities in the study area. Whereas local directories generally list public facilities only, the State directories identify public, private, and parochial facilities. The health facilities directory (Volume II, p. 32) lists health care facilities by location, and usually contains information on the types and sizes of facilities. Lists of public and private libraries are available in the library facilities directory (Volume II, p. 32). The State directory of schools (Volume II, p. 36) lists public, private, and parochial schools. It usually presents information on student enrollment and service area boundaries. State directories are normally updated annually.

7.2.3 Local Sources

The following records are commonly available from local sources:

- Comprehensive plans,
- Zoning ordinances,
- Property assessment files,
- Criss-cross area directories,
- Business directories,
- Community facilities registers,
- Public property inventories,
- Building permit files,
- Farm record cards,
- Business license files,
- Population statistics,
- Annual operating budgets,
- Capital Improvement Program (CIP) files,
- Multiple listing services, and
- Classified ads.

Those local sources containing aggregate data are chiefly consulted in preliminary assessment. Records presenting disaggregate information for individual property units are primarily used in detailed assessment. Most local records are revised annually, or on a continual basis, although practices vary by locality.

Community goals, objectives, and policies governing land use development are documented in the local comprehensive plan (Volume II, p. 30), sometimes called the master plan. Highway practitioners use this plan to (1) identify land use trends in the study area, and (2) determine whether the proposed highway project is consistent with these trends, and the planning goals of local agencies.

Zoning ordinances (Volume II, p. 36) present additional land use data in zoned communities. They indicate the types of land use activities, e.g., single-family, local commercial, light industrial, permitted in each zone, or district. They also regulate specific development criteria, e.g., permissible sizes of lots and buildings. Zoning data help users project future housing densities and the quality of neighborhoods. Comprehensive plans and zoning ordinances are first consulted early in preliminary assessment, but are generally of value throughout the planning process.

Property assessment files (Volume II, p. 34) give practitioners access to important information on individual parcels of land. Among the available data are (1) size of parcels and buildings, (2) assessed value of land and buildings, (3) estimated market value, and (4) names of property owners. Property assessment records cover most areas of the county, including residential, commercial, industrial, agricultural, undeveloped, and public lands. They are used in detailed assessment in conjunction with plat (or real property) maps. Property assessment records are updated continuously.

Several types of directories available from local sources are also keyed to individual property units. However, whereas assessment records identify property owners, community directories normally list the occupants or users of individual property units.* Criss-cross area directories (Volume II, p. 30), published by private firms but available in local libraries, list residents and businesses by street address and phone number.** Business directories (Volume II, p. 17) are similar in format to criss-cross directories, except businesses are frequently listed alphabetically by type. Community facilities registers (Volume II, p. 29) list all public and many private facilities. Facilities listed include health care facilities, schools, religious facilities, social and cultural centers, and recreation centers.

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*Hence, the owners of an apartment complex will be identified in the property assessment records, while the tenants of individual apartments are listed in the community directory.

**Representative samples are often drawn from criss-cross directories. Individuals in the sample are then surveyed in face-to-face interviews, by telephone, or with mail-back questionnaires.

More detailed information on individual facilities is presented in public property inventories (Volume II, p. 35). Inventoried data often include facility size, general design features, year built, and condition.

Several other local records help practitioners access information for individual property units. Building permit files (Volume II, p. 16) contain information on current and scheduled development projects. They include detailed site plans showing all structures planned for construction, estimates of development costs, and the names of owners or developers. A building permit is required before construction can begin, but its presence in the file does not necessarily mean construction has begun or will begin.

Farm record cards (Volume II, p. 31), available from the county Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture, give important information on individual farms. Among the pertinent data available are (1) total acres per farm, (2) acreage by land use and crop, and (3) average yield per acre.

Business license files (Volume II, p. 17) normally contain data on individual businesses. Stored information may include (1) business type, (2) location, (3) ownership, (4) years in operation, and (5) years at current address. Additional data are sometimes available on each businesses' employees, including distribution by labor category, sex, and race. The chief problem with license files is that recordkeeping procedures in some localities make access to data for individual businesses difficult or impossible.

Other types of local records contain more general, but no less important, information. Public and private planning agencies often publish local population statistics (Volume II, p. 34) for counties or municipalities. These statistics are reported for many of the same categories of data as Census population reports, and frequently include population projections. In many instances local statistics are more current than Census data. On the negative side, local population statistics are not usually reported for census tracts and blocks, although there are exceptions. Additionally, local statistics are usually developed using sample, rather than complete-count, collection procedures.

Annual operating budgets for local government units (Volume II, p. 15) identify projected revenues and expenditures for the fiscal year. Among the pertinent data shown are (1) property assessment rates, and (2) tax revenues by property type. These data help practitioners estimate total revenues generated by properties in different parts of the macro study area. Future trends in property tax rates and revenues can often be estimated when operating budgets from previous years are studied.

In the event that one or more of the alternative routes subject to detailed assessment will likely displace existing public facilities, Capital Improvement Program files (Volume II, p. 18) ought to be consulted. CIPs provide information on capital expenditures and improvements planned for periods of five or more years. These data help users estimate the functional replacement costs required to relocate displaced facilities.

The multiple listing services (Volume II, p. 33) maintained by local Boards of Realtors list residential, commercial, industrial, and undeveloped properties for sale or lease. Practitioners use these lists to (1) identify undeveloped lands and other properties ideally suited to highway development, and (2) determine the general availability of replacement properties for residents and businesses who may possibly be displaced. Similar information on the availability of replacement property may be found in the classified sections (Volume II, p. 28) of local newspapers.

7.3 SURVEY TECHNIQUES

Surveys used in impact assessment generate both factual and perceptual information. These data encompass all nine topical categories, ranging from land use to local government finance. Surveys are especially important for collecting information which is not available in maps and records, e.g., data on trip activity patterns or residents' opinions about the proposed highway project. Surveys are important sources of information in detailed assessment, and are used selectively in preliminary assessment as well.

Seven types of surveys are presented in this Manual. They are: (1) windshield surveys, (2) walk-through reconnaisance, (3) purposive surveys of area elites, (4) mini-surveys of area residents and businesses, (5) surveys of local facility managers, (6) surveys of area residents and businesses, and (7) trip activity surveys. The first two techniques require investigators to observe land use activities across the study area. The other techniques utilize respondent questionnaires, although trip activity surveys often combine observation and questionnaire approaches. Most of the respondent surveys may be used with small- or medium-sized sample groups. Surveys of area residents and businesses, which require selection of a comparatively large sample, are the sole exception.

Surveys of area elites and local facility managers use non-random sampling methodologies. These methodologies assume that certain individuals in the community -- elected officials, government agency staff, or facility managers -- have specialized knowledge about the subject areas being investigated; practitioners select groups of respondents from these experts.* Non-random methodologies include judgmental, purposive, and linked-chain sampling plans.**

Mini-surveys, surveys of area residents and businesses, and trip activity surveys generally use random sampling methodologies. Random sampling plans, when correctly executed, ensure that all persons in the survey population have an equal chance of being selected. Random methodologies include simple or systematic random, sequential, stratified, and cluster or multi-stage sampling plans. The size of the sample relative to the survey population is an issue in random sampling, with larger samples tending to yield more reliable survey results.***

The five techniques which utilize respondent questionnaires may be (1) self-administered and mailed back, (2) administered by phone, or (3) administered in face-to-face interviews. Self-administered surveys are the least expensive

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*When only a few people are qualified to discuss a particular subject, it may be practical to interview all of them. This is called a census survey.

**Volume II, Chapters 5-6 give more detail on sampling methodologies.

***Volume II, Chapter 7 includes a detailed discussion of sample size.

but have low return rates, ranging from 10 to 60 percent. They do not allow for interaction between interviewers and respondents, and there is no remedy for misinterpretation of questions. Self-administered questionnaires have a better rate of return when they are short, and when used with a target group having a high level of education. They also enable respondents to think through their answers before replying.

Phone surveys are more expensive than self-administered surveys, but less expensive than face-to-face interviews. Interviewers are able to rephrase questions and clarify responses, although verbal clues provide the only indication of respondent feelings. People are more likely to answer questions over the phone than to mail back questionnaires, but only persons with telephones can be sampled. There is a tendency with phone surveys for respondents to feel pressured to answer too quickly.

The face-to-face interview is the most expensive of the techniques. However, it is generally the best approach for gathering information about complex, emotionally-charged subjects. It allows for maximum interaction between interviewers and respondents, and enables interviewers to probe for sentiments which may underlie an expressed opinion. Personal interviews usually yield a better sample of the general population than the other approaches, since more people are willing to cooperate when all they have to do is talk. Nevertheless, as with phone surveys, respondents may feel pressured to answer quickly.

7.3.1 Windshield Surveys and Walk-Through Reconnaissance

Observation techniques familiarize practitioners with the physical, social, and economic characteristics of the study area. They are commonly used to update information shown on maps, collect data on the condition of houses or businesses, and conduct pedestrian counts. They also enable practitioners to to observe social phenomena unobtrusively, e.g., patterns of interaction among area residents. These observations can be used to assess cohesion and accessibility.*

*Observations of social phenomena, e.g., pedestrian traffic, should be conducted during various time periods and, when applicable, at different locations. This will help ensure the reliability of observations.

Observation techniques used in impact assessment include (1) windshield surveys (Volume II, pp. 39 & 53) and (2) walk-through reconnaissance (Volume II, p. 53). The two surveys differ in that the former is conducted by automobile, and the latter on foot. Windshield surveys are conducted in preliminary or detailed assessment, while walk-through reconnaissance is done in detailed assessment. Observation data are recorded on a base map or an observation checklist.

7.3.2 Purposive Surveys of Area Elites

Purposive surveys (Volume II, pp. 39 & 54) enable practitioners to elicit specialized data from informed members of the community. These community members are often local officials, realtors, planners, county agents, and tax assessors. They may also be spokespersons for organizations and special interest groups.

A substantial amount of expert judgment and opinion data may be gathered using purposive surveys. County planners, for example, might be asked whether the proposed project is consistent with plans for future development. Property assessors could be asked to develop projections about the effect a project will have on future tax revenues. Chamber of Commerce spokespersons might be questioned on members' preferences regarding route location.

Purposive surveys are used in both preliminary and detailed assessment. They are often loosely structured. The interviewer briefs the respondent on the proposed project, and then asks a series of questions and records the answers. Purposive surveys are most often conducted in face-to-face interviews, but may be done over the telephone or by mail.

In general, when a majority of experts indicate similar or identical positions, their judgments can be accepted as credible. Conversely, when expert judgments diverge and meaningful patterns are not discernible in the responses, the judgments should be regarded cautiously. Selection of alternative techniques for collecting the data on the issues treated is then probably in order.

7.3.3 Mini-Surveys of Area Residents and Businesses

Mini-surveying (Volume II, p. 47) is a procedure for generating information from extremely small samples. It is used in preliminary assessment to screen the attitudes and perceptions of study area residents and businesses. Mini-surveys may be used to assess attitudes toward the project, perceptions about the benefit or harm the project will have, and preferences concerning route selection. They may also be used to collect core socio-economic data on residents or businesses.

Questionnaires used in mini-surveys contain a small number of items, and are usually administered by phone. The small samples used in mini-surveys have a greater margin of error than the larger samples used in more traditional survey approaches. However, even with wider confidence bands, it is often possible to draw solid conclusions from the response patterns. Also, pinpoint accuracy is not usually required in the early periods of preliminary assessment, when opinions and perceptions are often only partially formed.*

7.3.4 Surveys of Local Facility Managers

Surveys of local facility managers (Volume II, p. 56) are used to determine levels of use, service areas, and modes of access to local institutions. The surveys also elicit information on the perceived impacts which route alternatives will have on facility use, and suggestions for mitigating negative impacts.

Facility surveys are usually conducted in detailed assessment. Generally, a census survey of institutions in or abutting on each of the ROWs under consideration is used. The surveys are often self-administered and mailed back; this gives facility managers time to search their records for the information requested.

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*See Volume II, Chapter 5 for a discussion of sampling procedures followed in mini-surveys.

7.3.5 Surveys of Area Residents and Businesses

Random surveys of residents and businesspersons (Volume II, p. 59) generate a broad range of factual and perceptual information. They provide core socio-economic data which are often used to improve on the currency and level of disaggregation of population profiles drawn from records. They also provide information on perceptions of effects which can be correlated with socio-economic data. Examples of perceptual data collected with random surveys are preferences among alternative routes, degree of attachment to neighborhood, perceived stability of neighborhood, importance of access to specified destination points and perceptions of the impacts the project will have on businesses.

Because they have high resource requirements, random surveys are usually conducted during detailed assessment. The surveyed population may consist of all residents and businesses in the macro study area or be drawn from residents along each alternative alignment. Random surveys are usually administered in face-to-face interviews, but can be administered by phone.

Since the probability of sampling error for data generated in random surveys is normally small, the potential for highly reliable findings is good. Maximum reliability, of course, is required of all data used in the route selection process.

7.3.6 Trip Activity Surveys

Trip activity surveys (Volume II, p. 84) are used to identify patterns of travel to and from community facilities, employment centers, shopping areas, and other destination points. Data are often collected on frequency of trips, mode of travel, origin and destination, route followed, and socio-economic characteristics of tripmakers. Information required to identify pedestrian dependency routes is also frequently collected.

Trip activity surveys commonly employ both observation and questionnaire approaches. Typically, surveyors make observations about the volume of traffic, number and demographic characteristics of travelers, travel modes, etc. Then a short questionnaire is administered -- usually in a face-to-face interview -- to collect additional information. Respondents may be randomly selected or all tripmakers may be surveyed, depending on the volume of traffic and other circumstances.

Trip activity surveys require minimal resources, and are extremely flexible. In many cases, conduct of the survey during different time periods will improve the reliability of findings.

The matrices presented in this chapter (Figures 13-21) link the information requirements specified in the data fields in Part 1 to the sources evaluated in the preceding chapter. Since data collection activities are normally conducted by topic (e.g., population), rather than by impact (e.g., cohesion), each matrix presents data elements associated with a single topical category. The 9 topical categories and 37 potential sources covered in the matrices are shown below in Figure 12.

Topics

- Land use
- Community facilities
- Population
- Housing
- Business activity
- Employment
- Agriculture
- Local government finance
- Attitudes and perceptions

Potential Data Sources

MAPS	
Aerial photographs	Soil maps
Census maps	Statewide highway maps
Comprehensive plan maps	USGS topographic maps
Land use maps	Zoning maps
Plat maps	

RECORDS	
Agricultural statistics	Employment statistics
Annual operating budgets	Farm record cards
Building permit file	Health facilities directory
Business directories	Library facilities directory
Business licenses	Multiple listing services
Capital Improvement Programs	Population statistics, local
Census reports	Property assessment records
Classified ads	Public property inventories
Community facility registers	School directories
Comprehensive plans, local	Zoning ordinances
Criss-cross area directories	

SURVEYS
Windshield surveys
Walk-through reconnaissance
Purposive surveys of area elites
Mini-surveys of area residents and businesses
Surveys of local facility managers
Surveys of area residents and businesses
Trip activity surveys

Figure 12. Topical categories and potential data sources.

The matrices are designed so that users can, starting with an individual data element, look across and locate the cells on that row that are bulleted, and then up, to find the source of the datum listed at the top of the column.

The data presented in each matrix are grouped under subheadings which appear on the left-hand margin. Subheadings used in eight of the matrices relate directly to the topics examined. Subheadings used in the ninth matrix on attitudes and perceptions (Figure 21) pertain to (1) preferences about project site and design, and (2) expected social and economic effects of the project.

The matrices are normally used at the beginning of data collection. They enable practitioners to identify data requirements, examine potential sources, and decide where to go for information.

The matrices should be used in conjunction with (1) the information on the advantages and disadvantages of available sources presented in Chapters 7 and 9, and (2) the detailed descriptions of individual sources in Parts 1 and 2 of Volume II. These reference materials will be particularly useful in cases where the the same data are available from more than one source.

Data Requirements on Land Use		Maps: U.S. Geological Survey Topographic Map	Maps: State Highway Map	Maps: Aerial Photos	Maps: Soil Map	Maps: Land Use Map	Maps: Zoning Map	Maps: Plat Map	Records: Comprehensive Plan	Records: Zoning Ordinance	Records: Property Assessment Records	Records: Building Permit File	Surveys: Windshield Survey	Surveys: Walk - Through Reconnaissance	Surveys: Purposive Survey of Elites (Realtors, Planners, Local Officials)
Aggregate Land Use Data	Total land area	●	●			●									
	Topographic features*	●	●	●	●								●		
	Boundaries														
	community	●				●									●
	neighborhood	●				●									●
	political	●				●									
	Land use by activity	●		●		●	●		●	●			●		
	Zoning restrictions						●			●					●
	Average market value of property by type														●
	Land use trends														
	land use by activity								●	●					●
	average market value of property by type														●
Planned Land Use	Goals and objectives								●						●
	land use								●						●
	transportation								●						●
	Importance and urgency of goals														●
	Strategies								●						●
	Growth and development plan														
	projected land use								●	●					●
	targeted levels of development								●	●					●
Scheduled Development Projects	Location											●		●	●
	Land use activity									●		●			
	Description											●		●	
	Estimated development cost											●			

*Includes manmade and natural features.

Figure 13. Data requirements by source: land use.

DATA REQUIREMENTS on Land Use	SOURCES	MAPS						RECORDS				SURVEYS		
		U.S. Geological Survey Topographic Map	State Highway Map	Soil Map	Land Use Map	Zoning Map	Plat Map	Comprehensive Plan	Zoning Ordinance	Property Assessment Records	Building Permit Files	Windshield Survey	Walk - Through Reconnaissance	Purposive Survey of Elites (Realtors, Planners, Local Officials)
Undeveloped Land	Location				●		●	●		●			●	
	Size						●			●			●	
	Topography				●								●	
	Zoning restrictions					●			●					
	Utility system													●
	Market value									●				
Data on Individual Parcels	Number						●			●			●	
	Size						●		●	●			●	
	Land use activity				●				●	●			●	
	Improvements									●				
	Estimated value of land and structure									●				

Figure 13. Data requirements by source: land use (continued).

Aggregate Data on Community Facilities — DATA REQUIREMENTS on Community Facilities \ SOURCES	MAPS			RECORDS						SURVEYS		
	U.S. Geological Survey Topographic Map	State Highway Map	Land Use Map	Directory of Schools	Health Facilities Directory	Library Facilities Directory	Community Facilities Register	Capital Improvement Program Files*	Public Property Inventories	Windshield Survey	Survey of Local Facility Managers	Trip Activity Survey
Police stations												
number									●	●		
types of stations								●	●			
location	●	●						●	●	●		
Fire and rescue facilities												
number									●	●		
types of facilities								●	●			
location	●	●						●	●	●		
Health care facilities												
number					●		●			●		
types of facilities					●		●	●				
location	●	●	●		●		●	●		●		
Schools												
number				●			●			●		
types of schools				●			●	●		●		
location	●	●	●	●			●	●		●		
Libraries												
number						●			●	●		
types of libraries						●		●	●			
location	●	●	●			●		●	●	●		
Religious facilities												
number							●				●	
types of facilities							●				●	
location	●	●					●				●	

*Contains information on public facilities to be constructed or remodeled.

Figure 14. Data requirements by source: community facilities.

DATA REQUIREMENTS on Community Facilities / SOURCES		MAPS			RECORDS						SURVEYS		
		U.S. Geological Survey Topographic Map	State Highway Map	Land Use Map	Directory of Schools	Health Facilities Directory	Library Facilities Directory	Community Facilities Registers	Capital Improvement Program Files*	Public Property Inventories	Windshield Survey	Survey of Community Facility Managers	Trip Activity Survey
Aggregate Data (continued)	Social/cultural centers												
	number							●		●	●		
	types of centers							●	●	●			
	location	●		●				●	●	●	●		
	Recreational facilities												
	number							●		●	●		
	types of facilities							●	●	●			
	location	●		●				●	●	●	●		
Data on Individual Facilities	Service area								●			●	
	Usage												
	enrollment/membership				●							●	
	total capacity								●			●	
	usage-to-capacity ratio											●	
	Population served												
	by age											●	●
	by race/ethnicity											●	●
	by income level											●	●
	by neighborhood of residence											●	●
	by mode of travel											●	●
	Facility-to-population standard								●			●	

*Contains information on public facilities to be constructed or remodeled.

Figure 14. Data requirements by source: community facilities. (continued)

DATA REQUIREMENTS on Population \ SOURCES		RECORDS: Census Block Statistics	RECORDS: Census Tract Statistics	RECORDS: Census Urban Transportation Planning Package	RECORDS: Census Summary Tape Files 1-2	RECORDS: Census Summary Tape Files 3-4	RECORDS: Local Population Statistics	SURVEYS: Windshield Survey	SURVEYS: Mini - Survey of Area Individuals (Residents)	SURVEYS: Random Survey of Area Individuals (Residents)	SURVEYS: Trip Activity Survey
Aggregate Population Data	Population density										
	persons per acre		●								
	persons per household	●	●	●	●						
	persons per room	●	●	●	●						
	Total population	●	●	●	●	●	●				
	by age	●	●	●	●		●				
	by race/ethnicity	●	●	●	●		●				
	by marital status	●	●		●						
	by household relationships	●	●		●						
	by occupation		●	●		●					
	by employment status		●	●		●					
	by family income		●	●		●	●				
	by number of automobiles		●	●		●					
	Population trends and projections										
	total population	●	●		●		●				
	by age	●	●		●		●				
	by race/ethnicity	●	●		●		●				
	by income		●			●	●				
Population Concentrations	Population centers		●					●			
	Elderly	●	●		●			●			
	Ethnic minorities	●	●		●			●			
	Religious minorities							●			
	Low-income families		●			●		●			
	Female-headed households	●	●		●						
	Foreign-born		●			●					
	Non-English speaking		●			●					

Figure 15. Data requirements by source: population.

DATA REQUIREMENTS on Population \ SOURCES		RECORDS: Census Block Statistics	RECORDS: Census Tract Statistics	RECORDS: Census Urban Transportation Planning Package	RECORDS: Census Summary Tape Files 1-2	RECORDS: Census Summary Tape Files 3-4	RECORDS: Local Population Statistics	SURVEYS: Windshield Survey	SURVEYS: Mini - Survey of Area Individuals (Residents)	SURVEYS: Random Survey of Area Individuals (Residents)	SURVEYS: Trip Activity Survey
Data on Individual Households	Residence										
	tenure of residence								●	●	
	time at current address								●	●	
	time in area								●	●	
	Composition of household										
	number of persons								●	●	
	relationship of residents								●	●	
	by sex								●	●	
	by age								●	●	
	by race/ethnicity								●	●	
	by educational background								●	●	
	Number handicapped								●	●	
	Number in school									●	
	Employment										
	number employed by occupation								●	●	
	number unemployed by occupation								●	●	
	Household income								●	●	
	Number of licensed drivers								●	●	
	Number of vehicles owned								●	●	
	Proximity to destination points										
	place of work									●	
	shopping areas									●	
	community facilities									●	
	Predominant mode of travel									●	

Figure 15. Data requirements by source: population. (continued)

	DATA REQUIREMENTS on Population / SOURCES	RECORDS						SURVEYS			
		Census Block Statistics	Census Tract Statistics	Census Urban Transportation Planning Package	Census Summary Tape Files 1-2	Census Summary Tape Files 3-4	Local Population Statistics	Windshield Survey	Mini - Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Residents)	Trip Activity Survey
Data on Individual Trips	Social interaction										
	frequency of contact with neighbors									●	
	participation in local organizations									●	
	frequency of mutual support									●	
	Individual trips*										
	mode of travel										●
	origin/destination										●
	route followed										●
	travel time										●
	cost										●
	purpose										●

*Includes trips to community facilities, shopping and recreation areas, and other important destinations.

Figure 15. Data requirements by source: population. (continued)

DATA REQUIREMENTS on Housing \ SOURCES		MAPS: U.S. Geological Survey Map	MAPS: Land Use Map	MAPS: Plat Map	RECORDS: Census Block Statistics	RECORDS: Census Tract Statistics	RECORDS: Census Summary Tape Files 1-2	RECORDS: Census Summary Tape Files 3-4	RECORDS: Building Permit File	RECORDS: Property Assessment Records	RECORDS: Comprehensive Plan	RECORDS: Multiple Listing Service	RECORDS: Classified Advertisements	SURVEYS: Windshield Survey	SURVEYS: Walk - Through Reconnaissance	SURVEYS: Purposive Survey of Elites (Realtors)
Aggregate Housing Data	Total housing units				●	●	●									
	by type				●	●	●									
	by tenure				●	●	●									
	by units per structure				●	●	●									
	by age of structure					●		●								
	by rooms per unit					●	●									
	by persons per room				●	●	●									
	by condition													●		●
	number without plumbing facilities				●	●	●									
	number without kitchen facilities					●		●								
	owner-occupied units by value				●	●	●									
	rented units by monthly rent				●	●	●									
	Vacancy rate															
	normal															●
	actual				●	●	●									
	Housing trends & projections															
	total housing units				●	●					●					●
	by type				●	●					●					●
	vacancy rate				●	●					●					●
	value of owner-occupied units				●	●				●						●
	monthly rent on rented units				●	●										●
Concentrations of Residential Structures	Locations	●	●											●		●
	Types of housing										●	●		●		●
	Condition of housing													●		●
	Approximate number of dwelling units										●			●		●

Figure 16. Data requirements by source: housing.

DATA REQUIREMENTS on Housing / SOURCES		MAPS: U.S. Geological Survey Map	MAPS: Land Use Map	MAPS: Plat Map	RECORDS: Census Block Statistics	RECORDS: Census Tract Statistics	RECORDS: Census Summary Tape Files 1-2	RECORDS: Census Summary Tape Files 3-4	RECORDS: Building Permit File	RECORDS: Property Assessment Records	RECORDS: Comprehensive Plan	RECORDS: Multiple Listing Service	RECORDS: Classified Advertisements	SURVEYS: Windshield Survey	SURVEYS: Walk - Through Reconnaissance	SURVEYS: Purposive Survey of Elites (Realtors)	SURVEYS: Sample Survey of Area Individuals (Residents)
Data on Individual Dwelling Units	Location			●						●					●		●
	Owner									●							●
	Tenure									●							●
	Structure																
	type									●					●		●
	number of units									●					●		●
	year built									●							●
	condition														●		●
	Unit																
	type									●					●		●
	number of floors									●							●
	number of rooms									●							●
	condition																●
	value of owner-occupied units									●							●
	monthly rent on rented units															●	●
	Description of surrounding area																
	land uses														●		●
	vacant lots, dwellings														●		●
	condition														●		●
Data on Available Dwelling Units	Location			●								●	●			●	
	Type											●	●			●	
	Size											●	●			●	
	Tenure											●	●			●	
	Condition											●	●			●	
	Cost											●	●			●	

Figure 16. Data requirements by source: housing.
(continued)

DATA REQUIREMENTS on Housing	SOURCES	MAPS: U.S. Geological Suvey Map	MAPS: Land Use Map	MAPS: Plat Map	RECORDS: Census Block Statistics	RECORDS: Census Tract Statistics	RECORDS: Census Summary Tape Files 1-2	RECORDS: Census Summary Tape Files 3-4	RECORDS: Building Permit File	RECORDS: Property Assessment Records	RECORDS: Comprehensive Plan	RECORDS: Multiple Listing Service	RECORDS: Classified Advertisements	SURVEYS: Windshield Survey	SURVEYS: Walk - Through Reconnaissance	SURVEYS: Purposive Survey of Elites (Realtors)	SURVEYS: Sample Survey of Area Individuals (Residents)
Housing Construction	Trends & projections																
	construction permits issued								●								●
	housing starts								●								●
	number of units completed									●							●
	number of units demolished									●							●
	net change in housing stock									●							●

Figure 16. Data requirements by source: housing. (continued)

DATA REQUIREMENTS on Business \ SOURCES		MAPS			RECORDS							SURVEYS				
		Land Use Map	Zoning Map	Plat Map	Economic Census Reports	Census County Business Patterns	Census Current Business Reports	Criss - Cross Directories	Local Business License Records	Business Directories	Property Assessment Records	Windshield Survey	Walk-Through Reconnaissance	Mini - Survey of Area Individuals (Businesspersons)	Purposive Survey of Elites (Chamber of Commerce)	Random Survey of Area Individuals (Businesspersons)
Aggregate Data on Businesses	Total number of businesses				●				●						●	
	by type (SIC code)				●	●			●						●	
	by legal form of organization				●				●							
	revenues by type				●		●								●	
	number owner-operated				●										●	
	Trends															
	total number of businesses				●				●						●	
	revenues by type of business						●								●	
Concentrations of Businesses	Number											●	●			
	Type		●									●	●			
	Location	●	●					●	●	●		●	●			
	General Description											●	●			
	Number of tenants							●		●						
Data on Individual Businesses	Name							●	●	●			●	●		●
	Type								●	●				●		●
	Legal form of organization													●		●
	Location			●				●	●	●				●		●
	years at current location													●		●
	years in area													●		●
	Street frontage															●
	Structure															
	age										●					●
	size								●		●					●
	condition															●
	special features										●					●
	location of entrance															●

Figure 17. Data requirements by source: business activity.

Data on Individual Businesses (continued)

DATA REQUIREMENTS on Business \ SOURCES	MAPS: Land Use Map	MAPS: Zoning Map	MAPS: Plat Map	RECORDS: Economic Census Reports	RECORDS: Census County Business Patterns	RECORDS: Census Current Business Reports	RECORDS: Criss - Cross Directory	RECORDS: Local Business License Records	RECORDS: Business Directory	SURVEYS: Property Assessment Records	SURVEYS: Windshield Survey	SURVEYS: Walk-Through Reconnaissance	SURVEYS: Mini - Survey of Area Individuals (Businesspersons)	SURVEYS: Purposive Survey of Elites (Chamber of Commerce)	SURVEYS: Random Survey of Area Individuals (Businesspersons)
Finances															
annual gross revenues															●
total monthly expenses															●
monthly payroll													●		●
revenue trends															●
sales trends															●
Number of employees								●	●				●		●
by labor category															●
by age															●
by sex															●
by race/ethnicity															●
by residential area															●
by mode of travel to work															●
Service area													●		●
Clientele served															●
by age															●
by race/ethnicity															●
by income level															●
by residential area															●
by mode of travel															●

Figure 17. Data requirements by source: business activity. (continued)

	DATA REQUIREMENTS on Employment / SOURCES	RECORDS: Census Tract Statistics	RECORDS: Census Summary Tape Files 3-4	RECORDS: Urban Transportation Planning Package	RECORDS: Census Country Business Patterns	RECORDS: State Employment Statistics	RECORDS: Business Directories	RECORDS: Classified Advertisements	RECORDS: Local Business License Records	SURVEYS: Windshield Survey	SURVEYS: Purposive Survey of Elites (Chamber of Commerce)	SURVEYS: Trip Activity Survey
Aggregate Employment Data	Total persons	●	●	●								
	by age	●	●	●								
	by race/ethnicity		●	●								
	Total employed people	●	●	●		●						
	by industry (SIC code)	●		●	●	●						
	by occupation	●		●								
	Job opportunities by occupation							●				
	Average wage by occupation							●				
	Unemployment rate											
	total	●				●						
	by industry					●						
	by occupation					●						
	Travel to work											
	mode of transportation	●	●									
	location of place of work	●	●									
Major Employment Areas	Number			●			●		●		●	
	Type			●			●		●		●	
	Location			●			●		●		●	
	Approximate number of employees			●			●		●	●		
	Residential concentrations of employees	●		●						●		●
	Employee modes of travel to work	●	●	●						●		●
Data on Individual Employees	Place of employment											●
	Length of service with current employer											●
	Location of residence											●
	Mode of travel to work											●
	Route followed											●
	Cost											●

Figure 18. Data requirements by source: employment.

Data Requirements on Agriculture		Maps: Aerial Photos	Maps: Soil Map	Maps: Land Use Map	Records: State Agricultural Statistical Bulletins	Records: Farm Record Cards	Surveys: Windshield Survey	Surveys: Purposive Survey of Elites (County Agent)	Surveys: Random Survey of Area Individuals (Farmers)
Aggregate Data on Agriculture	Total acres	●		●	●	●		●	
	by land use*	●			●	●		●	
	by crop				●			●	
	average productivity				●	●		●	
	average revenues					●		●	
	Prime and unique farmland		●						
	Farms								
	number	●			●	●	●	●	
	location	●		●		●	●	●	
	average acres				●	●		●	
Data on Individual Farms	General description								●
	years in operation								●
	tenure								●
	type of operation**					●			●
	season or year-round operation								●
	Productivity								
	total acres					●			●
	acreage by land use and crop					●			●
	average yield per acre					●			●
	trends					●		●	●
	Finances, current & projected								
	operational costs per acre				●				●
	revenues per acre				●				●

*Includes croplands, pasturelands, orchards, and forests.

**Includes dairyland, livestock, and orchard.

Figure 19. Data requirements by source: agriculture.

DATA REQUIREMENTS on Government Finance \ SOURCES		RECORDS: Property Assessment Records	RECORDS: Annual Operating Budget	SURVEYS: Purposive Survey of Elites (Tax Assessors)
Aggregate Assessment & Tax Data	Total tax base	●	●	
	by property type	●	●	
	Assessment			
	average assessed value of property by type	●		
	tax rate by property type	●		
	assessment ratio by property type	●		
	frequency of reassessment	●		●
	Property tax revenues		●	
	Tax assessment and revenue trends			
	average assessed values by property type	●		
	tax revenues		●	
Data on Individual Parcels	Assessed value	●		●
	Assessment ratio	●		●
	Tax rate	●		●
	Annual property tax	●		●

Figure 20. Data requirements by source: local government finance.

PROJECT DATA	DATA REQUIREMENTS on Attitudes & Perceptions / SOURCES	Purposive Survey of Area Elites	Mini-Survey of Area Individuals (Residents)	Mini-Survey of Area Individuals (Businesspersons)	Random Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Businesspersons)	Survey of Community Facilities Managers
Preliminary Assessment	Preferences Concerning Whether the Road Should be Built	●	●	●			
	Desirability of area with and without facility	●	●	●			
	Need for the facility	●	●	●			
	Value to the community	●	●	●			
	When the project should be implemented	●	●	●			
	Perceptions of the Opinions of Others Concerning the Proposed Project	●	●	●			
	Residents	●	●	●			
	Businesspersons	●	●	●			
	Elites	●	●	●			
	Area organizations	●	●	●			
	Opinions Concerning the Impact of the Proposed Project	●	●	●			
	Impact on the community	●	●	●			
	Impact on the individual		●	●			
	Perception of Ways in Which Proposed Project Would Benefit the Respondent		●	●			
	Nature of benefits		●	●			
	Degree of benefits		●	●			
	Perception of Ways in Which Proposed Project Would Harm the Respondent		●	●			
	Nature of harm		●	●			
	Degree of harm		●	●			
	Route Location	●	●	●			
	Rate/ranking importance of specified factors in route selection	●	●	●			
	Preferences on potential route locations	●	●	●			
	strength of preference	●	●	●			
	reason for preference	●	●	●			
Detailed Assessment	Preferences Concerning Route Alternatives				●	●	
	Rating the routes				●	●	
	reasons for rating				●	●	
	Specifying the best and worst routes				●	●	
	Expected reaction if least preferred route is selected				●	●	
	Most disruptive route				●	●	
	reason why most disruptive				●	●	
	Least disruptive routes				●	●	
	reasons why least disruptive				●	●	
	Problems associated with each alternative				●	●	
	Indirect methods for collecting data on preferences				●	●	
	perceived differences between routes in achieving specified effects				●	●	
	degree of difference				●	●	
	Rating the desirability of possible effects and the likelihood of each route producing each effect				●	●	
	Perception of impact of route options on respondent				●	●	
	Perception of Route Favored by Others				●	●	
	Area residents				●	●	
	Local businesspersons				●	●	
	State and local government officials				●	●	
	Other groups				●	●	
	Changes in Attitude Toward Project Over Time				●	●	
	Direction of change				●	●	
	Reasons for change				●	●	

Figure 21. Data requirements by source: attitudes and perceptions.

DATA REQUIREMENTS on Attitudes & Perceptions			Purposive Survey of Area Elites	Mini-Survey of Area Individuals (Residents)	Mini-Survey of Area Individuals (Businesspersons)	Random Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Businesspersons)	Survey of Community Facilities Managers
DESIGN FEATURES	Pre'y Ass't	Preference Among Design Features	●	●	●			
		Desirability of incorporating a series of design features into the facility	●	●	●			
	Detailed Assessment	Preferences on alignment						
		grade level						
		supports						
		use of areas under and beside facility						
		Preferences on access-related design features						
		on and off ramps						
		crossovers						
		service roads						
		median						
		Perceptions of Negative Impacts Requiring Special Efforts to Mitigate Harm						
ACCESSIBILITY	Preliminary Assessment	Perceptions of Transportation System	●	●	●			
		Adequacy of access to destinations	●	●	●			
		Accessibility problems	●	●	●			
		Need for a new road	●	●	●			
		Transportation-Related Community Concerns, Problems and Goals	●	●	●			
		Rating convenience of access	●	●	●			
		convenience of access to a series of pre-specified places		●	●			
		general convenience rating for the neighborhood/study area		●				
		convenience by mode of transportation		●				
		Importance of access to specified facilities		●				
		rating the importance of access to list of facilities		●				
		ranking three most important fac'ties		●				
	Detailed Assessment	Perception of impacts of project on accessibility	●	●	●			
		Impacts of alternative routes on access to destinations	●			●		
		Rating the importance of access to specified facilities	●					
		Ranking of most important destinations						
		Special Accessibility Problems	●					
		Preferences on Design Features Related to Accessibility						
		Expected changes in local facility use caused by proposed route						●
		Expected negative effects of project on service provision						●
		temporary, during construction						●
		permanent, beyond project completion						●
		Suggestions for minimizing harm						●
		during construction						●
		over life of facilities						●
		Expected changes resulting from project						●
		service area						●
		geographic destination of users						●
		means of access						●
		characteristics of users						●

Figure 21. Data requirements by source: attitudes and perceptions. (continued)

DATA REQUIREMENTS on Attitudes & Perceptions		SOURCES	Purposive Survey of Area Elites	Mini-Survey of Area Individuals (Residents)	Mini-Survey of Area Individuals (Businesspersons)	Random Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Businesspersons)	Survey of Community Facilities Managers
COHESION	Preliminary Assessment	Degree of Cohesiveness of Identifiable Communities/Neighborhoods	●					
		Recent Changes in Cohesiveness of Communities/Neighborhoods	●					
		Impact of Proposed Project on Cohesion	●					
		Ranking Communities	●					
		Cohesion and integration	●					
		Level of organization	●					
		Participation in local activities	●	●				
		Measures of Current Levels of Cohesion		●				
		Degree of attachment to neighborhood		●				
		Degree of satisfaction with neighborhood		●				
		desire to remain in neighborhood		●				
		rating specified characteristics of the neighborhood		●				
		rating of services		●				
		perceptions of emotional disposition of neighbors		●				
		judgments on best and worst features		●				
		rating area neighborhoods		●				
		Perceived stability of neighborhood	●	●				
		identification of changes	●	●				
		perceptions on degree of change	●	●				
	Detailed Assessment	Perception of Impacts of Each Route on Local Institutions					●	
		Membership					●	
		Facility usage					●	
		Effectiveness of service delivery					●	
		Future plans					●	
		Availability of alternative services					●	
		Impact of facility displacement on local cohesion					●	
		Rating of Neighborhood Features				●		
		Degree of attachment to neighborhood				●		
		Feelings towards neighbors				●		
		Satisfaction with neighborhood				●		
		Value of community-level interaction				●		
		Perceptions of Changes in Cohesion				●		
		Nature of change				●		
		Degree of change				●		
		Attitude toward change				●		
		Desire to Remain at Current Location				●		
		Future plans				●		
		Perceptions of Negative Effects of Alternative Routes on Cohesion				●		
		Identification of effects				●		
		Intensity of feeling about effects				●		
		Likelihood that alternative will cause each effect				●		

Figure 21. Data requirements by source: attitudes and perceptions. (continued)

DATA REQUIREMENTS on Attitudes & Perceptions		SOURCES	Purposive Survey of Area Elites	Mini-Survey of Area Individuals (Residents)	Mini-Survey of Area Individuals (Businesspersons)	Random Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Businesspersons)
DISPLACEMENT	Prelim'ry Ass'mnt	Area Residents		●			
DISPLACEMENT	Prelim'ry Ass'mnt	Perception of displacement impacts		●			
DISPLACEMENT	Prelim'ry Ass'mnt	Identification with place		●			
DISPLACEMENT	Prelim'ry Ass'mnt	Rating & ranking of neighborhood features		●			
DISPLACEMENT	Prelim'ry Ass'mnt	Attitude towards possible relocation		●			
DISPLACEMENT	Detailed Assessment	Importance of Features of Current Setting				●	
DISPLACEMENT	Detailed Assessment	Dwelling				●	
DISPLACEMENT	Detailed Assessment	Location				●	
DISPLACEMENT	Detailed Assessment	Neighborhood				●	
DISPLACEMENT	Detailed Assessment	Importance of Features at Any New Location				●	
DISPLACEMENT	Detailed Assessment	Having current neighbors close				●	
DISPLACEMENT	Detailed Assessment	Maintaining ethnic or religious ties				●	
DISPLACEMENT	Detailed Assessment	Having relatives, currently in same neighborhood, close by				●	
DISPLACEMENT	Detailed Assessment	Having friends, currently in same neighborhood, close by				●	
BUSINESS ACTIVITY	Preliminary Assessment	Opinions on Current Levels of Business	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Opinions on Trends in Business Activity	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Optimal Locations for New Businesses	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Effect of Proposed Project on Business	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Perceived positive effects	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	magnitude of effects	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Perceived negative effects	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	magnitude of effects	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Effect of Proposed Project on Employment	●		●		
BUSINESS ACTIVITY	Preliminary Assessment	Perceptions of Consumers in the Study Area		●			
BUSINESS ACTIVITY	Preliminary Assessment	Satisfaction with local retail opportunities		●			
BUSINESS ACTIVITY	Preliminary Assessment	Satisfaction with access to retail outlets		●			
BUSINESS ACTIVITY	Preliminary Assessment	Retail stores inaccessible due to inadequate transportation		●			
BUSINESS ACTIVITY	Detailed Assessment	Assessment of Current Location by Business Owners					●
BUSINESS ACTIVITY	Detailed Assessment	Advantages/disadvantages					●
BUSINESS ACTIVITY	Detailed Assessment	Problems Facing Neighborhood Businesses					●
BUSINESS ACTIVITY	Detailed Assessment	Factors Affecting Volume of Business					●
BUSINESS ACTIVITY	Detailed Assessment	Clientele					●
BUSINESS ACTIVITY	Detailed Assessment	sources					●
BUSINESS ACTIVITY	Detailed Assessment	income range					●
BUSINESS ACTIVITY	Detailed Assessment	ethnicity					●
BUSINESS ACTIVITY	Detailed Assessment	mode of access					●
BUSINESS ACTIVITY	Detailed Assessment	Traffic dependence					●
BUSINESS ACTIVITY	Detailed Assessment	Street frontage					●
BUSINESS ACTIVITY	Detailed Assessment	Project effect on individual businesses					●
BUSINESS ACTIVITY	Detailed Assessment	during construction					●
BUSINESS ACTIVITY	Detailed Assessment	permanent					●
BUSINESS ACTIVITY	Detailed Assessment	Ability to survive negative construction and accessibility effects					●
BUSINESS ACTIVITY	Detailed Assessment	Likelihood of business closure					●
BUSINESS ACTIVITY	Detailed Assessment	Effect of knowledge about proposed facility on decisions about current establishment maintenance					●
BUSINESS ACTIVITY	Detailed Assessment	Possible relocation					●
BUSINESS ACTIVITY	Detailed Assessment	Proximity effects of alternative routes					●
BUSINESS ACTIVITY	Detailed Assessment	Air and noise pollution					●
BUSINESS ACTIVITY	Detailed Assessment	Business owner plans					●
BUSINESS ACTIVITY	Detailed Assessment	if in ROW					●
BUSINESS ACTIVITY	Detailed Assessment	if proximate to ROW					●

Figure 21. Data requirements by source: attitudes and perceptions. (continued)

Data Requirements on Attitudes & Perceptions			Purposive Survey of Area Elites	Mini-Survey of Area Individuals (Residents)	Mini-Survey of Area Individuals (Businesspersons)	Mini-Survey of Area Individuals (Farmers)	Random Survey of Area Individuals (Residents)	Random Survey of Area Individuals (Businesspersons)	Random Survey of Area Individuals (Farmers)
RESIDENTIAL ACTIVITY	Preliminary Assessment	Perception of Impact of Project on Residential Activity	●						
		Highway-induced residential development	●						
		likelihood that increased business and access will attract new residents	●						
		likelihood that new housing construction will meet new residential demand	●						
	Detailed Assessment	Expected Decreases in Property Values Due to Proximity Effects	●				●	●	●
		Possible mitigative measures	●				●	●	●
		Availability of housing to meet needs of potential relocatees	●				●		
		adequacy of replacement housing for potential relocatees	●				●		
LAND USE AND DEVELOPMENT PLANS	Preliminary Assessment	Opinions on Community Goals & Development Plans	●						
		Rating the importance of development goals	●						
		Impact of project on community goals and development plans	●						
		Expected changes in specified uses	●						
		compatibilities	●						
		incompatibilities	●						
	Detailed Assessment	Perceived Effects of Alternative Routes	●						
		Compatibility of alternative routes with goals and development plans	●						
		Importance of perceived positive and negative effects	●						
		Mitigating adverse impacts	●						
		design features	●						
		planning assistance and regulatory measures	●						
AGRICULTURE	Preliminary Assessment	Effect of Proposed Project	●						
		On agricultural productivity	●						
		On conversion of farmland to other uses	●						
		Attitudes of Area Farm Owners	●			●			
		Development of farm land	●			●			
		all farms	●			●			
		own farms				●			
	Detailed Assessment	Perception of Proximity Effects by Route Alternative	●						●
		Conversion of farm land to other uses	●						●
		Changes caused by segmentation	●						●
		number of segmented acres	●						●
		travel time/distance to parcel segments	●						●
		effect on productivity	●						●
		effect on costs	●						●
		ability to maintain operations	●						●
LOCAL GOVERNMENT FINANCE	Preliminary Assessment	Perception of Financial Health of Local Government	●						
		Perception of project impact on local government finances	●						
		property values	●						
		sources of revenues	●						
		expenditures	●						
	Detailed Ass'mnt	Effects of Various Design Features on Value of Property Near the Selected ROW	●						
		Perceptions on decreases in tax base due to proximity effects	●						

Figure 21. Data requirements by source: attitudes and perceptions. (continued)

Chapter 9. TRADE-OFF EVALUATION OF ALTERNATIVE COLLECTION APPROACHES

Practitioners conducting socio-economic impact assessments must determine which information requirements can be effectively met by existing data bases and which will be best satisfied by the development of new data bases. Existing data are of two types -- maps and records. New data are usually developed using surveys. Thus for every datum required, practitioners must choose to collect the information from:

- Maps and records,
- Surveys, or
- Some combination of these sources.

The outcome of decisionmaking in this area is significant, for it will largely determine the quality and completeness of data available to the project team, and the extent to which these data accurately reflect conditions in study areas investigated. Decisions made at this point will also affect the costs, time, manpower, and other resources needed to gather the information.

This chapter discusses some of the major trade-offs among maps, records, and surveys. Five criteria are applied: (1) information available, (2) geographic coverage, (3) currency, (4) resource requirements, and (5) reliability and validity of the data.

The main recommendation to practitioners which emerges from these discussions is this: the possibility of collecting each required datum from maps and records ought, first, to be examined; data which cannot be extracted from these sources should then be gathered using surveys. When this collection procedure is followed, maps and records will generally be used heavily in preliminary assessment, while surveys are chiefly administered in detailed assessment. Exceptions to this rule of thumb are discussed in the sections which follow.

9.1 INFORMATION AVAILABLE

Information retrievable from maps and records is limited to data stored in the sources, while surveys can be designed to generate data tailored to specific assessment requirements. In other words, maps and records provide fixed categories of data which may or may not be appropriate in a given context. Surveys, on the other hand, allow users to collect selected information which is situation-specific.

However, because the collection of survey data tends to require the outlay of substantial resources (see Section 9.4), the survey option must be judiciously exercised. Often the information in maps and records -- though less versatile than survey data -- will meet practitioners' needs.

9.1.1 Factual vs. Perceptual Data

In the conduct of impact assessments, highway practitioners must examine both factual and perceptual data. Factual data denote information about tangible things which can be objectively verified. They include information about the location and operation of community facilities, demographic and economic data, trip-activity patterns, information on property tax rates, and policies and plans governing local development. In contrast, perceptual data refer to people's views and attitudes on particular subjects. These include citizens' attitudes toward a proposed highway project, businessowners' expectations concerning the effect the project will have on future business, and study area residents' statements on the neighborhood characteristics they value most highly.*

Most factual data may be collected using either maps and records or surveys. Some data, however, can be collected using only one of these approaches. For instance, trend data, e.g., changes in the annual housing stock, can be developed only from maps or records which contain time-series data. Other factual data, e.g., the conditions of buildings or trip activity patterns, are normally generated only by conducting observation surveys.

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*In this Manual, the professional judgments of community experts (e.g., planning officials, real estate assessors, etc.) are generally treated as factual information. It is important to remember, however, that when experts give information in areas where they are not specialists, or express personal opinions (e.g., how they feel about the project), their responses should be treated as perceptual information. Perceptual data are usually meaningful only when collected using representative sampling techniques.

When given a choice between collecting factual data using maps and records on the one hand, or surveys on the other, the former are generally preferred. As noted, this is because the time and resources required to generate survey data tend to be greater. Also, the scope, quality, detail, and accuracy of information on maps and in records frequently exceeds that of data generated through surveys.

Unfortunately, maps and records data do not always meet assessment requirements. The data may be (1) too aggregated, (2) available for large geographic areas only, or (3) out of date. Therefore, in many situations -- especially in detailed assessment -- surveys provide the sole means to secure the necessary information.

Unlike factual information, most perceptual data must be gathered using surveys. Again, there are exceptions. For instance, citizens' attitudes about a project can often be found in records of public hearings, newspaper articles, and other written materials. While these documents are a valuable source of information, they often do not provide data that is representative of the perceptions of all citizens potentially affected by a proposed project. Thus most of the detailed representative information required on attitudes and perceptions can only be generated by surveys. Expert judgment data, which are normally a mixture of factual and perceptual information, are also generally collected using surveys.

9.1.2 Aggregate vs. Disaggregate Data

Surveys are normally designed to generate disaggregate data. These data may be used as is, or combined into aggregate categories. Most maps and some records also report disaggregate data which can be aggregated if required by the situation. However, a majority of records available offer only highly aggregate information.

Aggregate data are often useful, particularly in preliminary assessment when general information on the entire area potentially subject to impacts is required. These data help practitioners profile the macro study area.

Aggregate data can present a problem in detailed assessment when precise information -- sometimes for individual property units -- is required. Data stored in records cannot normally be disaggregated. Thus, while records are regularly used to construct demographic and economic profiles of study area (and subarea) residents, they can rarely be used to profile residents of individual households. To collect disaggregate information of this type, surveys are usually needed.

Records data may be available at different levels of aggregation. For instance, the ages of children might be reported in records as (1) single variables (122 children are 1 year old, 97 are 2 years old), (2) ranges (679 children are less than 6 years old), or (3) averages (the mean age of children is 9.3 years). Each of these statistical sets conveys potentially valuable information. Yet, in most cases, the least aggregate data are preferable. This is because less aggregated data, e.g., single variables, can be used to calculate more summated information, e.g., averages, while the inverse of this is not true.*

9.2 GEOGRAPHIC COVERAGE

Information used in impact assessment is available for (1) large geographic areas, (2) small areas, and (3) individual property units. Generally, the smaller the geographic unit, the greater the utility of the data.

Large areas are defined by geographic or political entities such as municipalities, counties, standard metropolitan statistical areas (SMSAs), and States; these areas are usually bigger than the macro study area. Small areas include local planning districts, community service areas, residential neighborhoods, business districts, and census tracts and blocks; these are usually smaller than macro study areas. Individual property units refer to contiguous lands and buildings which have a common owner; they range in size from residential properties to public lands which cover many square miles.

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*For example, if practitioners know the number of 1 and 2 year olds, they can figure the mean age of all children. But if they know only the mean age, they will not be able to determine the number of 1 and 2 year olds.

Theoretically, surveys can be conducted for geographic areas of any size. In practice, however, they are best suited to the collection of data for small areas and individual property units. This is because surveys of large areas usually require large sample groups, and thus are expensive and time-consuming to administer.* Records, in contrast, are most frequently consulted when data for large areas are needed. But some records, including many of those specified in the preceding chapters, also contain important information for small areas and individual property units.**

9.2.1 Large Areas

Large-area data commonly available in records have several uses. First, they are used to make comparisons across different spatial units. For instance, the proportion of minority residents might be compared between the study area and larger, surrounding areas, e.g., the county or municipality. This comparison would help practitioners establish minority population norms for the region, and judge whether the study area is more or less vulnerable to negative highway effects than the region as a whole.

Secondly, large-area data may sometimes be used as proxy indicators of conditions in the study area, especially when the required information is not reported in records for small geographic units. Suppose practitioners need to know the unemployment rate for a macro study area in which employment statistics are not reported for areas smaller than counties. One practical solution might be to accept the county unemployment figures as indicative of unemployment in the study area. Adjustments could be made in the county rate based on practitioners' knowledge of special circumstances, e.g., that a disproportion-

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*Surveys of large areas need not always be resource-intensive. The mini-survey (Section 7.3.3) uses a very small sample group, and thereby cuts time and costs to a minimum.

**Unlike records and surveys, maps provide data for an essentially limitless number of geographic areas. For instance, practitioners examining a county map could determine the number of schools in the county, macro or micro study area, or other geographic subarea. Since they offer this special flexibility, maps are not discussed further in this subsection. However, a comparison of major geographic areas covered by various map sources is given in Section 7.1.

ately large number of workers at a newly closed factory reside in the study area.* Later, after alternative alignments have been defined, investigators might survey residents or businesses to determine the unemployment rate more precisely.

9.2.2 Small Areas

Data covering small geographic units, when available in records, are usually preferable to survey-generated data. This is particularly true in preliminary assessment, when the use of large random sample surveys to generate reliable data is not normally feasible due to the relatively high expenditure of resources required.

Records data for small geographic units can often be combined to yield a fairly accurate profile of the study area. For instance, to estimate the number of persons residing in a macro study area, practitioners could identify the census tracts comprising the area, and then calculate the total persons residing in all tracts. Of course, more exact population counts -- probably using surveys -- would be required for the detailed assessment of alternative alignments. Nevertheless, use of up-to-date records data to profile the macro study area is resource-efficient, and usually produces dependable results.

9.2.3 Individual Property Units

Information about individual property units is generally required in detailed assessment. This is true for all units in each alternative ROW, and additional units subject to proximity effects. The information is usually gathered using surveys, although selected data may be available in records, e.g., property assessment files. In either case, it is important that the information be reliable. At this stage in the planning process, having access to accurate and up-to-date information is essential.

*Estimation techniques of this kind are best used in preliminary, and not in detailed, assessment.

9.3 CURRENCY

Surveys almost always provide more current information than maps and records. This is because the data are usually collected at the time of impact assessment, whereas data from the other sources have been compiled earlier. Some map and record sources are updated monthly; some contain data which are 10 years or more out-of-date.

The currency factor often influences practitioners' decisions on whether to use data from maps and records, or to conduct surveys. Compilation dates are usually indicated on source documents, or can be obtained from the agency which gathered the information. However, there is no guarantee that all of the data in the source are current as of its publication date. One reason is that publishers follow different policies on the updating of information. Some sources, e.g., U.S Census Bureau population and housing counts, are updated in accordance with fixed schedules. Other sources, e.g., most local comprehensive plans, are revised only when significant changes in conditions documented in the source occur. In the latter case, it follows that an information source which has not been revised for several years is not necessarily obsolete in areas where no significant changes have occurred.

The pace of change in study areas varies. This pace naturally impacts on the currency of source data. When new construction activities are heavy, the key indicators for a community will change quickly. If residential turnover rates are especially high, dramatic shifts in demography may occur. Therefore, it may be that where data for two communities are published in the same year, the set covering one community reflects current realities three years later, while the other set does not.

Although the currency issue mainly applies to maps and records, it may also arise in dealing with survey data. For instance, practitioners may find that the survey results collected during preliminary assessment are no longer valid in the detailed assessment phase. The attitudes and perceptions of citizens concerning a controversial project are especially volatile indicators.

9.3.1 Using Dated Information Sources

Dated information on maps and in records, while it must be treated with care, is often very useful. When used in conjunction with other sources, this information can provide time-series data which show trends, and can be used to develop projections. Dated information can also be tested and validated using the results of small-scale surveys to ensure that it is representative.

Efforts to learn all that is possible from available maps and records -- regardless of their currency -- are usually resource-efficient. This is especially true during preliminary assessment, when an overview is sought and highly accurate data for small areas are not generally required.

The following suggestions may help practitioners who find that the major information sources available are dated:

1. Older information, e.g., population data, will frequently be available for small geographic areas such as census tracts, while more recent information covering the same variables is often only available for larger areas such as counties. In this case, practitioners may (1) determine the percent change for the smallest geographic area common to both sets of data, and (2) apply that percentage to the (smaller) study area. This allows practitioners to estimate changes which have occurred since the small-area data were compiled. (For instance, if current county population data in local records are 8 percent higher than data in a Census report that is five years out-of-date, it can be inferred that the population in each census tract also increased by 8 percent.)

2. Examination of trends in time-series data may help practitioners predict current and future conditions in the study area, even when recent information is not available. (Suppose that the population in a particular census tract increased by an annual average of 1.5 percent according to the three most recent decennial Census reports. Practitioners might then hypothesize that the population has continued to increase at a similar rate.)

3. Examination of additional maps and records sources may provide indirect indications of changes in the study area. (For instance, to estimate the population change in a study subarea, practitioners could examine records on available housing stock and annual housing starts. These records are often updated more frequently than population reports.)

4. Surveys of individuals responsible for compiling or monitoring the status of published data will frequently provide practitioners with

a basis for updating older information. Purposive sample surveys of this type are often cost-effective.

5. Practitioners may also conduct mini-surveys of residents or businesses in a study subarea. Survey findings often help substantiate a practitioner's estimate of the changes which have occurred since the last records were compiled.

Obviously, practitioners will want to use information which is as current as possible. However, through a combination of common sense and simple analytic techniques, practitioners can select, test, and update information in dated maps and records sources. Again, these techniques are best used in preliminary assessment. When current data are not available in detailed assessment, there is generally no substitute for conducting surveys.

9.3.2 Trend vs. Episodic Data

Surveys are mainly useful in generating episodic data, i.e., information which is accurate only at the time of the survey. Maps and records, in contrast, generally contain data published on a recurring basis which reveal change over time. Thus while surveys generally yield the most current information, they have limited value to practitioners interested in patterns of change. This is a significant limitation, since examination of past trends, and prediction of future developments, is an important part of impact assessment.

Given this trade-off in utility, it is often advantageous to use surveys in conjunction with maps and records.

9.4 RESOURCE REQUIREMENTS

The gathering of information using surveys normally requires more resources than does retrieval of data from maps and records. This is because information in maps and records is generally available to practitioners in usable form, and need only be excerpted. In contrast, survey questions must first be formulated and the data collected from original sources before it can be processed and examined. Thus surveys usually require more substantial outlays of time, money, and manpower than collection activities using maps and records.

9.4.1 Requirements for Maps and Records

Numerous factors influence the resources required to extract usable data from maps and records. These include:

- The ease with which the information source(s) containing required data can be located. Repeated difficulties in finding suitable sources delays assessment activities and results in excessive expenditures of time and money. Practitioners may occasionally find it will be more cost-effective to collect certain data using surveys than to spend time searching for elusive maps or records.

- The agency which compiled the source. Private firms usually charge more for their information than public agencies, although certain documents, e.g., business directories, are available free of charge. Some agencies will loan out copies of documents, or charge users only the costs of photocopying materials. Of course, many of the maps and records used in impact assessment are available in public libraries.

- The form in which the source data are reported. Published documents, e.g., U.S. Census reports, tend to be more expensive than unpublished information sources, e.g., farm record cards. But the savings are likely to be more than offset by the additional time required to access unpublished information. Information on computer tapes costs more to purchase, and is more time-consuming to use, than printed reports. However, use of computer tapes -- if data processing equipment is available -- allows practitioners to manipulate information to meet specific assessment requirements. This capability frequently justifies additional resource outlays.

- The number of data elements covered in the source. Sources which contain a small number of data elements may be less expensive than those containing many elements. At the same time, sources which meet a large number of data requirements will be proportionally more cost-effective than those which satisfy few requirements. Hence, it is most resource-efficient to collect as much information from as few sources as possible.

- The level of aggregation. Aggregate data normally require minimal resources to extract. But disaggregate data, especially when listed by individual property units, are relatively costly and time-consuming to collect. It is recommended that collection of disaggregate data for extremely small units be limited to uses during the detailed assessment of relatively small impact areas. This is because proportionally fewer resources will be required to collect disaggregate data for each alternative alignment than for the entire macro study area.

When data on individual property units are needed, in either preliminary or detailed assessment, sampling may be appropriate.* For instance, a stratified sample (see Volume II, Part 3) might be drawn from the property assessment file to determine average residential property values in the macro study area. The sample could be stratified for similar dwellings in each neighborhood.

9.4.2 Requirements for Surveys

The resources required to collect data using surveys vary greatly. Factors affecting survey costs are:

- The design of the survey instrument. Instrument development requires practitioners to (1) identify the information, i.e., facts or opinions, to be collected, (2) prepare clear, concise questions which will capture the information, (3) define mutually exclusive response categories for close-ended questionnaires, (4) determine the questionnaire format and order its contents, (5) prepare written instructions, especially for self-administered surveys, and (6) reproduce the instrument.** Normally, the larger and more complex the instrument, the greater the resources needed to develop it.

- The size of the sample. The bigger the survey sample, the more precise survey findings are likely to be.*** At the same time, bigger samples mean higher survey costs, since data must be collected from a larger number of respondents. Hence, practitioners are faced with the constant task of achieving an appropriate level of precision at reasonable costs. Often this can be done by conducting small-sample surveys in preliminary assessment, and using much larger samples in detailed assessment. Since less precise data are tolerable in preliminary assessment, findings with a higher-than-normal margin for error may be acceptable. In detailed assessment -- when precision is essential -- larger samples are used, and the margin for error is reduced. These issues are further discussed in Volume II, Chapter 7.

- The approach used to administer the survey. Respondent questionnaires may be (1) self-administered and mailed back, (2) administered by telephone, or (3) administered in face-to-face interviews. Self-administered surveys are the least expensive approach. Only clerical skills

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*Samples of records data can be taken only when the records represent complete-count information. Records which themselves were compiled from sample information cannot be resampled.

**Volume II, Part 2, Survey Techniques, gives examples of questions used in different types of surveys.

***This relationship between sample size and precision applies to random sampling techniques. It ordinarily does not apply to non-random techniques.

are required to mail questionnaires with an accompanying form letter; mailback surveys can be administered to a large number of individuals simultaneously. Telephone-administered questionnaires are more expensive than self-administered surveys, since trained interviewers are needed. A single interviewer can survey only one respondent at a time but the interviewer does not have to travel to the respondent's location. Face-to-face interviews are the most expensive. Trained interviewers are required, and interviewers must normally travel to the homes or offices of respondents. When respondents are scattered throughout a wide geographic area, the transportation costs incurred by interviewers are apt to be high.*

- The manner in which survey findings are tabulated. Findings may be tabulated either manually or by machine. Manual tabulation of responses usually requires a team of tabulators and takes time. Machine tabulations are fast, require relatively few people, but involve expenditures for data processing services. Generally, manual tabulation of completed questionnaires is most cost-effective when the sample size is small, e.g., in purposive or mini-surveys, while machine tabulation is most economical when the sample size is large or the questionnaire is especially long, e.g., surveys of area residents and businesses.**

Resource requirements can be lessened when survey activities are carefully planned. Thoughtful decisions about the groups to be interviewed and the questions to ask must be made in both preliminary and detailed assessment. Nothing is worse than to discover, after having conducted a large-sample survey, that several questions which should have been asked have been left out.

9.5 RELIABILITY AND VALIDITY

Reliability refers to the likelihood that the same information will be generated in repeated applications of the collection technique. Validity is concerned with the relationship between the properties measured and those the researcher intended to measure. Since major decisions about the highway project are made on the basis of collected data, the reliability and validity of

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*While the face-to-face interview is the most expensive of the three approaches, it offers interviewers greater flexibility and generally yields more reliable results. Thus, even though the face-to-face interview requires a higher investment of resources, it is likely to be justified when (1) the issues are complex, but important, and (2) very precise results are needed.

**Ordinarily, open-ended questionnaires are not machine tabulated.

collection procedures are of considerable significance, particularly in detailed assessment.

Several types of errors or biases are commonly associated with information gathered using surveys. These errors, which can affect the reliability or validity of findings, include:

- Errors in instrument construction. Response categories may not be mutually exclusive, or they may be worded poorly. These errors can be largely eliminated by pretesting and retesting the survey instrument. A bigger problem has to do with the legitimacy of the response categories, i.e., the extent to which each survey question captures the concept being measured. Most of the data elements identified in Part 1 of this Manual are valid indicators of the impacts with which they are associated, and may be used accordingly. Categorical validity may also be established by pretesting various response alternatives, interviewing experts, or using widely recogonized socio-economic indicators in records sources.

- Sampling errors. Practitioners must consider whether the sampling technique used will produce a representative sample. Even when an appropriate sampling technique is used, the sample will not be representative if non-response rates are high. Non-response can be lessened when face-to-face interviews are conducted; follow-up calls or visits will usually reduce non-response when surveys are administered by mail. Practitioners must also consider the validity of the sampling plan -- a reliable plan may or may not be valid, depending on the circumstances. In Volume II, Chapters 5-6 discuss the appropriateness of different sampling techniques.*

- Interviewer bias. Interviewers may make mistakes in recording respondent answers. They may also make comments or take other actions which inadvertently influence the answers given by respondents. Interviewer bias can be minimized when survey administation procedures are specified clearly and interviewers are carefully trained. Use of a pretest offers researchers the chance to observe interviewers in action, and correct behavior likely to produce biased responses.**

- Coding errors. When questionnaires are coded and key-punched or hand-tabulated, errors may occur. This problem can be largely eliminated

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*Also, Volume II, Chapter 8 provides a more complete technical examination of sampling error.

**Surveys and other information sources are valid only to the extent that respondents answer truthfully. Hence, interviewers should do all they can to ensure that respondents feel comfortable and understand the questions. While this will not guarantee that they will answer truthfully, it will increase the chances.

if coding procedures are specified clearly, and coded questionnaires and tabulations are spot-checked for completeness and accuracy.

A similar potential for error applies to maps and records compiled from survey data. Practitioners should familiarize themselves with the procedures used to compile each information source, and evaluate their reliability and validity. As noted in Section 9.3, the major reliability problem for maps and records pertains to the currency of information.

Another reliability problem is the completeness of map and records data. Suppose a social service agency gives practitioners a list of handicapped persons in the micro study area. What kinds of handicaps are covered on the list? Are all persons with those handicaps included, or only those persons who have been referred to the service agency? These kinds of questions can usually be answered by interviewing agency officials, comparing data from different sources, or using mini-survey findings to assess the reliability of records data.

Users of records are sometimes tempted to extract data from a source even though those data fail to capture the concept being measured. Data extracted under such circumstances are usually invalid, and can lead to erroneous conclusions. Rather than risk generating inaccurate data, users should try to locate the needed information in other sources or collect it using surveys.

Part 3. DISPLAY AND ANALYSIS OF DATA

This part focuses on the presentation of socio-economic data in formats which (1) profile the impact area(s), and (2) provide a basis for analyzing and documenting assessment results. These formats take the data specified in the fields appearing in Part 1 -- which are correlated with the matrices presented in Part 2 -- and organize them into displays suitable for use in completing the assessment process.

Chapter 10 describes and gives numerous examples of the use of maps and mapping techniques to locate the study area(s) in spatial terms, and to show the location and distribution of residential populations, business activity, etc., across the potentially impacted area. Major sections are devoted to project location maps, base maps, map supplements, and map overlays.

Chapter 11 discusses and provides examples of the use of tables and matrices to array and show relationships among the statistical data collected during the assessment process. It begins with a brief discussion of univariate, bivariate, and multivariate tables. Major sections which follow are devoted to use of tabular formats to compare data across spatial units, develop parcel logs, convey trip activity data, and present the results of surveys which collect judgmental information.

Chapter 12 discusses the utility of two other presentational modes -- graphic displays and narrative summaries -- to document assessment results. Again, several examples are provided to illustrate how each approach can be used to present different kinds of information.

Many of the displays shown in these chapters are taken from environmental documents developed by State practitioners. These documents are on file at FHWA and State highway offices.

Additional technical information on analysis of assessment data may be found in Volume II, Part 4, Analytic Techniques.

Chapter 10. MAPS

Maps are used to portray the study area and its socio-economic characteristics in spatial terms. A broad range of information is typically shown on these maps, including (1) topographic features, (2) community and neighborhood boundaries, (3) land use configurations, (4) trip activity patterns, (5) demographic and housing characteristics, and (6) patterns of business activity. These maps are used to present information about a proposed project and its impact to members of the general public and to interested parties in Federal, State, and local agencies.

Practitioners typically use the following maps:

- Project location maps,
- Base maps,
- Map supplements, and
- Map overlays.

Some general comments regarding the areas covered by these maps, map scale, and map symbols are provided below.

Areas Covered. Project location maps show the study area under investigation in a regional, area-wide, and local context. Base maps and map overlays are normally used to present information on the macro study area in preliminary assessment, and on each micro study area in detailed assessment. Supplemental maps may also be created which identify sectors of the study area requiring special treatment.

Map Scale. Map scale refers to the relationship between the measurement of features as they appear on a particular map and as they actually exist. The larger the map scale, the greater the detail shown. In general, the map scale selected should be large enough so the features displayed and their spatial relationships can be easily identified, but not so large that the map is unmanageable. In preliminary assessment, a base map scaled at 1:24,000 (i.e., one inch on the map equals 24,000 inches, or 2,000 feet, on the ground) is normally satisfactory. Base maps used in detailed assessment are often constructed on a scale of 1:6,000 or more.

Base maps and overlays are usually prepared using identical scales. This ensures that overlays created "fit" each base map developed.

Map Symbols. Maps tell their stories through the use of symbols, which assume a variety of shapes, sizes, colors, and shades. Although color-coding is often useful, particularly when practitioners are analyzing a wide array of data, the costs of reproducing multi-colored maps in project reports are often prohibitive. Fortunately, a broad range of mapping techniques exists -- some of which are shown on the following pages -- for presenting cartographic data in black-and-white.

10.1 PROJECT LOCATION MAPS

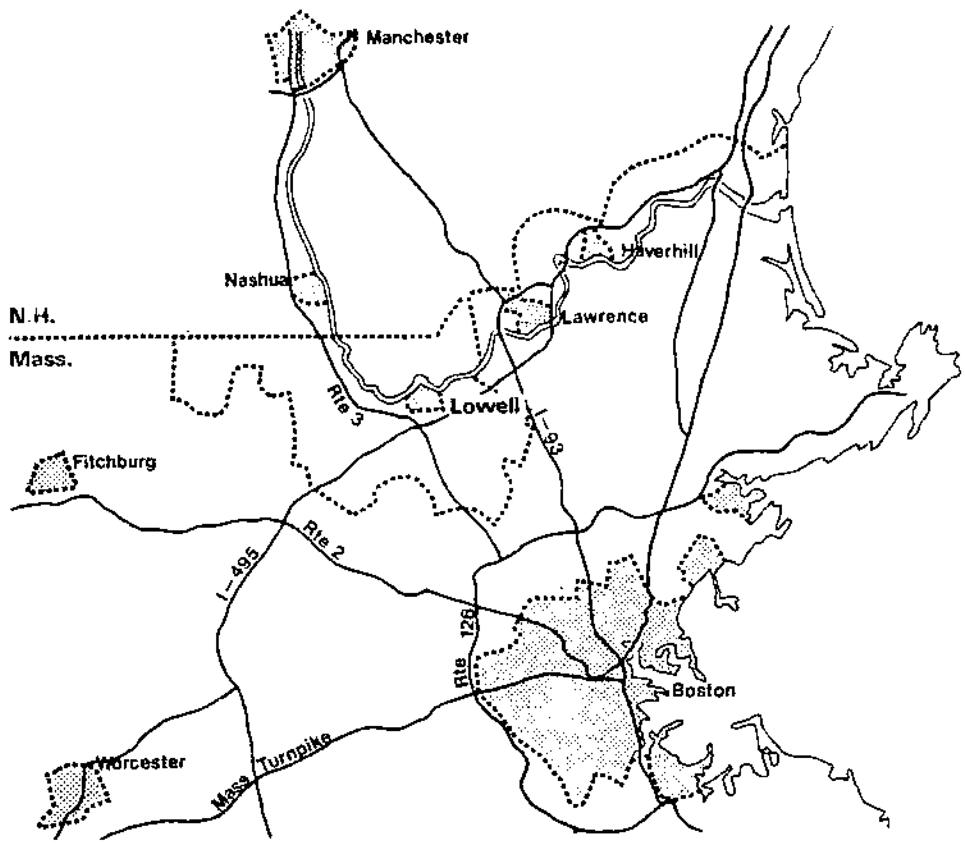
Project location maps, which show the study area in geographic perspective, may be used in both preliminary and detailed assessment. These maps help practitioners define the potential impact area in terms of selected topographic and manmade features. They enable planners, participants at public hearings, and readers of environmental documents to visualize the study area in physical terms.

Since project location maps are intended to provide an overview of an area, relatively few topographic features are normally shown. However, the characteristics are selected carefully to help users orient themselves to the most outstanding attributes of the study area. Elements which might be identified on location maps include municipal boundaries, major highways and roads, natural and manmade landmarks, and other prominent community institutions and features.

During preliminary assessment, project location maps are used to place the macro-scale study area in a regional and local context. Often a series of maps, each showing the study area on a progressively larger scale, are used to establish this context. For instance, Figures 22-23 (pp. 127-128) show how a study area in an urban community can be spatially represented using a series of three location maps. The number of location maps required will vary depending on such factors as the size of the study area and population density.

In detailed assessment, project location maps are used to show each micro study area, i.e., alternative highway alignment, in relation to the other alignments, and to the macro study area as a whole.

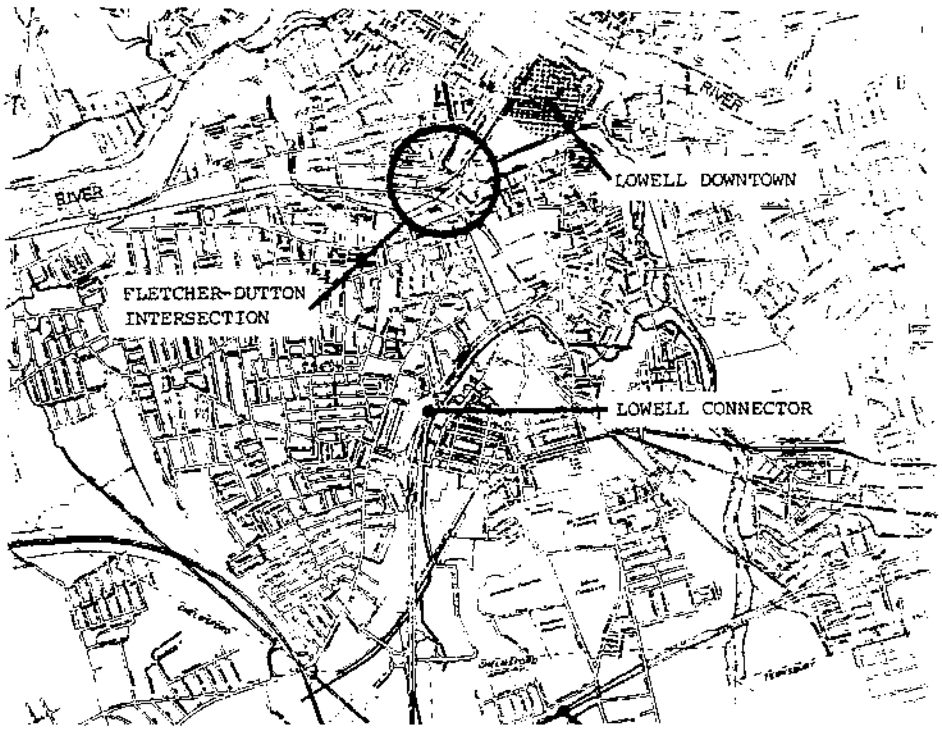
Each alternative alignment can be shown on a single map as in Figure 24 (p. 129). Alternative alignments -- particularly those which diverge significantly, or converge at a variety of points -- can also be shown on separate base maps. As demonstrated in Figure 25 (p. 130), these maps should be designed so they can be compared.



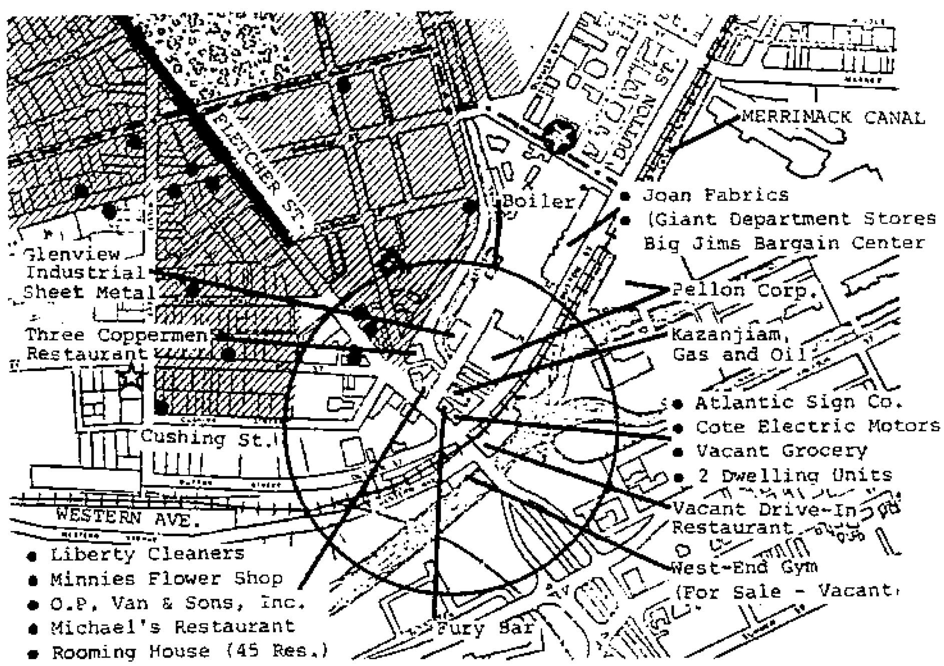
Lowell, Massachusetts　　　　Regional overview of the study area.

Source: Skidmore, Owings, and Merrill, The Environmental Assessment Notebook Series, Notebook 5: "Organization and Content of Environmental Assessment Materials," U.S. Department of Transportation, 1975, pp. 18-19.

Figure 22. Project location map in preliminary assessment.



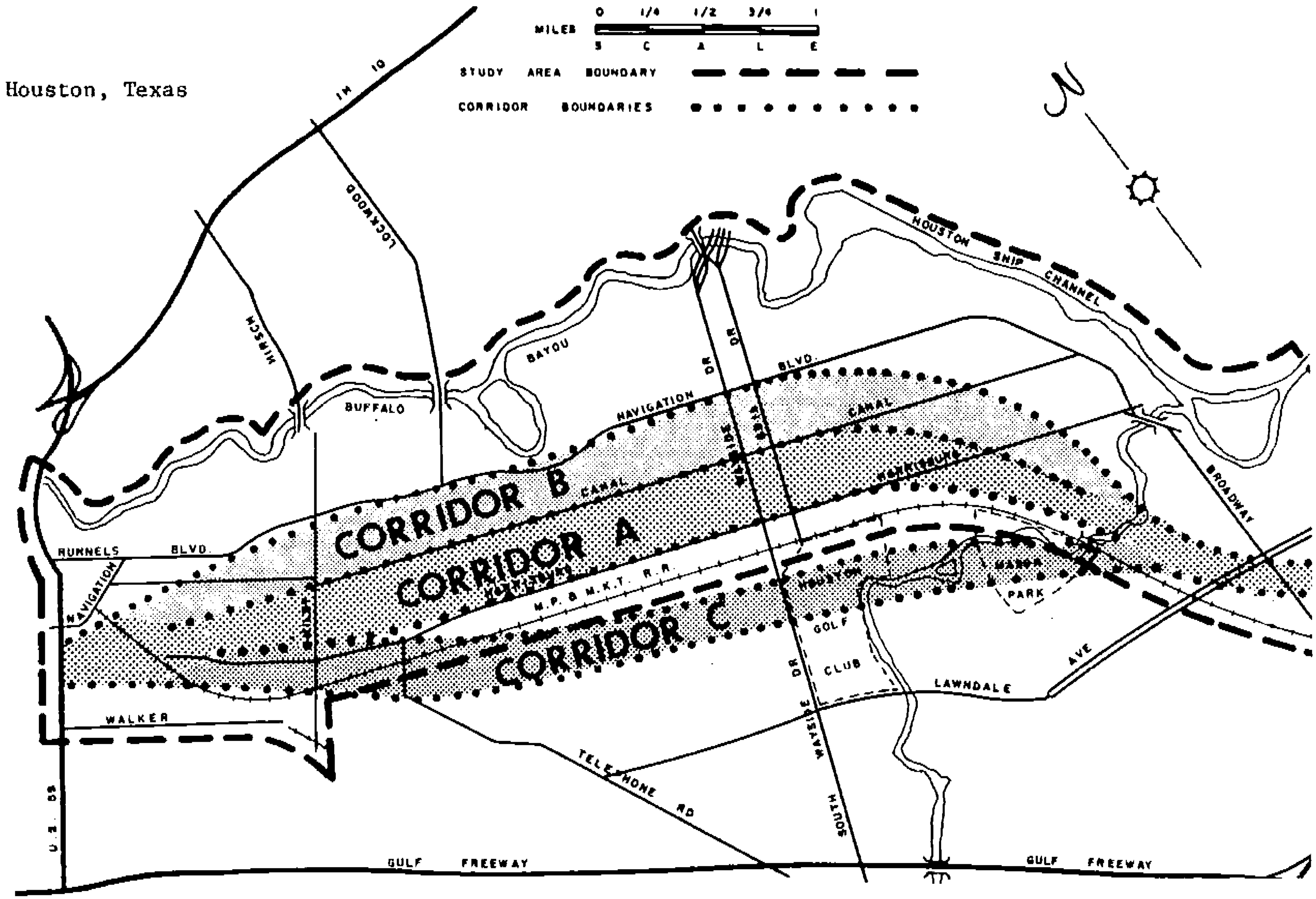
Lowell, Massachusetts Study area in a community context.



Lowell, Massachusetts Study area in relation to contiguous areas.

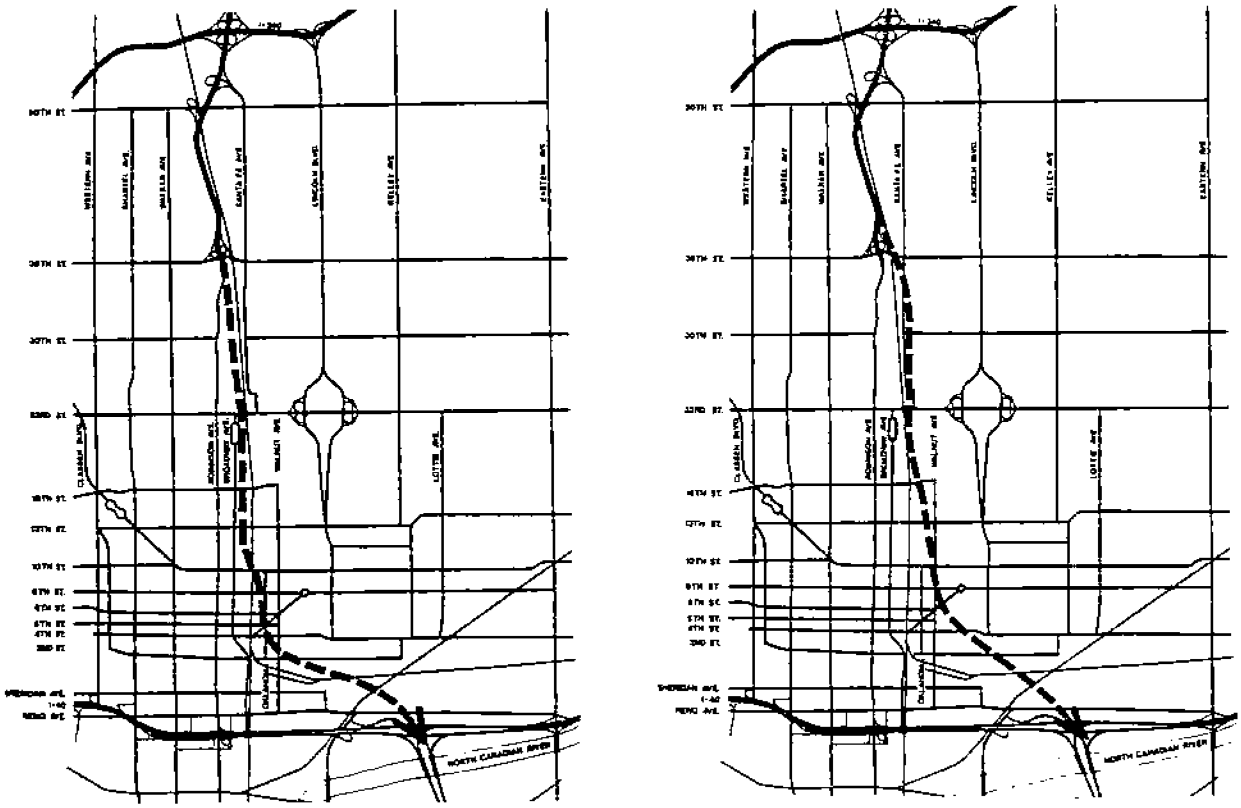
Source: Skidmore, Owings and Merrill, Notebook 5.

Figure 23. Different contexts in preliminary assessment.



Source: Texas Transportation Institute, Attitudes, Opinions, and Expectations of Businessmen in a Planned Freeway Corridor, Texas Highway Department and Federal Highway Administration, 1972, p. 5.

Figure 24. Project location map in detailed assessment: Alternative alignments shown on a single map of the study area.



Broadway Alternative — Oklahoma-East Alternative

Source: Interstate 235 Central Expressway: Final Environmental Impact Statement, Oklahoma Department of Transportation, 1980, pp. 8-6 and 8-9.

Figure 25. Project location maps in detailed assessment: Alternative alignments shown on multiple maps of the study area.

10.2 BASE MAPS

Base maps identify the most prominent features of the study area, and provide a back-drop on which map overlays identifying other selected elements of the area can be placed. In preliminary assessment, base maps will show the macro study area. In detailed assessment, individual base maps can be prepared for each alternative alignment.

Data profiled on base maps typically include:

- Boundaries (e.g., community, neighborhood, census and property lines),
- Key natural features (e.g., mountains and rivers, forests, concentrations of farmland, and vacant areas),

- Highways and roads,
- Important public facilities (e.g., civic centers and schools), and
- Major residential and shopping areas.

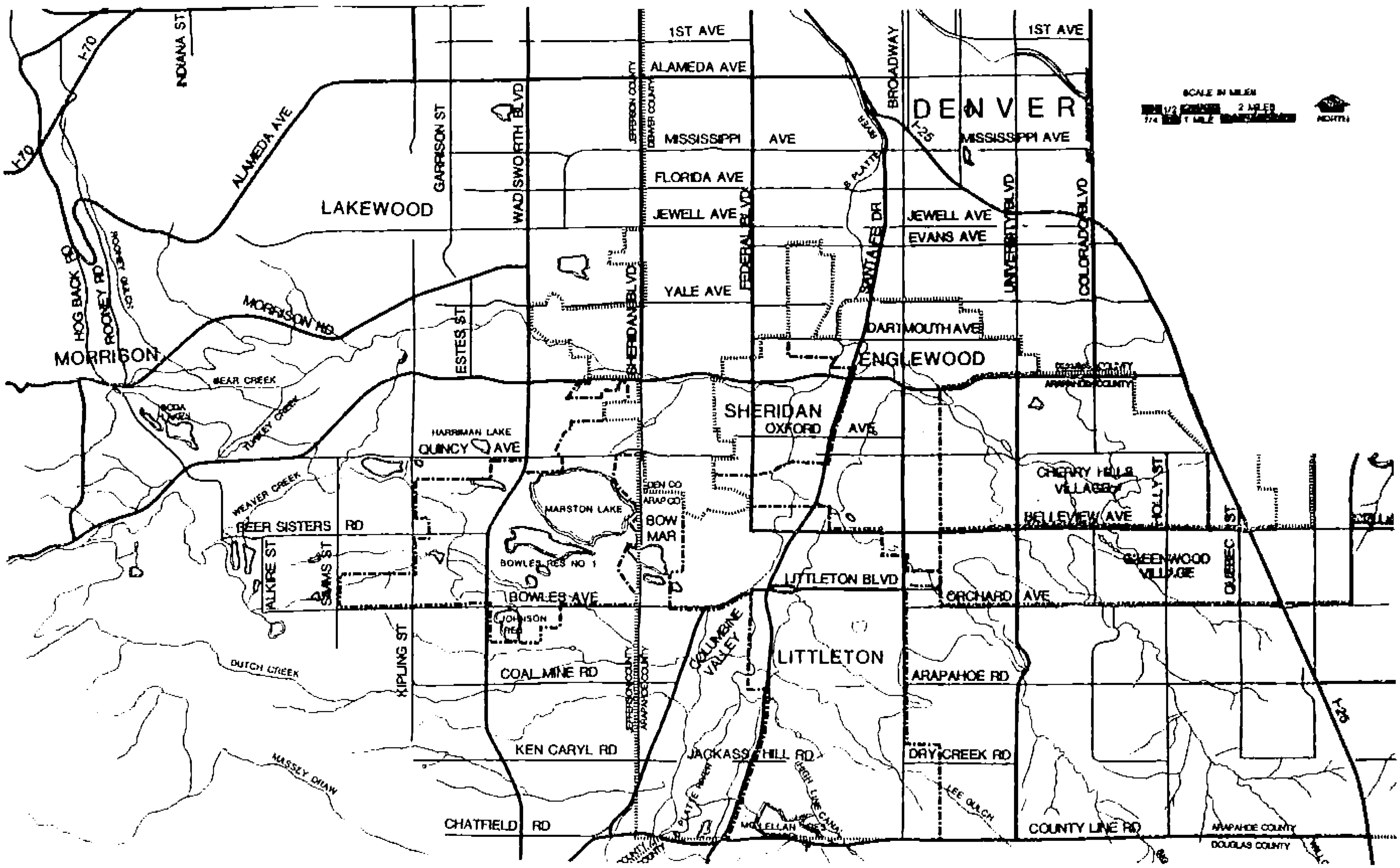
The elements shown on each project base map will vary depending on the type of study area, the stage in the assessment process, and the purposes of the mapping exercise. For instance, a base map of an urban study area might show major streets and emphasize the boundaries separating residential and commercial districts. A base map of a rural area, on the other hand, might highlight farmlands and distinguish between forested and cultivated areas.

During preliminary assessment, practitioners may prepare several types of base maps. One map type commonly developed at this stage shows prominent topographic and land use features across the macro study area. Another type of base map identifies planning area boundaries, other important boundaries, and statistical areas.

Figures 26 and 27 (pp. 132-133) show selected land features, major roads, and county and community boundaries. Because they portray an urban area, few land features are identified on these base maps. However, since the study area in Figure 27 is fairly confined, the base map is able to distinguish effectively between residential and commercial sectors. Both maps provide valuable information without appearing cluttered.

Often aerial photographs can be used effectively as base maps. Figure 28 (p. 134) shows an aerial photograph where key roads and a major community facility in the study area have been clearly labelled.

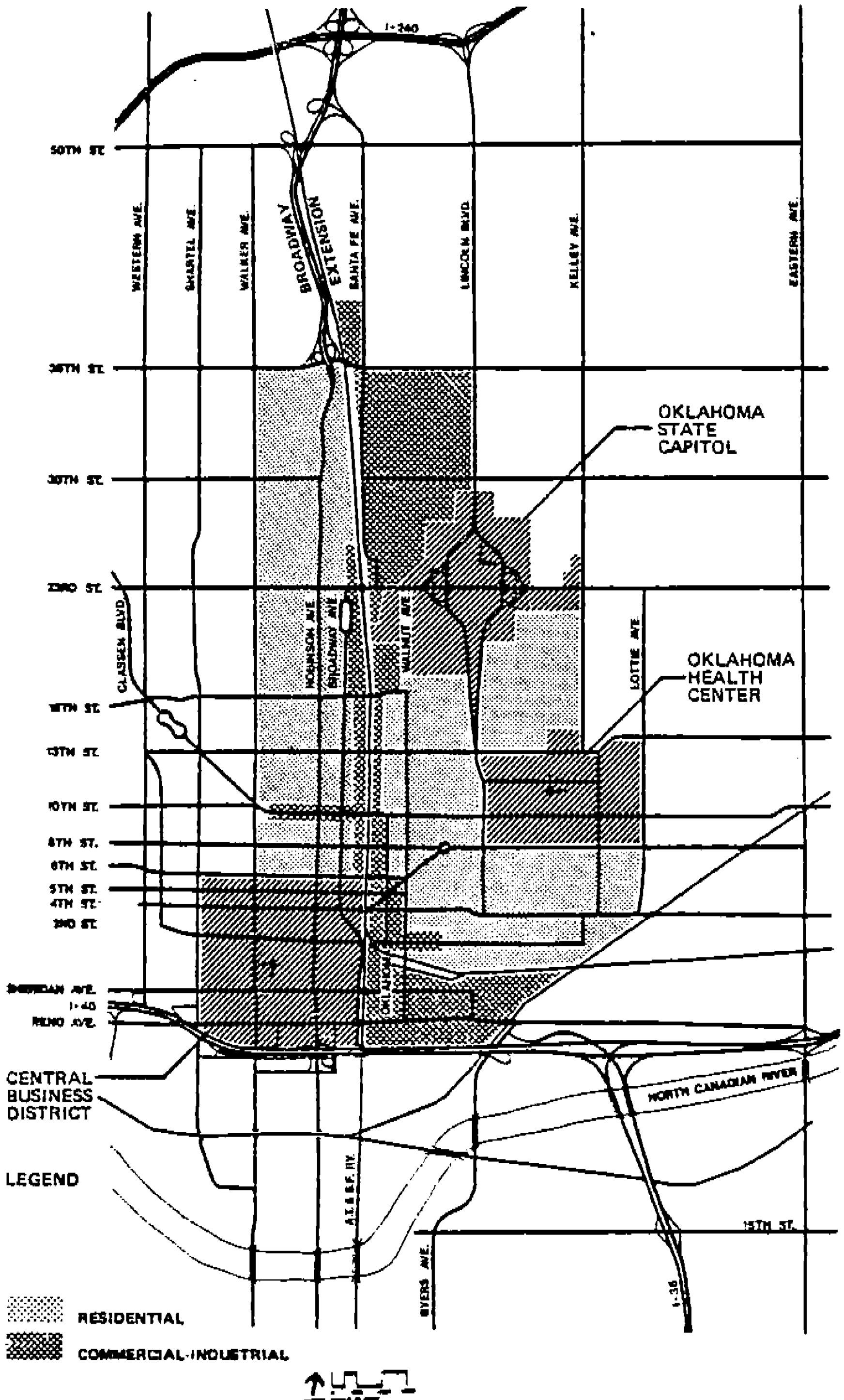
The base map in Figure 29 (p. 135) identifies census tract boundaries in the study area. Later, when demographic and housing data are examined for each tract, maps showing concentrations of residents subject to negative highway effects may be overlaid on a base map of this type (see Section 10.4). These



Denver, Colorado

Source: Detailed Assessment Report: I-470, Colorado Division of Highways, 1976, p. 1.1.7.

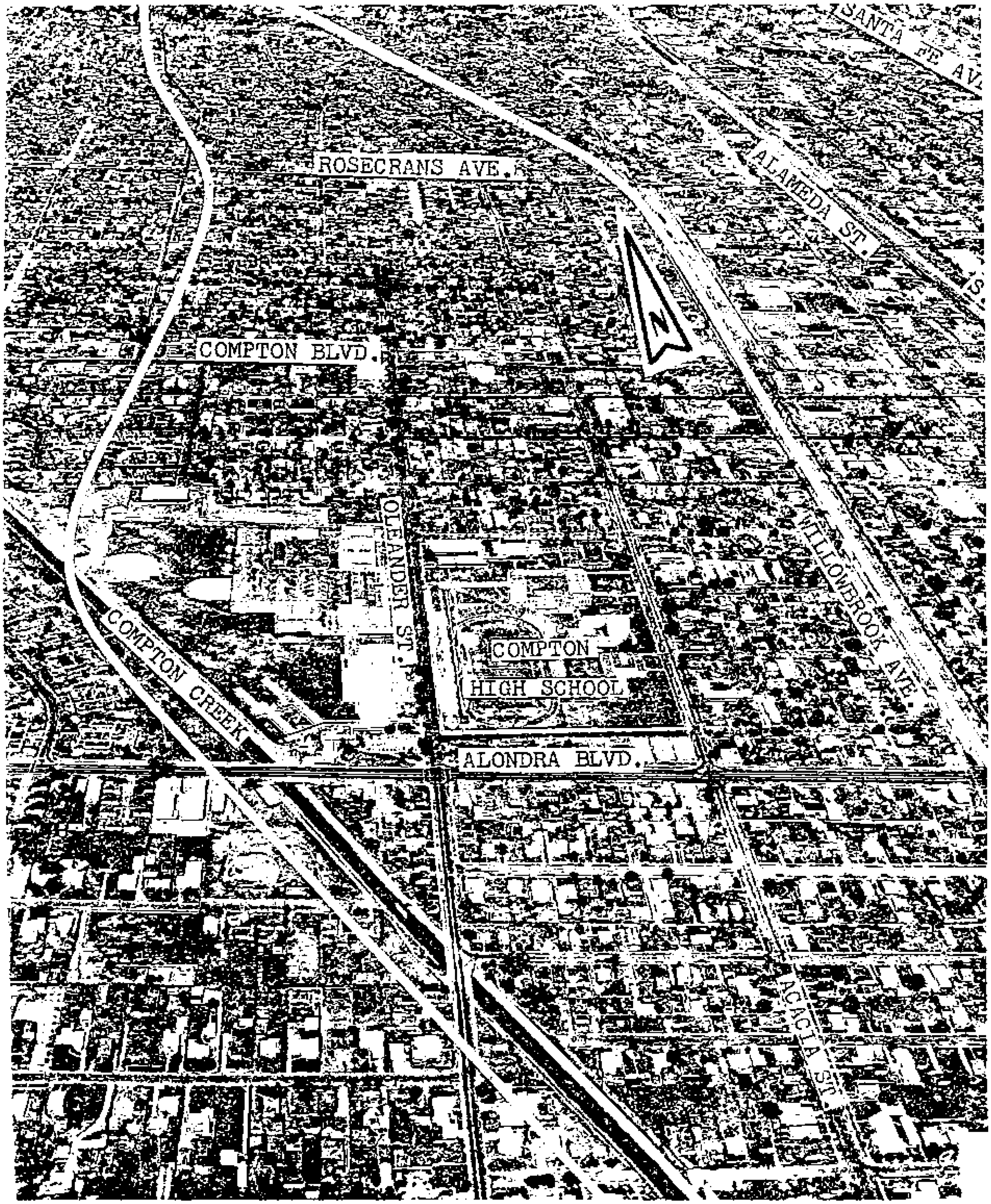
Figure 26. Standard base map in preliminary assessment.



Oklahoma City

Source: Interstate 235 Central Expressway, p. 2-6.

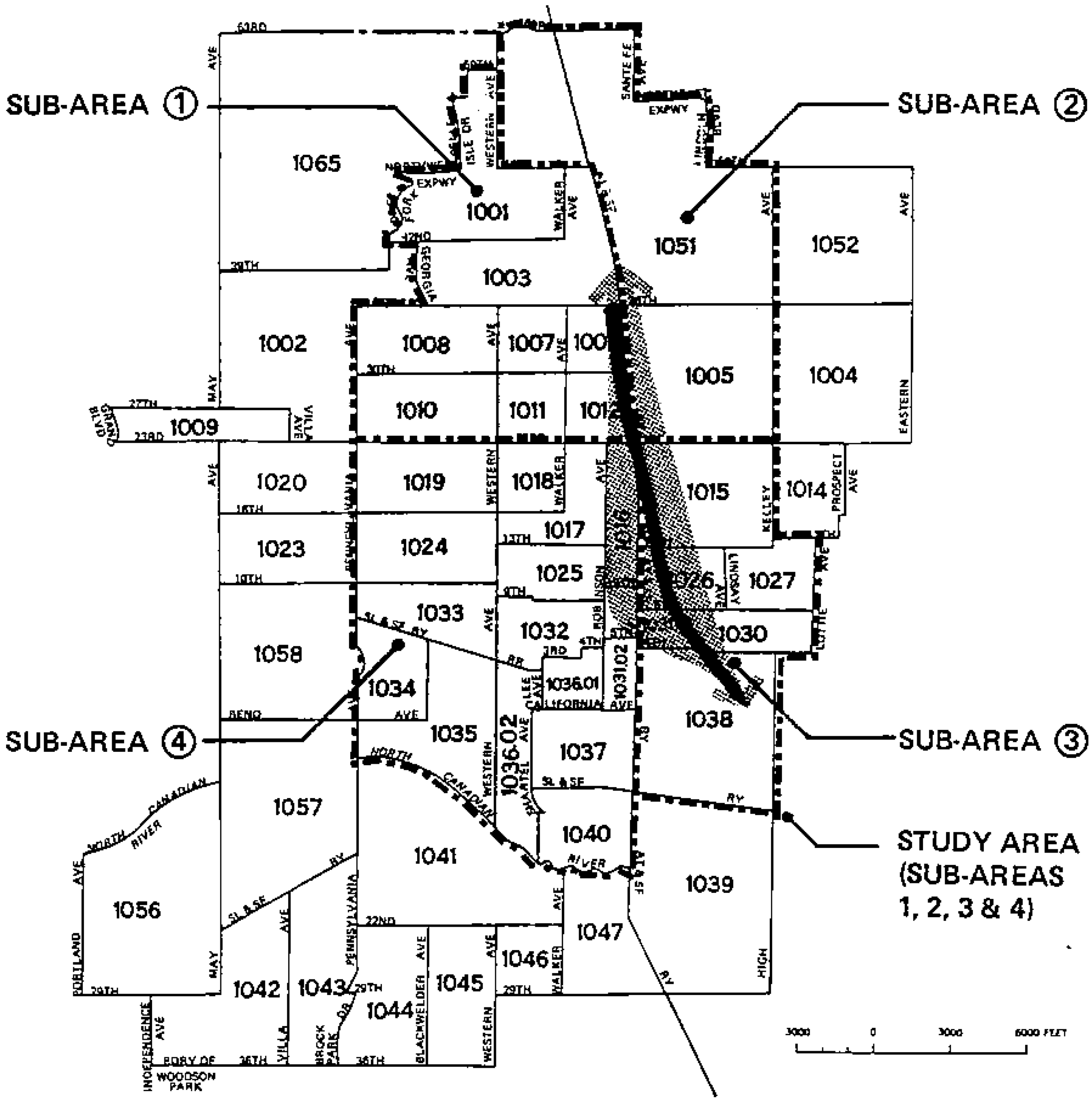
Figure 27. Identification of general land use on base map.



Compton, California

Source: Gordon J. Fielding, Group Dynamics in the Urban Freeway Division Process, California Transportation Agency, 1971, p. 49.

Figure 28. Use of aerial photograph as base map.



Oklahoma City (U.S. Census, 1970).

Source: <u>Interstate 235 Central Expressway</u>, p. 6-20.

Figure 29. Identification of census tracts on base map.

overlays will identify sectors of the study area which should probably be avoided when alternative alignments are defined.*

Base maps of other study area boundaries can also be developed. For instance, if information about projected land use is available by planning district, a base map showing those districts comprising the study area may be useful. Figure 30 (p. 137) provides an example of such a map. Map overlays showing existing and planned land use can then be created.

In detailed assessment, separate base maps are ordinarily prepared for each alternative alignment.** They usually identify individual land parcels in and proximate to each alternative ROW.

Figures 31, 32, and 33 (pp. 137-139) identify several kinds of base maps which may be used to show land use in detailed assessment.

10.3 MAP SUPPLEMENTS

Supplemental maps are used to highlight characteristics of the study area requiring special treatment. The supplement is normally constructed on a larger scale than the base map or overlay; it might show a single neighborhood within a large study area, a highway interchange, or individual parcels of land.

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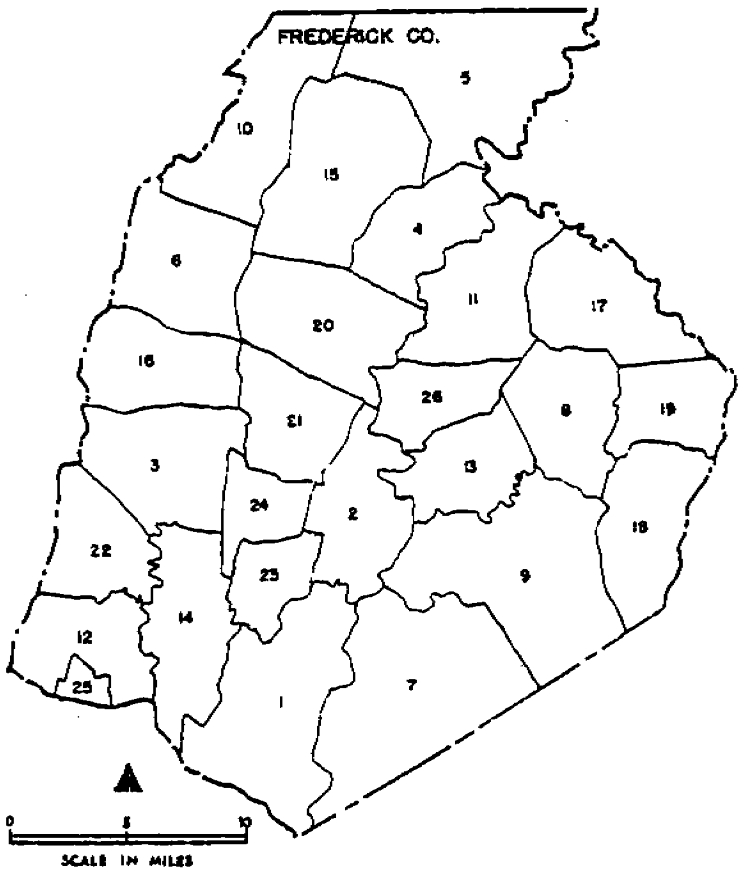
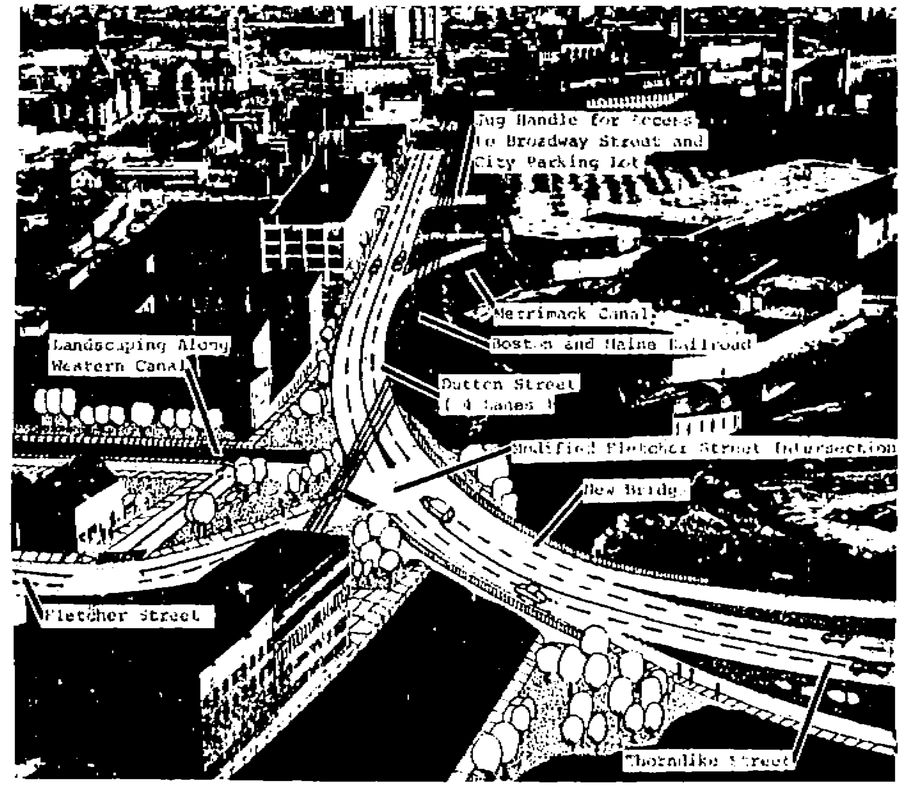
*Census tract boundaries are an example of the kinds of data which can be shown either on base maps or map overlays, depending on the circumstances. As noted, tract boundaries might be identified on base maps when analyses of demographic trends are conducted. On the other hand, suppose that planners wanted to identify residential districts spatially by census tract. One way to do this might be to place an overlay showing tract boundaries on a base map identifying general land use in the study area.

**When each viable alignment follows nearly the same pattern, use of a single base map may sometimes be appropriate. Figure 33 (p. 139) illustrates one such situation.



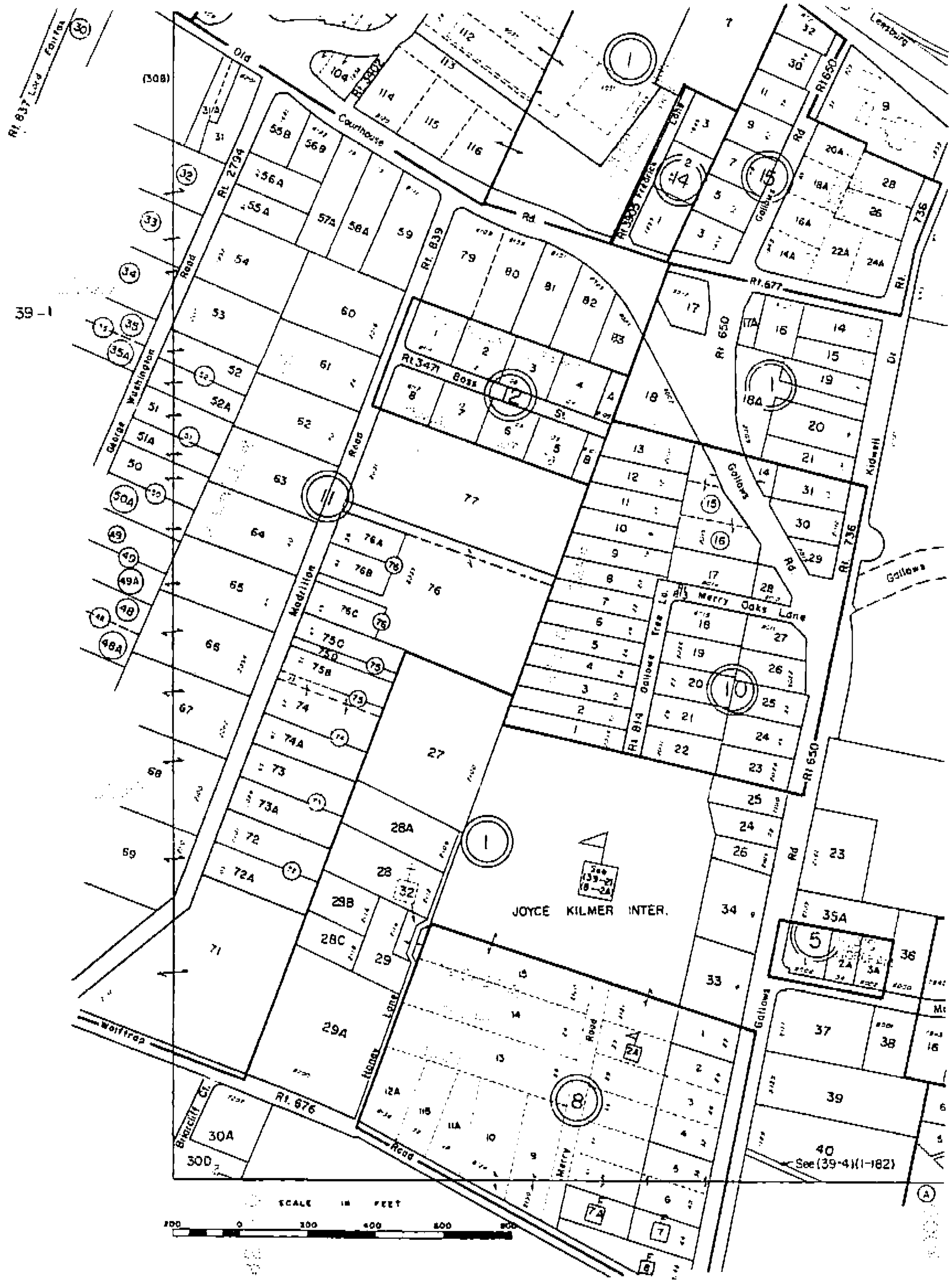
Source: Maryland 1970 Social Indicators Series, Vol. I: "Educational Characteristics," Maryland Department of State Planning, 1972, p. C-14.

Figure 30. Identification of planning districts on base map.



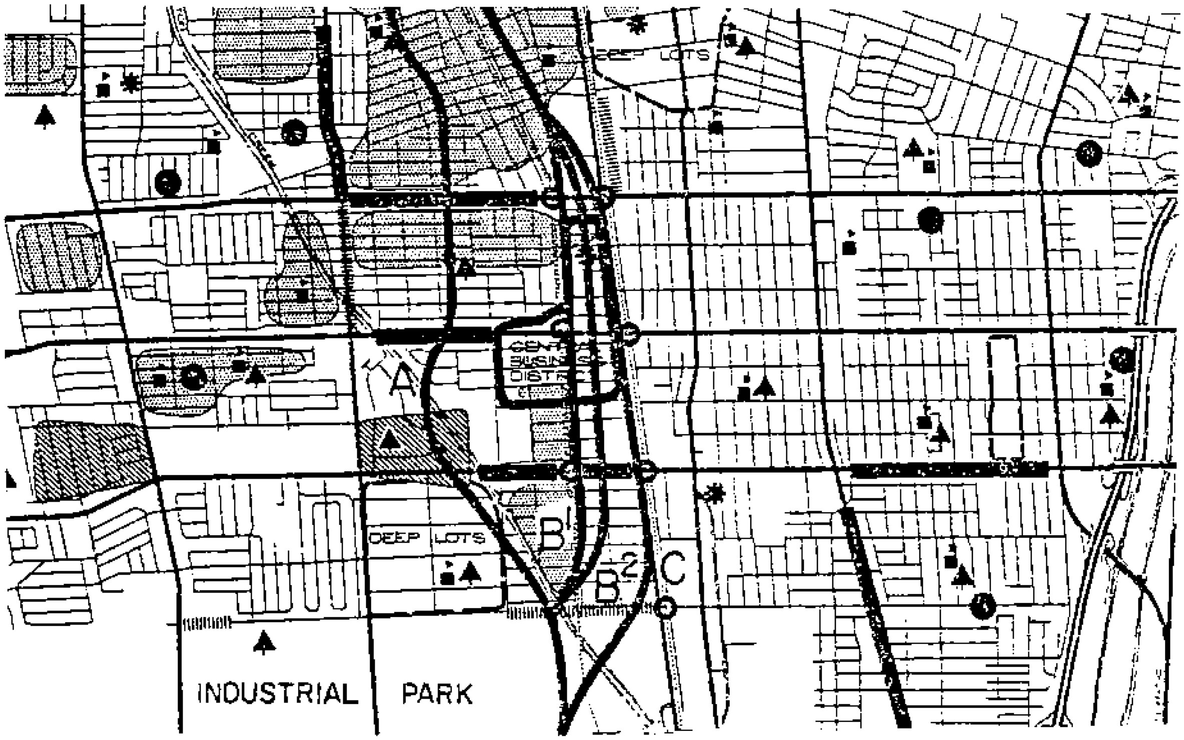
Source: Environmental Assessment Notebook Series, Notebook 5, p. 32.

Figure 31. Drawing of alternative corridor on an aerial photograph in detailed assessment.



Source: Property Assessment Files, Office of Assessments, Fairfax County, Virginia.

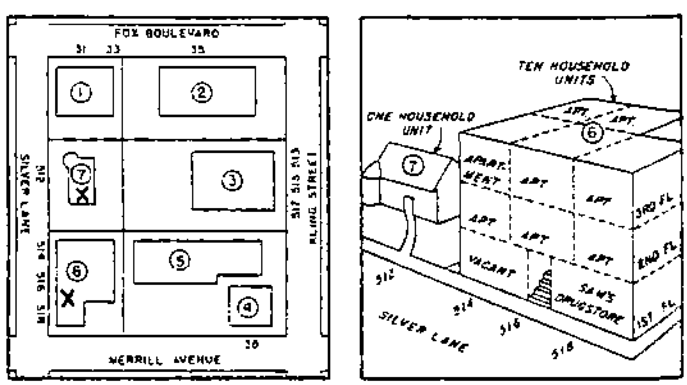
Figure 32. Use of property assessment map as base map.



Source: Fielding, p. 50.

Figure 33. Alternative corridors on a standard base map in detailed assessment.

Parcel schematics, such as those shown in Figure 34 below, are commonly used in detailed assessment to describe the buildings on individual land parcels. Parcel schematics are especially useful for describing the layouts of multi-use buildings, including apartment and office buildings and shopping malls.



Block Plan *Parcel Schematic*

Figure 34. Parcel schematic on map supplement.

10.4 MAP OVERLAYS

Specialized information about the study area may be profiled spatially on map transparencies, or overlays. These overlays, when placed on top of base maps, help planners to define alternative alignments and select the preferred alignment, if any are appropriate.

The placement of different types of data on separate overlays enables planners to examine various combinations of information, as necessary. An overlay identifying community shopping centers, for example, might be placed on a base map of the macro study area to show the number and locations of shopping areas affected by the proposed highway project. Use of a second overlay identifying neighborhood boundaries could provide further information on the location of residential populations served by each shopping facility.

The types of data typically shown on overlays include:

- Study area boundaries,
- Land use configurations,
- Facilities and other community destination points,
- Trip activity patterns, and
- Demographic, housing, and economic data.

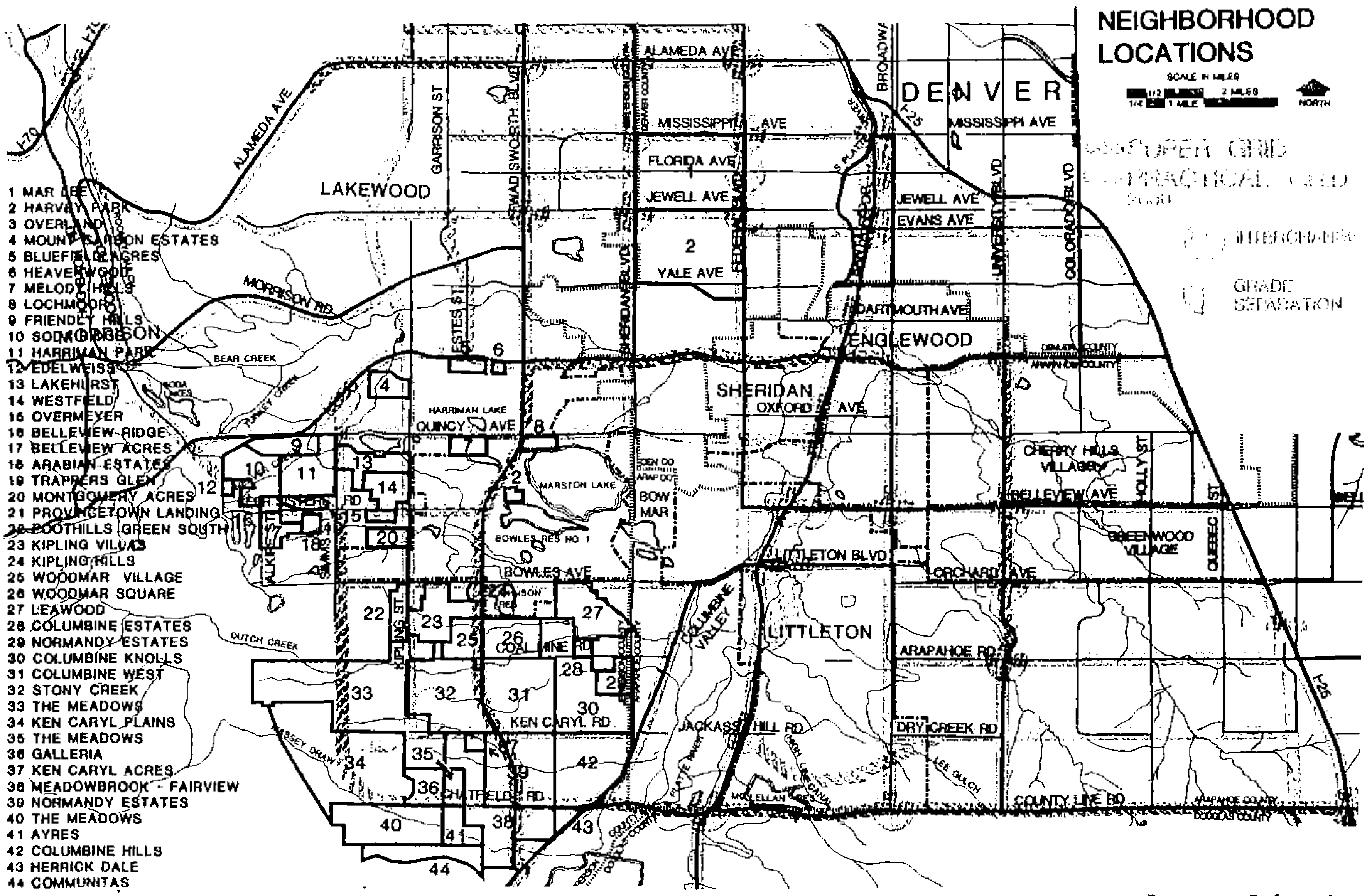
10.4.1 Area Boundaries

The map overlay in Figure 35 (p. 141) identifies neighborhood boundaries on a base map of the study area. This information could be used to assess levels of social cohesiveness within each bounded neighborhood.

Other boundaries, including those demarcating planning districts, U.S. Census areas, and areas served by particular community facilities, can be arrayed in much the same way.

10.4.2 Patterns of Land Use

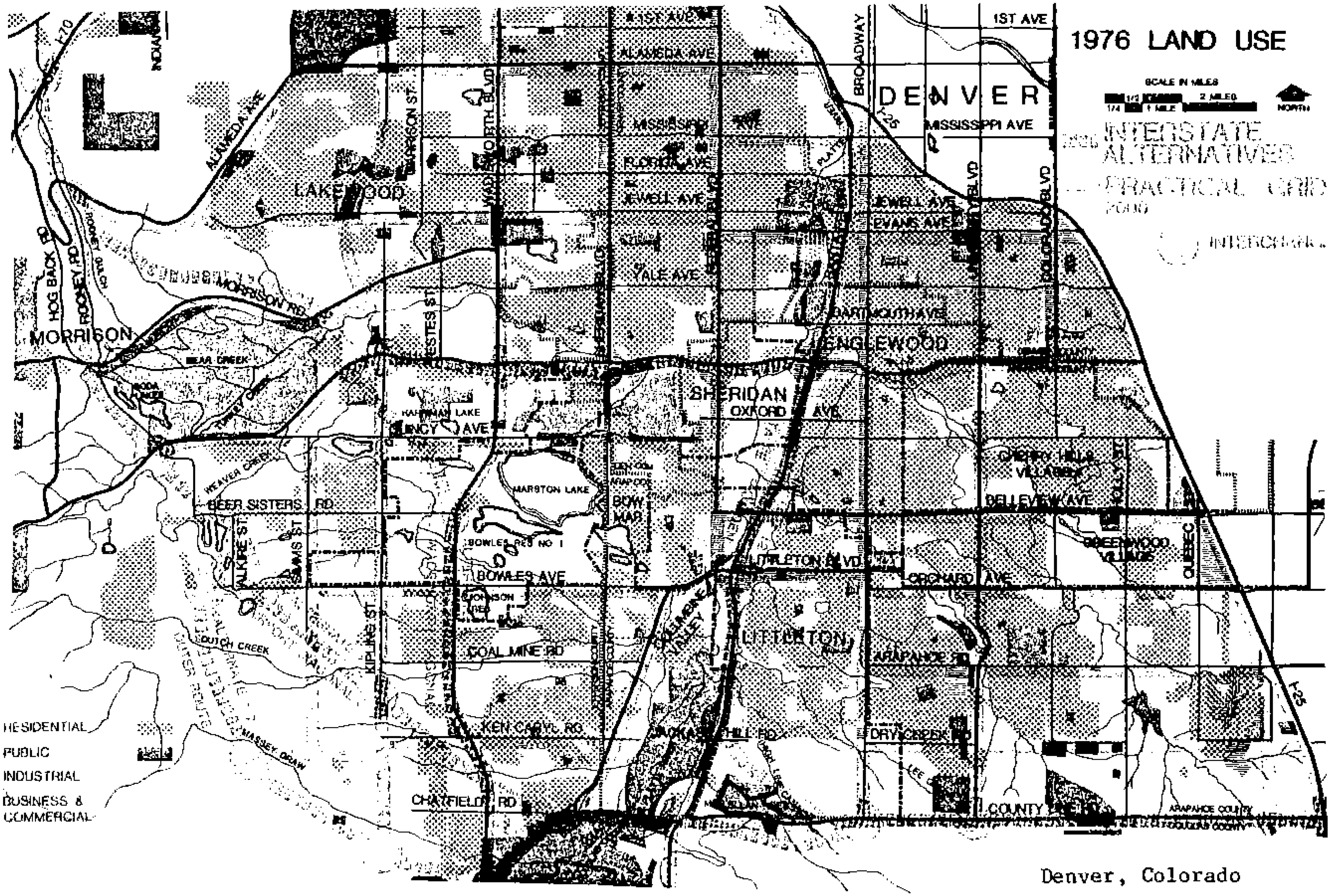
Overlays are often used to identify existing and planned land use activities across a study area. Figure 36 (p. 142) shows existing residential, public,



Denver, Colorado

Source: Detailed Assessment Report: I-470, p. 2.2.23.

Figure 35. Neighborhood locations on a map overlay.



Denver, Colorado

Source: Detailed Assessment Report: I-470, p. 5.6.31.

Figure 36. Existing land use on a map overlay.

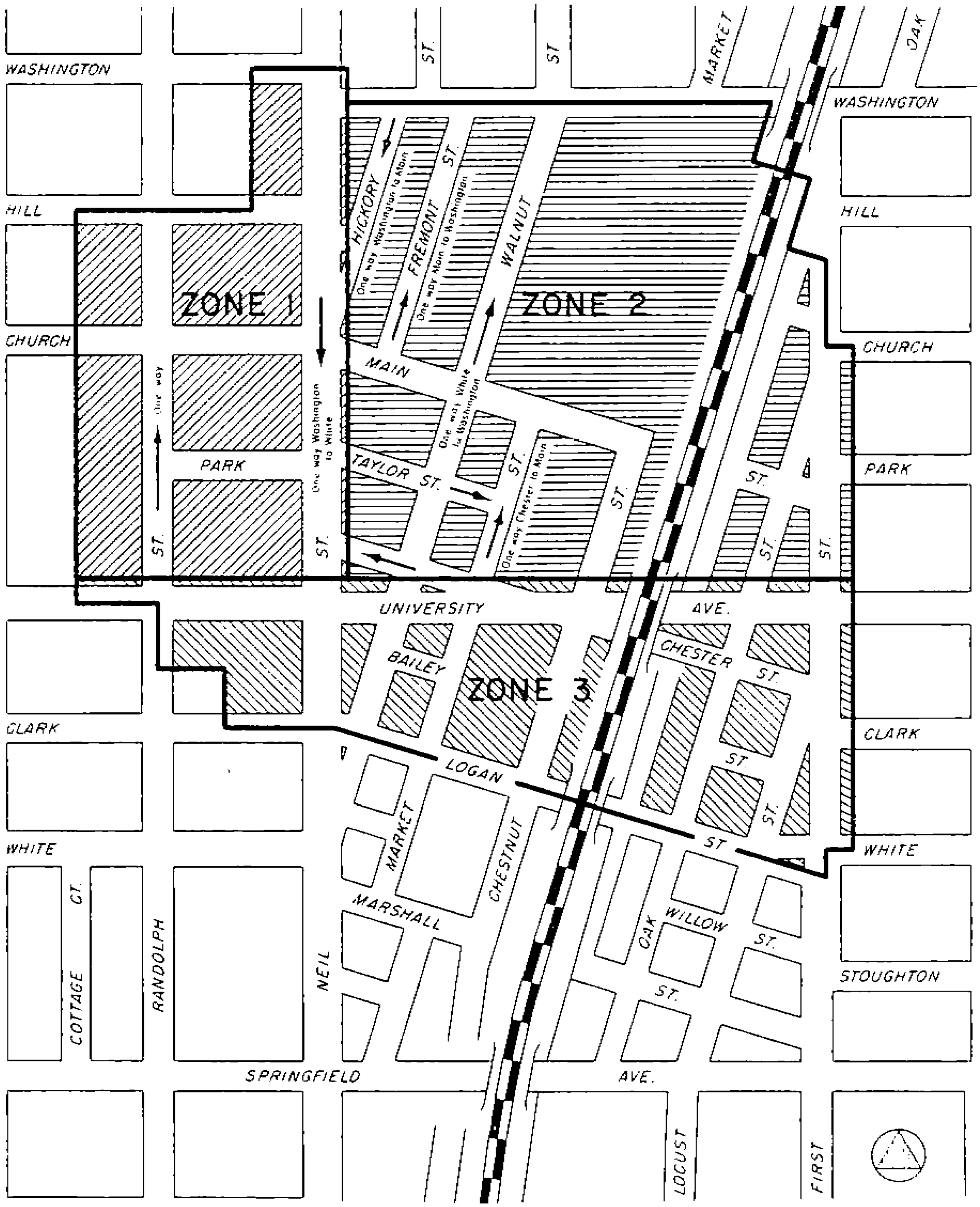
industrial, and commercial sections of a macro study area. This kind of map enables practitioners to visualize the spatial relationships between various land use activities in an area. It also helps them to choose alternative alignments which minimize displacement of existing activities.

Zoning overlays often furnish a greater amount of information than do general land use maps. For instance, Figure 37 (p. 144), used in conjunction with the text of the community's zoning ordinance, would enable practitioners to identify the different types of businesses located in, or planned for, the study area. Similar overlays designating residential districts could be used to identify detached homes, townhouses, condominiums, apartments, etc. Also, since zoning ordinances generally specify the maximum number of residential structures permitted per acre of land, zoning overlays can frequently be used to estimate planned residential density for an area.

In detailed assessment, planners normally identify the specific uses to which land parcels in each alternative alignment are put. This allows for the development of overlays which can be used to compare displacement and proximity effects in each ROW.

Specific land uses may be shown directly on a map overlay, as indicated in Figure 38 (p. 145). They may also be identified by (1) assigning a numerical code to each parcel and cross-referencing that code on a parcel log, or (2) using zone boundaries or other designations to identify usage when a number of contiguous parcels are put to similar use, e.g., a neighborhood of single-family dwellings. As described in Section 10.3 (above), parcel schematics are often developed to identify particular activities in the study area as well. Parcel schematics are especially valuable when multiple land uses are described.

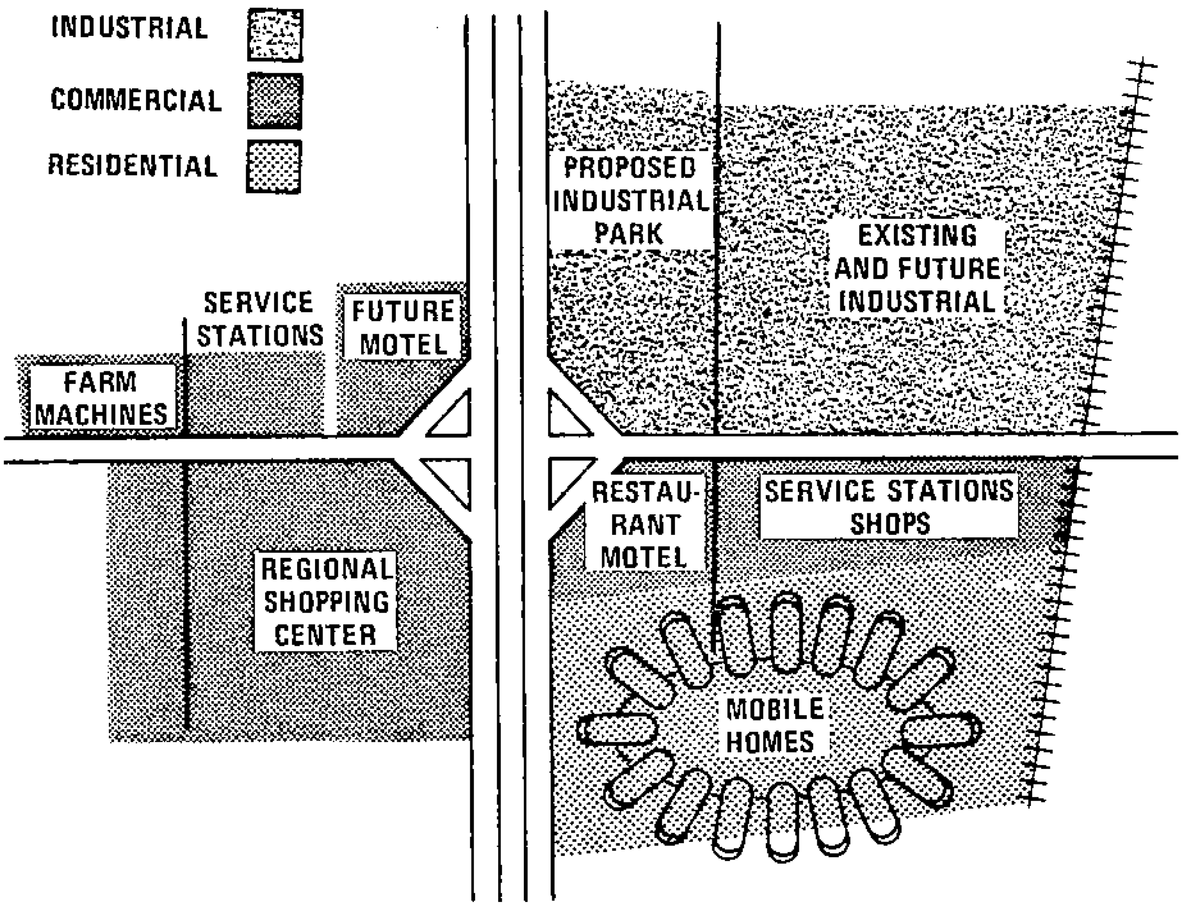
Figure 38 both identifies specific land uses proximate to an alternative alignment, and compares existing and planned land use. These comparisons are important since land which is vacant might, for example, be the site of a planned industrial park.



Champaign, Illinois

Source: Paul T. Kinney, The Impact of Traffic on Residential Property Values and Retail Sales in Champaign-Urbana, University of Illinois, College of Engineering, Urbana, 1966, p. 50.

Figure 37. Zoning overlay of commercial district.



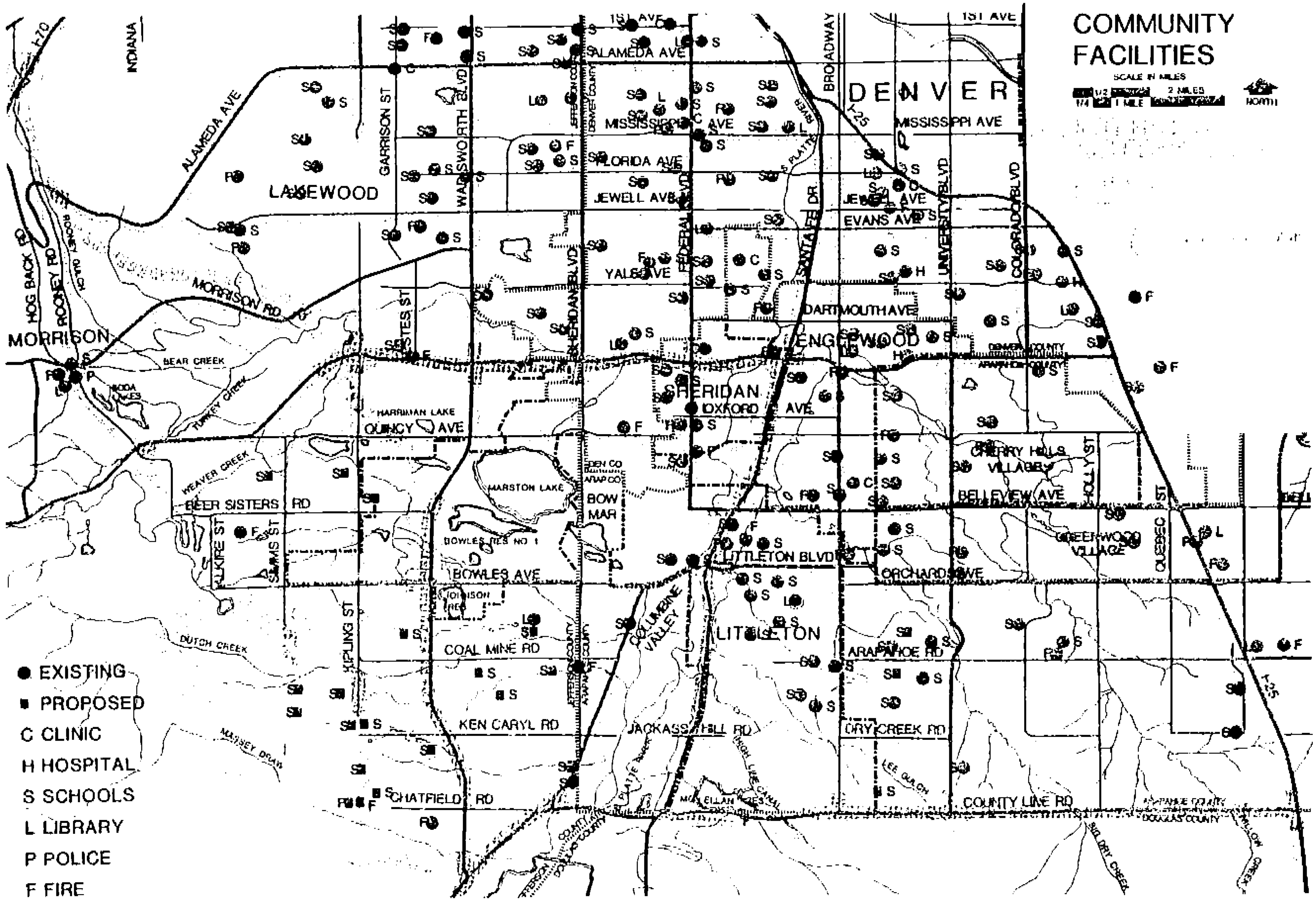
I-69 and Route 8, Indiana

Source: Social and Economic Effects of Highways, Office of Program Policy and Planning, Federal Highway Administration, 1976, p. 100.

Figure 38. Identification and comparison of existing and planned land uses.

10.4.3 Facilities and Other Community Destination Points

Community facilities and services may be identified on one or more map overlay, such as that shown in Figure 39 (p. 146). Often, individual groups of facilities, e.g., schools, hospitals, fire stations, etc., are arrayed on separate overlays; this makes it easier to identify service area boundaries around each group of facilities (see Section 10.4.4, below). Other major community destination points, such as shopping centers, can also be arrayed on overlays.



Source: Detailed Assessment Report: I-470, p. 5.7.20.

Denver, Colorado

Figure 39. Community facilities on a map overlay.

10.4.4 Trip Activity Patterns

Maps are often used to determine patterns of residential trip activity across the study area. Alignments which will make workplaces, shopping areas, and community facilities less accessible to large numbers of residents are generally to be avoided. Pedestrian dependency routes, in particular, should not normally be disrupted since the residents who depend most heavily on these routes often have limited mobility and are sensitive to changes in access routes.

One way to determine trip activity is to identify the residential areas served by various types of facilities. Some facilities, such as fire stations and local schools, serve identifiable sections of a community. The overlay in Figure 40 (p. 148), for instance, shows the location of public schools and the areas served by each. Similar maps may be prepared for other public facilities, retail centers, etc.

Figure 41 (p. 149) demonstrates a technique for making a more precise correlation between community facilities and the residential areas they serve. Here, school travel patterns are identified for students living in homes proximate to the alternative alignment. The overlay helps practitioners to (1) identify concentrations of school-aged children along the alignment, (2) compare the number of children attending each school, and (3) identify the routes followed to and from the schools.* Similar profiles may be prepared for trips to other community facilities, employment and commercial areas, and other community destination points.

A technique for comparing pedestrian dependency across a study area is discussed in the next section.

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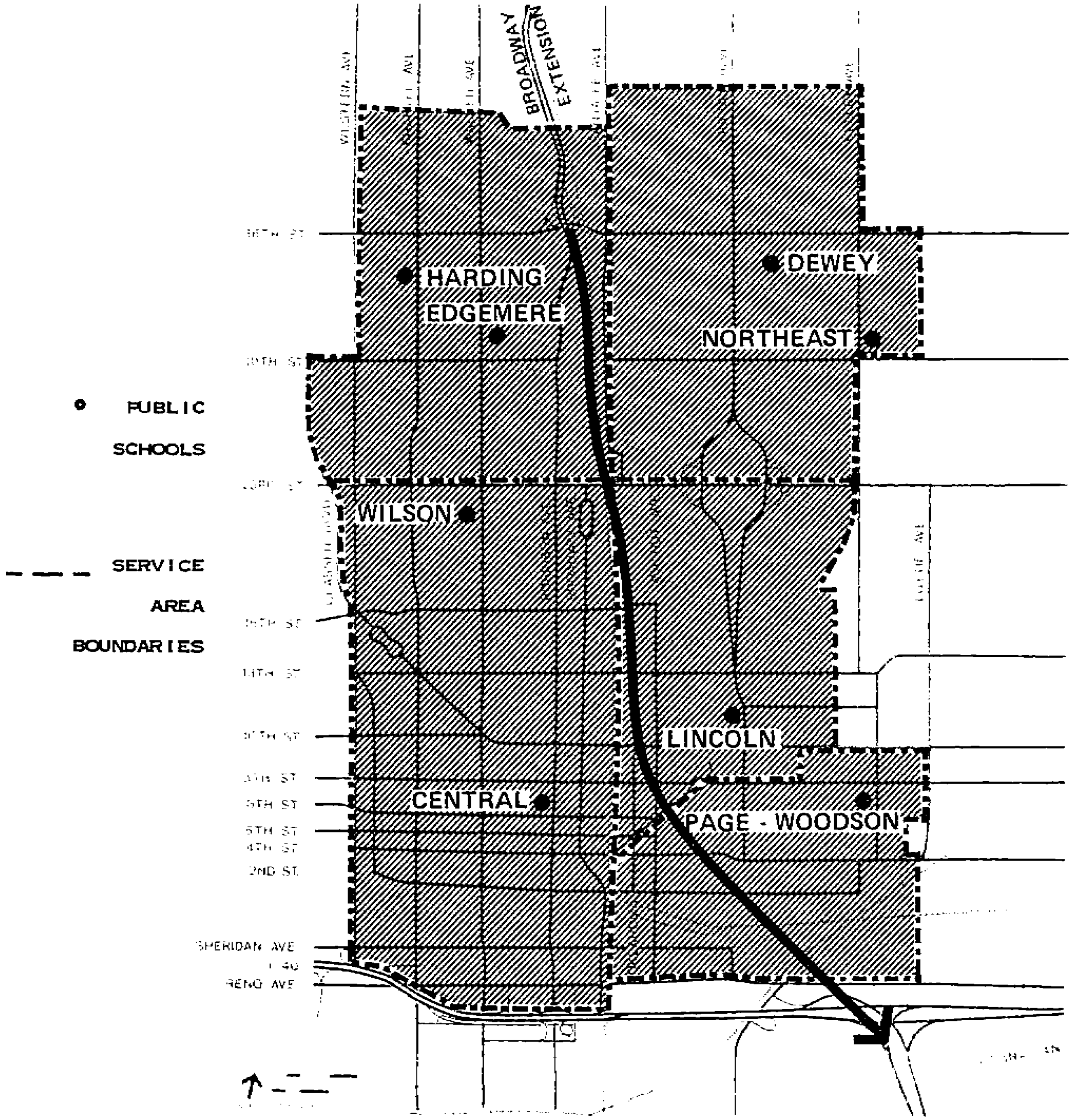
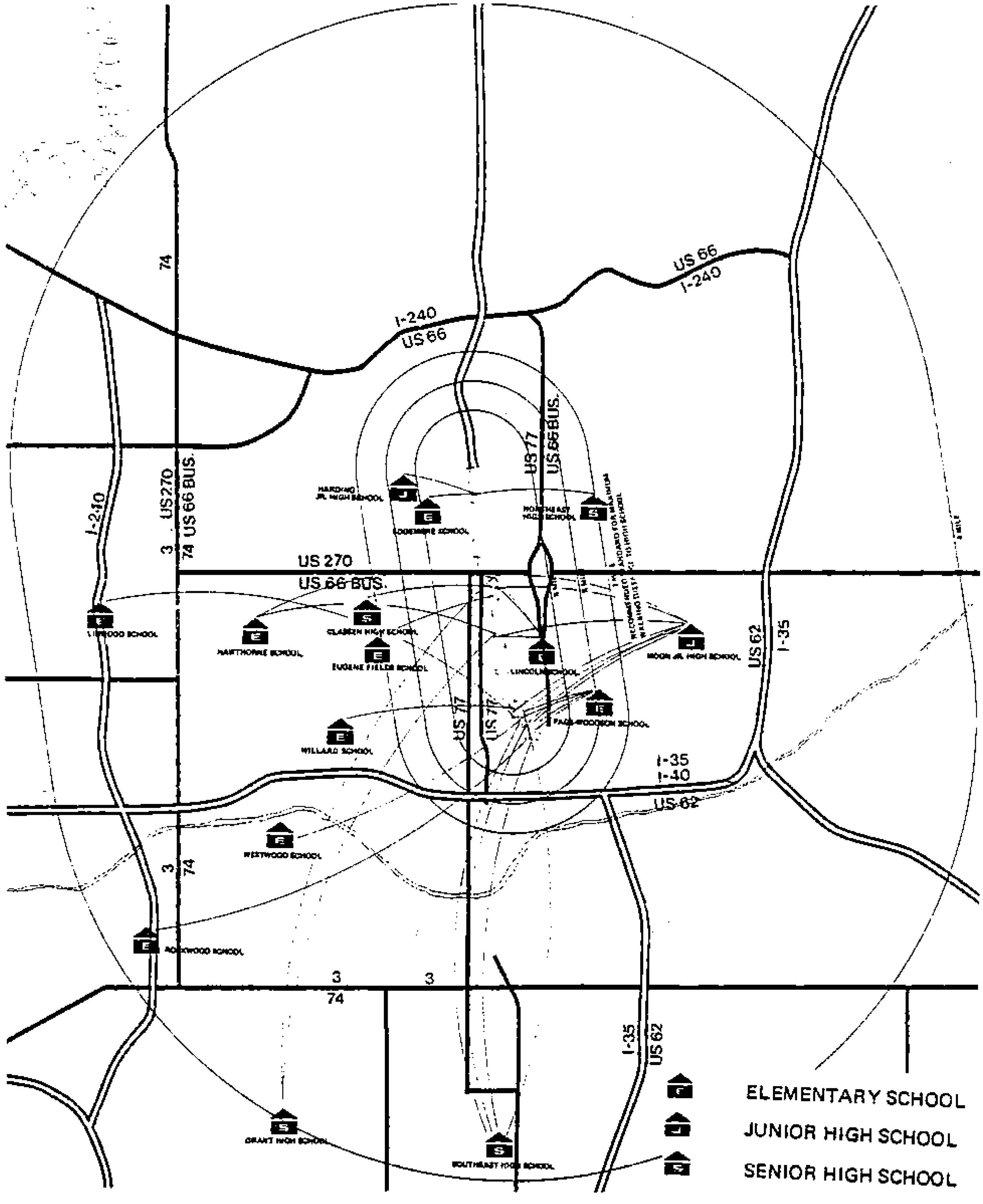
*Students living in homes proximate to the alignment depicted in Figure 41 are sometimes permitted to walk to school if the distance is one mile or less each way. Hence, travel paths to schools within a one-mile radius of the proposed alignment are designated on the map as pedestrian dependency areas.



I-235 Alignment, Oklahoma City

Source: Interstate 235 Central Expressway, p. 6-64.

Figure 40. School service areas on a map overlay.



Source: Interstate 235 Central Expressway, p. 6-66.

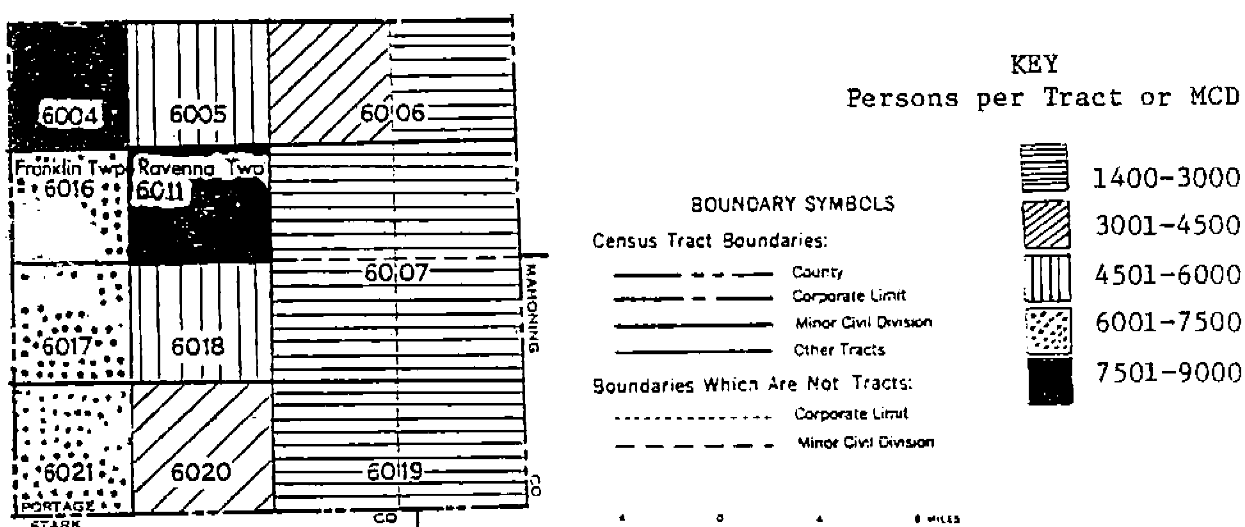
Figure 41. School travel patterns on a map overlay.

10.4.5 Demographic, Housing, and Economic Patterns

Map overlays are frequently used to show the spatial distribution of selected demographic, housing, and economic trends across a study area. They are particularly useful for locating populations which are likely to have special sensitivity to negative highway effects. Practitioners use overlays both to profile current trends in the study area and to array time-series data.

Overlays of this kind are generally used in preliminary assessment, when the study area is large enough that distributions of social and economic characteristics are readily apparent. They may also be used in detailed assessment to identify concentrations of special populations such as minority groups, elderly persons, and handicapped persons.

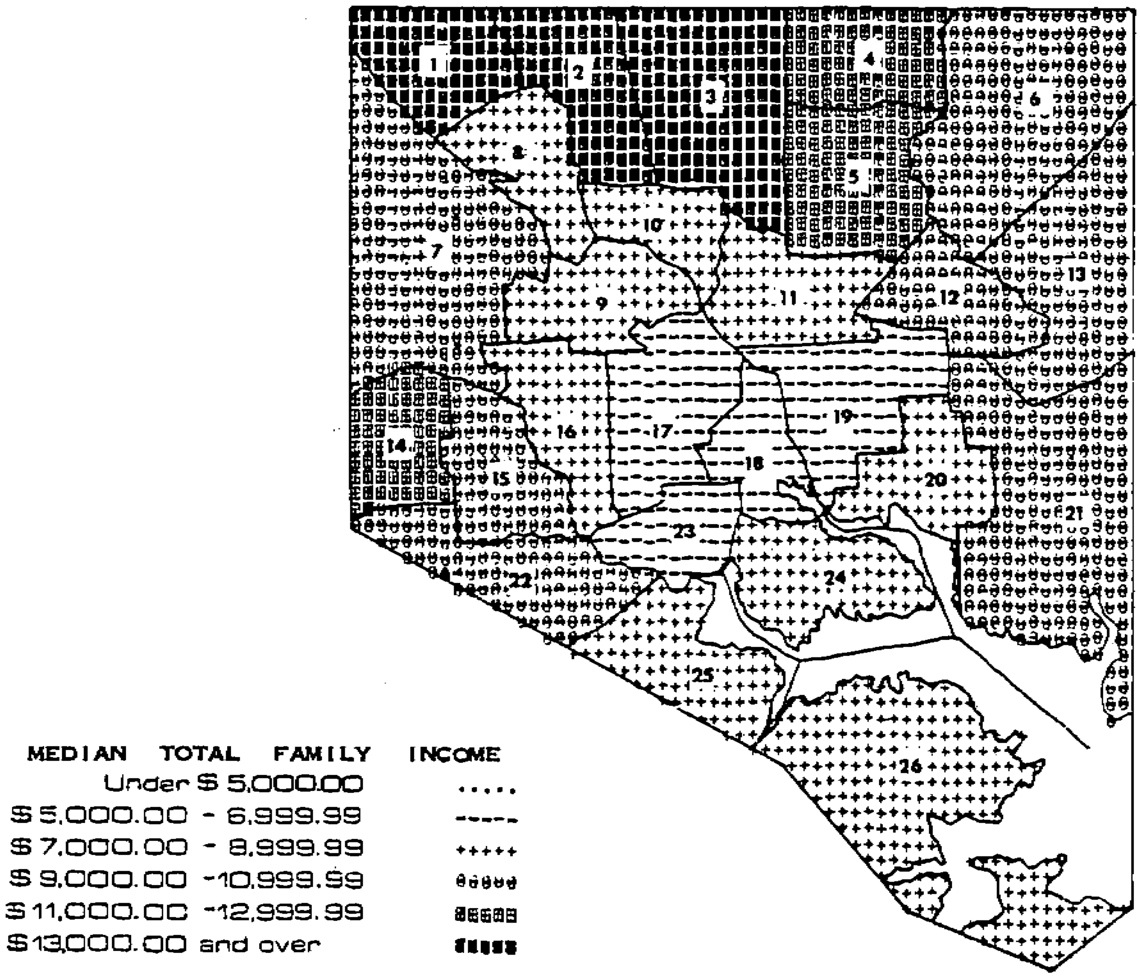
Figure 42 (below) compares population densities for census areas comprising a macro study area. Since the population data displayed in Figure 42 were compiled from U.S. Census records, a base map showing census tracts was used. Once the overlay is prepared, however, it can be placed on other base maps or used in conjunction with additional overlays. For instance, if placed on a base map showing neighborhood boundaries, the overlay would allow the comparison of population densities by neighborhood.



Source: Developed from 1980 Census of Population and Housing, "Census Tracts: Akron, Ohio SMSA," Final Report PHC(1)-2, U.S. Bureau of the Census, 1971.

Figure 42. Population density on a map overlay.

As noted, the location of populations especially sensitive to negative highway effects can be identified using maps. For example, Figure 43 (below) shows the distribution of median family income, by State planning district, across an urban study area. In this instance, planners may want to avoid highway alignments through low-income areas, most notably districts 17, 18, 19, and 23.

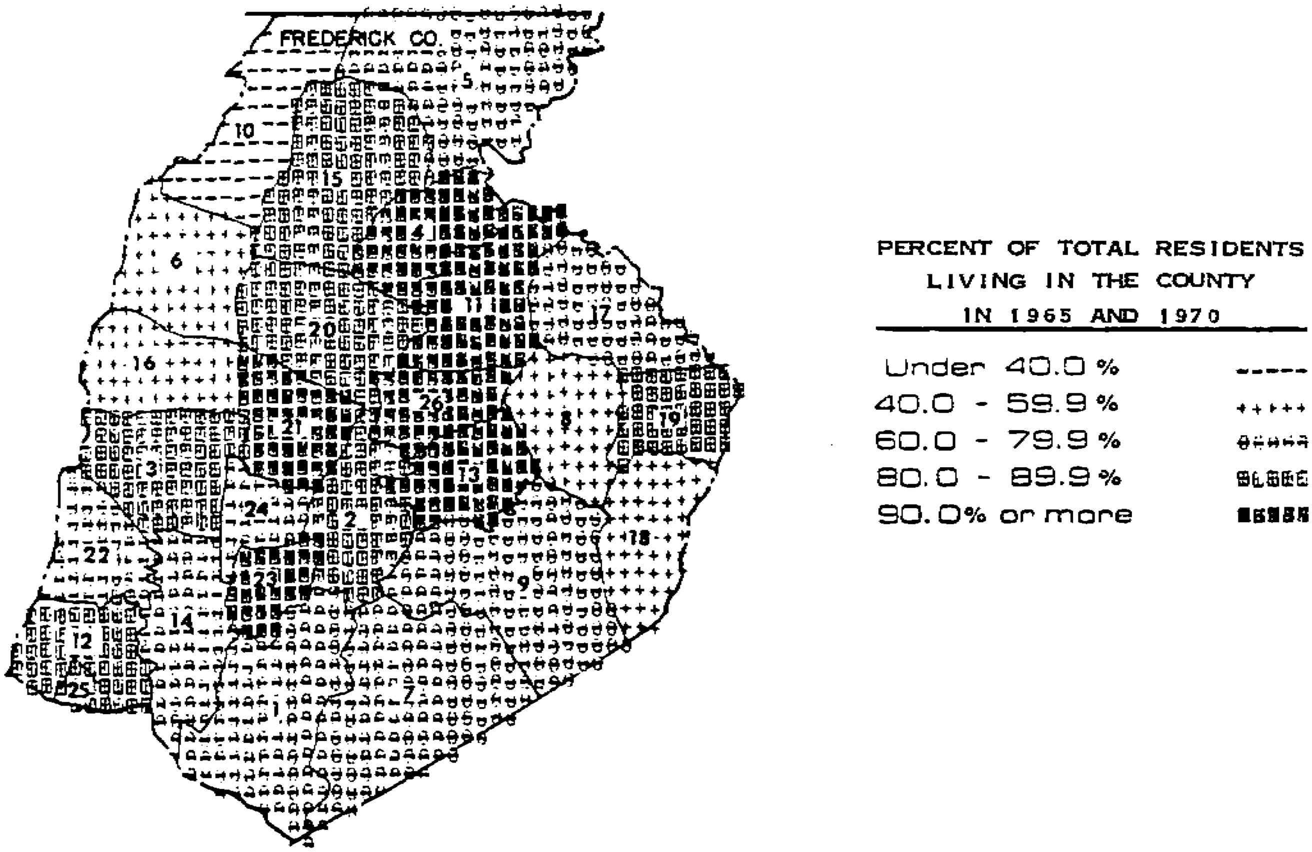


Baltimore City

Source: Maryland 1970 Social Indicator Series, Volume III: "Income Characteristics," p. D-57.

Figure 43. Distribution of median family income.

Figure 44 (p. 152) compares mobility rates for residents of planning districts in a suburban county. In this case, planners would normally attempt to define alignments which avoid those districts having relatively high stability quotients.



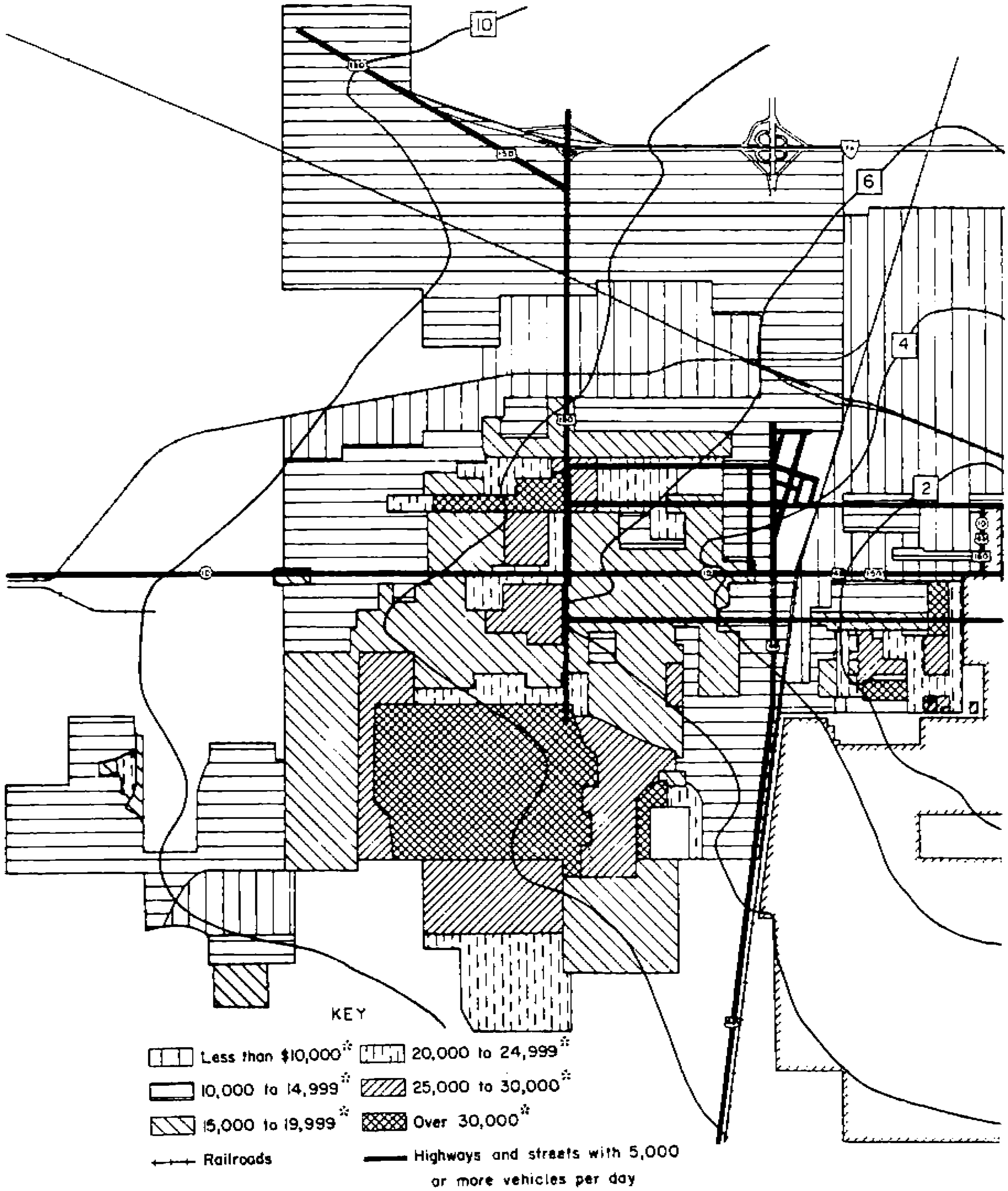
Source: Maryland 1970 Social Indicator Series, Volume II: "Age and Mobility Characteristics," p. C-16.

Figure 44. Proportion of population residing in area for five or more years.

Other types of data can also be displayed spatially. Figure 45 (p. 153) shows the distribution of residential property values across study area neighborhoods. (Similar distributions can, of course, be prepared for commercial and agricultural properties.) Again, the general assumption is that residents of dwellings having relatively low values are most susceptible to negative displacement and proximity effects.

Once the data of special interest to the assessment team have been spatially arrayed, one or more composite overlays may be prepared. These composite overlays provide a visual summary of areas which should be avoided in the definition or selection of ROWs.

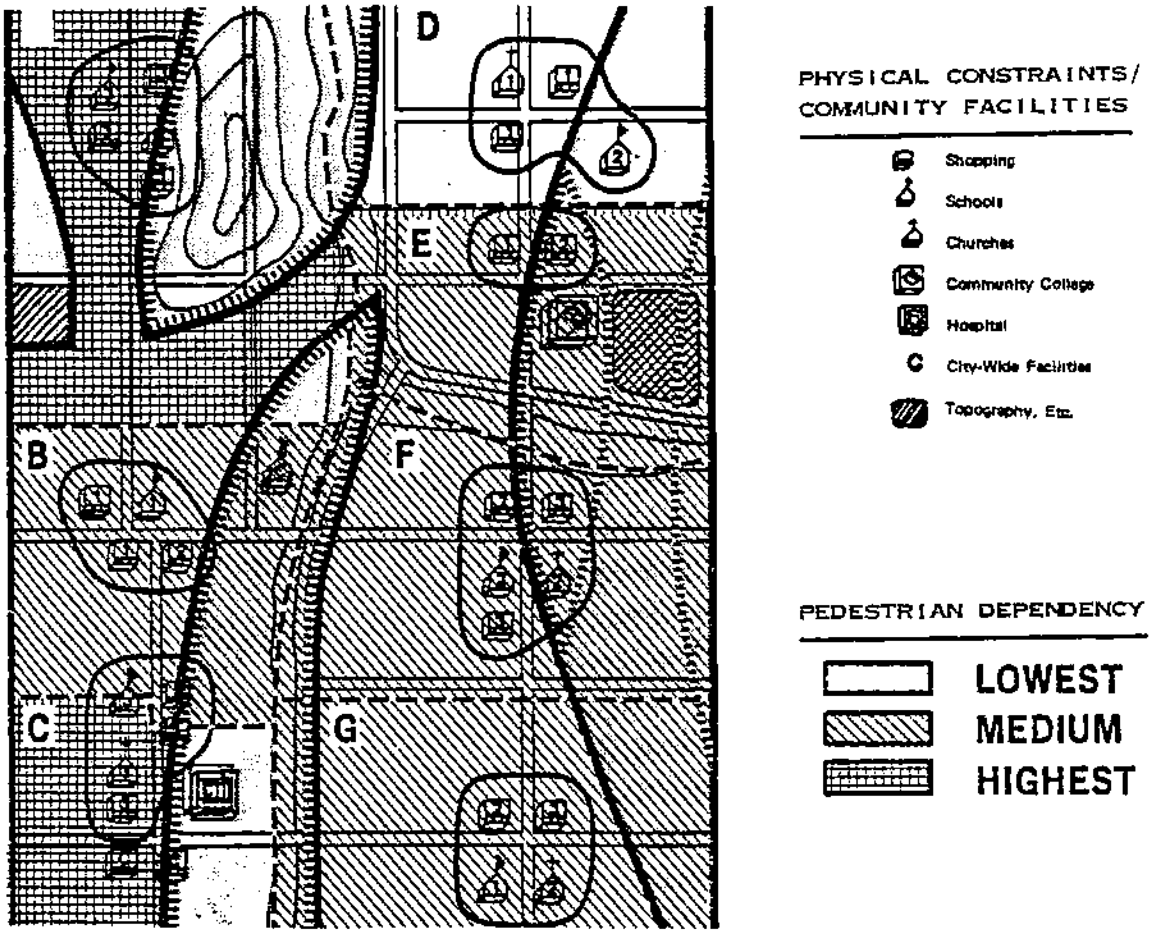
Figure 46 (p. 154) shows one kind of composite map. Here, a base map identifies the seven census tracts comprising a study area. One overlay shows phys-



Source: Kinney, p. 8. Champaign, Illinois

Figure 45. Distribution of residential property values.

ical constraints, e.g., land features and existing roads, which the proposed highway must avoid. A second overlay identifies neighborhood facilities; rings around each set of facilities indicate those areas with high concentrations of pedestrian dependent population. A third overlay is used to compare the relative levels of pedestrian dependency between neighborhoods.*



Source: Social and Economic Effects of Highways, pp. 54-58.

Figure 46. Physical constraints, neighborhood activities, and pedestrian dependency on composite overlay.

Visual displays of these kinds of data help practitioners to identify physically and socially feasible alignments.

*In this example, neighborhood dependency on walking was calculated as lowest, medium, highest on the basis of five factors: (1) household size and income, (2) ethnicity, (3) proportions of young and old persons, (4) automobiles available, and (5) residents in the same home for five or more years.

Chapter 11. TABLES

Most socio-economic impact data can be effectively displayed in tabular arrays. The information presented in these tables is generally of two types -- frequency distributions and summary averages. Frequency distributions are normally stated as raw numbers or percentages, while summary averages are shown in terms of arithmetic means, medians, or modes.

Tables present data which describe the study area or its surroundings. Many tables -- notably those which present data for two or more variables -- are both descriptive and enable practitioners to make inferences about the relationships among variables.

The simplest tables used to present data are univariate arrays. These arrays present data for a single variable only. Despite their limitations, valuable information can be shown in univariate arrays, like the following:

Addresses of Residents to be Displaced (Peach Street)					
294	295	296	297	298	299

While this format will enable the reader to reconstruct the original data completely -- which might be feasible in dealing with small numbers -- it will prove unwieldy in most cases. The alternative is to develop frequency tables for grouped data. For example, in treating the age variable, tables similar to the following can be constructed:

	0-18 years	19-39 years	40-65 years	65+ years
Study Area Population	183	261	201	98

Grouping will vary according to the interests of the analyst and the grouping used in standard statistical sources. In general, it is recommended that grouping be precoded on survey instruments, although it is possible -- and sometimes desirable -- to capture a single number on the survey instrument (e.g., age = 39, income = $16,500) and devise groupings later when the data are prepared for analysis.

Practitioners may wish to translate the raw data into percentages. For the previous example:

	0-18 years	19-39 years	40-65 years	65+ years
Study Area Population	25%	35%	27%	13%

Practitioners may also wish to present the data in the form of summary averages. Options here include the mode (the most frequently reported answer), either grouped or ungrouped, the arithmetic mean, or the median (the middle response). It might thus be reported that most respondents are ages 19 to 39 years (mode), that their mean age is 34 years, and that the median age is 35.

Averages have the virtue of reducing raw data to a single number (or category) which represents all the detailed information collected on an item. However, that advantage comes at a cost, since the reader cannot reconstruct the original data from an average.

More complex tables, called bivariate arrays, focus on the relationship between two variables. In the following example, two variables -- race and geographic area -- are cross-tabulated:

Population by Race (%)

Geographic Area	White	Black	Hispanic	Native American	Asian and Pacific Islander	Other	Total Population
Study Area	28%	41%	22%	1%	6%	2%	19,700
SMSA	45	32	19	0	3	1	342,000
State	69	19	9	2	1	0	1,098,000

The preceding table both describes the relative size of the minority population residing in the study area and identifies population norms for the larger surrounding area.

The use of bivariate tables to profile a population generally involves describing the distribution of responses to one variable for stratified subgroups of a second variable. In the following example the distribution of responses to the income variable is stratified by age group. The format is useful for descriptive purposes.

Distribution of Responses

Age	Income 0 - 5K	5 - 10K	10 - 15K	15K +
19 - 29	9	32	21	11
30 - 45	4	9	45	41
46 - 59	8	11	37	39
60 - 65	14	15	29	21
65+	25	11	7	2

In explanatory bivariate analysis, however, this format would not be useful, since age (the dependent variable) cannot logically be understood as a function of income (the independent variable). If attitude towards a project were substituted for age in the preceding table, the explanatory power of the table would increase. This is because support or opposition to the project (the dependent variable) may well be a function of income level.*

The third type of tables commonly used in impact assessments is the multivariate array. Such tables are similar to bivariate arrays, except now three or more sets of variables are treated. In the following example, the three variables are neighborhood, race, and number of automobiles:

Automobiles Available per Household by Neighborhood and Race (%)

	South Brunswick			Silver Hills		
No. of Automobiles	White	Black	Other	White	Black	Other
0	1.8%	57.5%	52.9%	0.5%	4.0%	11.2%
1	52.0	37.0	36.3	7.9	19.0	33.1
2	40.9	4.1	10.8	20.0	25.3	44.2
3 or more	5.4	1.4	0.0	71.6	51.7	11.5
Total Households	1431	1018	92	956	302	52

This table indicates that residents of South Brunswick have fewer automobiles and are far more dependent on alternative modes of transportation than are residents of Silver Hills. A similar inference could have been made from a bivariate array showing neighborhood and number of automobiles. However, introduction of the race variable extends the level of analysis. Now it is known that the minority residents of South Brunswick are primarily those without automobiles. Accordingly, project plans likely to affect South Brunswick

*See Volume II, Part 4 for a more detailed treatment of techniques for analyzing relationships among variables.

residents will have to take account of minority group dependency on alternative transportation modes.

This chapter suggests ways in which univariate, bivariate, and multivariate tables can be used to:

- Compare impact data across spatial units and over time,
- Construct logs identifying individual parcels of land,
- Document and compare trip activity patterns in a study area,
- Array judgment and opinion data, and
- Summarize large quantities of data in impact matrices.

11.1 TABULAR COMPARISONS ACROSS SPATIAL UNITS

Standard tabular arrays are often used to compare socio-economic characteristics across a variety of study area segments. Useful comparisons may be made between:

- The macro study area and larger surrounding areas,
- Spatial subunits of the macro study area, and
- Alternative alignments within the macro area.

Generally, comparisons of the first two types are made in preliminary assessment. Comparisons between alternative alignments are performed in detailed assessment.

Tables 1 and 2 (p. 159) show comparisons of data between macro study areas and larger spatial units. Comparisons of this type help practitioners assess the extent to which conditions in the study area resemble or deviate from conditions in surrounding regions. Large spatial units for which data are often examined include the city or town, county, SMSA, State, or other identifiable area in which the study area is located.

Tables 3 - 5 (pp. 160-162) compare important data elements across study areas. These comparisons familiarize planners with the socio-economic infrastructure of the study area. They also help to distinguish between subareas which are most conducive to highway development and those which are probably susceptible to negative highway effects. Subunits of the study area examined typically include community-designated planning areas, neighborhoods and census areas.

Table 1. Tabular comparisons of population and housing trends.

Analysis Area	1960		1970		Percent Change 1960-1970	
	Population	Dwelling Units	Population	Dwelling Units	Population	Dwelling Units
Study Area	83,129	37,096	66,317	31,102	-20.2	-16.2
Oklahoma City	324,253	115,067	366,232	138,343	+12.9	+20.2
SMSA	511,833	172,942	640,889	226,936	+25.2	+31.2

Source: Interstate 235 Central Expressway, p. 6-23.

Table 2. Employment estimates for study area and SMSA.

Proportion of Workers Employed in:	Study Area	SMSA
Agriculture	2.1 %	1.7 %
Mining	.1	1.2
Construction	7.3	6.3
Manufacturing	18.3	15.0
Transportation and Public Utilities	7.7	6.6
Trade	23.6	25.5
Finance, Insurance, and Real Estate	6.1	6.8
Services	14.4	13.3
Government	19.9	24.6
TOTAL PERSONS IN LABOR FORCE	50,750	620,600

Table 3. Retail sales data for study subareas.

Shopping Area	Center Size (sq.ft.)	Total Retail Sales ($000)	Total Market Area Population	Total Expendable Income ($000)	Average Per Capita Expendable Income	Average Sales Per Sq.Ft.	Average Sales Per Capita	Market Penetration Rate *
Central Business District	500,000	$50,000	100,000	$330,000	$3,300	$100	$ 500	15.2%
A & M Plaza	100,000	9,500	11,000	33,000	3,000	95	864	28.8
San Luis Mall	500,000	62,000	45,000	144,000	3,200	124	1378	43.1
Country Club	200,000	23,000	19,500	64,350	3,300	115	1179	35.7
Midtown Plaza	100,000	11,200	12,800	40,320	3,150	112	875	27.8

* Market Penetration Rate = Average Sales Per Capita ÷ Average Per Capita Expendable Income

Source: Adapted from Alan M. Voorhees and Associates, Social and Economic Considerations in Highway Planning and Design: Workbook and Resource Guide, for the FHWA, 1977, p. 226.

Table 4. Distribution of land use acreage by census tract.

Census Tract	Total Acres	Commercial	Industrial	Residential	Public	Agricultural	Vacant
1	580	66	1	46	426	--	41
2	779	30	--	318	261	--	170
3	2,065	42	--	621	524	21	857
4	379	101	54	125	69	--	30
5	255	11	10	71	125	--	20
6	324	53	1	226	34	--	20
7	481	107	--	212	132	--	30
8	413	93	--	217	83	--	20
9	3,768	114	10	813	400	--	2,431
10	788	45	--	579	70	--	94
11	1,416	3	11	305	658	1	438
12	351	45	30	167	69	--	40
13	265	43	--	16	216	--	8
14	644	27	--	200	123	--	249
15	867	9	--	654	50	--	94
16	3,409	40	--	878	277	5	2,207
17	3,291	10	--	1,129	372	--	1,780
18	5,431	72	25	557	624	--	4,152
19	4,506	57	17	702	625	474	2,631
20	2,590	129	28	553	621	--	1,259
21	1,888	22	--	811	200	76	779
22	7,343	7	--	1,150	793	685	4,692

Source: Voorhees, p. 532.

Table 5. Housing occupancy and tenure by census tract.

Census Tract	Percent of Units Occupied	Percent Vacant	PERCENT OWNER-OCCUPIED OF TOTAL OCCUPIED UNITS: Single-Family Dwelling	Multi-Family Dwelling	Total	PERCENT RENTER-OCCUPIED OF TOTAL OCCUPIED UNITS: Single-Family Dwelling	Multi-Family Dwelling	Total
SUB-AREA 1								
1001	91.18	8.82	67.91	4.48	72.39	24.18	3.42	27.61
1003	94.25	5.75	74.39	2.12	76.51	20.70	2.79	23.49
1006	89.46	10.54	45.00	15.00	60.00	21.25	18.75	40.00
1007	90.13	9.87	58.18	4.62	62.80	31.39	5.81	37.20
1008	91.97	8.03	49.06	12.02	61.08	24.10	14.82	38.92
1010	85.99	14.01	27.01	13.07	40.08	42.50	17.42	59.92
1011	82.72	17.28	13.87	17.39	31.26	31.74	37.00	68.74
1012	85.81	14.19	19.82	15.23	35.05	30.56	34.39	64.95
TOTAL	89.46	10.54	26.69	28.04	57.73	28.03	14.24	42.27
SUB-AREA 2								
1005	80.61	19.39	42.12	12.01	54.13	31.33	14.54	45.87
1051	86.67	13.33	56.23	12.47	68.70	20.29	11.01	31.30
TOTAL	82.95	17.05	45.40	21.43	66.83	26.87	6.30	33.17
SUB-AREA 3								
1015	83.95	16.05	34.49	11.62	46.11	39.09	14.80	53.89
1026	72.79	27.21	12.17	6.41	18.58	46.68	34.74	81.42
1027	87.61	12.39	12.83	4.60	17.43	9.21	73.36	82.57
1030	75.14	24.86	12.91	16.76	29.67	40.36	29.97	70.33
1038	68.94	31.06	19.39	5.92	25.31	55.83	18.86	74.69
TOTAL	77.38	22.62	21.40	10.24	31.64	40.59	27.77	68.36

Source: Interstate 235 Central Expressway, p. 6-29.
Statistics provided by R.L. Polk & Co., Urban Statistical Division, 1975.

Tables 6 - 9 (pp. 163-165) are examples of the kinds of data which can be compared across alternative alignments. These ROW tables are similar to arrays which compare study subareas, but they usually provide greater detail. ROW tables are used to profile each alignment, and to assist practitioners in selecting the most suitable route.

Regardless of the spatial units under investigation, impact data can be compared for either (1) a single point in time, or (2) designated time intervals. Examination of demographic, housing, economic, and land use variables over time will often yield valuable information about growth trends in an area.

11.2 PARCEL LOGS

Parcel logs are prepared in detailed assessment to identify residences, businesses, community facilities, farms, and other properties along each alternative alignment. They may be used to record information on (1) the physical

Table 6. Comparative summary of alternative alignments.

ALTERNATIVE	BROADWAY	RAILROAD	OKLAHOMA WEST	OKLAHOMA EAST
Project Length	3.8 Miles	4.1 Miles	3.4 Miles	3.7 Miles
Total Monetary Cost ($)				
Construction & Utilities	80 Million	95 Million	66 Million	84 Million
Right-of-Way	14 Million	18 Million	12 Million	19 Million
Relocation Assistance	4 Million	4 Million	4 Million	4 Million
TOTAL	98 Million	117 Million	82 Million	107 Million
Residential Displacement				
Housing Units, Single Family	123	79	131 (19 vacant)	93
Housing Units, Multi-Family	470	258	547 (81 vacant)	303
Residents	916	564	1,195	699
Business Displacement				
Businesses	51	49		54
Employees	1,339	818	393	617
Institutional Displacement	8	6		8
Traffic Service to Major Generators				
CBD	Good	Fair	Good	Good
Oklahoma Health Center	Poor	Good	Good	Good
Capitol Complex	Fair	Good	Good	Good

Source: Interstate 235 Central Expressway, p. 8-14.

Table 7. Comparison of retail facilities along alternative alignments.

ALIGNMENT SEGMENT	NUMBER OF FACILITIES							
	Convenience Goods	Food Stores	Automotive	Professional Services	Business/ Industrial Services	Hotel/ Motel	Vacant Commercial	TOTAL
Langley	1	1	4	0	5	0	1	12
Freemont	0	0	1	1	0	0	0	2
Waterfront	2	0	3	6	2	5	0	18
Meadowfield	4	2	4	0	2	1	2	15

Source: Adapted from Voorhees, Social and Economic Considerations, p. 355.

Table 8. Comparative fiscal impact of project by alignment. *

Alignment	# of Displaced Properties	Mean Property Values ($000)	Taxable Values ($000)	Est. Annual Property Tax Losses
A	121	$46.5	$18.6	$171,000
B	74	69.2	27.7	155,700
C	82	52.0	20.8	129,600

* Assumes an assessed value of approximately 40 percent of the market value, and a property tax rate of $76.00 per $1,000 of assessed valuation.

Table 9. Demographic and economic profile of alternative alignment.

Household Size	2.0
Age of Heads of Households	35% considered elderly
Sex of Heads of Households with Children under 18	Sex evenly divided
Ethnic Composition of Households	58% White, 41% Black, and 1% American Indian
Ownership, Tenancy and Ethnic Composition	70% of housing units: tenant-occupied 30% of housing units: owner-occupied 97% owner-occupants: white 58% of tenant occupants: black
School Children	Approximately 63 49% Grades K-5 11% Grades 6-8 40% Grades 9-12
Monthly Income	Average $640 ($7,680 a year) Ranges from $55 to $2,170
Estimated Fair Market Value of Owner-Occupied Units	$10,000 to $35,000
Average Monthly Rental	Average $101 predominantly 1 to 2 bedroom units

Source: Oklahoma West Corridor Survey, Oklahoma Department of Transportation, 1978.

and economic characteristics of individual facilities, and (2) the residents or users of those facilities.

As indicated by Tables 10 - 14 (pp. 166-168), the data shown on parcel logs are highly variable. Often a single log is prepared for the entire alignment. Other times, e.g., when the number of non-residential facilities along the alignment is large, specialized logs identifying different types of land uses are prepared. It is sometimes instructive to profile individual groups of facilities, e.g., schools, on a single log. This is particularly desirable when consideration is being given to displacing one or more individual facilities and reassigning users to other existing facilities (see Table 14).

Table 10. General land parcel log.

Street No.	Street Name	Map Code	Descrip. of Activity	No. of Bldgs.	Area of Parcel (sq.ft)	Dimension of Bldg. (ft.)	No. of Flrs.	Residential Structure Type	No. of Household Units	Tenure of Users	Total Assessed Value	Fair Market Value	Owner
602	ELM	39-15.11	Home Furniture Co.	2	33,000	200 X 100 75 X 50	1	-	-	Owned	$127,800	$142,000	C. Bricker
603	ELM	39-15.12	Household Units	1	14,000	125 X 80	3	Walk-up Apt.	10	Rented	$ 81,900	$ 91,000	S. Taylor
606	ELM	39-15.13	Household Unit	1	6,200	60 X 50	2	Single-Unit Detached	1	Owned	$ 46,800	$ 52,000	J. Ludwig
608	ELM	39-15.14	Physician's Office	1	6,500	70 X 45	2	-	-	Owned	$ 53,100	$ 59,000	R. Susskind
610	ELM	39-15.15	Drug Store	1	3,800	80 X 35	1	-	-	Owned	$ 52,200	$ 58,000	Flanders & Co.
612	ELM	39-15.16	Household Unit	1	2,600	60 X 32	1	Single-Unit Detached	1	Owned	$ 34,200	$ 38,000	D. Wright

Table 11. Characteristics of households along alignment.

Address	Type Unit Occupied	Household Size & Composition Adults	Children	Household Income (Estimate)	Tenure	Special Needs or Problems (Brief Description)
1. 17 Main	1-family	2	3	moderate	own	none
2. 6 Main	1-family	1	2	low	own	walks to work
3. 3 Main	1-family	1	0	welfare	rent	elderly & handicapped
4. 7 School	1-family	3	0	moderate	own	none
5. 9 Jackson	2-family	2	1	moderate	own	child emotionally disturbed
6. 9 Jackson	2-family	2	2	moderate	rent	resides in 2-family home with parents

Source: Adapted from Environmental Assessment Notebook Series, Notebook 3, "Economic Impacts," pp. 134-135.

Table 12. Retail business log.

Business Name	Address	SIC Code	Square Footage of Building	Condition of Building	Number of Years at Location	Tenure	Number of Employees	Gross Revenues ($000) '78	'79	'80	Net Profit ($000) '78	'79	'80
Acme Food Store	802 Duke	541	9900	Excellent	4	Rented	42	1,842	1,978	2,026	55.3	79.1	70.9
Southville Pharmacy	806 Duke	591	4700	Good	15	Owned	9	750	672	735	25.4	-15.2	9.3
Brian's Hardware	816 Duke	525	3500	Fair	10	Owned	5	345	382	413	25.9	28.6	24.8
Gibbon's Shoes	820 Duke	566	650	Fair	9	Owned	3	57	44	49	5.1	3.9	4.4

Table 13. Community facilities log.

Facility Group	Type	Name	Address	# of Bldgs.	# of Floors (each bldg.)	Square Footage	Year Built	Condition of Structure	Bldg. Capacity	Average # of Users	Control and Funding	Owners (if Private)
School	Elementary	Cedar Elementary School	540 Elm St.	1	1	37,000	1976	Excellent	1250	948	Public	—
Church	Protestant	First Baptist Church	10 Walnut St.	1	1	23,000	1959	Good	425	350	Private	Congregation
Health Care	Clinic: General Medicine	Southeast Health Center	818 Peach St.	1	1	8,200	1949	Fair	24	76 Patients per day	Public	—

Table 14. School and enrollment log.

Schools	Grades	Capacity	ENROLLMENT 1974/75	1975/76	% Change
Harding	6 - 8	1,350	1,138	1,103	-03.0
Edgemere	K - 5	400	307	358	+16.6
Dewey	K - 5	325	285	294	+03.2
Wilson	K - 4	350	262	282	+07.6
Central *	6 - 8	1,500	1,050	205	(N.A.)
Lincoln	K - 5	425	309	295	-04.5
Page-Woodson	K - 5	625	244	290	+18.9

* In 1975/76, Central became a high school.

Source: Interstate 235 Central Expressway, p. 6-63.

In constructing parcel logs, practitioners are encouraged to record uniform information for each alternative alignment. This expedites the comparison of data for potential ROWs and helps planners to select the most suitable route. Also, inclusion of street addresses or map codes on parcel logs (see Table 10) helps practitioners to spatially locate facilities on map overlays of the alignment (see Section 10.4).

11.3 TRIP ACTIVITY MATRICES

Trip activity matrices describe patterns of travel across a study area. They may be used to show a variety of important data, including (1) the relationship between trip origin and destination, (2) modes of travel, (3) frequency of trips, and (4) travel times, distances, and costs.

Tables 15 - 16 (below & p. 170) display trip data normally examined in preliminary assessment for two macro study areas. Figure 15, taken from U.S. Census reports, shows modes of travel by various categories of workers in a metropolitan area. Suppose this information was studied in conjunction with another table showing worker occupation by residential neighborhood. Practitioners would then be able to make general inferences about the mode of transportation used by workers in each neighborhood.

Table 15. Transportation mode to work by occupation and location of residence.

OCCUPATION OF WORKER	Total	In SMSA				Outside SMSA	
		In Central City		Outside Central City			
		By Auto	By Public Transportation	By Auto	By Public Transportation	By Auto	By Public Transportation
		Distribution by Location & Method of Transportation (%)					
All occupations	100 %	26%	11 %	31%	3 %	28%	1 %
Professional and managerial	100	26	5	39	3	26	1
Clerical and sales	100	26	16	29	6	22	1
Craftsmen, operatives, and laborers	100	26	9	30	1	33	1
Service and private workers	100	22	23	21	2	30	2
Others and nonavailables	100	22	22	27	2	27	-

Source: Stanford Research Institute, Methods of Evaluation of the Effects of Transportation Systems on Community Values, for Department of Housing and Urban Development, 1971, p. 44.

Table 16 compares origin-destination patterns for the nine zones within a particular study area. By measuring the extent of interaction between each combination of zones, practitioners are able to identify those routes which should not be obstructed by the proposed project.

Table 16. Trip activity patterns by zone.

Zone of Destination

Zone of Origin	A	B	C	D	E	F	G	H	I	No. of Samples
A	-	3	0	37	8	16	4	0	0	68
B	6	-	0	25	15	8	6	3	0	63
C	9	4	-	46	18	21	10	5	0	113
D	0	1	0	-	0	2	0	0	0	3
E	21	11	0	51	-	39	8	1	0	131
F	3	2	0	43	1	-	1	2	0	52
G	9	6	0	41	9	44	-	8	0	117
H	4	5	0	22	14	17	3	-	0	65
I	12	7	0	12	5	9	2	0	-	47
Total Trips	64	39	0	277	70	156	34	19	0	659

Tables 17 - 18 (pp. 171-172) identify trip data ordinarily examined in the detailed assessment of alternative alignments. The first table compares general information on travel mode and trip purpose along the alignment. The second provides more comprehensive information on the travel habits of users of two community facilities potentially subject to displacement.

Table 17. General trip patterns along prospective ROW.

TRAVEL MODES	TRIP PURPOSES											
	WORK		GROCERY		DOCTOR		DENTIST		HOSPITAL		CHURCH	
	No. of Samples	%	No. of Samples	%	No. of Samples	%	No. of Samples	%	No. of Samples	%	No. of Samples	%
PERSONAL CAR	55	90	89	83	71	83	47	82	71	85	50	88
NEIGHBOR'S CAR	1	1	11	10	6	7	5	9	6	7	4	7
TAXI	--	0	4	4	3	4	2	3	1	1	2	1
BUS	1	2	2	2	4	5	2	4	5	6	1	2
WALK	4	7	1	1	1	1	1	2	1	1	--	--
TOTALS	61	100	107	100	85	100	57	100	84	100	57	100
AVERAGE MILES PER TRIP	4.1		2.0		3.6		3.8		3.2		2.8	

Source: Interstate 235 Central Expressway, p. 6-41.

Table 18. Trip activity matrix for community facilities along Alignment #2.

	Bayview Recreation Center	Kensington Public Library Bayview Branch
FREQUENCY OF TRIPS		
Daily	34%	11%
Not daily, but at least weekly	42	27
Not weekly, but at least monthly	18	43
Less than monthly	6	19
NUMBER IN TRAVEL PARTY		
1	57%	41
2-3	34	58
4-6	7	1
more than 6	2	0
POINT OF ORIGIN		
Bayview Heights	35	52
Bell Forest	31	27
Eastern Hills	29	10
Other	5	11
MODE OF TRAVEL		
Walking	22	9
Bike	46	24
Car	20	52
Taxi	0	6
Bus	12	9
ROUTE FOLLOWED (may be displayed on a map)		
1	32	46
2	28	37
3	25	12
Other	15	5
TRAVEL TIME (Minutes)		
10 or less	48	37
11-20	36	35
21-30	14	19
Over 30	2	9
ESTIMATED TRAVEL COST		
No cost	68	33
$1 or less	22	25
$1 - $5	10	41
Over $5	0	1

11.4 TABULAR ARRAYS OF JUDGMENT AND OPINION DATA

When information of a judgmental nature is required, or the resources needed to collect certain types of statistical data are excessive, practitioners frequently rely on the judgments of experts. Judgmental data, like factual information, can be arrayed in bivariate or multivariate tables. It is advisable to collect information from a group of experts, rather than from a single specialist, whenever possible. This allows practitioners to identify and assess variations in judgments.

Sample arrays of judgmental data are shown in Tables 19 - 21 (below & pp. 174-175). Table 19 summarizes respondents' estimates of future development, given alternative highway scenarios. The table is of limited utility, however, in that it does not allow the reader to assess the range of expert responses. In other words, did two respondents interviewed predict that 25,000 single-family residential units would be constructed if the highway were not built? Or did one expert say 5,000 units would be built, while another predicted 45,000?

Table 19. Expected development along corridor, 1975 - 1985.*

Type of Development \ Circumstances	Without Highway	With Alternative: A	B	C
RESIDENTIAL UNITS				
Single Family	25,000	12,000	21,000	40,000
Multi-Family Rental	7,500	14,000	6,000	11,000
INDUSTRIAL USES				
Square Feet	400,000	320,000	332,000	230,000
COMMERCIAL USES				
Square Feet	750,000	600,000	623,000	1,170,000

*Based on interviews with County planning officials.

Source: Adapted from Voorhees, Social and Economic Considerations, p. 497.

Tables 20 and 21 correct this deficiency by indicating the proportion of respondents which adopted particular positions. For instance, Table 20 reveals that 86 percent of the experts believe construction of the proposed project will have a favorable effect on property values in areas proximate to new highway interchanges. Figure 21 both presents the range of response regarding the compatibility of the project with community plans and shows the compatibility quotient calculated for each alternative alignment. Here, the specialists agreed that, of the options available, Alternative No. 2 would be most compatible with community plans.

Table 20. Estimated effect of Alternative Alignment A on property values.*

(Percent of respondents indicating each rating)

Rating \ Property Values	Effect on Property Values Within 1.25 Mile of ROW	Effect on Property Values Within 200 Yds. of Highway Interchange	Effect on Property Values Along Main Street
No Direct Effect on Value	0%	7%	0%
Mildly Favorable Effect	13	13	27
Strongly Favorable Effect	0	73	13
Strongly Adverse Effect	27	0	0
Mildly Adverse Effect	40	7	13
Mixed Effect (Some favorable, some adverse)	7	0	47
Impossible to Say	13	0	0

*Based on interviews with 15 County assessment officials.

Table 21. Project compatibility with community plans.*

(Number of officials indicating each rating)

Rating \ Alternatives	No Build	Alternative #1	Alternative #2	Alternative #3	Alternative #4
1. Highly Compatible	0	0	5	0	0
2. Compatible	1	2	3	1	1
3. Somewhat Compatible	2	5	1	3	1
4. Not very Compatible	6	2	0	5	3
5. Incompatible	0	0	0	0	4
6. Mean Score	3.56	3.00	1.56	3.44	4.11

*Based on interviews with city planning officials.

In general, when a majority of experts indicate similar or identical positions, their judgments can be accepted as credible. However, when expert judgments diverge, and meaningful patterns are not discernible in the responses, the judgments should be regarded cautiously. Selection of alternative techniques for collecting the data on the issues treated is then probably in order.

Public opinion data, like judgmental data, may be effectively displayed in tables. Tables 22 - 25 (pp. 176-177) show how survey findings on citizens' attitudes toward a proposed project, businesspersons' expectations regarding the effect a project will have on future retail activity, and displaced residents' preferences for relocation sites can be presented in tabular formats. Descriptive information about respondents, when it can be introduced into an array, will nearly always enhance the table's analytic value. Table 23, for example, suggests a strong correlation between the percentage of customers residing in the study area and businesspersons' attitudes toward the highway.

Table 22. Citizen opinions on proposed project.

RESPONSE CATEGORY	RELATIVE FREQUENCY OF RESPONSE
No bypass needed	12.5%
Begin construction further south on 411	35.7
Begin construction further west of city	5.4
Bypass should exclude more of the urban area	33.9
Bypass should include more of downtown area	5.4
Bypass should extend further southeast	5.4
Miscellaneous	2.0

Source: Michael E. Gordon, Evaluation of an Attitudinal Criterion for Measuring Public Reaction to Proposed Highway Projects, University of Tennessee, Knoxville, 1974, p. 28.

Table 23. Businesspersons' attitudes toward highway project.

	ATTITUDE TOWARD FREEWAY			
CHARACTERISTIC	Favor	Opposed	No Opinion	Total Respondents (175)
Size of Business:				
Less than 10 employees	71%	17%	13%	103
10 or more employees	58	33	8	72
Percentage of Customers in Study Area				
10-25	86%	2%	12%	83
26-50	75	15	10	20
51-75	57	43	0	21
76-100	33	53	14	51
Type of Business				
Retail	60%	29%	11%	73
Service	66	20	14	59
Wholesale/Manufacturing	74	19	7	43

Source: Adapted from Attitudes, Opinions, and Expectations of Businessmen in a Planned Freeway Corridor, p. 20.

Table 24. Expected impact of project on retail businesses in study area.*

TYPES OF ESTABLISHMENT	PERCENT OF RESPONSES		
	Project will Help Business	Project will Hurt Business	Project will Not Affect Business
Appliance and record	8.5%	26.9%	64.6%
Clothing	13.6	30.9	55.5
Drug	8.6	14.6	76.7
Farm equipment	12.0	12.3	75.7
Foodstores, locally owned	14.3	18.2	67.4
Foodstores, chain	17.1	13.7	69.2
Furniture	8.3	38.7	53.0
Hardware	13.7	13.3	73.0
Hotels and motels	8.4	85.2	6.4
Restaurants	10.0	75.0	15.0
Service stations	7.0	84.6	8.4
AVERAGE, all responses	11.3%	37.0%	51.7%

*Based on interviews with owners and managers.

Table 25. Relocation preferences indicated by prospective displacees.

Relocation Area Desired	Percent of Residents North of 23rd Street		Percent of Residents South of 23rd Street	
	Owner-Occupants	Tenants	Owner-Occupants	Tenants
Northeast	—	1.8%	3.0%	23.4%
Northwest	19.5%	46.0%	5.1%	27.4%
Southeast	—	—	—	2.0%
Southwest	1.8%	5.3%	0.5%	2.5%
Central	—	1.8%	—	—
Other	3.5%	8.0%	2.0%	8.6%
No Preference	4.4%	8.0%	5.6%	19.8%

Source: Interstate 235 Central Expressway, p. 5-56.

11.5 IMPACT MATRICES

Most tabular data presented in the preceding sections are organized by topical category. These displays, taken together, provide a composite profile of the study area. However, the assessment process is incomplete until the profiles are formally evaluated in terms of the seven impact categories.

A simple but reliable technique for evaluating the data to identify potential impacts requires practitioners to construct impact matrices. These matrices list key indicators for each impact category, which are then quantified and compared across study subareas (in preliminary assessment) or alternative alignments (in detailed assessment).*

Tables 26 - 27 (p. 179) are examples of impact matrices used in detailed assessment to compare the probable effects of displacement and fiscal impacts, respectively. Normally, the information to be recorded on these matrices has already been gathered at this point. Now the practitioners' task is to summarize the key information related to each impact in a single table so that systematic comparisons can be made.

The key indicators chosen for each matrix will vary by project and study area. For instance, if one or more of the alignments will displace residences, a supplement to the table shown in Figure 26 would probably be in order. The supplemental matrix might list as key indicators those groups (e.g., elderly persons, families with young children, or handicapped persons) who are especially susceptible to negative displacement effects. The number of persons in each group residing in each ROW could then be recorded.

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*Numerous mathematical techniques can be applied to screen socio-economic impact data for indicators and potential negative impacts. Several of these techniques are presented in Volume II, Part 4.

Table 26. Impact matrix for comparing displacement effects.

Alternative ROWs	RIGHT-OF-WAY REQUIRED (# of Acres)						DISPLACEMENTS (#)					
	Residential	Commercial	Industrial	Undeveloped	Other	Total ROW	Dwelling Units	Farms	Businesses	Community Facilities	Total Residents Displaced	Total Workers Displaced
1												
2												
3												
4												

Table 27. Impact matrix for comparing fiscal impacts.

Alternative ROWs	(A) Acquisition Costs	(B) Estimated Relocation Costs	(C) Total Acquisition/ Relocation Costs (A + B)	(D) Direct Tax Base Loss	(E) Sales & Property Tax Loss/Gain for Land Proximate to ROW*	(F) Payroll Tax etc., Loss/ Gain for Changes in Economic Activity	(G) Estimated Costs/ * Savings for Providing Public Services to Areas Affected	(H) Total Tax Loss/ Gain (D+E +F+G)
1								
2								
3								
4								

*Costs per annum.

Another decision making tool, similar to the impact matrix, is presented in Table 28 (pp. 181-183). This "Level of Impact Assessment Matrix" enables practitioners to evaluate each of the seven impacts in terms of magnitude, duration, and area of impact. The matrix was originally designed for use in preliminary assessment to provide composite scores on each socio-economic impact across an entire study area. However, it can be used equally well to compare alternative alignments in detailed assessment, provided that a separate matrix is prepared for each prospective ROW.*

To use the matrix, practitioners evaluate the probable effects of the project for each impact category. (A sample list of important factors to consider appears beneath each impact.) Magnitude is scored on a continuum from "major beneficial" to "severe adverse." Impact duration extends from "construction period only" to "permanent." Area of impact ranges from the ROW to the entire study area.

The Level of Impact Assessment Matrix also provides space for the recording of "probable issues" and "probable affected publics." In preliminary assessment, this information can help identify (1) issues which need to be investigated in greater detail, and (2) individuals and groups who ought to be invited to participate in the decision-making process. In detailed assessment, these categories help to summarize data already collected.

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* The Levels of Impact Assessment Matrix first appeared in <u>Community Involvement in Highway Planning and Design: A Manual of Techniques</u>, jointly prepared by the Center for Urban and Regional Studies (Virginia Polytechnic Institute and State University, Blacksburg) and the Office of Environmental Policy, FHWA, 1977, pp. 34-44. However, the data elements listed in the Figure 28 matrix have been changed to conform with the presentation in this Manual.

Table 28. Level of impact assessment matrix.

Project Identification ______________________________

Project Type ______________________________

Planning Stage ______________________________

Important factors to consider are listed beneath each impact category below. EVALUATE the magnitude, duration, and area of impact in each category and ENTER THE NUMERICAL SCORE in the appropropriate box.	Impact: MAGNITUDE	Impact: DURATION	Impact: AREA	LIST "Probable Issues" with each impact score below.	LIST "Probable Affected Publics" below.
1.0 SOCIAL IMPACTS					
1.1 Cohesion Community and neighborhood boundaries. Population clusters. Populations w/ shared characteristics. Community and neighborhood organizations. Residential mobility. Attachment to neighbors and neighborhood.					
1.2 Accessibility Access to destination points: employment centers, shopping areas, community facilities and services. Transport modes used. Pedestrian dependencies. People w/ special needs.					

Impact Scoring Codes

IMPACT MAGNITUDE		IMPACT DURATION	IMPACT AREA
+3 Strong Beneficial	-3 Severe Adverse	0 Construction	0 ROW
+2 Moderate Beneficial	-2 Moderate Adverse	1 Few Years	1 Adjacent Property
+1 Minor Beneficial	-1 Minor Adverse	2 Many Years	2 Neighborhood
0 Negligible or No Impact		3 Permanent	3 Study Area

Table 28. Level of impact assessment matrix (continued).

Important factors to consider are listed beneath each impact category below. EVALUATE the magnitude, duration, and area of impact in each category and ENTER THE NUMERICAL SCORE in the appropriate box.	Impact MAGNITUDE	Impact DURATION	Impact AREA	LIST "Probable Issues" with each impact score below.	LIST "Probable Affected Publics" below.
1.0 SOCIAL IMPACTS (cont'd)					
1.3 Displacement Residential displacement: # of households, # of persons, characteristics of potential displacees. Commercial displacement: # of businesses, # of employees. Displacement of farmland. Displacement of community facilities. Relocation prospects. Attitudes toward relocation.					
2.0 ECONOMIC IMPACTS					
2.1 Employment, Income, and Business Activity Employment opportunities: as facility is built; when facility operates. Resident income effects. Business activity: firms displaced, firms bypassed, shopping & business pattern shifts, construction impacts, effects on commercial property values.					

Impact Scoring Codes

IMPACT MAGNITUDE		IMPACT DURATION	IMPACT AREA
+3 Strong Beneficial	-3 Severe Adverse	0 Construction	0 ROW
+2 Moderate Beneficial	-2 Moderate Adverse	1 Few Years	1 Adjacent Property
+1 Minor Beneficial	-1 Minor Adverse	2 Many Years	2 Neighborhood
0 Negligible or No Impact		3 Permanent	3 Study Area

Table 28. Level of impact assessment matrix (continued).

Important factors to consider are listed beneath each impact category below. EVALUATE the magnitude, duration, and area of impact in each category and ENTER THE NUMERICAL SCORE in the appropriate box.	Impact: MAGNITUDE	Impact: DURATION	Impact: AREA	LIST "Probable Issues" with each impact score below.	LIST "Probable Affected Publics" below.
2.0 ECONOMIC IMPACTS (cont'd)					
2.2 <u>Residential Activity</u> Housing stock. Demand for housing. Property values and housing costs.					
2.3 <u>Fiscal Impacts</u> Tax revenue losses and gains: displacement of private property, changes in property values, changes in economic activity. Costs of providing additional public services.					
2.4 <u>Land Use and Development Plans</u> Goals and objectives. Development plans by land use.					

Impact Scoring Codes

IMPACT MAGNITUDE		IMPACT DURATION	IMPACT AREA
+3 Strong Beneficial	-3 Severe Adverse	0 Construction	0 ROW
+2 Moderate Beneficial	-2 Moderate Adverse	1 Few Years	1 Adjacent Property
+1 Minor Beneficial	-1 Minor Adverse	2 Many Years	2 Neighborhood
0 Negligible or No Impact		3 Permanent	3 Study Area

Chapter 12. SUPPLEMENTAL DISPLAY MODES

As indicated in the preceding chapters, most socio-economic impact data can be presented effectively on maps and tables. Many times, however, the usefulness of information may be increased when selected data are arrayed in other display modes. These displays can convey valuable information which would be less meaningful in cartographic and tabular formats.

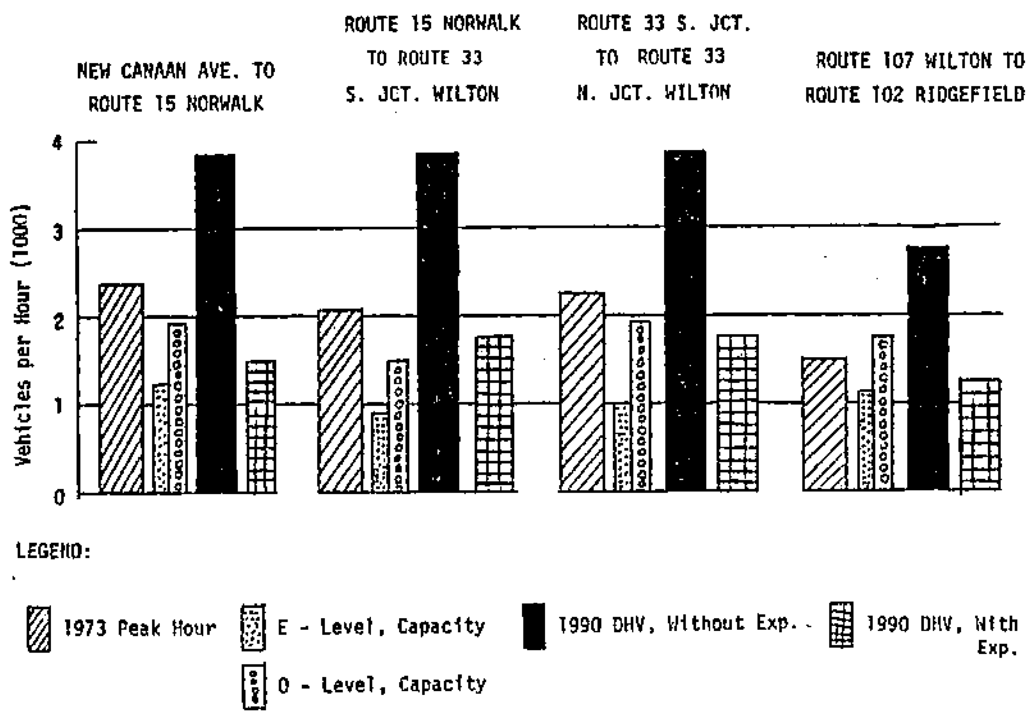
This chapter discusses the use of two types of supplemental displays: graphs and narrative summaries.

12.1 GRAPHS

Many categories of impact data shown in tables can also be displayed on graphs. Graphs typically present less information than tables, but they can bring out relationships and patterns in the data which are not apparent in tabular formats. Graphs can be used effectively to present frequency distributions pictorially, and to compare data across spatial units or over time. Like maps, graphs help planners make important assessments about a broad range of data. Graphs are also valuable tools for transmittig significant information about project impacts to readers of environmental documents.

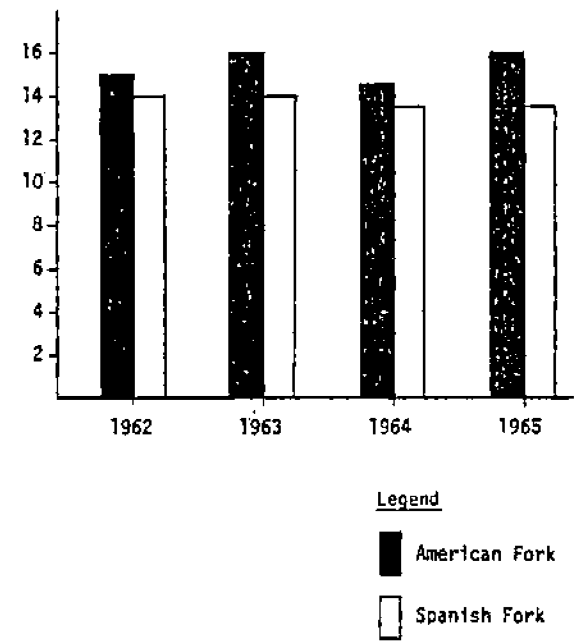
Figures 47-50 (pp. 185-187) are examples of bar graphs used to display impact data. The first two figures show information normally compiled in preliminary assessment; the other two show data normally prepared in detailed assessment. Figure 49, in particular, shows how comparisons across alignments can be made for an entire impact category. Here, displacement effects are compared in terms of impacted businesses, land area, and housing units.

Figure 50 shows how information previously recorded on a "Level of Impact Assessment Matrix" (see Table 28, pp. 181-183) can be graphically displayed. In this case, the expected duration of impacts is compared for two alternative alignments. Since it gives a concise, pictorial accounting of all seven socio-economic impact categories, this kind of graph is especially useful at the close of detailed assessment, when a preferred route is identified.



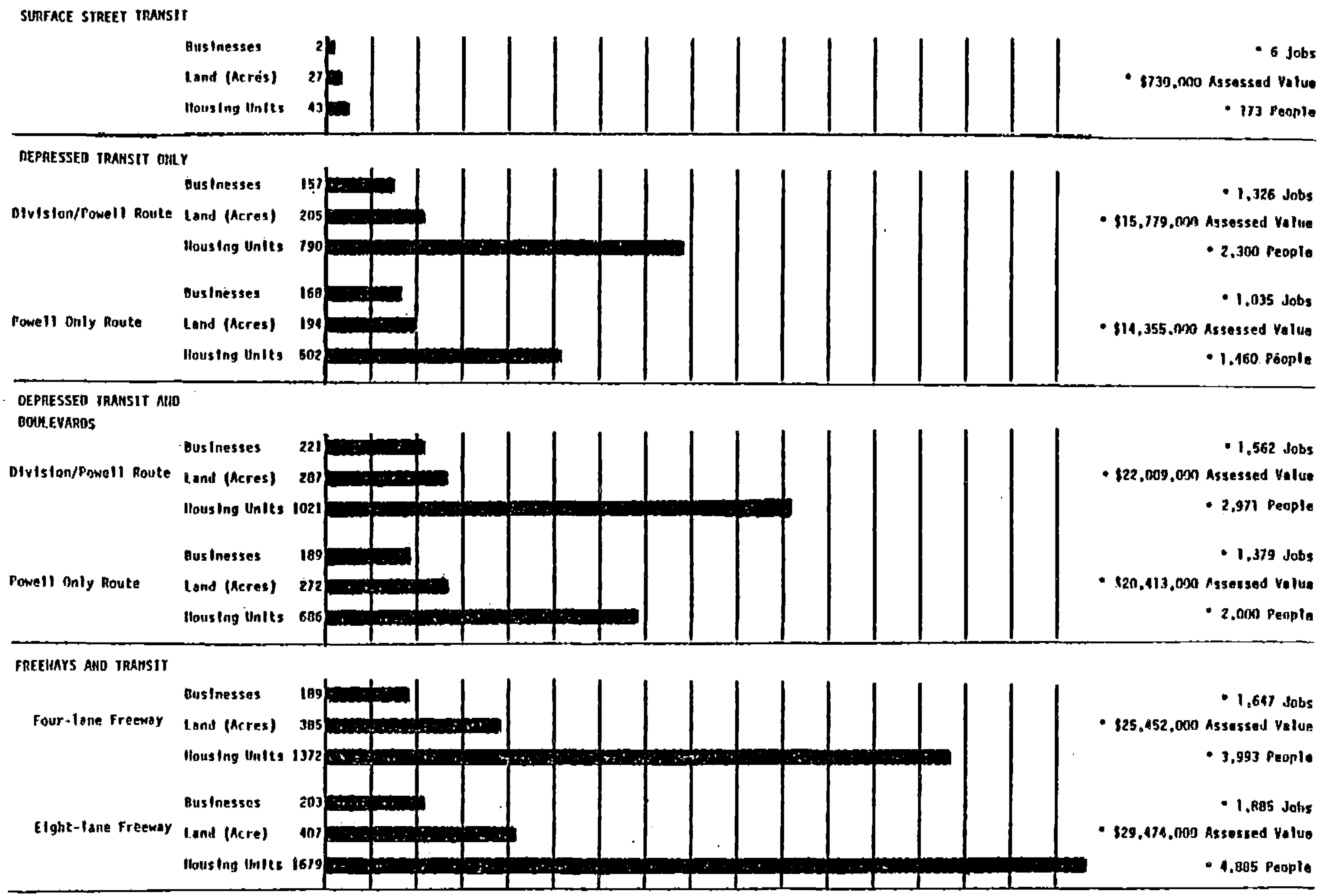
Source: Environmental Assessment Notebook Series, Notebook 5, p. 37.

Figure 47. Vehicular flow by route, 1973 and 1990.



Source: Economic and Social Effects of a Highway Bypass: American Fork, Utah, Volume 2, Utah State University for the Utah Department of Highways, 1968, p. 62.

Figure 48. Per capita retail sales by study subarea.



Source: Environmental Assessment Notebook Series, Notebook 5, p. 42.

Figure 49. Summary of displacement effects by highway alternatives.

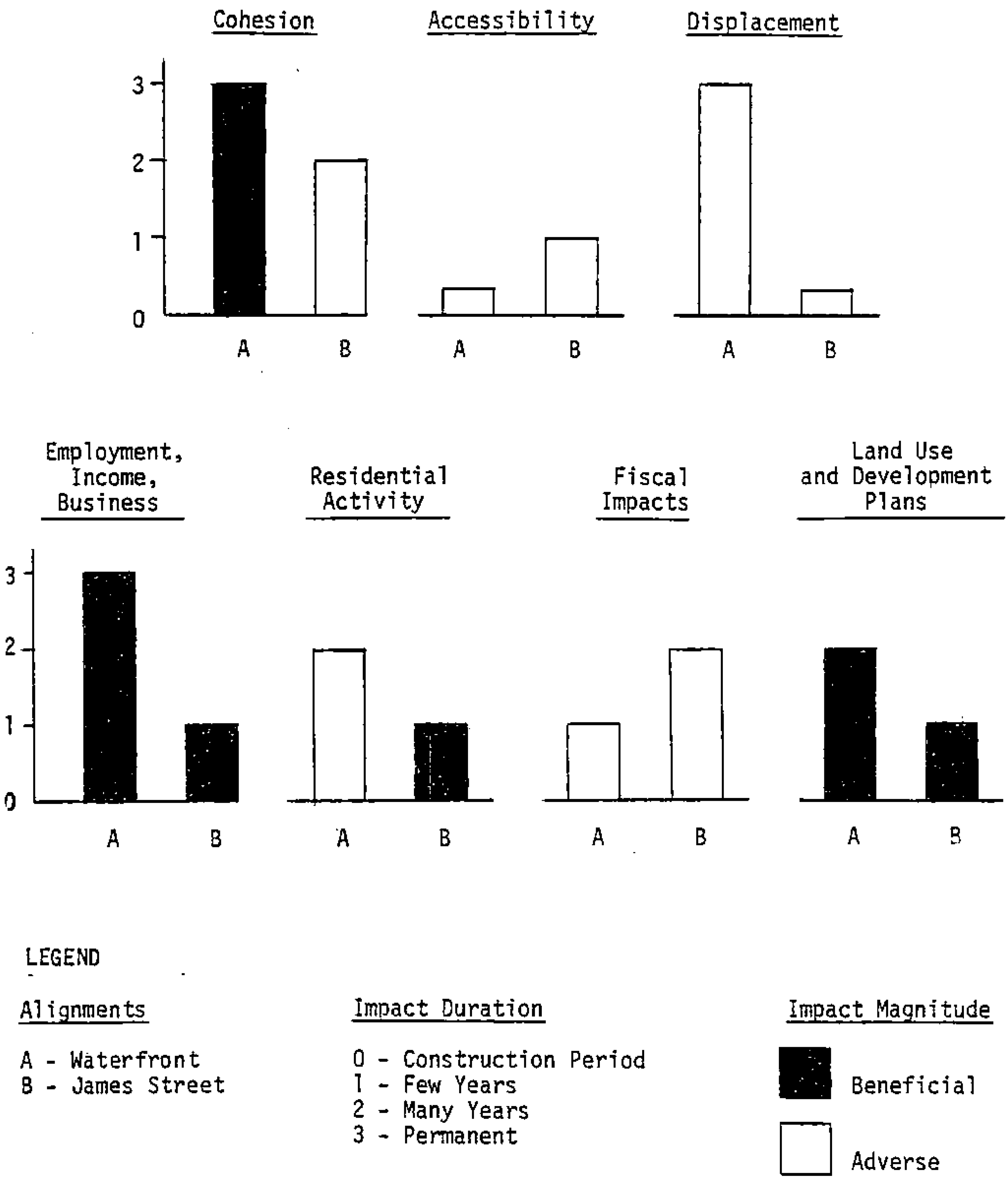


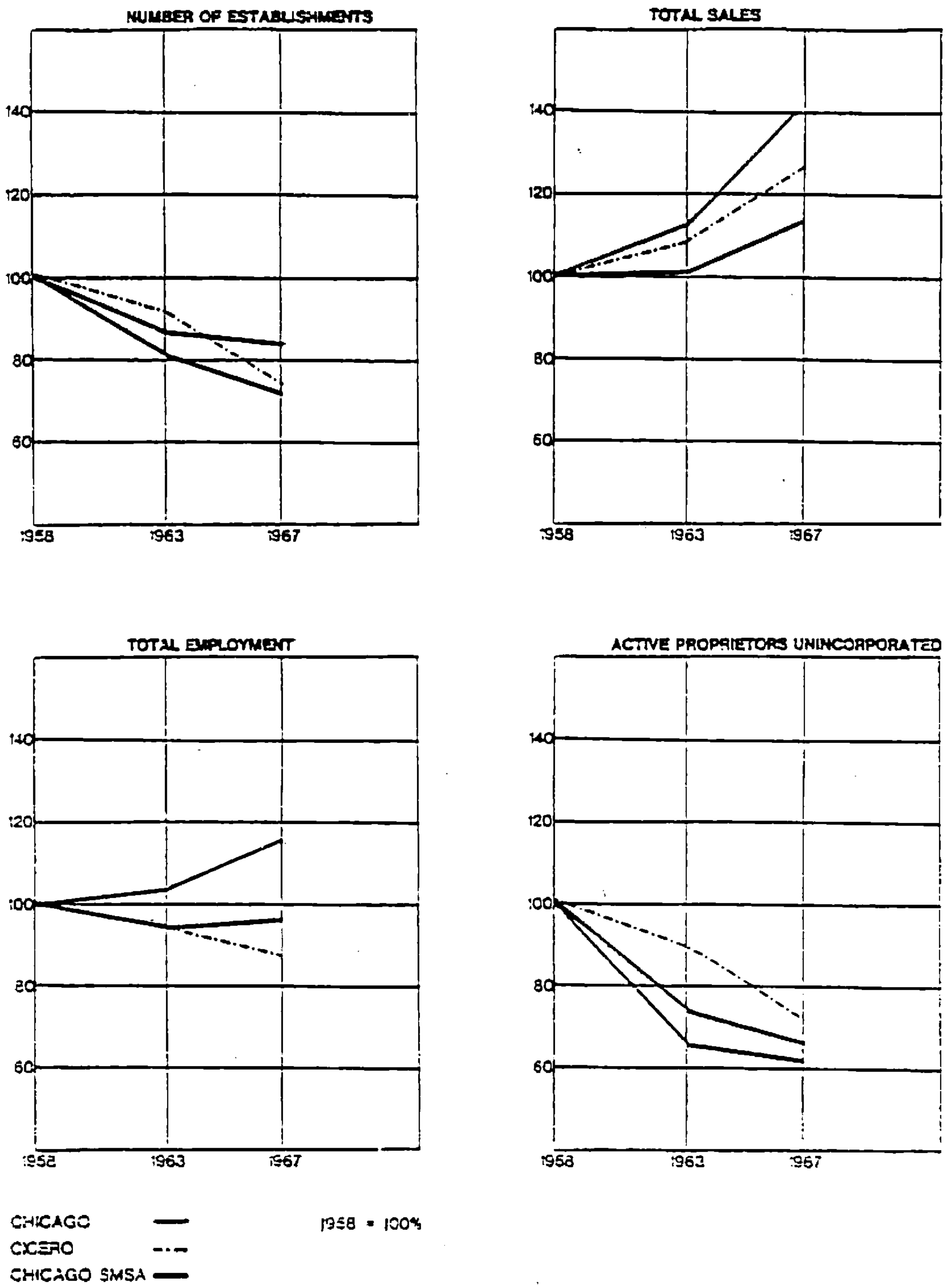
Figure 50. Summary of impact durations.

Examples of line graphs displaying impact data are shown in Figures 51 - 54 (pp. 189-192). The graphs in the first two figures, prepared in preliminary assessment, compare time-series data for different spatial units. These graphs present demographic, housing, retail, and employment data over a period of time which is sufficiently long that the associated trends are readily apparent. Identification of these trends is essential to the successful prediction of future patterns of growth and development in the study area.

The latter two figures show examples of line graphs prepared in detailed assessment. Figure 53 compares accessibility to employment opportunities for residents of a study area neighborhood, given the alternative choices of doing nothing or widening existing roads. It shows that virtually all job opportunities in the study area will be available to neighborhood residents, regardless of decisions about the proposed project. It also shows that the expanded facility would increase job opportunities available to residents within a fixed travel time. For example, while 20 percent of the study area's jobs are within 10 minutes travel time from Belleview, 45 percent of all jobs would lie within ten minutes travel time if the expansion project is completed. Similar graphs can be prepared to measure other socio-economic impacts.

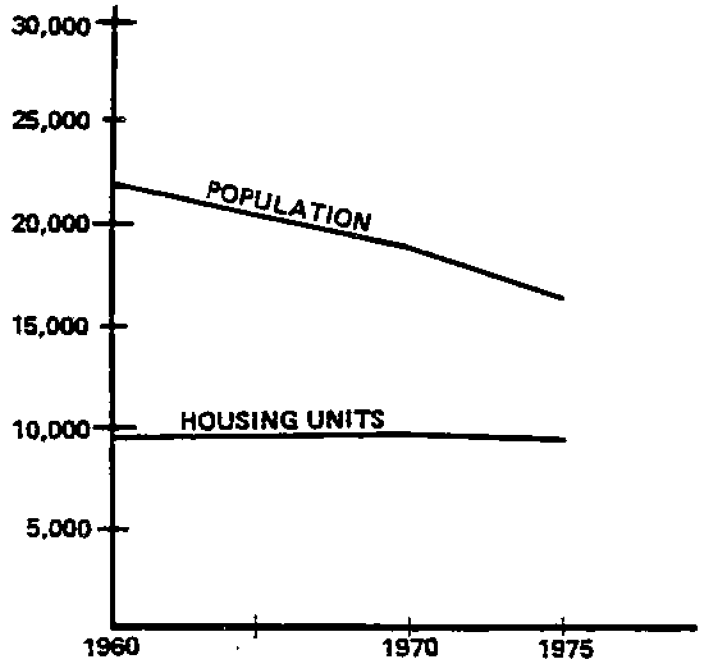
Figure 54 provides a pictorial representation of the expected magnitude of impacts -- for all seven impact categories -- across three alternative alignments. Like the bar graph in Figure 50, it draws on the tabular data presented in the "Level of Impact Assessment Matrix" (pp. 181-183). These graphs, which summarize vast amounts of information, may be used by practitioners to weigh the relative benefits and liabilities of each highway choice.

The impact graphs are particularly useful in the conduct of trade-off analyses. For instance, the impact curve for the no-build alternative indicates that while this option will not result in displacements, it is not likely to stimulate economic activity in the study area either. On the other hand, the impact curves for the two construction choices under consideration suggest that although displacements will occur, increased business, employment, and residential activity can be expected. Of the two construction choices, the

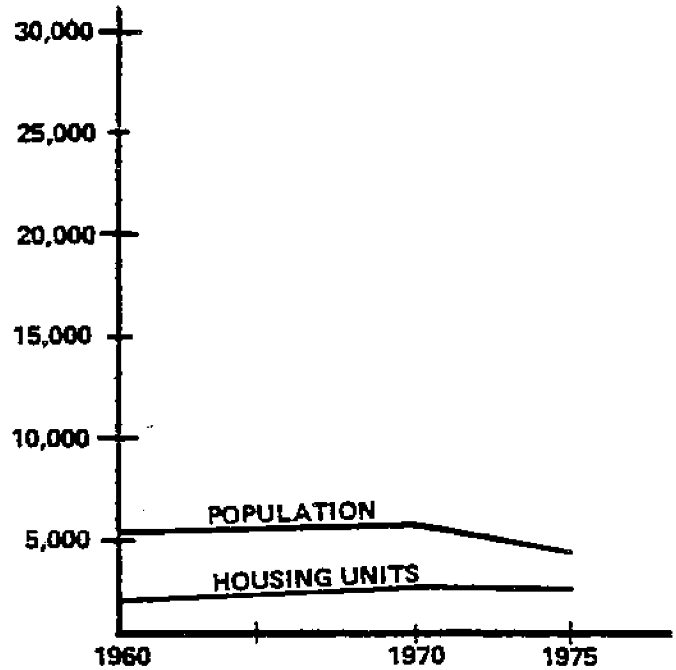


Source: Voorhees, p. 243.

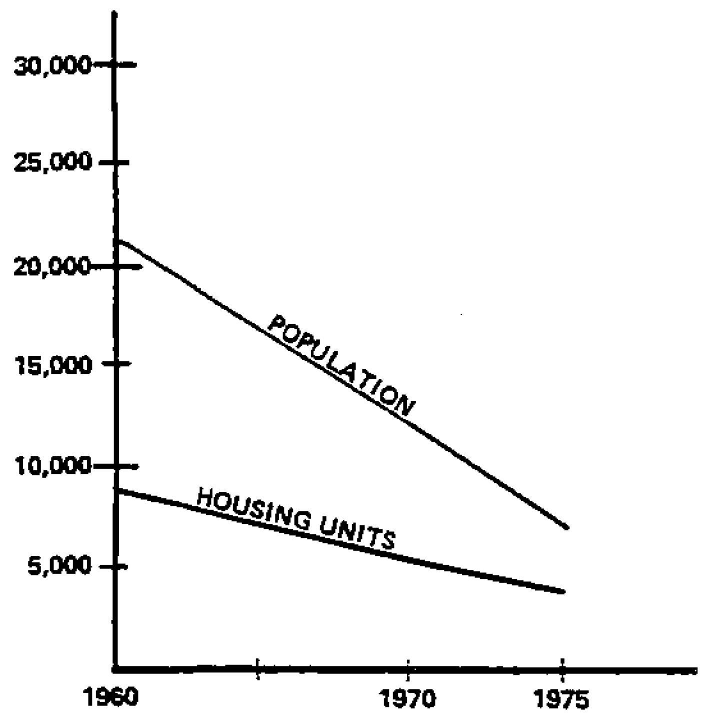
Figure 51. Business and retail trends for study subareas, 1958-1967.



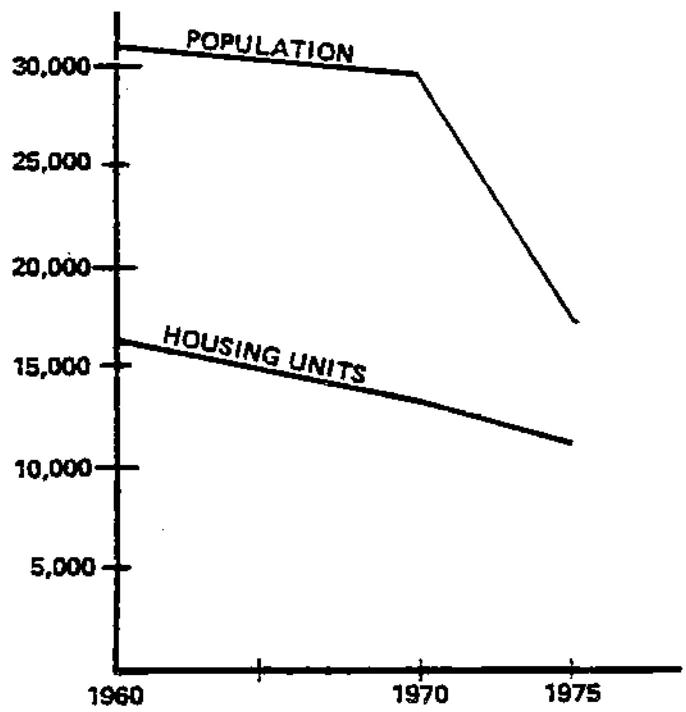
SUB-AREA 1: CROWN HEIGHTS/EDGEMERE (TRACTS—1001, 1003, 1006, 1007, 1008, 1010, 1011, 1012)



SUB-AREA 2: NORTH OF CAPITOL (TRACTS—1005, 1051)



SUB-AREA 3: HARRISON-WALNUT, LINCOLN-TERRACE, ETC. (TRACTS—1015, 1020, 1027, 1030, 1038)



SUB-AREA 4: HERITAGE HILLS, COMEBACK, ETC. (TRACTS—1016, 1017, 1018, 1019, 1024, 1025, 1031.01, 1031.02, 1032, 1033, 1034, 1035, 1036.02, 1037, 1040)

Source: Interstate 235 Central Expressway, p. 6-26.

Figure 52. Population and housing trends for study subareas, 1960-1975.

COMPARISON OF SOUTH RIDGE AND NO BUILD ALTERNATIVES

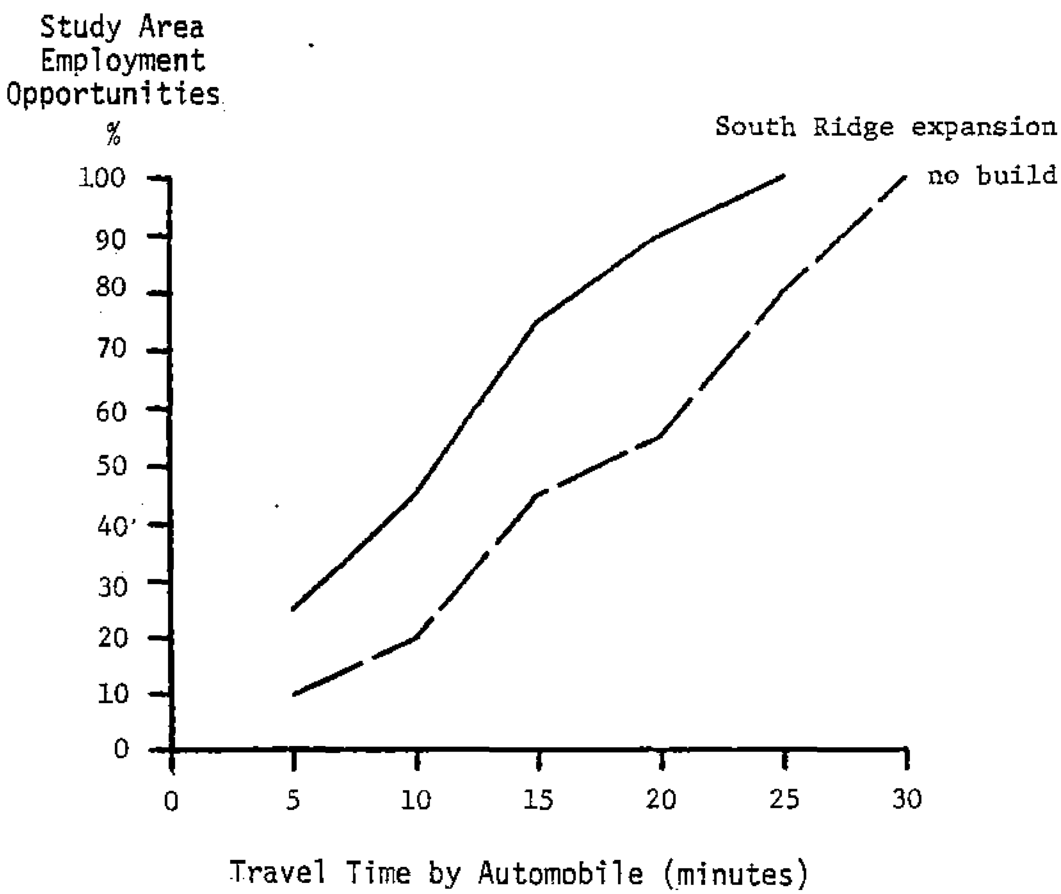
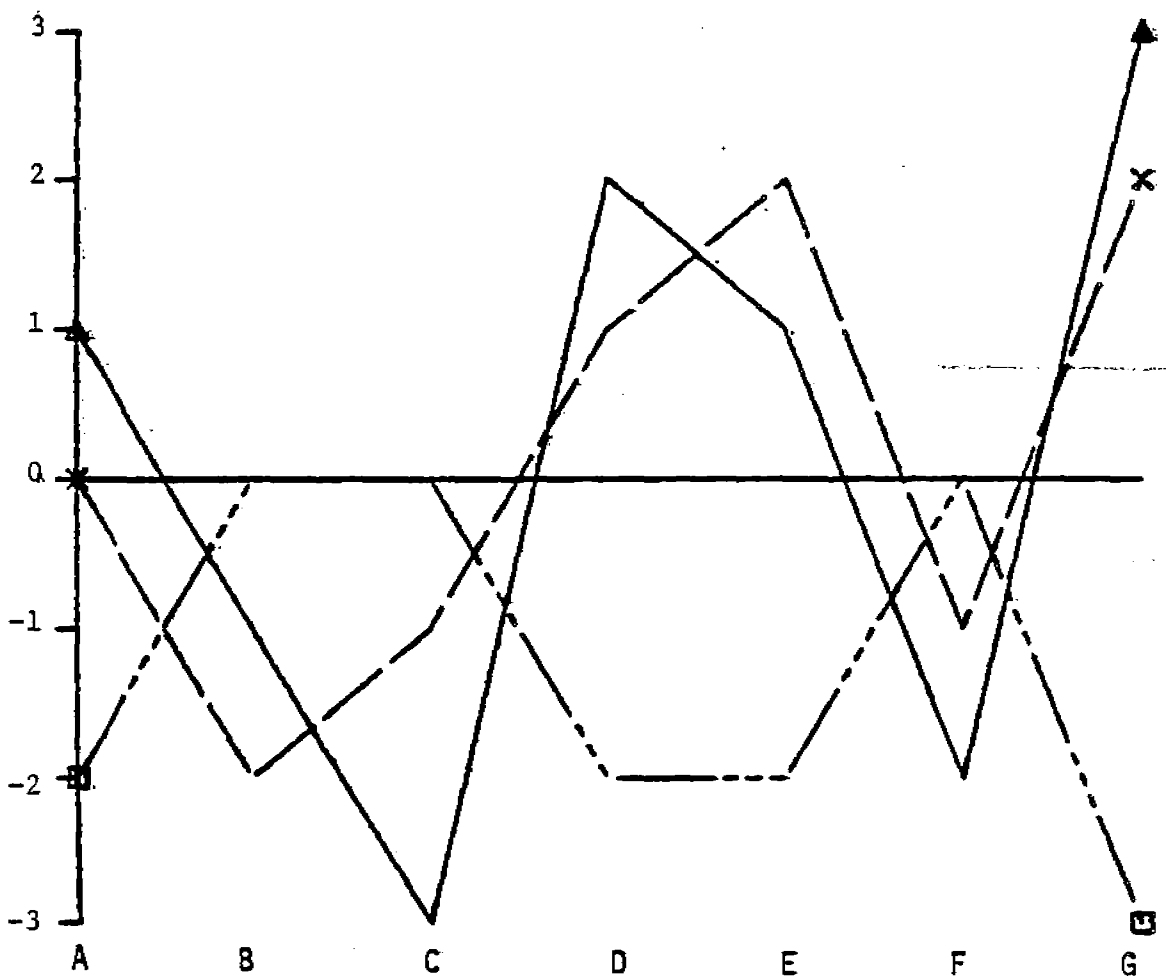


Figure 53. Accessibility to employment opportunities within study area for residents of Belleview Heights.

COMPARISON OF ALTERNATIVE ALIGNMENTS AND NO BUILD OPTIONS



LEGEND

▲ BREEZEWAY CORRIDOR

× MERRIMAC CORRIDOR

□ NO BUILD ALTERNATIVE

Impact Magnitude

+3 Major Beneficial
+2 Moderate Beneficial
+1 Minor Beneficial
 0 Negligible or no impact
-3 Severe Adverse
-2 Moderate Adverse
-1 Minor Adverse

Impacts

A - Cohesion
B - Accessibility
C - Displacement
D - Employment, Income, and Business
E - Residential Activity
F - Fiscal Impacts
G - Land Use and Development Plans

Figure 54. Magnitude of impact curves.

Breezeway alignment is expected to result in the greatest number of displacements. However, this alignment will also produce the highest levels of business activity.

12.2 NARRATIVE SUMMARIES

Narrative summaries present concise descriptions of socio-economic impact data. They are used to summarize findings and present data which cannot be meaningfully reduced to statistical or graphic form. The goals and objectives governing land use and development in a community are one example of information frequently presented in narrative form. Observations about the composite effect displacement will likely have on a particular family are another example.

Narratives are also used to augment cartographic and tabular displays. For instance, narratives might describe the location of alignments shown on accompanying maps. They might also summarize complex data displayed in adjoining tables.

Carefully written narratives prepared in preliminary and detailed assessment can often be used, largely verbatim, to document assessment findings in EIS's and other project documents.

Figures 55 - 59 (pp. 194-196) give examples of data recorded in narrative formats. The utility of the information presented in these narratives is self-explanatory.

Oklahoma-East Alternative

The Oklahoma-East Expressway alternative parallels the east side of the A.T. & S.F. railroad tracks from north of 36th Street to 7th Street, then proceeds diagonally to the Interchange with I-35/I-40. The expressway would be elevated from 36th Street to 15th Street; depressed from 15th Street to 5th Street; and then elevated from 5th Street to the I-35/ I-40 Interchange.

This alternative would tentatively provide either full or partial ramps at the following streets: 36th, 23rd, 21st, 11th, 6th, and 2nd Streets, Lincoln Boulevard and Sheridan Avenue. A connection to Reno Avenue would be provided as part of the I-35/I-40 Interchange improvements.

Source: Interstate 235 Central Expressway, p. 8-9.

Figure 55. Narrative description of alternative alignment.

Northwood Mall

The Northwood Mall will be located approximately two miles north of the State Capitol (0.8 miles south of the Tallahassee Mall) on North Monroe Street. Northwood, which is expected to open in 1969, will contain a total of 463,176 square feet, of which 60,000 square feet will be occupied by one department store. The other major tenant will be a supermarket. Mall space will occupy approximately 275,000 square feet on two levels.

Source: Voorhees, Social and Economic Considerations, p. 489.

Figure 56. Description of future development project in relation to alignment.

The New Valley Nature Center, 1001 North Forest Road, lies within the selected ROW. The center conducts afternoon, evening, and weekend programs for children and young adults, ages 5-17. Sixty-five children, on average, participate in the center's programs each day; 478 children have attended one or more center programs in the last six months. More than 70 percent of all program participants live in the Poplar Hills or Cedar Creeks developments, and nearly all of these children walk or bike to the center. Most of the programs revolve around the nature center's proximity to New Valley State Park, and include hikes and arts-and-crafts.

The center building is 65-by-40 feet, and consists of two large work rooms, a supplies closet and cleaning area, and two restrooms. The grounds of the center measure 125-by-65 feet, and include eight picnic tables. The nature center is operated jointly by the Department of Recreation and County School Board.

Figure 57. Narrative summary of facility replacement requirements.

ARLINGTON COUNTY

A. GOALS. Goals identified for Arlington County and relevant to the study are:

To develop a flexible and efficient transportation system.

To maintain and improve the quality of neighborhood life.

To provide a high standard of public services.

To continue a policy of limited, controlled growth.

To improve the fiscal situation of the County.

To make a wider range of social services available and accessible to all citizens of Arlington County, particularly the elderly, poor, handicapped and all minority groups.

To improve the quality of life for Arlington County residents by preserving and protecting the quality of the natural environment.

B. OBJECTIVES. Relevant objectives derived from these goals are as follows:

Transportation

1. Emphasize and actively promote public transportation.

2. Reduce reliance on private autos by expanding and improving public transport services.

3. Develop the ability to provide public transportation service, which will be a major determinant in future development on specific sites.

4. Improve cross-county and circumferential transportation facilities and services.

5. Make more efficient use of existing transporation facilities.

6. Promote a transportation system that provides maximum flexibility for citizens to adapt to future conditions that cannot be predicted.

Growth and Development

7. Limit high density development to targeted areas at rapid transit stations.

8. Preserve low-medium population density.

9. Preserve and acquire adequate open space to protect community amenities.

10. Encourage the completion of Rosslyn development.

11. Preserve single family neighborhoods.

12. Preserve older garden apartments.

Public Services

13. Better provide for recreation needs.

14. Improve health care facilities.

15. Increase police protection.

16. Provide adequate water and sewer service within population limits.

17. Maintain high quality of education.

Employment

18. Expand employment potential consistent with the best interests of the community.

19. Encourage the location of non-Federal employment in employment centers.

Environmental

20. Maintain air quality at acceptable levels.

21. Reduce noise pollution.

22. Reduce water utilization.

23. Control storm water runoff and stream erosion.

24. Preserve natural beauty of the Potomac Palisades and other natural features.

25. Ensure that future development enhances aesthetic values.

Fiscal

26. Retain real property tax rate.

27. Increase local revenue sources.

28. Reduce reliance on bonds for financing capital improvements.

Source: A summary of the Master Plan of Arlington County, Virginia, 1961.

Figure 58. Narrative summary of local land use and development.

NEIGHBORHOOD TYPE	LOCATION	CHARACTERISTICS OF RESIDENTS	SOCIAL CHARACTERISTICS	ECONOMIC CHARACTERISTICS
1 Skid Row District	Older parts of the inner city. Declining commercial or industrial areas	° Generally transients, the aged, or the poor ° Low levels of education ° Low levels of mobility; pedestrian oriented	° Few family ties - no family structure ° Lack of any shared behavioral or residential patterns	° Low income levels ° Facilities and services generally marginal operations run by institutions or elderly people ° No owner occupancy
2 Lower Class Apartments	Older parts of of the inner city	° All age groups ° Low levels of education ° Frequently female head of household ° High percentage of transients ° Low level of mobility - pedestrian oriented	° Existence of a family unit ° Some shared behavioral patterns but little identity with the particular area or group ° Interactions with those close by basically in form of "street activity" ° Low level of participation in formal activities	° Low income levels ° Facilities and services are marginal; may be run by institutions
3 Ethnic Neighborhoods	Older parts of the inner city. Often near existing industrial and commercial areas	° All age groups, large numbers of families (often extended) ° Low levels of education ° Low level of mobility - generally pedestrian oriented	° Areas of shared behavioral patterns ° Strong family unit; activities family oriented ° Identification with small geographic area ° Great identification with people of the area ° Fairly high level of participation in formal activities	° Lower income to lower middle income ° No owner occupancy ° Facilities and services often owned and operated by local people and often marginal
4 Middle to Upper Class Townhouses and Apartments	At the edge of the central business district, in some cities adjacent to major commercial centers	° Generally single people of all ages and childless couples ° High levels of education ° High mobility - less need for facilities within walking distance ° Possibly a high percentage of transients	° If population is largely transient, there will be a lack of shared patterns and a generally weak identification with the area ° If population is not transient, area characterized by shared perceptual patterns and general identification with the area ° High level of participation in formal community and neighborhood organizations	° Middle to upper income ° Some owner occupancy ° General facilities and services are small and expensive
5 Middle Class Single Family Homes and Apartments	The edge of the urban area before it becomes the suburbs No industry, only localized commercial establishments	° Older families and individuals ° High levels of education ° High levels of mobility; less need for facilities within walking distance	° Strong family unit ° Shared perceptual and behavioral patterns ° Good deal of informal and formal interaction ° Home ownership increases identity and commitment	° Middle to upper income ° High percentage of homeowners
6 Working Class Single Family Homes and Apartments	These areas exist in various parts of city, but originate generally near industrial or commercial sources of employment	° Older families and individuals ° Medium level of education ° Reasonably good mobility	° Strong family unit ° Shared behavioral patterns ° High levels of informal interaction ° Some formal interaction ° Strongly identify with commitment to the neighborhood	° Lower to middle income ° Fairly high percentage of home ownership
7 Upper Class Single Family Homes	Edge of urban area and suburbs Generally no industry; commercial facilities grouped in larger centers	° Older families ° Older childless couples ° High level of education ° High mobility; less need of facilities within walking distance	° Strong family unit ° Shared perceptual and behavioral patterns ° Good deal of formal and informal interaction ° High level of participation in formal community/neighborhood organizations	° Upper income ° Majority are homeowners ° Facilities and services generally high quality

Source: Adapted from Vorhaes, p. 93.

Figure 59. Typology of neighborhoods comprising study area.

Report No. FHWA-RD-83-

THE CONDUCT OF SOCIO-ECONOMIC IMPACT ASSESSMENTS: A MANUAL FOR STATE HIGHWAY PERSONNEL

Vol. II. Resource Materials

January 1983

User's Guide

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

Prepared for

FEDERAL HIGHWAY ADMINISTRATION

Offices of Research & Development

Washington, D.C. 20590

FOREWORD

This two-volume user's guide is designed for State highway personnel responsible for assessing the potential impacts of highway projects and reporting the results in environmental documents. It focuses on site-specific assessment activities performed in conjunction with Class I major actions and Class III environmental assessments.

The Manual was developed by J.A. Reyes Associates, Inc. Stan Jorgensen, Joel Ticatch, Linda Kobrin, and John Sheridan were the principal authors. Technical inputs and guidance were provided by Ron Giguere, FHWA project manager; Joan Bossert, Environmental Research Consultants, Ltd., Denver, Colorado; Dale Hilliard, Maryland State Department of Transportation; and Carl Miller, Oklahoma Department of Transportation. Doug Willier and Kathy Osen performed research assignments on the project; Lin Webster and Nan Boova produced the final copy. Mr. Jorgensen and Mr. Ticatch served as project director and principal investigator, respectively.

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16. Abstract

This Manual is designed to assist State highway personnel to assess the socio-economic impacts of new highway construction and major improvements. It presents procedures and tools intended to simplify the conduct of thorough, systematic assessments. Seven major impacts are covered, and techniques for examining the attitudes and perceptions of local residents and leaders receive special emphasis.

Volume II provides detailed technical information on (1) available data sources, (2) sampling approaches, and (3) analytic techniques which may be used to complete the assessment process.

This is the second of two volumes comprising the Manual. Volume I discusses "The Impact Assessment Process" (Report No. FHWA - RD - 83 -).

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CONTENTS

Volume I. The Impact Assessment Process

FIGURES

FIGURES (continued)

TABLES

CONTENTS

Volume II. Resource Materials

FIGURES

TABLES

INTRODUCTION

Since 1972, environmental impact assessments have been a required part of the planning process for all major highway projects supported by Federal Aid highway funds. In that year, the Federal Highway Administration (FHWA) published initial guidelines for implementing the transportation component of the National Environmental Policy Act (NEPA) of 1969. Over the past 10 years, these guidelines have been elaborated by FHWA (most notably in the Process Guidelines published in 1974) and adopted by many States.

Existing Federal and State guidelines provide general criteria and standards on (1) what impacts to look for when performing an assessment, and (2) the information to be assembled, analyzed, and presented in environmental documents which show assessment results. Road construction and improvement projects are normally planned and implemented at the State level. Therefore, State highway agency personnel are normally responsible for applying existing guidelines in the performance of assessments.

PURPOSE

This Manual is designed to be used by State highway personnel who are responsible for assessing the potential impacts of new highway projects and reporting the results in environmental documents. It focuses on the systematic assessment of site-specific displacement and proximity effects, and the use of findings to plan projects which stimulate positive socio-economic development and minimize adverse effects.

The Manual provides a set of checklists, procedures, and analytic techniques which State practitioners may use to:

- Define the information required to investigate impacts in study areas subject to displacement and proximity effects,
- Locate and collect this information, and
- Organize the information in formats which profile the areas subject to impacts and provide a basis for analyzing and documenting assessment findings.

The emphasis on performance of these basic activities is intended to simplify the assessment process, make it more cost-effective, and improve the quality of results.

COVERAGE

The Manual covers the assessment of social and economic impacts. Physical impacts, which are also examined in the environmental assessment process, are not covered.

The three social impacts examined are:

- Impacts on the accessibility of intra-community and outside destination points to community residents,
- Impacts on community and neighborhood cohesion, and
- Impacts on local residents caused by the displacement and forced relocation of households, local businesses, and community institutions within the right-of-way (ROW).

The four economic impacts examined are:

- Impacts on employment, income, and business activity caused by ROW acquisition and changes in accessibility,
- Impacts on residential activity, including changes in the cost and availability of existing housing, and the need for and rate of new construction in the study area,
- Fiscal impacts on local governments, including highway-induced changes in the local tax base and revenues, and in expenditures required to provide local government services, and
- Impacts on local land use and development plans.*

The Manual also covers techniques for profiling the attitudes and perceptions of local leaders, interest groups, businesspersons, and residents. Data of

*The categorization of social and economic impacts used here and throughout the Manual was developed by Skidmore, Owings and Merrill and presented in the Environmental Assessment Notebook Series (Washington: U.S. Department of Transportation, 1975). This work was a pioneering effort to codify the FHWA's guidelines and systemize the assessment activities needed to satisfy the established requirements.

special interest in this area include:

- The attitudes of respondents toward the proposed project,
- Their preferences on route location and design features, and
- Their perceptions concerning possible effects of the project on the social and economic life of affected communities.

The Manual provides guidance on the identification, collection, and presentation of data needed to explore the seven impact areas listed above, and to profile the attitudes and perceptions of potentially affected populations.

Assessment activities are normally conducted in two stages, referred to in the Manual as preliminary and detailed assessment. In preliminary assessment, practitioners identify concentrations of local residents and economic activities subject to project impacts and screen for indicators of special sensitivity to negative impacts. In detailed assessment, practitioners conduct an in-depth examination of the corridors defined by alternative alignments to determine the scope, magnitude, and duration of possible impacts.

ORGANIZATION

The Manual consists of two volumes. Volume I focuses on the three major steps in the assessment process: (1) identification of information requirements, (2) collection of data, and (3) presentation of findings. Volume II provides resource materials which can be used, as needed, to support the assessment and documentation activities described in the first volume.

The materials presented are designed for use with different types of highway projects in a variety of settings. Hence, users are free to select and use those sections of the Manual which satisfy their special needs.

Volume I: The Impact Assessment Process. The opening section of Volume I, The Context of Socio-Economic Impact Assessment, provides information which can be used to classify highway construction and improvement projects. It specifies the assessment activities and documentation requirements associated with each project category, and shows how these activities fit into the overall project planning process.

This section also discusses the seven major socio-economic impact areas examined in the assessment process. It covers the types of impacts to look for in each of these areas, and the information needed to screen for potential impacts and estimate their scope, magnitude, and duration. The discussion concludes with a description of information needed to profile the attitudes of affected populations towards the project and their perceptions concerning its possible effects.

The three main sections of Volume I focus on the mechanics of the assessment process. Part 1, Information Requirements, specifies the data needed to (1) define local study areas, (2) assess potential socio-economic impacts, and (3) profile public attitudes and perceptions. Core information requirements for completing both preliminary and detailed assessment activities are presented in a series of data fields. These fields are a checklist of the information potentially needed to conduct assessment under each of the impact areas treated in the Manual.

Part 2, Data Collection, examines the use of (1) maps, (2) records, and (3) surveys to collect socio-economic data. It identifies and discusses 9 map types, 21 record sources, and 7 survey techniques which are potential sources of the information requirements specified in Part 1.

A set of matrices is used to correlate individual data elements specified in the Part 1 data fields with the sources of these data. Since data collection activities are normally conducted by topic (e.g., population), rather than by type of impact (e.g., cohesion), the data/source matrices in Part 2 are organized in nine topical categories:

- Land use
- Community facilities
- Population
- Housing
- Business activity
- Employment
- Agriculture
- Local government finance
- Attitudes and perceptions

Part 2 concludes with a discussion of the trade-offs involved in using maps, records, and surveys as data sources. These sources are evaluated using the following criteria: (1) information available, (2) geographic units covered, (3) currency of data, (4) resources required to collect the data, and (5) reliability and validity of the data.

Part 3, Display and Analysis of Data, focuses on the use of (1) maps, (2) tables, (3) graphics, and (4) narrative formats to organize and present assessment data. These formats are used both to identify potentially adverse impacts and to present findings which meet Federal and State documentation requirements. Numerous examples are provided on the use of maps and mapping techniques, statistical and analytic tables, graphs, and narrative summaries for these purposes. Most of the examples are excerpted from environmental documents prepared by State highway agencies.

In summary, Volume I presents checklists, matrices, and procedures which can be used to complete the following assessment activities:

ACTIVITY	CONTENTS OF MANUAL	PERTINENT DISPLAYS
Define information requirements.	Part 1 specifies potential information requirements for each impact area.	Data fields are presented in Figures 3 - 11.
Locate sources and collect data.	Part 2 links individual data elements with their sources.	Topical matrices are presented in Figures 13 - 21.
Analyze and present findings.	Part 3 shows organizing mechanisms commonly used by practitioners to identify and estimate impacts and document findings.	Sample maps, tables, graphs, and narratives for organizing data are presented in Figures 22 - 59 and Tables 1 - 28.

Volume II: Resource Materials. Volume II provides backup materials -- detailed information on available data sources, sampling approaches, and analytic tools -- which may be used, as needed, to support the assessment activities described in Volume I.

Part 1, Information Sources, consists of an alphabetical listing and critical evaluation of the 9 map and 21 record sources covered in the Manual. The map sources which receive individual treatment are:

Aerial photographs
Census maps
Comprehensive plan maps
Land use maps
Plat maps
Soil maps
Statewide highway maps
USGS topographic maps
Zoning maps

The record sources examined are:

Agricultural statistics
Annual operating budgets
Building permit files
Business directories
Business licenses
Capital Improvement Programs
Census reports *
Classified ads
Community facility registers
Comprehensive plans
Criss-cross area directories
Employment statistics
Farm record cards
Health facilities directories
Library facilities directories
Multiple listing services
Population statistics
Property assessment records
Public property inventories
School directories
Zoning ordinances

Part 2, Survey Techniques, provides a listing and critical evaluation of the seven survey techniques covered in the Manual. These are:

Windshield surveys
Walk-through reconnaissance
Purposive surveys of area elites
Mini-surveys of area residents and businesses
Surveys of local facility managers
Surveys of area residents and businesses
Trip activity surveys

The description and evaluation of these survey approaches are followed by a series of questions and response categories which can be used to collect data using each technique.

Part 3, Sampling Procedures, describes state-of-the-art sampling methodologies. It focuses on the utility and limitations of different sampling plans in solving problems encountered in generating reliable survey results, while minimizing the cost of data collection.

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*Census reports covered include:
Block Statistics
County Business Patterns
Current Business Reports
Economic Census Reports
Tract Reports
Urban Transportation Planning Package

Part 4, Analytic Techniques, describes state-of-the-art analytic methodologies which can be applied in the assessment process. Each methodology is discussed in terms of its particular utility in identifying significant relationships among available socio-economic data and developing reliable measures of potential effects.

Volume II may be used in conjunction with Volume I, or read independently as a compendium of sources and techniques. The relationship between activities covered in the two volumes is shown below:

ACTIVITY	VOLUME I	VOLUME II
Define information requirements.	Part 1 specifies potential information requirements for each impact area.	
Locate sources and collect data.	Part 2 links individual data elements with their sources.	Part 1 examines the utility of specific map and record sources. Part 2 evaluates individual survey techniques, and includes questions and sample response categories. Part 3 provides technical coverage of random and non-random sampling methodologies.
Analyze and present findings.	Part 3 shows organizing mechanisms commonly used by practitioners to identify and estimate impacts and document findings.	Part 4 covers advanced analytic techniques.

* * * * *

The Manual is predicated on the belief that assessment activities can frequently be simplified, and the results improved, when practitioners concentrate on a limited number of clearly stated data requirements and widely available information sources. In this context, the information requirements covered serve as a checklist of the core socio-economic data needed to conduct impact assessments. The sources identified are those most commonly available. The presentational formats offered are those widely used in current documentation.

Part 1. INFORMATION SOURCES

This part focuses on the sources of the data needed to complete socio-economic impact assessments. Chapter 1 presents nine maps which are major sources of useful data. Chapter 2 presents 21 record sources which contain statistical and narrative information used in preliminary and detailed assessments.

The maps and records are presented in alphabetical order. The subsections under each entry are listed below:

- *Abstract* -- *provides an overview of the source.*
- *Utility* -- *links the source to the major subject areas which are covered.*
- *Coverage* -- *discusses the geographical units covered by data available in the source.*
- *Information* -- *a listing of specific data elements available in the source.*
- *Currency* -- *contains information on how current the data are, and on any scheduled updating procedures.*
- *Source* -- *provides the name and location of the organization(s) that originate the source materials.*
- *Retrieval* -- *describes steps necessary to gain access to the data.*

These subsections are designed to make practitioners aware of what each source offers, and to present information that can be used to evaluate its utility in meeting particular information requirements.

These materials may be used in conjunction with Volume I, Part 2, Data Collection. Whereas the matrices presented in Volume I link data requirements and sources, the chapters here provide a more detailed description of each source and explain how to get the information that each contains. The materials also have intrinsic value as listings of sources generally available to any practitioner conducting an assessment.

Chapter 1. MAP SOURCES

AERIAL PHOTOS

Abstract: The most common aerial photographs are taken perpendicular to (i.e., immediately over) an area and depict the tops of trees and roofs of buildings. Oblique aerial photos are shot at angles of less than 90° and show height or elevation more clearly. All aerial photos may be produced in a range of sizes and scales; topographic contours and names of roadways can be superimposed on them.

Utility: Identification of land use and topographic features. Comparison of current and dated photos provides visual documentation of land use trends.

Coverage: Most areas of the country are covered by aerial photographs. The USGS computerized system -- the Aerial Photography Summary Record System -- provides a centralized listing of available photographs from the 1930s forward.

Information:

- Aggregate Data on Land Use
  - Topographic features
    - waterways
    - woodlands
  - Land use by activity
- Aggregate Data on Community Facilities
  - Number
  - Location
  - Size
- Concentrations of Residential Structures
- Transportation Data
  - Roads
  - Bridges
  - Railroads
  - Airports

Currency: Varies.

Sources: National Cartographic Information Center, U.S. Geological Survey, 507 National Center, Reston, Virginia, 22092.
County and local governments.
Private aerial photography firms.

Retrieval: When ordering aerial photos from the National Cartographic Information Center, the geographic coordinates of the area of interest should be specified. If unavailable, the area can be circled on a USGS map, or on a State or local highway map. Special requirements should accompany the order. These include preferences on the type of film (i.e., black-and-white, color, color-infrared), approximate date of photograph, time of year, level of desired ground detail (eg., low altitude, photo scale, etc.), size, whether stereoscopic photos are desired, and the intended use of the photograph.

COMPREHENSIVE PLAN MAPS

See "Comprehensive Plans, Local" in Chapter 2.

CENSUS MAPS

See "Census Reports, Population and Housing Data" in Chapter 2.

LAND USE MAPS

Abstract: Maps showing existing land use depict how a community's land is currently being used.* Land use is classified typically as (1) single-family residential, (2) multi-family residential, (3) commercial, (4) industrial, (5) agricultural, or (6) open space. Though the classifications may vary by community, existing land maps provide a general description of what land has been developed and how it is being used.

Utility: Used to identify agricultural and land use characteristics.

Coverage: Counties and local municipalities.

Information:

Aggregate Data on Land Use	Aggregate Data on Agriculture
Land use by activity	Total acres
	Location

Currency: These maps are intended to be updated with every major change in land use. Actual practice varies by community.

Source: Regional, county or local planning commission.

Retrieval: Available for review on request. Copies may be purchased for a nominal fee.

PLAT MAPS

Abstract: Plat maps identify the location and dimensions of each parcel of property in local areas. Each lot created when property is divided into residential subdivisions, industrial parks, etc., is represented on the plat map. Information shown includes lot line dimensions, the location and dimension of utility and access easements, and the location of waterways, roads, and railroads.

Utility: Map overlays showing proposed ROW locations, used with plat maps, facilitate the identification of parcels within and near the ROW. Recent subdivision of property may indicate the owners' intentions to develop the property in the near future.

*Maps showing proposed land use indicate how a community wants land to be used at some point in the future. This type of map is frequently one component of a community's comprehensive plan.

Coverage: Counties and municipalities maintain plat maps of property in their jurisdictions.

Information: Data on Individual Parcels

- Property lines
- Property dimensions
- Access and utility
  - location
  - dimensions
- Acreage of lots
- Tax lot numbers
- Roads
- Railroads
- Waterways

Currency: Varies by municipality. Property lines and tax lot numbers are usually current, although other information may be dated.

Source: Real Estate Assessment or Property Management office of the county or municipality.

Retrieval: Available for review on request.

SOIL MAPS

Abstract: Soil is classified by texture, composition, percolation rate and other characteristics. Soil maps show the geographic distribution of each soil type found in an area. Topographic maps are commonly used as base maps for soil maps. Map scales and geograhic coverage vary depending on the variety of soils found, base map used, and size of the county or soil district.

Utility: Soil charateristics are factors to consider when the development potential of land is assessed. Prime agricultural land and land ill-suited for development can be identified.

Coverage: Counties and soil districts.

Information: Aggregate Data on Agriculture

- Soil characteristics
- Location of soil types
- Prime and unique farmlands
- Wetlands
- Waterways

Currency: Once an area is mapped, it is not usually revised unless environmental circumstances change.

Source: State Soil Conservation Service.

Retrieval: Available on request for a nominal fee. Technical assistance in interpreting the maps is also available.

STATEWIDE HIGHWAY MAPS

Abstract: An overview of the transportation network in each State is presented in the official State highway map. More detailed highway coverage is provided by a series of large-scale maps covering geographically confined sections of the State. The latter are generally organized by county, although county size frequently requires that two or more map sheets be used to present a single county. In addition to depicting the existing transportation network in a State, the large-scale highway maps show some community features.

Utility: Used to identify selected community and land use features.

Coverage: State.

Information:

- Aggregate Data on Land Use
  - Topographic features
    - waterways
    - mountains
    - woodlands
  - Boundaries
    - community
    - neighborhood
    - political
- Aggregate Data on Community Facilities
  - Government and municipal buildings
  - Military installations
  - Schools
  - Hospitals
  - Libraries
  - Religious facilities
  - Historical sites
  - Parks and recreation areas
- Transportation Data
  - Primary and secondary highways
  - Light-duty roads
  - Bridges and tunnels
  - Mass transit systems
  - Railroads
  - Airports
- Concentrations of Businesses

Currency: Generally, highway maps are regularly updated as a State's transportation network grows and changes. Practitioners, however, should communicate with State highway cartographers regarding data currency, particularly when using the maps as a primary source for profiling the study area. The publication date which appears on the map does not necessarily mean that all topographic features were field-verified as of that date.

Source: Map Distribution Section, State highway agency.

Retrieval: The appropriate map in the State highway series may be accessed when the counties comprising the study area are specified.

U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS

Abstract: Geological survey topographic maps depict natural and selected cultural features of an area. Contour lines, map symbols, and colors are used to show such features as the shape and elevation of terrain, water areas, roads, towns, and major buildings and landmarks. The topographic maps most commonly used are the standard quadrangles which include the 7.5-minute and 15-minute series.* The map scale in the 7.5-minute series is 1:24,000 (1 map inch represents 24,000 feet on the ground); the scale in

*A quadrangle, or quad, is the area of land shown on a single map sheet.

the 15-minute series is 1:62,500 (1 inch represents about 1 mile).* Approximately 75 percent of the United States has been mapped in one or both series.

Utility: Used to identify major community and selected land use features.

Coverage: Geological survey quadrangles cover geographic areas ranging in size from 49-71 square miles, in 7.5-minute maps, to 197-282 square miles in 15-minute maps. Quadrangles showing only neighborhoods and sections of towns, however, may be pieced together to examine municipalities, counties, regions, or States.

Information:

- Aggregate Data on Land Use
  - Topographic features
    - waterways
    - mountains & valleys
    - woodlands & marshes
    - orchards & vineyards
  - Boundaries
    - community
    - neighborhood
    - political
- Aggregate Data on Community Facilities
  - Government & municipal buildings
  - Military installations
  - Schools
  - Hospitals
  - Libraries
  - Religious facilities
  - Pits, mines, & quarries
  - Museums & historical sites
  - Parks & recreation areas
  - Reservoirs & wells
  - Utilities, towers, and pipelines
- Concentrations of Residential Structures
- Concentrations of Businesses
- Transportation Data
  - Primary and secondary highways
  - Light-duty roads
  - Bridges and tunnels
  - Mass transit systems
  - Railroads and train stations
  - Airports
  - Canals

Currency: The Geological Survey constantly updates the 7.5-minute and 15-minute maps. However, because all quadrangles in the series are not revised simultaneously, the currency of particular maps, even within a single State, can vary greatly. It is thus important for practitioners to be aware of the currency of maps covering the study area. The year the map was compiled from field surveys, revised from aerial photographs, and field checked (when applicable), is clearly indicated in the margin of each map. This information is also summarized in the State Index (see Retrieval, below).

Source: Geological Survey maps for areas east of the Mississippi River may be ordered from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202. Maps for areas west of the Mississippi River may be ordered from the Branch of Distribution, U.S. Geological Survey, Box 25286 Federal Center, Denver, Colorado 80225. The Geological Survey also maintains sales counters at a variety of locations

*The 7.5 minute maps show greater detail than any other topographic series providing nationwide coverage. For example, in non-urban areas covered by these maps, individual houses are shown.

around the country. Commercial dealers who sell topographic maps are listed in each State Index.

Retrieval: Each topographic map is identified by name, series and State. Detailed instructions on identifying and ordering the maps are provided in each State Index. State indices may be ordered, free of charge, from the distribution branches listed above.

ZONING MAPS

See "Zoning Ordinances" in Chapter 2.

AGRICULTURAL STATISTICS, STATE

Abstract: State Agricultural Statistics Bulletins provide comprehensive statistics on agricultural activities. These statistics cover (1) crop acreage, (2) the productivity and value of land, and (3) the number, output, and value of livestock. Data showing change over time are also normally available.

Utility: Highly useful in rural areas. Reliability of data varies by State, since reports are often based on responses to voluntary mail-out questionnaires.

Coverage: States and counties.

Information:

- Aggregate Data on Agriculture
  - Total acres
  - Number of farms
  - Average acres per farm
  - Acreage by crop
  - Average productivity per acre
  - Average revenues per acre
- Data on Individual Farms
  - Costs and revenues
    - operational costs per acre
    - revenues per acre

Currency: Updated annually. More current data are frequently available from State Departments of Agricultural (DOA).

Source: Issued cooperatively by the U.S. and State DOAs. The Crop and Livestock Reporting Services Division of each State DOA prepares statistical documents.

Retrieval: Available on request.

ANNUAL OPERATING BUDGETS, LOCAL GOVERNMENTS

Abstract: Local government units develop and operate under annual budgets which present projected revenues by source and expected expenditures by cost item. These budgets also contain balance sheets showing revenues and expenditures for previous years.

Utility: Used in the examination of local government finances.

Coverage: All local government units.

Information:

- Aggregate Assessment and Tax Data
  - Total tax base
  - Assessment rates
  - Property tax revenues
  - Other sources of funds
- Local Government Expenditures
  - New construction
  - Operations and maintenance costs
  - Interest charges

Currency: Budgetary documents are developed annually. Most government units also generate quarterly financial statements.

Source: Budget or Finance Departments of local government units.

Retrieval: Available on request.

BUILDING PERMIT FILES

Abstract: The building permit file consists of building permit applications and official building records. Prior to the construction, alteration, or demolition of a structure, a permit must be issued by the appropriate Building Inspector's office. The building permit application briefly describes work to be done and gives the dimensions of new structures planned. The official building record includes more detailed information such as (1) a site plan which shows existing structures and the dimensions of planned structures, (2) a record of all inspections, and (3) a record of other permits that have been issued, e.g., zoning and sewer permits.

Utility: A useful source of data on land use, housing, and business activity.

Coverage: Counties and incorporated municipalities.

Information:

- Scheduled Development Projects
  - Location
  - Land use type
  - Description of each project
  - Estimated development costs
  - Owner/developer
- Aggregate Housing Data
  - Total housing units
  - Housing types
  - Number of units in structure
  - Age of structure
  - Plumbing facilities
  - Kitchen facilities
  - Number of rooms
  - Year dwelling built
- Data on Individual Dwellings
  - Type of housing
  - Number of dwellings in unit
  - Location
  - Dimensions
  - Size of land parcel
  - Finished floor area
  - Number of floors
  - Number of rooms by type
  - Description of rooms
  - Style of unit
  - Condition
  - Special features
  - Condition of facade and building
  - Surrounding area
  - Land uses
  - Physical condition
- Housing Construction
  - Construction permits issued previous year
- Data on Individual Businesses
  - Street frontage
  - Physical plant/operating area
  - Street frontage
  - Acreage/square footage
  - Type of construction
  - Special features
  - Age

Currency: Once a permit is issued, the user has approximately 180 days to begin construction. If construction does not begin in the allotted time, the user must secure a new permit. Information is regularly updated as new permits are issued and ongoing projects are inspected.

Source: Local Building Inspectors' Offices and County Building Divisions within the County Planning or Zoning Department.

Retrieval: Permits for buildings within a municipality's boundaries are issued by the local Building Inspector's Office. These records are maintained at the local level. Permits for buildings outside the municipality, but within the county, are issued by the county Building Inspector's Office. In most cases, records are filed by location.

BUSINESS DIRECTORIES

Abstract: Business directories in most municipalities are published either by the local chamber of commerce or a private company. Formats vary, but typically include (1) alphabetical listings by name, (2) alphabetical listings by business type, and (3) listings by street name and address. Directories developed by the chamber of commerce may be limited to the area's largest employers or only to businesses which are members of the chamber.

Utility: Provides detailed data on employment and business activity.

Coverage: Municipalities.

Information:

Aggregate Data on Businesses
- Total businesses
  - by type (SIC)

Concentrations of Businesses
- Number
- Type
- Location

Data on Individual Businesses
- Name
- Type
- Location

Major Employment Areas
- Type
- Location
- Estimated number of employees

Currency: Currency varies, although the directories are frequently updated annually.

Source: Local chambers of commerce or private firms.

Retrieval: Can be reviewed at source or purchased for a fee. Local libraries often maintain reference copies.

BUSINESS LICENSE FILES, LOCAL

Abstract: Most municipalities require businesses to obtain a license to operate. License applications typically include information similar to, but considerably more detailed than, data found in business directories. The major drawback to using license files is that information on a particular business is often difficult to access. However, in recent years, some municipalities have automated license data, enabling users to retrieve listings by census tabulation area, SIC code, number of employees, and other criteria.

Utility: Business licenses are a source of detailed information on business activity and employment. However, records may be incomplete, difficult to access, or out-of-date.

Coverage: Most municipalities.

Information:

- Aggregate Data on Businesses
  - Total number of businesses
    - by industry (SIC)
    - by tenure
- Concentrations of Businesses
  - Number
  - Type
  - Location
  - Number of tenants
- Data on Individual Businesses
  - Name
  - Type
  - Location
  - Ownership
  - Years in operation
  - Years at current address
  - Employees
    - number by business
    - distribution by sex
    - distribution by occupation
    - distribution by ethnicity
- Aggregate Employment Data
  - Number by business
  - Distribution by sex
  - Distribution by labor category
  - Distribution by race/ethnicity
- Major Employment Areas
  - Number
  - Type
  - Location
  - Estimated number of employees

Currency: Normally updated annually. New businesses are required to have a license prior to opening.

Source: Municipal finance or business license office.

Retrieval: Users should contact the Finance Department or Office of Business Licenses for information regarding that municipality's recordkeeping procedures. If the licenses are organized by name only, and not cross-indexed by SIC, address, number of employees or other useful categories, extraction of pertinent data may prove difficult and time-consuming.

CAPITAL IMPROVEMENT PROGRAM FILES

Abstract: Capital Improvement Program (CIP) files document a municipality's planned capital expenditures, (e.g., non-operating expenditures for construction of a police station or acquisition of new parklands) for periods of five years or more. They also contain data on capital expenditures for improvement of existing facilities (e.g., an addition to the main library). Improvement plans are usually grouped by functional area (e.g., police protection).

Utility: CIP files may be used to determine (1) the number, type and location of facilities to be built or remodeled, and (2) the resources to be expended in these areas.

Coverage: Municipalities and other local government units.

Information: Aggregate Data on Community Facilities
- Type
- Location
- Physical description
  - year built
  - condition
- Service area boundaries
- Recommended facility-to-population standards
- Physical Description
  - size
  - capacity
  - date construction began
  - date operational
- Funding and administration
  - funding level
  - source of funds
  - owner
- Usage/capacity ratio

Planned Community Facilities
- Number
- Type
- Location

Currency: Varies by municipality. CIP files are normally updated annually to reflect project additions, deletions and amendments.

Source: Municipal planning or budget office.

Retrieval: Available from the originating office. Local libraries often maintain reference copies.

CENSUS REPORTS

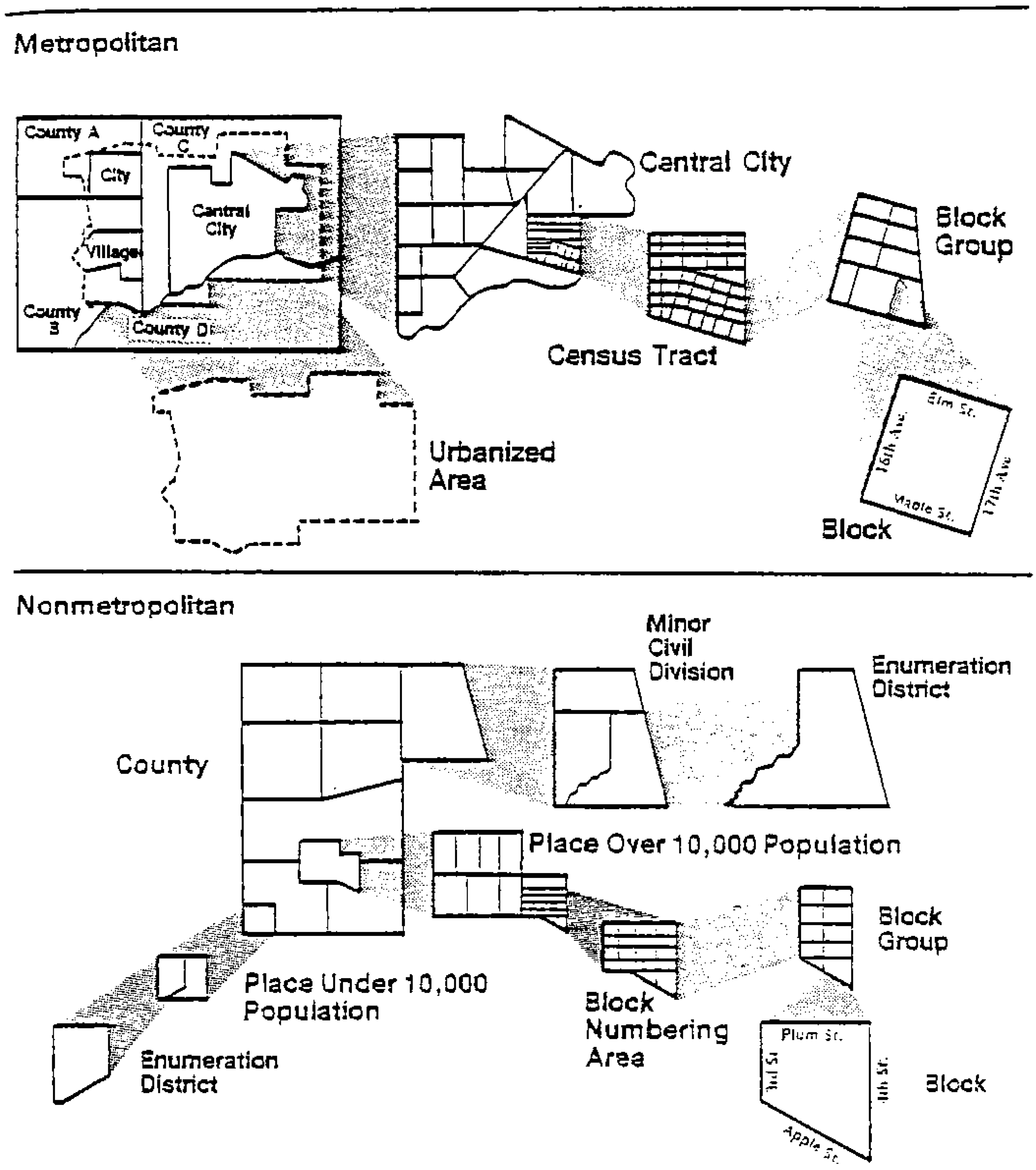
Two types of census surveys conducted by the U.S. Bureau of the Census provide standardized sources of nationwide data which play a central role in socio-economic impact assessments: (1) the population and housing census, and (2) the economic census. The former is conducted every 10 years and the latter every 5 years. The Bureau also conducts sample surveys on a more frequent basis. Survey findings are combined with data from administrative records to update data from the censuses. However, this updating is generally done at a high level of aggregation which makes the results of limited value to impact analysts.

The Bureau compiles data for the U.S., its regions and divisions, and the following political and statistical areas:

- Government Areas
  - States
  - Counties
  - Places (by population size)
  - Congressional Districts
  - Minor Civil Divisions (MCDs)
  - Indian reservations
  - Alaskan native villages
- Statistical Areas
  - Urban areas
  - Standard consolidated statistical areas (SCSAs)
  - Standard metropolitan statistical areas (SMSAs)
  - Census county divisions (CCDs)
  - Census tracts
  - Block groups
  - Blocks
  - Enumeration districts

Figure 1 (p. 20) shows the geographical hierarchy of statistical units covered in census reports.

SCSAs are consolidated SMSAs. An SMSA consists of a central city with a population of 50,000 or more, the county or counties in which it is located, and contiguous counties which are socially and economically integrated with the



Source: 1980 Census of Population and Housing, User's Guide, Part A, Bureau of the Census, U.S. Department of Commerce, p. 57.

Figure 1. Census geographic hierarchy.

central city. Urbanized areas are based on population density and consist of a central city and surrounding areas which have a combined population of 50,000 or more.

Places are either incorporated municipalities or concentrations of residences which the census designates as places. County subdivisions are either legal minor civil divisions (MCDs), usually called townships, or census county divisions (CCDs).

Census tracts are statistical divisions of SMSAs with an average population of 4,000. Blocks, averaging 60 people, are the smallest area for which census data are tabulated. They are used in urbanized areas with a population of 10,000 or more. Enumeration districts average 800 persons each, or around 250 households, and are assigned in non-blocked areas.

Census reports provide the core data required to profile the social and economic characteristics of the study area. They also provide time-series data which are used to identify trends and predict future changes.

Reports are available in one or more of the following media: (1) printed reports, (2) microfiche, and (3) summary tape files (STFs). Figure 2 (p. 22) shows the correlation between spatial unit coverage and storage media for major Census reports. Summary descriptions of the Census reports which are most useful in impact assessment are presented below.

CENSUS REPORTS: Population and Housing Data

Census Tracts

Abstract: Census tract reports present data for complete-count and sample-estimate population and housing questions collected during the decennial census. Data are tabulated by census tract and for larger statistical units of which the tracts are components. For tracts with 400 or more blacks, American Indians, Asians and Pacific Islanders, or persons of foreign origin, detailed data on these groups are presented on separate tables.

Utility: Are a primary source of demographic and housing data for impact assessments.

Coverage: SMSAs, counties aggregated by census tracts, and tracted places with populations of 10,000 or more.

Information:
- Aggregate Population Data
  - Population density
    - density per acre
    - persons per household
  - Total population
    - by age
    - by employment status
    - by occupation
    - by family income
    - by mode of travel to work
    - by automobiles available
    - by residence five years ago
    - by race/ethnicity
    - by marital status
    - household relationships
    - enrollment in school
  - Population trends
    - total population
    - density
    - race/ethnicity

	Type of data and series	Places: Under 1,000 pop.	Places: 1,000-2,499	Places: 2,500-9,999	10,000+ pop.	Counties	Minor civil divisions (MCD's) in 20 States	Census county divisions (CCD's) bal. of MCD's	School and special districts	Census tracts	Block numbering areas	Enumeration districts/block groups	Blocks	Indian reservations and Alaska Native villages	Congressional districts	Remarks
POPULATION AND HOUSING	PHC80-V, Final Population and Housing Counts	□	□	□	□	□	□	□							□	*Incorporated places only
	PHC80-1, Block Statistics	▦	▦	▦	▦	▦	▦	▦		▦	▦		▦			*Only areas where statistics collected by block
	PHC80-2, Census Tracts				▦	▦				▦						*Only in counties with census tracts
	PHC80-3, Summary Characteristics for Governmental Units and SMSA's	□	□	□	□	□	□									*Incorporated places only
	STF 1 (Complete count data)	⊕ ▦	⊕ ▦	⊕ ▦	⊕ ▦	⊕ ▦	⊕ ▦	⊕ ▦		⊕ ▦	⊕ ▦	⊕ ▦	⊕		⊕ ▦	
	STF 2 (Complete count data)		⊕	⊕	⊕	⊕	⊕	⊕		⊕				⊕		
	STF 3 (Sample estimate data)	⊕	⊕	⊕	⊕	⊕	⊕	⊕		⊕		⊕			⊕	
	STF 4 (Sample estimate data)			⊕	⊕	⊕	⊕	⊕		⊕				⊕		
POPULATION	PC80-1-A, Number of Inhabitants	□	□	□	□	□	□	□								
	PC80-1-B, General Population Characteristics		□	□	□	□	□	□						□		
	PC80-1-C, General Social and Economic Characteristics			□	□	□								□		
	P-25, Population Estimates and Projections	□ ⊕	□ ⊕	□ ⊕	□ ⊕	□ ⊕	□ ⊕									*Incorporated places only
	P-26, Population Estimates					□ ⊕										
	P-28, Special Censuses	□	□	□	□	□	□	□		□		□				*By contract only
HOUSING	HC80-1-A, General Housing Characteristics		□	□	□	□	□	□						□		
	HC80-1-B, Detailed Housing Characteristics			□	□	□										
	C40, Housing Authorized by Building Permits and Public Contracts	□	□	□	□	□	□									*16,000 permit-issuing jurisdictions
AGRICULTURE	Vol. 1, State and County Data					□ ⊕										
	Vol. III, Agricultural Services					□										
	Vol. V, Special Reports					□										
	A20, A30, Cotton Ginnings					□										
ECONOMIC	RC77-A, Retail Trade			□ ⊕	□ ⊕	□ ⊕										
	WC77-A, Wholesale Trade			□ ⊕	□ ⊕	□ ⊕										
	SC77-A, Service Industries			□ ⊕	□ ⊕	□ ⊕										
	MC77-A, Manufactures			□ ⊕	□ ⊕	□ ⊕										*Based on No. of eligible firms, not pop. size
	MIC77-A, Mineral Industries					□ ⊕										
	MB77, Minority-Owned Businesses				□	□										*Do
	WB77, Women-Owned Businesses				□	□										*Do
	CBP, County Business Patterns					□ ⊕										
GOVERNMENTS	Vol. 1, Governmental Organization					□										
	Vol. 2, Taxable Property Values and Assessment-Sales Price Ratios					□	□	□								Selected local areas
	Vol. 3, Government Employment	⊕	⊕	⊕	□ ⊕	□ ⊕	□ ⊕	□ ⊕								No CCD's
	Vol. 4, Government Finances	⊕	⊕	⊕	□ ⊕	□ ⊕	□ ⊕	□ ⊕	□ ⊕							*Do
	Vol. 5, Local Government in Metropolitan Areas				□											Inside SMSA's only
	Vol. 6, Topical Studies				Regional organizations (□)											
	GE, Government Employment (Annual)				□ ⊕	□ ⊕										*Local government with less than 50,000 pop.
	GF, Government Finance Reports (Annual)				□ ⊕	□ ⊕										*Do
	GT, Quarterly Summary of State and Local Tax Revenue					□										

Printed report □
Summary tapes ⊕
Microfiche only ▦

Source: Factfinder for the Nation, Bureau of the Census, U.S. Department of Commerce, September 1981, p. 9.

Figure 2. Small-community areas covered in reports and summary tape files (STFs).

Aggregate Housing Data	Year dweller moved in
Total housing units	Value of home (if owned)
by type	Monthly homeowner costs
by units in structure	Monthly rent (if rented)
by age of structure	Monthly utility costs
Vacancy rates	Residential Concentrations
Tenure	Ethnic minorities
owner-occupied	Foreign-born
renter-occupied	Non-English speaking
Presence of plumbing facilities	Female-headed households
	Low-income households
Presence of kitchen facilities	Housing Construction
	Trends
Number of rooms	tenure
Persons per room	housing costs

Currency: Population and housing censuses are conducted every 10 years, in years ending in "0".

Source: U.S. Department of Commerce, Bureau of the Census. 1980 tract data are available in printed reports, Series PHC80-2, Census Tracts. All four STFs provide tract-level data. STFs 1 and 2 contain data based on a complete count; STFs 3 and 4 contain sample-estimate data. STFs 2 and 4 offer more detail than do STFs 1 and 3.

Retrieval: Available as a printed report, on microfiche and on computer tape.* Printed copies may be used at or ordered from Department of Commerce district offices and Census regional offices. Libraries and State Data Centers often have reference copies available. Microfiche and computer tapes may be purchased from the Data User Services Division (DUSD), Bureau of the Census, Washington, D.C. 20233.

To extract data for a particular study area from a printed report, identify the tract numbers on the appropriate tract outline map (available with the tract report), and then locate pertinent data element for those tracts in the corresponding report. Tract data are generally arranged alphabetically by SMSA, and then numerically by county and principal cities within the county. Since tract boundaries frequently cross municipal or county lines, it may be necessary to review data elements under multiple listings. Detailed information on accessing tract data from the STFs is provided in the 1980 Census User's Guide, Part B.

*Data from complete-count questions are on STF 2. Data from sample questions are on STF 4.

Block Statistics

Abstract: Block reports are the only source of census data tabulated at the block level. Block data are limited to complete-count questions.

Utility: Blocks are the smallest statistical units for which census data are reported. Block reports provide population and housing data in detailed assessment.

Coverage: Urbanized areas, incorporated places of 10,000 persons or more, and other areas which have contracted for block-level statistics.

Information:

- Aggregate Population Data
  - Population density
    - persons per household
  - Total population
    - by age
    - by race/ethnicity
    - by marital status
    - by household relationship
  - Population trends
    - total population
    - race/ethnicity
- Aggregate Housing Data
  - Total housing units
    - by housing type
    - by units in structure
    - by tenure
    - by number of rooms
    - by persons per room
    - by value of home (if owned)
    - by monthly rent (if rented)
  - Vacancy rate
  - Number with plumbing facilities
- Housing Construction
  - Trends
    - tenure
    - housing costs

Currency: Block statistics are collected during each decennial population and housing census, in years ending in "0".

Source: 1980 block data are available on microfiche, Series PHC80-1, Block Statistics. STF 1 provides both block-level and enumeration district data.

Retrieval: To extract block data for a particular study area from microfiche, identify the block numbers on the appropriate Metropolitan Vicinity Map (available with the block report), and then locate the pertinent data elements for those blocks on the corresponding microfilm sheet.* Block data are arranged alphabetically by State, then by urban area; tracts and blocks are listed numerically in chronological order. Detailed information on accessing block and enumeration data from the STFs is provided in the 1980 Census User's Guide, Part B.

*Maps in the Metropolitan Vicinity Map Series, though they show block boundaries and major roadways, are not always current. These maps should be used only to identify census tracts and blocks, and not for other profiling purposes.

Urban Transportation Planning Package

Abstract: The Urban Transportation Planning Package (UTPP), available through the Census Bureau, is a special computer software program which provides a predefined set of tabulations for SMSAs and urban and rural subareas. The program compiles data on the characteristics of (1) persons by census tract and block group, (2) workers by census tract and block group, and (3) the traffic flows between major residential and employment areas.

Utility: This source is particularly useful in areas with a heavy flow of traffic to and from major employment centers.

Coverage: SMSAs.

Information:

- Aggregate Population Data
  - Population density
    - density per acre
    - persons per household
  - Total population
    - by age
    - by race/ethnicity
    - by marital status
    - by household relationships
    - by enrollment in school
    - by employment status
    - by occupation
    - by family income
    - by mode of travel to work
    - by automobiles available
    - by residence five years ago
  - Population trends
    - total number
    - density
    - race/ethnicity
    - income
- Residential Concentrations
  - Population centers
  - Ethnic minorities
  - Foreign-born
  - Non-English speaking
  - Female-headed households
  - Low-income households
- Aggregate Housing Data
  - Total housing units
    - by type
    - by units in structure
    - by age of structure
    - by tenure
    - by number of rooms
    - by year dweller moved in
    - by value of home (if owned)
    - by monthly rent (if rented)
  - Presence of plumbing fac'ties
  - Presence of kitchen fac'ties
  - Vacancy rate
- Housing Construction
  - Trends
    - tenure
    - housing costs

Currency: Population and housing censuses are conducted every 10 years, in years ending in "0".

Source: U.S. Department of Commerce, Bureau of the Census.

Retrieval: Available on microfiche and STF 1. Microfiche may be purchased from the Government Printing Office, Washington, D.C. 20402. Libraries and State Data Centers may have microfiche available for use. Printed copies may be purchased from the Data User Services Division (DUSD), on request. Computer tapes or printouts may be purchased from DUSD or State Data Centers.

CENSUS REPORTS: Economic Census Data

Abstract: Economic census reports provide a standard data base on business activities. Individual reports cover: (1) retail trade, (2) wholesale trade, (3) service industries, (4) construction industries, (5) manufactures, and (6) mineral industries. Data are gathered through questionnaires and administrative records, and tabulated using the Standard Industrial Classification (SIC) system.*

Utility: Are a primary source of statistical data on business activities.

Coverage: Figure 3 (p. 27) shows the geographic coverage of pertinent 1977 Economic Census reports.

Information:

	Total No. by Type	Total No. by Type of Organization	Total Sales by Type
Retail Trade	X	X	X
Wholesale Trade	X		X
Service Industries	X	X	X
Construction Industries	X†	X	X†
Manufactures	X†		
Mineral Industries	X†		

(†Data for all establishments with payrolls.)

Currency: Economic censuses are conducted every 5 years, in years ending in "2" and "7".

Source: U.S. Department of Commerce, Bureau of the Census.

Retrieval: Available in printed reports and on computer tape. Printed reports are available at many libraries, most Census Bureau regional offices, and Commerce Department district offices. Copies may be purchased from the Government Printing Office. Computer tapes may be purchased from the Data User Services Division, Bureau of the Census, Washington, D.C., 20233.

County Business Patterns

Abstract: This Census Bureau publication contains economic data collected from records maintained by county governments and through annual surveys. The data are similar to the information in the economic census reports, except they are reported annually.

*The Department of Commerce's SIC system numerically classifies businesses by their primary activity. Two digit numbers are assigned to major groups of economic activity, e.g., "food stores." Three digits represent industry subgroups, e.g., "food stores, retail bakeries." Four digits identify industries in even greater detail, e.g., "food stores, retail bakeries -- baking and selling."

Selected 1977 Economic Censuses reports		State	SMSA's and SCSA's	Summary for area outside SMSA's	Selected counties	All counties	Major cities	Towns, townships, & unincorporated places [1]	All incorporated places with 2,500 or more population
RC77-A	Retail Trade—Geographic Area Series:								
	Detailed Kind-of-Business Data.	X	X	X[2]	X[3]		X[3]	X[3]	X
	Limited Kind-of-Business Data					X		X	X
RC77-C	Retail Trade—Major Retail Centers								
	Series.		X[4]				X[5]		
RC77-L	Retail Trade—Merchandise Line								
	Sales Series	X[2]	X[2,4]	X[2]					
WC77-A	Wholesale Trade—Geographic Area Series:								
	Detailed Kind-of-Business Data.	X	X	X[2]	X[9]		X[3]	X[3]	
	No Kind-of-Business Data					X	X	X	X
SC77-A	Services Industries—Geographic Area Series:								
	Detailed Kind-of-Business Data.	X	X	X[2]	X[3]		X[3]	X[3]	
	Limited Kind-of-Business Data					X		X	X
CC77-A	Construction—Geographic Area Series.	X	X[6]						
MC77-A	Manufactures—Geographic Area Series:								
	Detailed Industry Data	X	X		X[7]		X[7]	X[7]	X[7]
	No Industry Data.					X			
MIC77-A	Mineral Industries—Geographic Area Series:								
	Detailed Industry Data	X			X[8]				
	No Industry Data.					X[8]			

[1] Towns in the New England States which include an urban population (cluster of population of 2,500 or more) or have a total population of 10,000 or more; townships in New Jersey and Pennsylvania with a population of 10,000 or more; and unincorporated places with a population of 25,000 or more.
[2] Available only on microfiche.
[3] Counties, cities, towns, and unincorporated places with 500 establishments or more.
[4] SMSA's only.
[5] Cities containing central business districts and major retail centers.
[6] Selected SMSA's only, based on a 1970 population of 500,000 or more.
[7] Only industry groups with 450 or more manufacturing employees are shown.
[8] Only counties or industry groups within a county with $5 million in total value of shipments are shown.
[9] Only counties in the 200 wholesale establishments or more.

Source: Mini-Guide to the 1977 Economic Censuses, Bureau of the Census, U.S. Department of Commerce, p. 5.

Figure 3. Primary geographic areas for which 1977 Economic Census data are available.

Utility: This source can be used to update county-level data reported in the economic census, and to detect trends.

Coverage: Counties.

Information: Aggregate Employment Data
- Employment by industry (SIC)

Aggregate Data on Businesses
- Total businesses by type (SIC)

Currency: Updated annually.

Source: U.S. Department of Commerce, Bureau of the Census.

Retrieval: May be purchased from the Government Printing Office, Washington, D.C. 20402.

Current Business Reports

Abstract: This printed report provides economic data on retail and wholesale trade and selected service industries. Estimates are based on sample surveys. Data are presented in both unadjusted and adjusted (for seasonal variations) form. Historical data are also included.

Utility: Useful for updating other sources of economic data and identifying short-term trends.

Coverage: United States, selected large States, SMSAs, and cities.

Information: Aggregate Data on Businesses
- Number by type
- Total revenues by type

Currency: Issued monthly.

Source: U.S. Department of Commerce, Bureau of the Census.

Retrieval: Order forms available from Subscriber Services Section (Publications), Bureau of the Census, Washington, D.C. 20233; Census Bureau Regional Offices; U.S. Department of Commerce District Offices; and State Data Centers.

CLASSIFIED ADS

Abstract: Classified ads in local newspapers provide information on employment opportunities and the availability of goods, services, and property. Job descriptions are often limited, but normally include an address or phone number, making follow-up possible.

Utility: Provide insight into the availability of residential and business properties for sale or lease and employment opportunities.

Coverage: All areas served by one or more local newspapers.

Information: Data on Available Dwelling Units
- Location
- Tenure (for sale or rent)
- Cost
- Financing options
- Size
- Types of rooms
- Special features

Aggregate Employment Data
- Employment opportunities
  - name of business
  - type of occupation
  - location of business
  - wage or salary

Data on Available Business Space
- Location
- Tenure (for sale or lease)
- Cost
- Financing options
- Size
- Special features

Currency: Varies with frequency of publication, i.e., daily, weekly, or biweekly.

Retrieval: May be purchased at newsstands and selected business establishments, or read at public libraries.

COMMUNITY FACILITIES REGISTERS

Abstract: Local chambers of commerce compile general information on most community facilities within the municipality and in surrounding areas. These registers include data presented in a variety of formats on public and private facilities. The name and phone number of the facility's administrator is also often provided.

Utility: Convenient source of data on community facilities.

Coverage: Counties and municipalities. Contiguous areas may also be included.

Information: Aggregate Data on Community Facilities
- Health care facilities
  - number by type
  - location
- Schools
  - number by type
  - location
- Religious facilities
  - number by type
  - location
- Social/cultural centers
  - number by type
  - location
- Recreation centers
  - number by type
  - location
- Facility administrators
  - name
  - phone number

Currency: Currency of data will vary by community. Chamber of commerce personnel can normally verify and update materials.

Source: Local chamber of commerce.

Retrieval: Available on request.

COMPREHENSIVE PLANS, LOCAL

Abstract: A comprehensive plan provides a blueprint for a community's future development. The plan may be devoted exclusively to written goals, objectives and policies, or it may consist only of a proposed land use map for the community. Some community plans may (1) describe existing patterns of land use, (2) identify community needs, (3) provide growth projections, (4) present a plan for modifying existing land use patterns to meet projected needs, and (5) recommend legislative and regulatory actions to implement the plan. Comprehensive plans, while not legally binding, provide guidelines for subsequent legislative and regulatory actions on, e.g., taxation, annexations, and zoning.

Utility: Describe community plans regarding land use and related issues, e.g., transportation and recreation facility development, that are required to support various land use activities.

Coverage: Counties, local municipalities, or planning areas.*

Information: Planned Land Use
- Projected land use
- Consistencies/inconsistencies of project with community goals, objectives, and policies

Currency: Although comprehensive plans should be updated at least once every five years, actual practices vary by community. Information regarding the currency of a particular plan may be obtained from the agency responsible for its preparation.

Source: County or municipal planning board.

Retrieval: A comprehensive plan for a county or municipality may be presented in one or more volumes. Some plans cover particular sections of the locality (e.g., a community plan or downtown urban renewal plan). Others address specific land use activities across the locality (e.g., an agricultural land preservation plan for rural areas). Most comprehensive plans consist of a text and a series of maps. Large maps are sometimes packaged separately from the text.

CRISS-CROSS AREA DIRECTORIES

Abstract: Criss-cross area directories normally provide the most comprehensive, up-to-date listings of residents and businesses.

Utility: Used to identify individual businesses and residences in a study area. Addresses and phone numbers in the directories may be used to sample and survey residents and businesses.

*A planning area may be a region encompassing several municipalities or counties. It may also be a specific section of a municipality, such as a central business district (CBD).

Coverage: Metropolitan communities. Since criss-cross directories are compiled by private publishers, some municipalities will not have directories.

Information: Data on Individual Residences
- Address
- Name of resident
- Phone number

Data on Individual Businesses
- Name
- Address
- Phone Number

Concentrations of Businesses
- Location
- Number of tenants

Currency: Varies by municipality.

Source: Private firms such as R.L. Polk Co., Haines and Co., and Hill Directory Co., publish the directories.

Retrieval: The local chamber of commerce and public libraries usually have reference copies.

EMPLOYMENT STATISTICS, STATE

Abstract: Employment agencies in most States publish extensive statistics on employment.* These publications often contain narratives highlighting developments in major industrial sectors and time-series data useful in identifying trends and anticipating future changes.

Utility: Provides monthly data on employment by industry and unemployment rates.

Coverage: States, SMSAs, labor market areas, counties, municipalities.

Information: Aggregate Employment Data
- Employment by industry (SIC)
- Unemployment rate
  - total
  - by industry

Currency: Available monthly.

Source: State employment agencies.

Retrieval: Available on request.

FARM RECORD CARDS

Abstract: The U.S. Department of Agriculture, through its Agricultural Stabilization and Conservation Service (ASCS), collects data on individual farms. These data are stored on Farm Record Cards,

*State employment agencies are variously called Departments of Employment Security, Employment Commissions, Departments of Labor and Industry, or a similar name.

and are kept at the county level and filed by sections (standard land subdivision units). They provide information on individual farm acreage and yield. The cards are kept for five years and thus provide historical data showing change over time. They also provide crop projections for the following year.

Utility: Useful in providing detailed agricultural data for rural areas.

Coverage: Individual farms, collected at the county level.

Information:

- Aggregate Data on Agriculture
  - Total acres
  - Number of farms
  - Average acres per farm
  - Average acreage by crop
  - Average productivity per acre
- Data on Individual Farms
  - Total acres
  - Acreage by land use and crop
  - Average yield per acre

Currency: Updated annually.

Source: County offices, Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture.

Retrieval: Available on request. Farm Record Cards may be reviewed and copied at the county ASCS office. Cards are filed by farmer's name and by location.

HEALTH FACILITIES DIRECTORY

Abstract: State Departments of Health publish directories containing the names and addresses of all public and private health care facilities operating in the State. These directories often contain information on the type and size of the facility, and the name and phone number of its chief administrative officer.

Utility: Used to locate health care facilities in the study area when community facilities are profiled.

Coverage: Individual facilities, compiled for the entire State.

Information:

- Data on Individual Facilities
  - Health care facilities
    - number by type
    - address
    - name of administrator
    - phone number

Currency: Updated annually.

Source: State Department of Health.

Retrieval: Available on request for a nominal fee.

LIBRARY FACILITIES DIRECTORY

Abstract: The American Library Directory is published by a private firm for the American Library Association. It contains names and locations of all public and private libraries in each State.

This includes university, medical, law and other special interest libraries. The Directory also contains the names and phone numbers of chief administrators, and a listing of the special services provided.

Utility: Used to locate libraries in the study area when community facilities are profiled.

Coverage: Individual libraries. Data are organized by State and municipality.

Information: Data on Individual Facilities
- Libraries
  - number by type
  - address
  - chief administrative officer
  - phone number

Currency: Updated annually.

Source: State Office of Libraries.

Retrieval: Photocopies of pages covering pertinent geographic areas may often be ordered from the State Office of Libraries for a small reproduction charge. Also, public libraries frequently maintain reference copies of the directory.

MULTIPLE LISTING SERVICE

Abstract: Multiple listing services centralize individual real estate office listings of properties for sale or lease. The service increases the circulation of a property's availability beyond the realtor's office which originated the listing.

Utility: Commercial, industrial, residential and undeveloped properties in the multiple listing provide insight into residential activity and, in particular, the availability of replacement properties for those displaced by a new facility. Although all properties for sale or lease are not covered in the listing, it does serve as an important indicator of property trends.

Coverage: Most metropolitan areas.

Information: Data on Available Dwelling Units & Other Properties
- Address
- For sale or rent
- Asking price
- Financing options
- Taxes
- Size of structure(s)
- Size of lot
- Types of rooms
- Type of construction
- Type of utilities

Currency: Up-to-date.

Source: Provided by the local Board of Realtors on a subscription basis to individual member real estate offices.

Retrieval: Contact a real estate office which subscribes to the service.

POPULATION STATISTICS, LOCAL

Abstract: Population trends and projections are commonly developed by regional planning agencies, counties, and municipalities. Trends are identified from population estimates for previous years and used to develop projections for future periods of 10 to 30 years. Both trends and projections typically utilize decennial census data as a data base. Data on building and demolition permits, school enrollment and residential vacancy rates are also used in developing projections. Fertility, birth and mortality rates, migration patterns, and unemployment figures may also be considered. Assumptions are made on interrelationships of these factors with the local and regional economic bases, quality of schools, services and amenities, and the community's goals and policies regarding growth.

Utility: Helpful in identifying trends and in determining future demand for housing, goods and services. Projections made prior to the announcement of a new highway facility, however, will not reflect its impacts on growth.

Coverage: SMSAs, counties, municipalities, and communities.

Information: Aggregate Population Data
- Population trends and projections
  - total population
    - by age group
    - by race/ethnicity
    - by income range

Currency: Varies.

Source: Municipal planning department or research-statistics branch of the regional planning agency.

Retrieval: Available on request.

PROPERTY ASSESSMENT RECORDS

Abstract: Different types of property assessment data may be found in (1) county real property map books, (2) county land books, and (3) county real estate cards. The county real property map books show the location of each parcel of land within the county. In addition, these maps identify land that has been subdivided plus existing roads, railroad tracks, and waterways (creeks and rivers). County land books present an overview of real estate taxes and assessments for each parcel of land. The county real estate cards provide more detailed information, including a summary of current and past land use for a particular parcel of land, structural descriptions, and assessed values by land and property type.

Utility: Provides detailed data on land use, housing, local government finance, and business activity.

Coverage: County or municipality.

Information:

- Data on Individual Parcels
  - Number
  - Size
  - Location
  - Assessed value, land and structures
  - Estimated market value
  - Owner
- Data on Undeveloped Land
  - Location
  - Description
    - size of parcel
  - Assessed value
  - Estimated market value
  - Owner
- Data on Individual Dwellings
  - Assessed value of land and house
  - Date of last assessment
  - Previous assessed values
  - Current market values
  - Location
  - Owner
  - Current costs (owner)
  - Price Paid
- Concentrations of Businesses
- Data on Individual Businesses
  - Approximate size of building
  - Condition of building
  - Building owner
  - Financing
  - Value of property, building
- Aggregate Assessment and Tax Data
  - Total tax base
  - Average assessed values by property type
  - Tax rate by property type
  - Assessment-to-market ratio by property type
  - Annual property taxes

Currency: Real estate cards are continuously updated. The land books are normally updated following the annual property assessment. The real property maps are updated less often, but the date of the last revision appears on the map.

Source: Property or real estate assessment office.

Retrieval: Generally, a parcel of land is first identified on the county real property maps which give a map reference number. This reference number is used to locate the real estate cards which are filed by map reference number and by property owner name. The county land books list parcels alphabetically by owner and numerically by map reference number.

PUBLIC PROPERTY INVENTORIES

Abstract: Municipalities often maintain inventories of public properties -- usually compiled for insurance purposes -- which list the names and locations of facilities. Additional information sometimes includes year built, type of construction, acreage or square footage, and market value.*

Utility: Useful in locating and profiling public facilities in the study area.

Coverage: Municipalities.

*State governments provide similar information on State-owned public facilities in the area.

Information: Aggregate Data on Community Facilities
- Number
- Type
- Location

Data on Individual Facilities

Physical description
- acreage/square footage
- general design features
- year built
- condition
- owner
- market value

Currency: Varies by municipality.

Source: Municipal property management office. If such an office does not exist, contact the chief administrator of the planning or budget office.

Retrieval: Available on request.

SCHOOL DIRECTORIES

Abstract: Most States publish a Directory of Schools which provides the names and addresses of public, private and parochial schools within the State. The name and phone number of each school's principal are included, along with the number of students enrolled for the preceding year.

Utility: Used to locate schools in the study area when community facilities are profiled.

Coverage: Individual schools, organized by State, county and municipality.

Information: Data on Individual Facilities
- Schools
  - number by type
  - address
  - service area boundaries
  - enrollment
  - phone number of administrator

Currency: Updated annually.

Source: State Department of Education.

Retrieval: Available on request for a nominal charge.

ZONING ORDINANCES

Abstract: Zoning is the most widely employed technique for implementing land use policies, particularly those policies specified in comprehensive plans. By establishing specific development requirements for an area, zoning ordinances, in effect, regulate the size and quality of housing, population density, and location of commercial and industrial centers.* The ordinance

*While some communities do not have zoning ordinances, virtually all exercise varying degrees of control over land-use activities. In communities where zoning ordinances are not in effect, the planning board can usually provide information on implementation of local land-use policies.

typically consists of (1) a map depicting the boundaries of each zone, and (2) a text specifying development requirements in each zone. There are two major kinds of zoning plans: fixed and flexible. Fixed zoning plans generally designate geographic sections of the community as residential, business, or commercial districts. Sometimes several additional zones (e.g., agricultural districts, airport approach areas, historic preservation districts, or critical environment zones) are assigned to meet special community needs. Whereas fixed zoning plans describe all allowable activities, flexible zoning plans prescribe types of permissible activities without requiring that an area be devoted exclusively to one of them. Typically, a prospective developer is invited to demonstrate that his ideas for development of a parcel of land in a flexible zone are consistent with the community's land use policies. Many communities use a combination of fixed and flexible zoning.

Utility: Provides data on permitted land use activities and required development regulations.

Coverage: Counties and municipalities.

Information: Planned Land Use — Development requirements by district
- Activity districts
- Zoning Restrictions

Currency: Currency can generally be assured if the zoning ordinance text, and all amendments to it, are thoroughly examined. Zoning maps may not be revised each time a property's zoning classification changes, so practitioners are encouraged to examine the written amendments for legal descriptions changes in zone boundaries.

Source: Local zoning or planning board.

Retrieval: Zoning ordinances consist of two parts: (1) a zoning map, and (2) a zoning text. The map specifies the geographic location of the zones in an area. The text provides a detailed schedule of requirements for each of the zones. Map and text should not not be used independently of one another. Both may be borrowed on request, or may be purchased.

Part 2. SURVEY TECHNIQUES

Surveys are an extremely flexible tool for collecting useful information. Users are free to tailor surveys to their needs -- to define what information they want, choose their sources, go to those sources when they are ready, and record the findings in a preselected format. Since the information collected generally costs more, it follows that it usually has a special utility. Examples are surveys which collect:

- *Data unavailable in record and map sources, e.g., route and design preferences, or perceptions of potential negative impacts.*
- *Data more current than information in records and maps that can be used to test and update information from those sources. Currency is often an issue in cases where the study area is undergoing rapid social and economic change.*
- *Data keyed to smaller geographic units and selected population subgroups. Examples are areas subject to the proximity effects of alternative routes, and residents and businesses displaced by the preferred route.*

This part of Volume II focuses on Survey Techniques. Chapter 3 presents approaches tailored to meet information needs which arise during preliminary assessment. Chapter 4 describes approaches used during detailed assessment, when route alternatives are known and micro study areas have been defined.

Each survey technique is discussed and evaluated in terms of:

- *The objectives it can be used to meet,*
- *How it can be implemented,*
- *Possible sampling approaches,*
- *Resource requirements, and*
- *The utility and limitations of the approach.*

The discussion of each technique is followed by a listing of questions and response categories commonly used to collect data with that approach. The questions listed include both information items and questions on attitudes and perceptions. The questions can be selected, combined, and supplemented to suit practitioners' objectives, the target group, and the area being investigated.

This material on survey approaches is intended to complete the bridge between data requirements and sources established in the matrices of Volume I, Part 2. It covers the observational and respondent survey techniques which were presented on those matrices.

Chapter 3. USE OF SURVEY TECHNIQUES FOR PRELIMINARY ASSESSMENTS

The following sections describe and evaluate observation and questionnaire approaches useful in the preliminary phase of the assessment process. A listing of survey questions and response modes is provided at the end of the discussion of each respondent survey technique.

3.1 WINDSHIELD SURVEYS

Objective. To become familiar with the physical, social, and economic characteristics of the study area; to identify natural and man-made barriers; to identify areas of possible negative impact; and to update selected baseline data.

Description. This observation survey is conducted using a car and driver. The surveyor uses a base map to record the data elements listed below. Emphasis, at this stage, is on identifying and characterizing clusters of activity and land use. The surveyor may have to drive the study area several times if data concerning population characteristics and social activities are desired.

Data Items. Commercial, industrial, and residential areas (including types of dwellings); civic centers; public and private institutions; parks and recreational areas; major employment areas; minority clusters; etc.

3.2 PURPOSIVE SURVEYS OF AREA ELITES

Surveys of area elites focus on local officials, realtors, planners, county agents, tax assessors, and chambers of commerce. Questions may also be directed at spokespersons for organizations, clubs, special interest and advisory groups.

Objectives. To test hypotheses about area characteristics and potential impacts developed from an analysis of records and maps; to supplement socioeconomic data with information on attitudes towards the project and perceptions of effects.

Description. These are often loosely structured surveys in which the State highway representative briefs respondents on the proposed project, and then asks a series of questions and records the answers. Targeted groups can also be given questionnaires to complete and mail back, or they can be questioned over the telephone.

Sampling Approach.* To elicit data from elected officials, a census sample is often taken since there is a limited number of respondents and each will represent different levels of government and different constituencies. A non-random judgmental or purposive sample is often used to select spokespersons for other targeted elites.

The sampling frame can be partly constructed from lists containing names, addresses and phone numbers of public officials and area organizations. These lists are available through State, county, and local government offices. State highway agency mailing lists may be used to supplement government office listings.

If available lists are not adequate and the user wants to expand coverage, the linked chain technique can be used. This technique involves asking readily identifiable respondents to indicate other individuals and organizations which meet the selection criteria. In this way, names and phone numbers of respondents not in the initial sampling frame can be collected, and these individuals can be questioned until new names or organizations in the targeted group no longer turn up.

In selecting the sampling frame, the following criteria may be considered:

- The number of people from the study area represented by the individual or organization,
- The kind of information about the study area that is available from the target group,
- The existence of a designated spokesperson who is qualified to comment for the organization, and

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*See Part 3 for more detail on sampling methodologies.

- The involvement of the individual or organization in issues related to potential impacts identified.

Resource Requirements. Resource requirements are low. Agency personnel usually administer the survey to familiarize themselves with the views of area elites and interest groups. The number of respondents is generally small, although the number of spokespersons and elites can be 25 or more. The size of the sample and method of data collection will depend on resources available. The mailback questionnaire requires only postage costs and, given the audience, will probably have a high response rate.

Utility and Limitations of Approach. The user has a great deal of flexibility in the selection of respondents. For example, if screening identifies potential negative impacts on minority clusters, then organizations representing minority interests may be included in the sample. If cultural or religious organizations are particularly active in the area, the planner may want to speak to the leaders of these groups. If citizen advisory committees have been established by local governments, they might be included. These groups will probably have detailed information to supplement the core socio-economic data, and their perceptions will help to confirm or deny any hypotheses developed. They also serve as indicators of public attitudes and perceptions toward the project. However, information collected from elite groups may be biased, reflecting special interests, and not representative of the population of the study area. This should be considered when reviewing responses.

The approach assures that public officials and organizations have been informed about the project and that they are asked to comment early in the planning process. Respondents are expected to be more cooperative based on this early consultation.

Since it is assumed that route alternatives remain unidentified at this point, the range of questions is limited accordingly. For example, questions on perceived impacts may suffer from lack of specificity on route locations.

3.3 QUESTIONS USED IN PURPOSIVE SURVEYS OF AREA ELITES

The following questions can be selected, combined, and supplemented at the user's discretion, depending on project objectives, particular target groups, and the nature of the study area.

Information Questions

1. Identification of the Respondent/Group

   (1) Name of person completing questionnaire (or being interviewed)________________

   (2) Position held by respondent____

   (3) Organization/constituency represented________________________________

   (4) Number of persons in organization/constituency__________________________

Attitude and Perception Questions

I. Views Regarding Community Goals and Development

- Transportation-Related Goals

  (1) What are your/your organization's views regarding community concerns, goals, and problems related to transportation? Have you/has your group developed papers or reports concerning these issues? (IF YES, LIST AND ATTACH COPIES)

  (2) Can you identify the transportation-related improvements in this area/community which are most important to your constituency/organization? (LIST IN RANK ORDER AND PROVIDE EXPLANATIONS OF EACH)

  (3) What are your/your organization's specific recommendations regarding each improvement mentioned?

  (4) Based on a prepared list of 10 transportation-related objectives for this area/community (SEE NOTE), please rank each objective, putting a number 1 by the most important, number 2 by the next most important, etc.

  NOTE: A list of objectives for use in Q4 can be compiled based on analogous cases, content analysis of newspaper articles, planning documents, and other written materials or brain-storming sessions. Indepth interviews with area specialists and elites are another source of information.

- Effects on Local Government Plans (for Governmental Officials Only)

  (1) For each planning area listed below, please indicated how the proposed road will affect plans and goals for future development.

  Planning Area A: _____ Positive Effect _____ Adverse Effect _____ No Effect

  Planning Area B: _____ Positive Effect _____ Adverse Effect _____ No Effect

  Planning Area C: _____ Positive Effect _____ Adverse Effect _____ No Effect

  NOTE: Planning areas listed may be counties, municipalities, State-designated areas, etc.

  (1a) For each planning area where positive or adverse effects are expected to occur, please describe.

(2) What is the development policy of local government bodies responsible for planning and zoning in the study area? (PROVIDE MAP)

	Government Body	Rapid Development	Moderate Development	Slow Development	No Development
(A)	________	1	2	3	4
(B)	________	1	2	3	4
(C)	________	1	2	3	4

2. Perceptions of Community Character

° Identifying Cohesive Communities

(1) Community cohesion is generally defined in terms of interdependency, levels of mutual attraction and support, and common cultural or religious bonds. Please rate each of the communities (or neighborhoods) listed below in terms of their degree of cohesiveness.

	Name of Community	Not Cohesive	Somewhat Cohesive	Highly Cohesive
(A)				
(B)				

(2) Please explain your ratings for each community.

NOTE: The respondent can be asked to supply the list of communities based on a map of the study area provided by the surveyor.

° Screening for Recent Changes in Key Indicators

(1) What is the pace of development in the study area? (PROVIDE MAP)

1 Rapid 2 Moderate 3 Slow 4 None 5 Declining

(2) For each community or neighborhood listed above, please indicate the degree of change* in the factors listed below over the last five years.

	Community (A)	Community (B)	Community (C)	Community (D)
Cohesion	________	________	________	________
Accessibility to Key Facilities	________	________	________	________
Employment, Income and Business Activity Levels	________	________	________	________
Residential Turnover	________	________	________	________
Property Values	________	________	________	________

* Use the following codes: 1 = No change 2 = Some change 3 = Notable change

(2a) For each community where change has occurred, please describe the nature of the change.

3. General Attitudes Toward the Proposed Project

° Use of Scales to Measure Opinion

(1) In general, how do you feel about the proposed project:

OPTION 1: Do you:

Very Strongly Approve	Strongly Approve	Approve	Feel Undecided	Disapprove	Strongly Disapprove	Very Strongly Disapprove
1	2	3	4	5	6	7

OPTION 2: Are you:

Extremely Favorable . . . (3 or 5 intermediate points) . . . Extremely Unfavorable

OPTION 3: Do you feel it is an:

Extremely good idea . . . (3 or 5 intermediate points) . . . Extremely bad idea

° Use of Categorical-Response Questions

— Yes/No Question

(2) Do you think a highway should be built in the area?

— Desirability of Area in Relation to Project

(3) Do you think it would be more desirable to live in this are during the next 10 years with the proposed highway or without the proposed highway?

1 With the highway | 3 About the same
2 Without the highway | 4 Don't know

— Advantage/Disadvantage Question

(4) Do you think the new highway will be an advantage or a disadvantage to (SPECIFY AREA) and its people?

1 Advantage 2 Disadvantage 3 Both 4 No effect 5 Don't know

NOTE: These categorical questions tend to polarize opinion in contrast to the approval, favorability, and good-bad idea scales which precede them.

° Probing for Reasons (Perceptions of Effects) Behind Responses

— For Use with Q1-3

(5) Why do you feel that way?

OPTION: Response categories for persons giving positive responses to Q1-3 can be taken from the list in Addendum A following Chapters 3-4. Response categories for persons giving negative responses can be taken from the list in Addendum B.

— For Use with Question 4

(6) What are the advantages and disadvantages?

OPTION: Response categories for recording advantages and disadvantages cited by respondents in Q6 can be chosen from the lists in Addendums A & B.

4. Importance of Specific Factors in Route Selection

° Ranking Factors in Order of Importance

(1) What factors should have the most influence on the choice of routes? Rank the factors listed below from 1 to __, with 1 being the most important.

NOTE: The positive and negative factors used for Q1 can be selected from the lists in Addendums A & B. The question can also be left open-ended.

° Rating the Importance of Factors

(2) There are many factors to be considered in determining the location and design of the new highway. Even though all of these factors are important, they are not considered of equal importance by each person. What is the relative importance of each of the following items to you?

	Extremely Important	Important	Relatively Important	Not Important
Displacement of Businesses				
Increased Property Values				

NOTE: Other positive and negative factors can be selected from the lists in Addendums A & B.

° Paired Comparisons (Trade-off)

(3) Of the following paired items, which should be <u>the most important</u> in designing and locating a highway in this area?

1 Displacement of Businesses 2 Increased Property Values

NOTE: Other pairs of positive and negative factors can be selected from the list in Addendums A & B for use in Q3.

5. Preferences Concerning Route Location

(1) Where do you think a new freeway coming through this area should be located?

NOTE: The use of a map is recommended both as a means of stimulating responses and recording them. The interviewer can also record route preferences by noting their relationship to the existing road network, major topographic features, etc.

° Probing for Reasons Behind Responses

— For Use with Q1

(2) Why do you favor that location?

6. Opinions Concerning Project Impact on Area

° General Perception of Effects

(1) What effect do you think the proposed project would have on this area as a place to live? As a place to live, would this area be:

Very Much Improved	Somewhat Improved	Unaffected	Somewhat Downgraded	Very Much Downgraded
1	2	3	4	5

° Perceived Benefits to the Area

— General Benefit

(1) Do you feel that the area in general would benefit from a highway?

— Degree of Benefit (General)

(1a) (IF YES) Do you feel the benefit would be very great, moderate, or rather small?

— Nature of Benefit

(2) How would the area benefit?

OPTION: Possible response categories are listed in Addendum A.

-- Degree of Benefit (for Each Benefit Named)

(3) Is the benefit the area would derive from __________ (READ FIRST BENEFIT IDENTIFIED IN Q2) very great, moderate, or rather small? (REPEAT AND RECORD FOR EACH BENEFIT MENTIONED IN Q2)

° Perceived Detriments to the Area

-- General Harm

(1) Do you expect that a highway would have a harmful effect upon the area in general?

1 Yes   2 No   3 Don't know

— Degree of Harm

(1a) (IF YES) Do you feel the harm would be very great, moderate, or rather small?

— Perceived Negative Effects

(2) How would a highway be harmful to the community?

OPTION: Response categories can be selected from the list of negative factors listed in Addendum B.

— Degree of Harm

(3) Do you feel that the negative effect from __________ (READ FIRST NEGATIVE EFFECT MENTIONED IN Q2) would be very great, moderate, or rather small for the neighborhood in general? (REPEAT AND RECORD FOR EACH NEGATIVE RESPONSE MENTIONED IN Q2)

7. Information on Positions of Other Area Groups

(1) Do you know any organizations which support the project? (IF YES) Please indicate name and address.

1 No

2 Yes   Name__________________   Name__________________
         Address________________   Address________________
         _______________________   _______________________

(2) Do you know of any organizations which oppose the project? (IF YES) Please indicate name and address.

1 No

2 Yes   Name__________________   Name__________________
         Address________________   Address________________
         _______________________   _______________________

(3) Are there any other key organizations or officials you think should be asked to complete this questionnaire? (SPECIFY)

NOTE: Q3 enables practitioners to use the linked-chain technique to test and expand the sample frame (See p. 91).

3.4 MINI-SURVEYS OF AREA RESIDENTS AND BUSINESSES

Objective. To get a preliminary reading on citizen attitudes toward the proposed project, perceptions of potential negative effects, and preferences on route location.

Description. These are short surveys (30 items or less). Information is collected from a small random sample (80 respondents or less) of area residents or businesspersons. The survey is usually administered by phone.

Sampling Approach.* A simple random sampling plan is generally used to survey residents or businesspersons. This means that all residences or businesses in the frame will have an equal chance of being selected.

A criss-cross area directory can serve as a sampling frame. Practitioners select respondents by randomly choosing pages in the directory and picking names, using a random start-and-interval procedure.

Resource Requirements. Resource requirements are very low. The sampling frame is readily available. It takes very little time to select respondents. Conducting the survey by phone involves only the costs of local calls.

An interviewer will be required to administer the survey. At an average length of 20 minutes per completed interview (allowing for all non-responses, dialing and recording), a total of twenty interviews can normally be completed in a maximum of two working days.

Utility and Limitations of Approach. The small sample allows practitioners a controlled way to screen public opinions concerning the project, and perceptions of effects, early in the planning process. This approach is simple and inexpensive, and it gives results that practitioners can speak about with some degree of confidence. Open-ended questions are often used to identify potential impacts on businesses and residents that are not apparent in the screening of baseline data.

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*See Part 3 for more detail on sampling approaches.

Small samples do, of course, have a greater margin of error than larger samples. However, even with wide confidence bands, it is often possible to draw solid conclusions from the response patterns. Also, pinpoint accuracy is neither possible nor required during preliminary assessment, when opinions and perceptions generally are only partially formed.

3.5 QUESTIONS USED IN MINI-SURVEYS

The following questions can be selected, combined and supplemented at the user's discretion depending on project objectives, the target groups, and the nature of the study area.

Information Questions.

1. Knowledge of the Proposed Project

   (1) Do you know of any plans for constructing a highway in the area/neighborhood?

   (2) Have you ever heard of (project name)?

   NOTE: Questions (1) and (2) may be used to determine whether the respondent has sufficient knowledge of a proposed project to have formed an opinion. If the respondent has insufficient knowledge of the project, he or she should be given additional information before the survey is continued.

2. Socio-Economic Data

   NOTE: These questions are normally asked at the end of the mini-survey.

   ° Data on Residents

   — Sex

   Interviewer records: 1 Male 2 Female

   -- Age

   (1) In which of the following age groups do you fall?

   1 16-24 2 25-34 3 35-49 4 50-64 5 65 or older

   — Ethnic Background

   (2) Which of the following categories best describes your ethnic background?

   1 American Indian or Alaskan Native
   2 Black/Afro-American
   3 Caucasian/White
   4 Pacific Islander
   5 Hispanic/Spanish-American
   6 Other (SPECIFY)

-- Family Income

(3) What was your total family income last year prior to taxes?

1 Less than $3,000	4 $ 8,000 - $ 9,999	7 $25,000 and over
2 $3,000 - $4,999	5 $10,000 - $14,999	8 Refused
3 $5,000 - $7,999	6 $15,000 - $24,999	

-- Employment

(4) Are you currently employed?

1 Full-time	3 Unemployed	5 Other (SPECIFY)
2 Part-time	4 Student	

-- Dwelling Unit

(5) In what type of dwelling do you reside?

1 Single family	3 Apartment	5 Condominium	7 Other (SPECIFY)
2 Duplex	4 Townhouse	6 Mobile home	

-- Driver's License

(6) Are you a licensed driver? 1 Yes 2 No

-- Auto Ownership

(7) Do you own a registered vehicle? 1 Yes 2 No

° Data on Businesses

-- Type of Business

(1) What type of activity is this business engaged in?

1 Manufacturing	3 Retail trade	5 Service
2 Wholesale trade	4 Finance, insurance, or real estate	6 Other (SPECIFY)

-- Annual Revenues

(2) What have the gross dollar sales of your business (at this location) been during the past year? (IF THE EXACT AMOUNT IS NOT KNOWN →) Please give your best estimate.

1 $ 10,000 or less	5 $ 75,001 - $100,000	9 $300,001 - $400,000
2 $ 10,001 - $ 25,000	6 $100,001 - $150,000	10 $400,001 - $500,000
3 $ 25,001 - $ 50,000	7 $150,001 - $200,000	11 $500,001 - over
4 $ 50,001 - $ 75,000	8 $200,001 - $300,000	

-- Number of Employees

(3) How many people, including management, are employed by this business?

1 One	3 6-10	5 16-20	7 26-30	9 41-50	11 76-100
2 2-5	4 11-15	6 21-25	8 31-40	10 51-75	12 101-over

-- Payroll

(4) What is your monthly payroll (at this location) including management?

1 Less than $5,000	3 $10,000 - $19,999	5 $50,000 - $99,999
2 $5,000 - $9,999	4 $20,000 - $49,999	6 $100,000 - over

Attitude and Perception Questions

1. General Attitudes Toward the Proposed Project (See page 43)

2. Importance of Specific Factors in Route Selection (See page 44)

3. Preferences Concerning Route Location (See page 45)

4. Opinions Concerning Project Impact on the Area (See page 45)

5. Opinions Concerning Project Impact on Individuals

° Perception of the Proposed Project as a Benefit to the Respondent

-- General Perception of Personal Benefit

(1) Do you feel that you personally/your business would benefit from a highway in or near your neighborhood (or the neighborhood in which your business is located)?

1 Yes 2 No 3 Don't know

(2) Do you feel that you personally/your business would benefit from a highway if it does not result in your relocation or increased noise in your block?

1 Yes 2 No 3 Don't know

NOTE: Q2 can be used instead of, or in addition to, Q1. It is designed to minimize the likelihood of negative responses based on generalized anxiety about the proposed road.

-- General Degree of Benefit

(2a) (IF YES) Do you feel that the benefit would be very great, moderate, or rather small?

-- Nature of Benefit

(3) How would you/your business benefit from a highway?

NOTE: Response categories can be selected from the list of positive factors in Addendum A.

-- Degree of Benefit (for each benefit identified)

(3a) Do you feel that the benefit from (READ FIRST BENEFIT MENTIONED IN Q3 ABOVE) is very great, moderate, or rather small? (REPEAT AND RECORD FOR EACH RESPONSE IDENTIFIED IN Q3)

Very Great	Moderate	Rather Small	Don't know
1	2	3	4

° Perception of the Proposed Project as Harmful to the Respondent

-- General Perception of Harm

(1) Do you expect that a highway in or near your neighborhood (or the neighborhood of your business) would have a negative effect on you personally/your business?

-- Degree of Harm

(1a) (IF YES) Do you feel the negative effect would be very great, moderate, or rather small?

(2a) What negative effects would you expect from a highway?

NOTE: Response categories can be selected from the list of negative factors in Addendum B.

— Degree of Harm (for each negative effect identified)

(2b) Do you feel that the negative effect from (READ FIRST NEGATIVE EFFECT MENTIONED IN Q2a ABOVE) is very great, moderate, or rather small? (REPEAT AND RECORD FOR EACH RESPONSE IDENTIFIED IN Q2a)

Very Great	Moderate	Rather Small	Don't know
1	2	3	4

6. Perceptions on the Opionions of Others Concerning the Project

° Perceptions of Local Residents

— Concerning the Opinions of Neighbors

(1) Since learning of the proposed highway, have you discussed it with your neighbors?

1 Yes 2 No

(1a) How often would you say you have discussed the proposed highway with your neighbors?

1 Frequently 3 Seldom
2 Occasionally 4 Don't know

(2) In general, how would you say most of the people in your neighborhood feel about the proposed highway? Are they. . .

1 Extremely favorable 4 Somewhat unfavorable
2 Somewhat favorable 5 Extremely unfavorable
3 Neutral 6 Don't know

OPTION: Alternative response categories for Q2 are:

1 Most favor it 4 Indifferent
2 Most oppose it 5 Don't know
3 Divided evenly

— Concerning the Preferences of Elected Officials and Community Leaders

(1) Do you know of any elected officials or community leaders who support the proposed road? (IF YES) Please list the names and positions of these persons.

1 No
2 Yes Name____________________ Name____________________
Position____________________ Position____________________

(2) Do you know of any elected officials or community leaders who oppose the proposed freeway? (IF YES) Please list the names and positions of these persons.

1 No
2 Yes Name____________________ Name____________________
Position____________________ Position____________________

— Concerning the Preferences of Area Organizations (See p. 46 for questions)

- Perceptions of Local Businesspersons

— Concerning the Opinions of Other Businesspersons

(1) What is the general opinion of the business community regarding the proposed project?

1 Most favor it	4 Indifferent
2 Most oppose it	5 Don't know
3 Divided evenly	

— Concerning the Opinions of Area Residents

(1) Do you live in this area? 1 Yes 2 No

(1a) What is your ZIP code? __________

(2) What is the general attitude of area residents toward the project?

Chapter 4. USE OF SURVEY TECHNIQUES FOR DETAILED ASSESSMENT

4.1 WINDSHIELD SURVEYS

Objective. To update and supplement building and land use maps covering each corridor, i.e., the ROW and area proximate to each route alternative; to record observations concerning selected socio-economic characteristics of each corridor; to aid in drawing community boundaries; and to identify possible impacts associated with each route corridor.

Description. This survey is conducted with a car and driver as described in Section 3.1 (p. 39). The base map used at this stage will have a smaller scale. A building map can be used to facilitate recording the use and conditions of each structure and uses of undeveloped land. The surveyor should also have a clipboard on hand to make notes on non-physical characteristics observed. Again, several trips may be required to record all of the data elements listed below for each study area. When uncertain, the surveyor is encouraged to verify building use by speaking to people in or around the buildings. Useful comments should be recorded.

Data Elements. Use, condition, approximate age and scale of structures; vacant structures; abandoned buildings and lots; facade conditions and maintenance levels; land use; parks, recreational and other open spaces; historic or archeological sites; natural and manmade barriers; approximate age, sex and ethnicity of persons observed; areas with heavy pedestrian activity; use of public facilities.

4.2 WALK-THROUGH RECONNAISSANCE

Objective. See Windshield Surveys, above.

Description. The walk-through reconnaissance is an observation survey conducted on foot. This makes it easier to talk with area residents and use them as an information source. In all other ways this approach is like the windshield survey.

Data Elements. See Windshield Surveys, above.

4.3 PURPOSIVE SURVEYS OF AREA ELITES

Objective. To obtain expert opinions of the alternative routes, the vulnerability of communities through which the routes pass, and the possible negative impacts to be suffered by each affected community.

Description. This survey is described in Section 3.2 (p. 39).

Sampling Approach. The sampling frame developed in preliminary assessment can serve as the complete frame from which to select respondents. An additional criterion to be used for selection is the familiarity of the individual or group with sub-units, i.e., neighborhoods and communities, in the study area.

Resource Requirements. See Section 3.2.

Utility and Limitations of Approach. See Section 3.2.

4.4 QUESTIONS USED IN SURVEYS OF AREA ELITES

The following questions can be selected, combined, and supplemented at the user's discretion, depending on project objectives, target groups, and the nature of the study area.

Information Questions

1. Identification of the Respondent/Group (See page 42)

Attitude and Perception Questions

1. Views Regarding Community Goals and Development (See page 42)
2. Perceptions of Community Character in Each Corridor

° Ranking Communities in Terms of Cohesion and Integration, Level of Organization, and Participation in Local Activities

(1) Can you identify communities in the areas around alternative alignments and compare them on their degree of cohesion and integration? (LIST COMMUNITIES FOR EACH ROUTE, OBTAIN A RANKING; RECORD REASONS FOR RANKING)

(2) Can you rank these same communities on their degree of neighborhood organization?

(3) Now rank them on their degree of participation in community and areawide activities.

(4) Overall, which communities would you say are the most cohesive? (LIST IN ORDER MENTIONED)

3. Evaluation of Alternative Routes

° Rating the Routes

(1) What is your attitude (the attitude of your constituency/organization) toward each alternative?

	No Build	Alternative A	Alternative B	Alternative C
Very Unfavorable				
Favorable				
Somewhat Favorable				
Neutral				
Somewhat Unfavorable				
Unfavorable				
Very Unfavorable				

° Best and Worst Routes

(2) What is the best alternative from your point of view (the point of view of your constituency/organization)?

(3) What is the worst alternative from your point of view (the point of view of your constituency/organization)?

° Effects of Best and Worst Routes

(4) Taking the best alternative, what do you think its consequences will be for the affected areas (for your constituency/organization)?

(5) Taking the worst alternative, what do you think its consequences will be for affected areas (for your constituency/organization)?

° For Elected Officials and Organization Spokespersons Only

(6) What percentage of your constituency/organization will be directly affected by the worst alternative?

° Expected Actions in Response to Choice of the Least Preferred Route

(7) What will you (your constituency/organization) do if the worst alternative is chosen?

° Most and Least Disruptive Routes and Reasons

(8) Which of the routes would be the most disruptive of life in the neighborhood(s) affected? Why?

(9) Which would be the least disruptive? Why?

° General Probe Regarding Problems Associated with Alternative Routes

(10) What other problems should be pointed out about the various alternatives?

4.5 SURVEYS OF LOCAL FACILITY MANAGERS

Objectives. To determine level of use, service areas and modes of access to local institutions; and to identify perceived impacts of the proposed route alternatives on service provision.

Description. A self-administered questionnaire of approximately 20 questions. It is distributed to local institutions -- including public and private facilities, fraternal organizations community centers, etc. The survey is usually conducted by mail.

Sampling Approach.* A census sample of local institutions in or abutting each of the ROWs under consideration is recommended. A smaller sample would be inadequate because levels of use, service areas, and access to each institution will be different. Activity patterns of all institutions will be uniquely affected by the various alternatives.

Institutions on the State highway agency mailing list will provide part of the sampling frame. Names and addresses of other facilities can be extracted from results of the windshield survey and walk-through reconnaissance. Local informants may be able to supplement the frame.

The survey is most effectively conducted by mail. Administrators will often have to search the records to give accurate responses to information questions. A mailback questionnaire insures adequate time for this, and thereby increases the likelihood of reliable results.

Resources Requirements. The survey of local institutions requires minimal resources. The frame may take several days to develop, but this work can be done in-house. Postage to and from the institutions will be the only substantive cost. The use of follow-up phone calls to increase response rates will result in small additional costs.

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*See Part 3 for more detail on sampling approaches.

Utility and Limitations of Approach. This approach offers an inexpensive way to gather extensive data on the vitality of local institutions, and on perceived impacts. Frequently the number of facilities to be surveyed in the corridors under consideration prohibits any other type of survey.

Surveyors may have difficulty constructing a complete sampling frame. The suggestions offered under sampling approaches should, however, minimize this limitation. Another potential problem -- the low response rates typically associated with postal surveys -- should be minimized by the importance institutions will likely place on having input in the route selection decision.

4.6 QUESTIONS USED IN SURVEYS OF LOCAL FACILITY MANAGERS

The following questions can be selected, combined, and supplemented at the user's discretion, depending on project objectives, target groups, and the nature of the study area.

Information Questions

1. Data on Community Facilities
   - Name, Address, Type, and Age of Facility
     (1) What is the name of this institution?
     (2) What is the address of the institution (or the branch that serves this area)?
     (3) Please describe the function of this facility.
     (4) In what year was this institution established in the area?
2. Data on Facility Users
   - Geographic Distribution of Users
     (1) Approximately what percent of your users come from the following geographic areas?
     ___this neighborhood (NAME)________________
     ___this community
     ___other communities
     (2) What proportion of your users reside in the study area? (SHOW RESPONDENT A MAP OF THE STUDY AREA.)
     1 Most 2 Majority 3 Some 4 Very few
     (3) Please indicate on the map the boundaries of the facility's service area.

° Profile of Users

(4) What characteristics distinguish users of the facility? (FIRST ELICIT RESPONSES WITHOUT SUGGESTING CATEGORIES. FOLLOW-UP WITH QUESTIONS ON RACE, ECONOMIC CLASS, ETHNICITY, RELIGION, EDUCATION, ETC.)

° Users' Access to Facility

(5) What form of transportation is most widely used by people coming to the facility?

Attitude and Perception Questions

1. Perceptions of Project Impact on Facility, Users, and Modes of Access

° Changes in Geographic Distribution of Users

(1) Do you think the geographic distribution of users will change if Alternative A is constructed? How? What if Alternative B is constructed? Alternative C?

° Changes in Profile of Users

(2) How do you think the characteristics of users will change due to the construction of Alternative A? Alternative B? Alternative C?

° Changes in Modes of Access

(3) Do you expect users will have to find new means of transportation to the facility if Alternative A is chosen? Alternative B? C?

2. Expectations Regarding Negative Project Effects

° Construction Effects

— Disruptions Caused by Construction

(1) Will highway construction activities disrupt service provision if Alternative A is chosen? How about Alternative B? C?

(2) (ASK ABOUT EACH ROUTE PERCEIVED AS DISRUPTIVE) Please describe the service disruption expected to occur during construction if Alternative ___ is chosen.

— Mitigation of Harm Caused by Construction

(3) What provisions could be made by the State highway agency to minimize disruption caused by construction of Alternative ___? (REPEAT FOR OTHER ROUTES PERCEIVED AS DISRUPTIVE)

° Operational Effects

-- Permanent Disruption of Services Following Completion of Highway Facility

(4) Will Alternative A have an adverse impact on service provision? How about Alternative B? C?

(5) (ASK ABOUT EACH ROUTE PERCEIVED AS DISRUPTIVE) Please describe the service disruption expected to occur if Alternative ___ is constructed?

-- Mitigation of Harm Caused by Highway Operation

(6) What provisions could be made by the State highway agency to minimize disruption caused by Alternative ___? (REPEAT FOR OTHER ROUTES PERCEIVED AS DISRUPTIVE)

4.7 SURVEYS OF AREA RESIDENTS AND BUSINESSES

Objectives. To determine the route preferences of residences and businesspersons in the impacted corridors; to identify perceptions of negative and positive effects associated wtih each alternative route; and to determine the relationship between responses and proximity to the proposed ROWs. The survey is also used to gather information useful in evaluating the vulnerability of potentially affected population subgroups to highway effects.

Description. The survey begins with descriptions of the alternative routes. The questionnaire, which follows, is often lengthy, taking 30 or more minutes to administer. Respondents are residents and businesspersons in the original study area. The sample can be designed to focus on responses located in each of the impacted corridors. Preferably, interviews are conducted in person.

Sampling Approach.* Some form of random sampling -- whether it be simple, proportional, stratified, or multi-phase -- is strongly recommended. While it will be impossible to interview everyone in the corridor to determine the preferred route, the results of a random sample can be used to make inferences about a population's preferences with a specified degree of confidence.

Use of a simple or systematic random sampling approach insures that every residence and business in the study area has an equal and known probability of being selected for sampling. The sample actually drawn, however, will not necessarily be an accurate representation of the population. For example, a simple random sample of 10 people, drawn from a study area composed of 90 blacks and 10 whites, could contain all whites. Although the probability of drawing such an unrepresentative sample is very low, the possibility cannot be eliminated using a simple random procedure. The reliability of the results will depend on the representativeness of the sample, which cannot be determined (1) until the sample has already been drawn, and (2) unless characteristics of the population used to determine representativeness are known. Information about the population, when available, can be used to design a more precise sample, i.e, one that better estimates population preferences.

*See Part 3 for more detail on sampling approaches.

Two sampling frames may be required: one that lists all residences in the study area and one that lists all businesses. If study area boundaries are drawn to coincide with some existing statistical areas (e.g., voting districts, census tracts, or local planning areas), a list of residences may be available. If not, a residential frame can be compiled from a city directory -- published for many urban areas -- which lists all residences on every block by address. Base maps developed through the windshield survey or walk-through reconnaissance can also be used. These maps identify residential structures, but do not often show the number of individual dwelling units.

Business sampling frames must often be developed from a number of sources, including records kept by local chambers of commerce and other business groups, shopping center managers, and county governments. Again, base maps will show commercial structures, but will not always identify individual businesses.

Respondents can be selected from the frame by a purely random method. The dwellings or businesses in the frame are enumerated and matched up with numbers drawn from a random numbers table. Systematic selection, a slightly different and easier variant, involves using a skip interval to select respondents. The number between selected elements is picked randomly prior to selection.

Cluster sampling is an alternative random selection method used to geographically group the residences or businesses to be sampled, and thereby reduce the time and resources required to administer the survey. For example, in choosing residences, blocks would be randomly selected instead of individual residences. Then all residences in the cluster -- or selected block -- would be surveyed. The requirements for a sampling frame are reduced significantly since the frame is simply a listing of blocks in the study area. Once blocks are selected, lists of residences and businesses are developed only for the subset of blocks.

The survey is best conducted in person in order that a clear description of the routes can be provided. Visual aids, such as demarcated maps, photographs of the alternative ROWs and design features, or a model of the study area, showing alternative corridors, can be used to describe the routes under consideration and their spatial relation to the respondent. The more informed respondents are, the more accurate and reliable survey results will be. Additionally, lengthier interviews are usually possible based on the rapport established between the interviewer and respondent.

A stratified random sample places certain restrictions on the random process which insure that a particular segment, or segments, of the universe will be represented in the sample. The universe is divided up according to the attributes of interest, e.g., location or race in the case of households, or amount of street frontage for businesses. Samples are drawn from each stratum.

The surveyor must have prior knowledge about individual residences and businesses to draw a stratified sample. For example, if he wants to stratify by location, the surveyor must know the address of every member of the frame. Without this knowledge, there is no way to determine the strata to which individual elements belong.

In a stratified sample, identification of a frame occurs simultaneously with the selection of attributes by which to divide the population. All available data on individual residences should be examined to identify potential stratification attributes. Once the attributes are chosen, a frame which includes that information is compiled or obtained. For example, if existing data sources -- containing information on ages, addresses, and vehicle ownership -- are scanned and location is chosen as the stratifying variable, the surveyor should attempt to use the source as a frame. If this is impossible, for security or other reasons, a frame must be constructed.

Proportional stratified sampling, a variant of the stratified method in which the number of respondents drawn from each stratum is proportional to the number of items in the stratum, can also be used to further increase the representativeness of the sample. This procedure weights each stratum in the sample by the number of elements it contains. In the following simplified example, the population is stratified by location in relation to the two alternative ROWs:

Universe: 100 Sample Size: 10

Stratum	Proportion & Percent of Frame in Each Stratum	% of Sample Drawn from Each Stratum	Calculation of # Sampled from Each Stratum
Proximate to ROW A	20/100 = 20%	20%	20% of 10 = 2
Proximate to ROW B	10/100 = 10%	10%	10% of 10 = 1
Proximate to ROWs A & B	50/100 = 50%	50%	50% of 10 = 5
Proximate to Neither A nor B	20/100 = 20%	20%	20% of 10 = 2

Like simple random surveys, stratified surveys ought to be administered in person.

Multi-phase sampling can be used when the universe of residences or businesses in the study area cannot be easily defined and little is known about it. The first phase of the approach involves taking a large sample to collect general data on population characteristics. This initial survey is inexpensive to conduct. In the second phase, a smaller subsample is selected from the original sample group; interviews are then conducted to obtain more costly, indepth attitudinal data. Subsample-to-sample relationships are used to draw conclusions about the attitudes of the remainder of the universe.

There is no preferred sampling frame for the initial sample because the universe is not clearly defined. Respondents should be selected from a list that is as complete as possible, e.g., a criss-cross area directory. Only residents living in the study area should be selected. Respondents to the large survey become the frame for the subsample.

Respondents are selected for the second phase survey using some form of random selection. Sampling cannot be purely random, however, due to the absence of a complete frame.

Telephone interviews are commonly used to collect data in the first round of interviewing. The short, mostly closed-ended questionnaire lends itself to the limitations of telephone surveying. The subsample should be surveyed in face-to-face interviews.

Resource Requirements. Surveys of area residents and businesses can be costly to administer, although resource requirements will vary according to the sampling approach chosen. A comparatively large sample is required since the practitioners will usually want to apply standard confidence level requirements to survey results. Interviews may last up to one hour, and must be performed by skilled interviewers who can describe and answer questions about the alternative routes, and react appropriately to respondent concerns about having a new highway in or near their neighborhood.

The costs of transportation to the homes and businesses of respondents scattered throughout the study area are generally high. Cluster sampling reduces transportation costs because geographic groupings of respondents, such as persons on the same block, are interviewed. Similarly, in a sample stratified by location, respondents will be concentrated in subareas corresponding to the individual strata.

Regardless of the sample design, a random sample is time-consuming and expensive to develop and administer. However, the choice of a preferred route is a crucial point in project planning, and access to accurate, reliable information regarding public opinion is an essential component of the decision-making process.

4.8 QUESTIONS USED IN SURVEYS OF AREA RESIDENTS AND BUSINESSES

The following questions can be selected, combined, and supplemented at the user's discretion, depending on project objectives, target groups, and the nature of the study area.

Information Questions

1. Socio-Economic Data on Residents in the Study Area

° Data on Individual Respondents

-- Sex (see p. 48)

-- Age (see p. 48)

-- Ethnic Background (see p. 48)

-- Marital Status

(1) What is your marital status?

1 Married 2 Divorced 3 Widowed 4 Separated 5 Never Married

— Education

(2) Could you please tell me how many years of school you have completed?

1	Elementary	3	Finished high school	5	Finished college
2	Some high school	4	Some college	6	Graduate study

-- Employment

(3) Are you:

1	Currently employed?	3	Retired?	5	Student?
2	Looking for work?	4	Homemaker?	6	Other? (SPECIFY)

(3a) (IF EMPLOYED) What job are you now working at? (BE SPECIFIC)

(3b) (IF UNEMPLOYED) What did you do at the last regular job you had? (BE SPECIFIC)

° Data on Households

-- Composition of Household

(1) What is your household presently composed of?

1	One person	4	Single parent with children
2	Married couple only	5	Unrelated persons
3	Married couple with children	6	Other (SPECIFY)

— Number of Persons in Household

(2) How many persons, including yourself, reside in your household?

— Distribution by Sex

(3) How many of these persons, including yourself, are male? Female?

— Distribution by Age

(4) How many household members, including yourself, are in each of the following age groups?

_____ 0-5 years _____ 25 - 44 years
_____ 6-17 years _____ 45 - 64 years
_____ 18-24 years _____ 65 and over

— Number of Family Members Employed, or in School

(5) How many adult members of your household (including yourself) are presently employed?

_____ full-time _____ part-time

(5a) Please indicate the number of household members, including yourself, employed in each of the following occupational categories:

___ Professional (doctors, teachers, engineers, lawyers, etc.)
___ Manager or administrator (business owners & managers, government administrators, etc.)
___ Clerical worker (office workers, secretaries, bookkeepers, etc.)
___ Craftsman (carpenters, mechanics, upholsterers, machinists, etc.)
___ Equipment operator (truck drivers, sewing machine operators, etc.)
___ Laborer (window washers, maintenance workers, etc.)
___ Sales worker (salesmen, checkers, clerks, etc.)
___ Service worker (firemen, policemen, beauticians, practical nurses, etc.)
___ Homemaker
___ Student
___ Retired
___ Other (SPECIFY)

___ Fill in only if not employed in another category for 20 or more hours a week (applies to Homemaker, Student, Retired, Other)

(6) How many adult members of your household attend school? ____

— Licensed Drivers

(7) How many members of this household are licensed drivers? ____

— Vehicles

(8) How many licensed motor vehicles (autos, trucks, recreation vehicles, motorcycles, etc.) are owned by, or available to, you and members of your household?

— Sex and Employment Status of Head of Household

(9) Is the head of the household male or female?

1 Male   2 Female   3 No Response

(10) Is the head of this household employed?

(10a) Employed: 1 Full-time   3 Not employed   5 Not looking
2 Part-time   4 Looking   6 Retired

(10b) What is the occupation of the head of the household? (See above, Q5a, for response)

— Household Income

(11) What was your total family income last year prior to taxes? (See p. 49 for response)

(12) Does anyone in this household receive income from one or more of the following?

1 Social Security or VA benefits
2 Pension plan
3 Food stamps
4 Aid to Families with Dependent Children
5 Aid to the Blind or Disabled
6 State assistance programs
7 Unemployment compensation
8 Alimony/child support
9 Assistance from friends and relatives
10 Other (SPECIFY)

- Data on Dwelling Units

-- Location

(1) Street Address ______________________________

(2) In what type of dwelling unit do you reside? (See p. 49 for response categories)

-- Years At Address

(3) How many years have you lived in this house/apartment? _____ years

-- Tenure

(4) Do you own this house/apartment or do you rent?

1 Own or buying   2 Rent

-- Estimated Value (for Homeowners Only)

(5) What, in your judgment, is the present value of this home?

1	Under $20,000	5	$60,000-$74,999
2	$20,000-$29,999	6	$75,000-$94,999
3	$30,000-$44,999	7	$95,000 or more
4	$45,000-$59,999		

-- Rental Costs (for Renters)

(6) How much rent do you pay each month?

1	No rent	5	$200-$249
2	Under $100	6	$250-$299
3	$100-$149	7	$300-$350
4	$150-$200	8	$350 or more

(6a) Is this for a furnished or unfurnished rental unit?

1 Furnished   2 Unfurnished

(6b) Do payments include utilities?   1 Yes   2 No

(IF NO, INDICATE AVERAGE MONTHLY UTILITY CHARGES)

-- Floor Space

(7) How much floor space do you have? (IF RESPONDENT DOESN'T KNOW, ESTIMATE)

1 Less than 500 sq. ft.   2 500-999   3 1000-1499   4 1500 or more

-- Number of Rooms

(8) How many rooms do you have here? (DO NOT COUNT BATHROOMS, HALLS, OR HALF ROOMS)

1 1-3   2 4-5   3 6 or more

(9) How many bathrooms do you have?   1 One   2 More than one

2. Socio-Economic Data on Businesses in the Study Area

° Businesses by Type, Organization, Revenues, Employees, and Wages

-- Type of Activity

(1) (OPEN-ENDED) What type of activity are you currently engaged in?

OPTION: Q1a, which allows the respondent to classify the activity according to Standard Industrial Classification (SIC) categories, can also be used.

(1a) Please classify this activity under one of the following SIC categories (used in the Economic Census):

1	Agriculture, Forestry, Fishing, Hunting, and Trapping	6	Wholesale Trade
2	Mining	7	Retail Trade
3	Construction	8	Finance, Insurance, and Real Estate
4	Manufacturing	9	Services
5	Transportation, Communication, Utilities	10	Public Administration
		11	Nonclassifiable

— Organization of Activity

(1b) How is this business organized?

1 Sole proprietorship 2 Partnership 3 Corporation 4 Estate or trust

— Sales Revenues

(2) What were the gross dollar sales of your business (at this location) during the past year? ________

OPTION: A question can be added to determine the distribution of sales by business sector.

(2a) Approximately what percent of the gross dollar sales at this location fall into each of the following categories?

____ % Retail sales ____ % Wholesale ____ Don't know

____ % Services ____ % Manufacturing

OPTION: Q2 can also be used to collect information on sales trends.

(2b) Have your gross sales changed much in the last five years?

1 Stayed same 2 Increased 3 Decreased 4 Don't know

— Employees

(3) How many people, including management, are employed by your business? ___ employees

OPTION: The following question is designed to classify employees under census labor categories.

(3a) Please indicate the number of people, including yourself, employed under each labor category as defined by the U.S. Census. (See p. 65 for response categories)

(4) What is your current monthly payroll (including management) at this location? (See Q4, p. 49, for response categories)

° Length of Time in Study Area

(1) How long has this business been in operation? ____ years

(2) How long has it operated at this location? ____ years

(3) How many years has this business been operating in this area/neighborhood? (IF LONGER THAN TIME AT CURRENT LOCATION, ASK Q4)

(4) How many moves has it made within the area before reaching this site?

1 One 2 Two 3 Three or more 4 Don't know

° Customer Profile

NOTE: Q1-2 may be used to determine the interdependence between retail and wholesale businesses and local clientele. Q3-3a may be added to explore less tangible aspects of the relationship.

(1) What percentage of your customers live in this neighborhood?

(2) (SHOW MAP OF STUDY AREA) What percentage of your customers live in this area?

(3) Are there any special services or favors that you extend to your regular customers, such as setting aside newspapers or magazines, keeping keys, or extending personal credit? 1 No 2 Yes (SPECIFY)

° Square Footage

(4) Approximately how much land do you have in this location?

1	Less than 5,000 sq. ft	4	20,000 - 49,999
2	5,000 - 9,999	5	50,000 or more
3	10,000 - 19,999	6	Don't know

(4a) What is the approximate floor space used by your business in this location?

1	Less than 1000 sq. ft.	5	5,000 - 9,999
2	1,000 - 1,999	6	10,000 or more
3	2,000 - 2,999	7	Don't know
4	3,000 - 4,999		

° Modes of Transportation Used (Wholesale and Manufacturing Activities)

(1) What percentage of your goods is received by the following modes of transportation?

____ % Motor vehicle ____ % Water

____ % Rail ____ % Other (SPECIFY) Don't Know ___

(2) What percentage of your goods is shipped from here by these modes of transportation?

3. Information Used to Measure Current Levels of Cohesion

° Tenure (See p. 66)

° Residential Turnover

-- Time at Current Address

(1) How long have you lived in this house/apartment? ____ Years ____ Months

(1a) (IF RESPONDENT HAS DIFFICULTY RESPONDING) Do you remember the month and year you moved to this address?

-- Time in Neighborhood

(2) How long have you lived in this neighborhood? (RECORD IN YEARS)

-- Time in Area

(3) How long have you lived in this area? (RECORD IN YEARS)

-- Previous Address

(4) (IF RESIDENCY IS LESS THAN TEN YEARS) Where did you live before moving to this address?

Town/City ______________________________

State ______________________________

(5) What was your former address? (STREET ADDRESS IS PREFERRED. IF NOT KNOWN, OBTAIN STREET NAME AND APPROXIMATE LOCATION.)

(6) Why did you move from your previous address?

(7) How long did you live there?

° Social Interaction

-- Contact with Neighbors

(1) Since moving to this neighborhood, how many of your neighbors' homes have you visited more than one time?

(2) How often do you invite any of your neighbors to visit your home, or visit in their houses?

1 Nearly every day
2 2 or more times a week
3 About once a week
4 Several times a month
5 About once a month
6 Less often than once a month
7 Almost never

-- Relatives and Close Friends in Proximate Areas

(3) How many relatives or close friends live within walking distance of your home? Within a 15-minute drive? Within a 30-minute drive?

	Number of Relatives	Number of Close Friends
Walking Distance		
Fifteen-Minute Drive		
Thirty-Minute Drive		

OPTION: Q4 can be used in place of Q3 to locate friends and relatives in the macro or micro study area.

(4) (SHOW MAP OF STUDY AREA OR SUBAREA) Do you have any close friends or relatives who live in the area covered by the map? 1 No 2 Yes

(IF YES, HAVE RESPONDENT LOCATE FRIENDS' AND RELATIVES' HOUSES ON MAP. MARK EACH LOCATION WITH AN "F" FOR FRIEND OR AN "R" FOR RELATIVE, AS APPROPRIATE.)

— Frequency of Interaction with Close Friends and Relatives

(5) About how often do you get together with any of these friends or relatives that live in this area? (See Q2 for response categories.)

° Involvement in Community Organizations

— Screening Question

(1) How involved do you get in local and community activities? Would you say you are frequently involved, sometimes involved, hardly ever involved, or never involved?

1 Frequently involved
2 Sometimes involved
3 Hardly ever involved
4 Never involved
5 Don't know

— Involvement in Neighborhood Organizations

(2) Is there a neighborhood association here? (IF YES) What type of issues does the neighborhood association concern itself with? (RESPONDENT MAY INDICATE MORE THAN ONE RESPONSE.)

1 Neighborhood beautification (gardens, etc.)
2 Neighborhood recreation (pool, parks, etc.)
3 Development issues (buildings, roads, etc.)
4 Political issues (discrimination, tenants' rights, etc.)
5 Issues dealing with the larger community (voting, pollution, etc.)
6 Other (SPECIFY)

(3) Do you hold, or have you ever held, office in this neighborhood association?

(4) Have you done any work for the association?

(5) (IF NO WORK) Have you attended meetings?

— Involvement in Other Organizations

(6) Do you or does any member of this household belong to any clubs, lodges, unions, PTA, church, social or professional organizations?   1 No   2 Yes

(7) (IF YES) What are the names of these organizations?

(8) How would you rate your interest and participation in (ORGANIZATION)? Would you say you are:

1 Very active and interested, attending meetings regularly

2 Interested and moderately active, attending meetings when you can

3 A member only, attending meetings only rarely

(REPEAT FOR EACH ORGANIZATION MENTIONED IN Q2)

(9) Of the clubs/organizations that you just mentioned, which are located in your neighborhood?

Attitude and Perception Questions

1. Change Over Time in Attitudes Toward the Proposed Project

° Presence of Change

(1) Have your feelings concerning the proposed highway changed since you first learned about the project?

1 Yes   2 No   3 Don't Know

° Direction of Change

(2) (IF YES) Have your feelings become more favorable or less favorable?

1 More Favorable   2 Less Favorable   3 Don't Know

° Explanation of Change

(3) (IF CHANGED) Why have your feelings changed? (PROBE FOR DETAIL)

2. Evaluation of Alternative Routes

° Designation of a Preferred Route

(1) Which route do you prefer?

1 Alternative X   2 Alternative Y   3 Neither   4 Prefer Both the Same   5 Don't Know

° Ranking Routes (USED WHEN MORE THAN 2 ALTERNATIVES ARE UNDER CONSIDERATION)

(2) If the highway decision were to involve the following options, which would you most prefer? Which would be your second preference? Your third? (RANK ORDER)

____ Route A   _____ Route B   _____ Route C   _____ "No build" option

OPTION: The following question can be used with or instead of Q2 to more precisely determine variations among preferences for alternative routes.

(3) Please tell us your preference for the two routes by dividing 100 points between Routes A and B. Assign the greatest number of points to the route you most prefer, and the remaining points to the other route. For example, a person who slightly prefers Route A to Route B might answer this question in the following manner:

Route A 60

Route B 40   100 = total points

Please indicate your preferences below for the two routes:

Route A _____

Route B _____ 100 = total points

NOTE: This format can be adapted to include additional alternatives and the no-build option.

° Intensity of Preferences

-- Route Chosen First

(4) How strongly do you feel about your choice of Route ____ as the most preferred alternative?

1 Strongly Positive 2 Mildly Positive

(5) If the highway were to be located on the route which you chose first, how would you feel about it? Would you be:

1 Very Favorable 2 Somewhat Favorable 3 Neutral 4 Somewhat Unfavorable 5 Very Unfavorable

(6) What is the major advantage of the alternative you have chosen? In other words, what is the principal or main reason you chose Route _____?

(6a) (IF RESPONDENT PROVIDES A REASON) Are there any other reasons you picked Route ____ as your first choice?

(7) Does it have any disadvantages, problems or shortcomings?

OPTION: Q8 can be added concerning the respondent's opinion of the significance of perceived disadvantages.

(8) Is this a minor disadvantage or a serious problem?

(9) What do you think its consequences will be?

-- Route Chosen Last

(10) How do you feel about your choice of Route ____ as the least preferred alternative?

1 Strongly Negative 2 Mildly Negative

(11) If the highway were to be located on the route which you chose last, how would you feel about it? Would you be:

1 Very Favorable 2 Somewhat Favorable 3 Neutral 4 Somewhat Unfavorable 5 Very Unfavorable

(12) Why did you rank Route ____ as the least desirable location for a road? That is, what is the principal reason you consider Route ____ to be the poorest choice?

° Importance of Specific Factors in Route Selection

— Perceptions of Differences Between Routes

(1) Which route do you think will be more (convenient*) for most people in the area?

1 Alternative X 2 Alternative Y 3 Neither 4 Equally Convenient 5 Don't Know

(2) How much more (convenient*) will Route ____ be than Route ____?

1 Slightly 2 Moderately 3 Very Much More 4 Don't Know

(3) How important should the question of (convenience*) be in choosing between the two routes?

1 Not Important 2 Somewhat Important 3 Extremely Important 4 Don't Know

*NOTE: This three-question series about convenience should be repeated to probe perceptions about other types of impacts. Examples of impacts which may be used with this format are provided below. Practitioners may also adapt factors and statements listed in Addendums A & B for use with these questions.

Cohesion: Divide or split the area into two separate communities

Accessibility: Make it harder for children to get to school
Disrupt people more when they want to shop or go to church

Displacement: Cause more people to have to move out of their homes and find new places to live
Destroy more parks

Employment, Income, & Business Activity: Encourage companies to build new stores and shopping centers
Encourage companies to build new factories which will provide jobs for people in the area

Property Values & Taxes: Produce increases in construction costs

Land Use: Improve land uses that are now deteriorating

— Summated Instrumentalities

(1) When a road is built it usually causes changes to occur in the community through which it runs. Use the rating form below to tell us how you would feel if the following possible changes occurred in (SPECIFY TOWN OR CITY) as a result of road construction.

	Extremely Unhappy	Very Unhappy	Somewhat Unhappy	Neutral	Somewhat Happy	Very Happy	Extremely Happy
	7	6	5	4	3	2	1
If residential property values increased, I would feel							
If homes had to be moved, I would feel							

NOTE: Other possible effects which can be explored using this format are listed below by impact area:

Accessibility: If driving to social activities (e.g., visits to friends, movies, amusement parks) becomes easier
If driving to business districts becomes easier
If driving to public facilities becomes easier

Displacement: If businesses have to be moved
If public facilities have to be moved
If social facilities have to be moved

Employment, Income & Business Activity: If the number of jobs in the area increases

Property Values & Taxes: If commercial and industrial property values increase
If rates and fees (e.g., gasoline taxes or license fees for operating vehicles) increase

NOTE: Additional questions to explore other dimensions of the impact areas can be derived from the list of factors and statements in Addendums A & B.

OPTION: Q2 and 2a can be added to identify the most and least desirable changes.

(2) Which of the changes in item (1) above would make you most happy? Please specify one and rank the top 3.

(2a) Which of the changes would make you most unhappy? Please specify one and rank the top 3.

(3) Rate the likelihood that each of the changes listed under item (1) will occur if Alternative A is chosen for the new route.

	Surely Will Not	Probably Will Not	May or May not	Probably Will	Surely Will	
Construction of Alternative A						Increase Residential Property Values
Construction of Alternative A						Cause Homes To Be Moved

(REPEAT FOR EACH POSSIBLE EFFECT USED IN Q1)

(4) Now rate the likelihood that each of the changes will occur if Alternate B is chosen. (USE Q3 FORMAT, SUBSTITUTING ALTERNATIVE B FOR ALTERNATIVE A, AND REPEATING THE CHANGES LISTED IN Q1. CONTINUE FOR EACH ALTERNATIVE.)

3. Opinion Data Used to Measure Neighborhood Cohesion

° Feelings of Attachment to Neighborhood

(1) Some people feel they are really part of a neighborhood, while others see it more as just a place to live. How do you feel about living in this neighborhood? Do you :

1 Feel you are really part of the neighborhood

2 See the neighborhood as just a place to live

3 Don't know

° Feelings of Satisfaction with Neighborhood

-- Overall Satisfaction

(2) How do you rate your neighborhood as a place to live? Would you say it's:

7 Excellent 6 Very Good 5 Above Average 4 Average 3 Below Average 2 Poor 1 Very Poor

-- Identification of Best and Worst Features

(3) What things do you like best about living in this neighborhood?

OPTION: Response categories can be selected from list of positive neighborhood characteristics in Addendum A.

(4) What things do you like least?

OPTION: Response categories can be selected from the list of negative neighborhood characteristics in Addendum B.

-- Rating Neighborhood Against Others in Area

(5) Which statement best describes how you feel about your neighborhood?

1 One of the best neighborhoods in the area

2 Considerably better than most

3 Slightly better than most

4 About the same as most

5 Slightly worse than most

6 Considerably worse than most

7 One of the worst in the area

8 No opinion

° Perceived Stability of Neighborhood Over Time

-- Presence and Description of Changes in Neighborhood

(6) Has this neighborhood changed much since you moved here?

1 Yes   2 No   3 Don't know

(6a) (IF YES) In what ways has it changed?

-- Degree of Change and Identification of Major Changes

(7) Do you think the neighborhood is changing a lot, somewhat, or not changing at all?

1 Changing a lot   2 Changing some   3 Not changing   4 Don't know

(8) In your opinion, what has been the biggest changes in this neighborhood in the past two years?

° Future Plans

-- Expectation Concerning Future Moves

(9) How long do you expect to live in this neighborhood?

(10) (IF PLAN TO MOVE WITHIN FIVE YEARS) Why are you planning to move?

— Desire to Remain in Neighborhood

(11) If you could chose, would you want to stay in this neighborhood, or would you want to move somewhere else?

1 Stay in neighborhood   3 Doesn't matter
2 Move somewhere else   4 Don't know

— Evaluation of Perceived Changes

(12) Has this neighborhood gotten better or worse?

(13) How do you feel about changes going on around here? Do you think they are really improving things a lot, improving things somewhat, not improving things at all, or are they hurting the neighborhood?

1 Really improving   3 Not improving   5 Don't know
2 Improving somewhat   4 Hurting

— Expectations Concerning Future Changes

(14) What changes, if any, do you expect to see in this area in the future?

(15) What kind of changes, if any, would you like to see in this area in the next ten years?

4. Predicting the Effects of the Project on Cohesion

° Separation from Community

(1) Do you feel a freeway near your neighborhood would cause any undesired separation from the community with which you wish to identify?

1 Yes   2 No   3 Other (SPECIFY)   4 Don't know

(1a) Please explain your feelings.

° Rating Specific Characteristics of the Neighborhood

— Semantic Differential

(1) Rate your neighborhood in accordance with the following characteristics. Check one space between each pair of words or phrases.

<u>Example</u>:

	1	2	3	4	5	6	7	
Noisy	___	___	___	___	___	___	___	Quiet

If you think the neighborhood is "noisy" mark the space next to the word "noisy." If you think it is "quiet", mark the space next to the word "quiet"; and if you think it is somewhere in between, mark the space where you think it belongs. The closer the check is to the left or right, the more you feel that word describes your neighborhood.

	1	2	3	4	5	6	7	
Congested	___	___	___	___	___	___	___	Spacious
Dangerous	___	___	___	___	___	___	___	Safe

NOTE: Combine other positive and negative neighborhood characteristics to form pairs of words or phrases for this question format.

— Five-Point Rating Scale

(2) Rate the following neighborhood characteristics:

	Very Good	Good	Fair	Poor	Very Poor
Low Noise Levels					
Cleanliness					

NOTE: Repeat for other positive neighborhood characteristics.

• Rating Public Services

(3) I'll read a list of public services. For each one, please indicate your opinion of the quality of that service <u>in this area</u>, according to these categories:

1. Very good
2. Good
3. Not good or bad
4. Bad
5. Very bad
6. Don't know

1. Parks and recreation facilities? ____
2. Public schools? ____
3. Water for drinking and recreation? _____
4. Police service? _____
5. Fire services? _____
6. Condition of city streets? _____
7. Expressways? ______
8. Mass transit service? _____
9. Health and hospital services? _____
10. Welfare programs? _____
11. Urban renewal? _____
12. Street lighting? ______
13. Garbage collection? ______
14. Parking? _____
15. Preservation of historical sites? _____

° Exploration of Emotional Dimensions of Cohesion

— Emotions Associated with Neighborhood

(4) To indicate your feelings about living in this neighborhood, please check one space between each pair of words or phrases. Living in this neighborhood makes me feel:

	1	2	3	4	5	6	7	
Happy	___	___	___	___	___	___	___	Unhappy
Not Lonely	___	___	___	___	___	___	___	Lonely
Proud	___	___	___	___	___	___	___	Ashamed
Peaceful	___	___	___	___	___	___	___	Angry
Important	___	___	___	___	___	___	___	Unimportant
Powerful	___	___	___	___	___	___	___	Powerless
Contented	___	___	___	___	___	___	___	Discontented
Safe	___	___	___	___	___	___	___	Unsafe
Cared For	___	___	___	___	___	___	___	Neglected

— Perceptions of Emotional Disposition of Neighbors

(5) Please give your impression of the people who live in your area. I feel that the people in this area are:

	1	2	3	4	5	6	7	
Friendly	___	___	___	___	___	___	___	Unfriendly
Helpful	___	___	___	___	___	___	___	Not helpful
Interesting	___	___	___	___	___	___	___	Dull
Not Snobbish	___	___	___	___	___	___	___	Snobbish
Happy	___	___	___	___	___	___	___	Unhappy
Not Lonely	___	___	___	___	___	___	___	Lonely

5. Opinion Data Used to Measure Accessibility

° Proximity to Area Facilities

— Rating the Importance of Proximity to Specific Facilities

(1) People are often concerned about the convenience of certain facilities in their neighborhood. Is it very important, important, or not so important for the people in this (house)(apartment) to be very close to the following?:

	Very Important	Important	Not So Important
Food store			
Other shopping			

NOTE: Repeat pattern for: hospital or clinic; church (SPECIFY); public transportation; elementary school; park or playground; daycare center; club or other social organization (SPECIFY); local bar or restaurant; other entertainment (SPECIFY); other neighborhood destination points (SPECIFY).

— Identifying the Most Important Facilities

(2) Of all the facilities in your neighborhood (in Q1, ABOVE) which one facility is the most important to be near? The second most important? The third?

(3) What kind of transportation do you usually use to go to the ...? (RECORD TRANSPORTATION CODE FOR EACH ITEM LISTED IN Q1 ABOVE)

1 Walk	3 Borrow car	5 Use public transportation	7 Don't go there
2 Use own car	4 Take taxi	6 Other (SPECIFY)	

(4) About how many minutes does it usually take to go to the ____? (RECORD NUMBER OF MINUTES FOR EACH RELEVANT ITEM)

° Rating Convenience of Access to Neighborhood or Study Area Destinations

— Convenience of Access to Pre-Specified Destinations

(1) I'd like to get some idea of how convenient you find this area for getting to various places. For each place I mention, please tell me (a) whether you ever go to that place or do that thing, (b) which one form of transportation you use most often to get there, and (c) how convenient you generally feel it is for you to get there.

Let's start with "Going to and from work."

(1a) Do you (go to and from work)? 1 Yes 2 No

(1b) (IF YES) How do you usually (go to and from work)?

1 Drive own car
2 Friend/relative drives me
3 Use public transportation
4 Take a cab
5 Ride a bike
6 Walk
7 Other (SPECIFY)

(1c) How convenient is it to (go to and from work)?

1 Very convenient; rarely have problems
2 Fairly convenient; occasionally have problems
3 Fairly inconvenient; often have problems
4 Very inconvenient; usually have problems

NOTE: Repeat Q1a-c for: take children to school; do the grocery shopping; shop for clothing and other things; visit friends who live in my area; visit friends who live outside my area; go to church or synagogue; go to the doctor, health clinic or dentist; go out to eat; go to movies or other entertainments; go to parks or playgrounds; other (SPECIFY).

-- Convenience Rating by Mode of Transportation

(1) Now, I'd like you to rate a number of other aspects of this area that relate to convenience. First, how would you rate the ____ (READ EACH ITEM AND GET AN ANSWER FOR EACH)

	Excel-lent	Good	Fair	Poor	Does Not Apply	Don't Know
a. Ability to get around this area by car	1	2	3	4	5	0
b. Ability to get around this area by walking	1	2	3	4	5	0
c. Ability to get around this area by bicycle	1	2	3	4	5	0
d. Access to public transportation	1	2	3	4	5	0
e. Access to freeways	1	2	3	4	5	0

° Opinions on the Importance of an Existing Road (Scheduled For Major Improvements)

(1) Does the existing highway make it difficult or easy for you and your family to get to ____ (READ EACH ITEM AND GET AN ANSWER FOR EACH)

(a) Work
(b) Local schools
(c) Medical facilities
(d) Shopping districts
(e) Church or synagogue
(f) Neighborhood parks and playgrounds
(g) Friends and relatives

6. Predicting the Effect of the Project on Accessibility

° General Impact

(1) Would the proposed highway make it easier or more difficult to make the following trips?

Trip Type	Easier	More Difficult	Not Applicable
To work			
To school			

NOTE: Repeat pattern for trips to grocery shopping; church or synagogue; doctors, clinics, hospitals; and recreation areas.

° Comparison of Impacts for Designated Route Alternatives

NOTE: Q1 can be modified to collect data on residents' perceptions about the advantages and disadvantages of each route alternative.

(2) Please indicate the effects of each proposed route on accessibility to the following activities.

	Route A		Route B	
Trip Type	Easier	More Difficult	Easier	More Difficult
To work				
To school				

(REPEAT FOR OTHER TRIP TYPES INDICATED IN Q1, ABOVE)

7. Opinion Data Used to Measure Business Activity

° Opinions Regarding Level of Retail Activity in Area

— Number of Stores and Service Facilities

(1) Do you feel your local community has enough retail stores and service facilities? Or do you feel more are needed?

1 Enough 2 More are needed 3 Other (SPECIFY) 4 Don't know

(2) Please explain why you feel there are enough or more are needed.

-- Optimal Locations for New Businesses

(3) If more businesses were to locate in your community, where would the best location for them be? (SHOW RESPONDENT MAP OF AREA)

° Perceptions of the Area as Suitable Business Location

— Assessment of Current Location by Owners

(1) Here are some words and phrases which we would like you to use to describe your business in relation to its location. For example, if you think it is in a good location, put an (X) right next to the words "good location". If you think it is a poor location, please put an (X) right next to the words "poor location". If you think it is somewhere in between, please put an (X) where you think it belongs.

	VERY MUCH SO	YES	IN BETWEEN	YES	VERY MUCH SO	
Good location						Poor location
Adequate parking						Inadequate parking
Not dependent on traffic from the expressway						Dependent on traffic from the expressway
Low capital investment in this location						Has a high capital investment in this location
Has adequate room to expand						Needs more land for expansion
Closely tied to other organizations located in this area of the city						Not closely tied to other organizations located in this area of the city

— Advantages and Disadvantages of Location to Individual Owners

(1) What are the advantages for your organization in your current location?

(2) The disadvantages?

— Problems Facing Neighborhood Businesses

(1) As you see it, what are some of the important problems facing businesspersons in this neighborhood?

(2) (IF MORE THAN ONE PROBLEM) Of the problems you mentioned, which do you consider the most important?

- Expectations Regarding Future Locations of Businesses

— Plans Over Next Two Years

(1) Do you plan to move your business from this location within the next year or two?

1 Yes 2 No 3 Don't know

(1a) (IF YES) Why are you planning to move?

— Plans Over Next Five Years

(2) Do you expect this organization to remain in this location for the next 5 years?

1 Yes 2 No 3 Unsure

(2a) (IF NO OR UNSURE) What would be the chief cause of your moving?

(2b) If your organization did move, do you believe it would stay in this area of the city?

1 Yes 2 No 3 Unsure

— Desire to Move

(3) Would you like to move? 1 Yes 2 No 3 Don't know

(3a) (IF YES) Why would you like to move?

1 Related to highway 2 Unrelated to highway

(3b) Would you want to stay in this neighborhood, or would you move somewhere else?

1 Stay in neighborhood   3 Doesn't matter
2 Move somewhere else   4 Don't know

8. Predicting the Effect of the Project on Business Activity

° Overall Effects on Individual Businesses

-- General Expectations

(1) Considering all of the good and bad effects, how would do you generally feel about the impacts of the proposed highway on your business? Are you:

1 Very Favorable   2 Somewhat Favorable   3 Neutral   4 Somewhat Unfavorable   5 Very Unfavorable

-- Effect on Sales Volume

(2) How would the dollar volume of your business be affected by the freeway? (IF IT DEPENDS, GIVE DETAILS)

1 Increase it   3 Wouldn't change   5 Don't know
2 Decrease it   4 It depends

OPTION: Q2a can be added to secure information useful in determining effects on area business in general.

(2a) If built, what effect would the freeway have on the general level of dollar sales for businesses of your type in the area?

1 Increase it   3 Wouldn't change   5 Don't know
2 Decrease it   4 It depends

° Benefits to Individual Businesses

-- Overall Benefit

(1) Do you feel that your business would benefit from a highway in or near this neighborhood?

1 Yes   2 No   3 Don't know

-- Perceived Benefits

(1a) (IF YES) How would your business benefit from a highway?

1 Relieve traffic congestion
2 Increase property values
3 Better neighborhood appearance
4 Increase accessibility for customers
5 Increase accessibility for suppliers
6 Other (SPECIFY)
7 Don't Know

OPTION: Q1a can also be left open-ended.

-- Rating Benefits

(1b) Please tell how you feel about (READ 1st BENEFIT MENTIONED IN Q1a). Do you feel that the benefit from (REPEAT BENEFIT) would be very great, moderate, or rather small? (REPEAT FOR EACH BENEFIT RESPONDENT HAS MENTIONED)

1 Very great   2 Moderate   3 Rather small   4 Don't know

° Negative Effects on Individual Businesses

-- General Expectation of Negative Effects

(2) Do you expect that a highway in or near this neighborhood will have any negative effects on your business?

1 Yes 2 No 3 Don't know

-- Perceived Negative Effects

(2a) (IF YES) What negative effects would you expect from a highway? (SEE ADDENDUM B FOR LIST OF NEGATIVE EFFECTS)

-- Rating Negative Effects

(2b) Please tell me how you feel about (READ 1st NEGATIVE EFFECT MENTIONED IN Q2a RESPONSE). Do you feel that the negative effect from (REPEAT NEGATIVE EFFECT) would be very great, moderate, or rather small? (REPEAT FOR EACH NEGATIVE EFFECT RESPONDENT HAS MENTIONED)

1 Very great 2 Moderate 3 Rather small 4 Don't know

° Effects of Knowledge About Project on Business Decisionmaking

-- Decisions to Date

(1) Have you already made specific decisions about your business because of the proposed freeway?

NOTE: Either Q1a or 2a-c can be used to secure additional information on decisionmaking. Responses to Q2a-c capture more detailed data concerning the effects of knowledge about the proposed road on upgrading and maintaining the business.

(1a) (IF YES) What decisions have you made? (RESPONDENT MAY GIVE MULTIPLE ANSWERS)

1 Move out of area
2 Relocate in area
3 Will not remodel or enlarge building
4 Will remodel or enlarge building
5 Will acquire more land
6 Others (SPECIFY)
7 Don't know

(2) If you have been thinking of remodeling or renovating your business or property, has knowledge of the proposed highway strengthened, weakened, or not affected your decision?

1 Strengthened 2 Weakened 3 Remained the same

(2a) Has knowledge of the proposed highway affected your attitude toward maintaining your business premises?

1 Yes 2 No 3 Don't Know

(2b) (IF YES) Would you say you are more inclined or less inclined to maintain your business premises?

1 More inclined 2 Less inclined 3 Don't know

-- Expected Decisions

(1) If the highway is built within 10 years, what will you do? (RESPONDENT MAY GIVE MULTIPLE ANSWERS)

1 Depends on highway's distance from business
2 Depends on location of access ramps
3 Will acquire more land for business
4 Depends on presence of service road
5 Will remodel or enlarge building
6 Other (SPECIFY)
7 Don't know

(2) If your business is in the ROW, what will you most likely do?

1 Relocate in area
2 Relocate out of area
3 Go out of business
4 Other (SPECIFY)
5 Don't know

-- Knowledge of the Businesspersons' Decisions

NOTE: This question can secure data useful for broadening knowledge of study area changes.

(1) Have any businesses already moved out of the area because of the proposed freeway? (IF YES, GIVE NAME)

1 Yes   2 No   3 Don't know

9. Opinion Data Used to Measure Land Use and Development Trends

° Perception of Development Options

-- Most Important Option

(1) What do you believe is the one most important thing which could be done to improve this area of the city?

-- Rating the Desirability of Specific Proposals

(2) The location, design and access of transportation facilities are largely determined by the manner in which an area develops over an extended period of time. What is the relative desirability of development of each of the following items for the (SPECIFY AREA) in the years ahead? Please check one column for each item.

	Highly Desirable (1)	Desirable (2)	Relatively Desirable (3)	Undesirable (4)
Single family housing on urban lots				
Single family housing tracts of one acre or larger				

NOTE: Repeat this sequence for multi-family housing tracts, mobile home parks, no new housing development; new commercial centers; improve or expand existing centers, no change in commercial centers; more parks, more indoor recreation facilities, more outdoor recreation facilities; preserve wildlife habitat, preserve farmland; enlarge colleges and technical schools; additional health care facilities; new industrial facilities, develop or expand existing industrial facilities, no change in industrial activity.

— Agreement or Disagreement with Specific Proposals

(3) Listen to the following development proposals and indicate whether you agree or disagree with them. I'll also ask how strongly you feel about these issues.

The city should beautify deteriorating areas of the city even though it will involve relocating some families.

1 Strongly agree	3 Tend to disagree	5 Don't know
2 Tend to agree	4 Strongly disagree	

NOTE: Q3 can be used for any development proposals facing the area. Each proposal should be phrased as a positive statement to which the respondent can agree or disagree.

— Rating the Urgency of Development Proposals

(4) For each development proposal listed below, indicate whether you consider it to be urgent, important, or not important. If undecided, e.g., somewhat important or somewhat unimportant, mark either 2 or 4.

	Urgent		Important		Not Important
Beautification of deteriorating housing areas	1	2	3	4	5

NOTE: This questioning pattern can be used to measure reactions to any development proposal being considered in the study area.

10. Predicting the Effect of the Project on Land Use and Development Trends

° Change in Neighborhood Features

(1) How would the following items change if the proposed project is constructed?

		More/ Larger	Less/ Smaller	About Same	Don't Know
Apartment Houses:	Number	1	2	3	4
	Size	1	2	3	4
Retail Businesses:	Number	1	2	3	4
	Size	1	2	3	4
Service Businesses:	Number	1	2	3	4
	Size	1	2	3	4
Industrial Businesses:	Number	1	2	3	4
	Size	1	2	3	4

4.9 TRIP ACTIVITY SURVEYS

Objective. To record information on trip activity patterns within the study area, and from locations within the study area to outside destination points.

Description. The key to this survey approach is the selection of a location at which surveyors will observe trip activities, select respondents, and elicit information from them. Depending on practitioners' needs, the survey location may be the entrance of key local service centers, shopping centers, parking lots, employment centers, etc. Once the location is determined, and the time intervals for collecting data are established, the survey team will make observations and ask questions concerning frequency of trips, modes of travel, origin and destination points, time of day, and socio-economic characteristics of trip-makers.

Sampling Approach.* Depending on the situation, the surveyors may take a census sample, or use an interval or quota sampling approach.

Resource Requirements. Resource requirements are usually low. The surveyors generally remain in one place, or are stationed at only a few selected locations. The observations made and questions asked are limited and relatively simple in nature.

Utility and Limitations of Approach. The trip activity survey is a simple way to secure data not available in record sources on intra-community trip activities. It can also generate data on through traffic and trips to outside destination points. The approach may be used to identify important pedestrian and bicycle routes, and to determine the frequency of use of local facilities and the characteristics of users.

This approach is extremely flexible, allowing practitioners to select observation points which are consistent with project needs. Its major use is to generate data used to explore accessibility questions. However, information can

*See Part 3 for more detail on sampling approaches.

also be collected which is useful in exploring community cohesion, potential displacement effects, employment patterns, and business activity.

4.10 QUESTIONS USED IN TRIP ACTIVITY SURVEYS

The following questions can be selected, combined, and supplemented at the user's discretion, depending on project objectives, target groups, and the nature of the study area.

Information Questions

1. Information on Current Trip Activity (from Residence to Selected Locations)

NOTE: Mapping techniques are often used to graphically represent trip activities. This aids in the identification of areas with high levels of intracommunity trips and focuses particular attention on trips by foot. (See Vol. 1, p. 147, for a description of mapping of trip activity data.)

• Trips to Workplace

NOTE: These questions should be asked for each wage earner contributing 25% or more of the total family income.

— Screening Question

(1) Does (SPECIFY NAME OF WAGE EARNER) expect to stay on this job for another year or more? 1 Yes 2 No

NOTE: This question is used to determine if the major wage earner plans to work at the present location long enough to make it worthwhile to continue the questioning.

— Place of Employment

(2) What is the name and address of 's place of work?

— Mode of Travel, Route Taken, and Distance to Work

(3) How does ____________ usually go to work?

1 Walks	4 Uses taxi
2 Uses own car	5 Uses public transportation
3 Borrows car or carpools	6 Other (SPECIFY)

(4) What streets or highways are used to get to work? (IDENTIFY ROUTE ON MAP)

(5) How far does ____________ travel to get to work?

In Miles? 0-5 ___ 6-10 ___ 10-15 ___ 15-20 ___ 20 + ___

In Minutes? (SAME RESPONSE CATEGORIES AS FOR "IN MILES")

• Trips to School

(1) (Do you/does the student) go to school full-time or part-time?

(2) What is the name and address of the school?

(3) What type of school is it?

(4) How (do you/does the student) get there?

1 Walks	4 Borrows car or carpools	7 Other (SPECIFY)
2 Takes school bus	5 Uses taxi	
3 Uses own car	6 Uses public transportation	

(5) What streets or highways are used to get there? (IDENTIFY ROUTE ON MAP)

(6) How far (do you/does the student) travel to get to school? (SEE Q5 IN PREVIOUS SUBSECTION FOR RESPONSE CATEGORIES)

° Trips to Frequently Used Services

(1) Where do members of your household go to perform the following activities? How far is each from your home?

		Distance in Miles					
Activity	Name & Address	0-1/2	1/2-1	1-3	3-5	5+	D/K
Grocery shopping	____________	1	2	3	4	5	6
Bank	____________	1	2	3	4	5	6

NOTE: Repeat pattern for dry goods stores, friends, church; doctor care; movie theater; other entertainment and public parks.

OPTION: The first part of Q1 can be rephrased as follows: Where did someone from this household most recently go (for groceries)? This more direct question is often easier for respondents to answer.

(2) How often do members of your family go to these places?

	At Least Once Every					
	Day	Week	Month	Year	Don't Know	Not Applicable
Grocery Store						
Bank						

(REPEAT FOR SERVICES LISTED IN Q1, ABOVE)

(3) How do members of your family usually get to and from these places?

	Mode of Travel					
	Drive Auto	Rider in Auto	Bus	Taxi	Walk	Other
Grocery Store						
Bank						

(REPEAT FOR SERVICES LISTED IN Q1)

° Identification of Destination Points Inside and Outside the Study Area

(1) Which of the following do you or your family usually do in (NAME AREA)? Which do you go outside the area to do, and which do you do both in and out of this area? Do you usually do your grocery shopping in (NAME AREA), go outside, or go both inside and outside? (IDENTIFY ALL CATEGORIES THAT APPLY AND REPEAT FOR ITEMS LISTED IN Q1b, BELOW)

NOTE: In cases where respondents go to destination points outside the community, the following questions generate information on (1) whether this is by choice or because services are not available within the area, and (2) recent changes in the availability of services.

(1a) (IF "GO OUTSIDE" ASK) Are there any (READ ITEM) located in this neighborhood? (IF "NO" RECORD UNDER "NO FACILITIES IN AREA" in Q1b, BELOW)

(1b) (IF "GO OUTSIDE" OR "BOTH IN AREA AND GO OUTSIDE," ASK) Were any of the (READ ITEM) that you go to now formerly located in this neighborhood? (IF "YES" RECORD UNDER "FORMERLY IN AREA")

Destinations	Not Applicable	Do In Area	Both in and Outside	Go Outside	No Facil. in Area	Formerly in Area
Grocery						
Bank						

Repeat for: dry goods stores, church or synagogue, movies or theaters, parks and playgrounds, doctor, and health clinics.

° Use of Map to Show Major Facilities in Relation to Respondent's Home

NOTE: Used to plot the location of the respondent's residence and the places where the respondent goes to secure services.

(SHOW THE RESPONDENT A MAP) Here is a map of the area which may help us as we talk. To help us get located, let's find your house on the map. (FIND RESPONDENT'S HOUSE ON THE MAP AND MARK IT AS PRECISELY AS POSSIBLE. BE SURE TO SHOW THE HOUSE ON THE CORRECT SIDE OF THE STREET. THEN HAND MAP TO RESPONDENT.)

Now, looking at the map, please find and mark the following:

(1) Where you do most of your food shopping? (CIRCLE AREA ON MAP AND LABEL "FOOD")

(2) Where you do most of your shopping for things other than food? (CIRCLE AREA ON MAP AND LABEL "SHOP")

(3) If you have any children in school, where is the school located? (CIRCLE AREA ON MAP AND LABEL "SCHOOL")

° Use of an Existing Route for Selected Activities

(1) Do you presently travel over _______ Avenue? For what purposes? (RESPONDENT MAY SELECT MORE THAN ONE CATEGORY)

1 Shopping
2 Travel to school
3 Travel to town
4 Commuting to work
5 Taking children to school
6 Other (SPECIFY)

Attitude and Perception Questions

Importance of Trips

(1) How important do you consider trips to ____________________ ?

1 Extremely Important
2 Very Important
3 Important
4 Not So Important
5 Unimportant

(ASK SAME ABOUT TRIPS TO EACH PLACE MENTIONED BY RESPONDENT IN INFORMATION SECTION, ABOVE)

Addendum A

PERCEIVED POSITIVE EFFECTS OF THE PROPOSED PROJECT

Sample Response Categories

COHESION
- Promote community togetherness

ACCESSIBILITY
- Improve access to schools
- Improve access to religious facilities
- Improve access to employment centers
- Improve access to business districts
- Improve access to public facilities
- Improve access to parks and historical sites

EMPLOYMENT, INCOME AND BUSINESS ACTIVITY
- Increase employment opportunities
- Increase opportunities for private development
- Improve customer access
- Improve access to suppliers
- Stimulate community development
- Encourage construction of new shopping centers
- Encourage construction of new industrial facilities

PROPERTY VALUES & TAXES
- Increase property values

LAND USE
- Rehabilitate deteriorated areas

RESIDENTIAL ACTIVITY
- Stimulate housing construction

AESTHETICS
- Improve general appearance of community
- Improve neighborhood appearance

PHYSICAL
- Control air pollution
- Control noise
- Control water pollution

HEALTH & SAFETY
- Improve fire protection
- Improve police protection
- Improve medical service (including ambulance)
- Decrease auto accidents

AUTO RELATED
- Reduce fuel consumption
- Relieve traffic congestion
- Relieve public transit congestion

Addendum B

PERCEIVED NEGATIVE EFFECTS OF THE PROPOSED PROJECT

Sample Response Categories

COHESION
- Split the neighborhood
- Separate family and friends
- Change social character of neighborhood

ACCESSIBILITY
- Decrease access to schools
- Decrease access to religious facilities
- Decrease access to employment centers
- Decrease access to public and shopping facilities

DISPLACEMENT
- Displace residential housing
- Displace commercial areas
- Displace industrial areas
- Displace parks and recreational facilities
- Displace wildlife and natural terrain
- Displace too many homes

EMPLOYMENT, INCOME AND BUSINESS ACTIVITY
- Commercial encroachment
- Dislocate businesses
- Loss of goodwill

PROPERTY VALUES & TAXES
- Facility construction or improvement costs will be prohibitive
- Decrease property values
- Raise property taxes
- Increase user fees and rates

RESIDENTIAL ACTIVITY
- Discourage residential development

AESTHETIC
- Downgrade neighborhood appearance
- Discourage owners from maintaining property

PHYSICAL
- Increase air pollution
- Increase noise
- Destroy land, wildlife, and other natural resources

AUTO SAFETY
- Increase automobile accidents
- Change local traffic patterns
- Increase traffic congestion

Part 3. SAMPLING PROCEDURES

Part 3 is devoted to the discussion and critical evaluation of sampling approaches available to practitioners interested in conducting cost-effective surveys. The objective here is to describe available sampling techniques in terms of their applicability to the socio-economic impact assessment process -- depending on the stage in the two-step assessment activity, the target population, information requirements, time and resources available, and the desired level of confidence.

Chapter 5 describes sampling approaches which may be used in preliminary assessment. Special emphasis is placed on the use of small sample surveys to get a quick, inexpensive reading on public attitudes and perceptions concerning the project.

Chapter 6 focuses on sampling approaches tailored to practitioners' needs during the detailed assessment of route alternatives. Here emphasis is placed on alternative approaches to the random sampling of area residents and businesspersons. Subsections in this chapter discuss the particular utility and limitations of stratification and multiphase sampling.

Chapter 7 is devoted to a discussion of how to determine optimum sample sizes, i.e. samples which will generate representative results while at the same time keeping the number of respondents required, and the associated costs, to a minimum. Optimization is discussed in relation to a variety of situations faced by impact analysts.

Chapter 8 focuses on the types of errors which are associated with estimates based on samples and how to avoid them or minimize their effects. Separate sections here discuss error components, sampling variance, and bias.

The material in this part is designed to (1) help practitioners select the sampling approach which meets their particular needs, and (2) achieve the maximum reliable information from their samples at the lowest cost.

Chapter 5. SAMPLING DURING THE PRELIMINARY ASSESSMENT PHASE

5.1 NON-RANDOM SAMPLES OF AREA ELITES

Samples of community leaders, elected officials, community groups, and other elites are usually taken on a non-random basis. This is because the practitioner needs informed opinions concerning the impacts of a proposed road from a limited number of individuals with an overall understanding of the study area and major sub-areas in the initial phase of the assessment process.

This perspective can be best captured by questioning selected respondents who customarily think in these broader categories. Therefore, in his selection, the practitioner will want to be certain he has identified the appropriate individuals. Time and cost considerations are a second reason for selecting a small target group.

The sampler may use any of several techniques to select a sample. For instance, the planner may choose a set of individuals or groups because he believes these people fit the general criteria stated above -- or some other criteria -- without testing this assumption using explicit measures. Sampling done in this manner is called <u>judgmental sampling</u>. Judgmental sampling is predicated on the assumption that the sampler himself can identify those individuals whose perceptions and opinions are most useful to him.

In contrast, suppose the sampler chooses a set of individuals because he has some objective evidence -- independent of his own, subjective considerations -- that they will have insight into the community's reactions. An example of this would be the choice of publicly elected officials who have been in office for two or more years and represent a constituency in the study area. Such a selection, made on a more objective basis, is called a <u>purposive sample</u>. Purposive sampling attempts to control the potential bias associated with the sampler's subjective judgments.

An ancillary sampling technique which is potentially applicable to this stage, and is more purposive than judgmental, is called <u>linked chain sampling</u>. Here, the sampler chooses an initial set of individuals or spokesmen for organizations who meet his criteria, and -- after interviewing them -- asks them to identify others who should also be interviewed. This selection may be subjective on the part of the interviewee, but it is objective on the part of the sampler.

The process of asking interviewees to name other possible respondents who fit the established criteria is repeated during each new interview until no persons who have not been interviewed are named. This approach is sometimes called sampling through qualified informants.

A potential hazard of both the judgmental and purposive sampling approaches is the possibility that bias will be introduced whenever influential individuals or groups which hold conflicting viewpoints are not interviewed. Thus the practitioner should collect as much information as possible about the area infrastructure when developing frame listings. Purposive samples based on such detailed information are more reliable than judgmental ones.

5.2. MINI-SURVEYS (SMALL SAMPLE SURVEYS)

During preliminary assessment, the practitioner may want to obtain information on the initial attitudes of local residents towards the project. He also may choose to screen the residents regarding their perceptions about potential project impacts and other concerns. A mini-survey can accomplish these goals while using a limited amount of time and resources.

Mini-surveying is a procedure for obtaining information using a small sample. Since precision in surveys is usually related to sample size -- with greater precision achieved using larger samples -- the question arises as to what conclusions can legitimately be drawn from a small sample survey. Under the right conditions, some clear conclusions can be drawn with a high level of confidence. However, in other circumstances, the results may be inconclusive. The following discussion examines those situations in which the mini-survey can provide useful information.

Suppose the practitioner wishes to screen a target residential area for potential negative attitudes about road construction. More specifically, suppose he would like to know if the majority of individuals in the area are basically opposed to construction, i.e., are more than 50 percent of the residents in the area opposed to the construction? Can the results of a telephone survey of 20 respondents provide a definitive answer, i.e., do the results have an adequate level of precision?

The precision of survey results is based on the amount of error associated with the estimated results. In the case of the question of negative attitudes, the estimate would be based on the percent responding negatively. When a percent is estimated, the error of the estimate (or variance) associated with the percent is:

$$Var(p) = pq/n,$$

where p is the percent (as a decimal) responding negatively, $q = 1 - p$, and n is the sample size (20 in this case). Using this formula to calculate error, it is possible to determine the confidence that one can place in the results.

Suppose 20 randomly selected individuals are asked whether or not they approve (a yes/no question) of the construction of a highway. What confidence statements can be made about the results of a survey this size?

To see this, suppose 10 percent ($p = .10$) of the individuals in the sample say they are opposed to the construction. The variance of p, Var(p), is:

$$\begin{aligned} Var(p) &= pq/n \\ &= (.10)(.90)/20 \\ &= .0045 \end{aligned}$$

The standard deviation associated with the estimate p is then .067. A 95 percent confidence range (see Section 7.4) around p - .10 will be 2(.067) = .134 (2 is used because the sample is small; the t-distribution is used in place of a normal distribution to correct for the uncertainty associated with small samples). Thus, one can be 95 percent confident that the true population value is somewhere between .10 + .134 and .10 - .134, i.e., between .234 and .00 (p cannot be less than .00).

This example demonstrates that a planner can be 95 percent confident that less than 50 percent of the individuals in the target area will have a negative reaction to the new construction. This represents a significant amount of information given the limited resources required to generate the data.

The foregoing example, however, may represent an extreme response situation because p could be larger than 10 percent. If 40 percent (p = .40) of the 20 individuals respond negatively, the information would be less clear. In this case, a 95 percent confidence range would be .40 plus or minus .219, or .619 to .181. One cannot have the same confidence as before that less than 50% are opposed, even though 40 percent stated so in the survey. If one could lower the confidence placed on the results, then one could state that there is a slightly larger than 60 percent chance that the true negative response is below p = .50. In the marginal area, the decision is placed in the hands of the impact analyst. A chart showing the confidence intervals associated with various results (i.e., p values) appears in Table 1 (p. 95).

It should be remembered that a mini-survey is really a screening procedure. If the results are unclear or suggest significant resistance to new construction, a more extensive survey may be required at a later stage. However, if the results show low negative attitudes with high confidence, then resources may be better utilized at a later stage for activities other than the performance of a large-scale opinion survey.

<u>Sequential Sampling for Screening Attitudes</u>. An alternate method for screening area residents' attitudes is sequential sampling. This approach allows the analyst to randomly select individual residents, one at a time, and after each response make a decision, for example, as to whether attitudes are against construction or for it and whether it is necessary to sample another resident. The type of question used in this procedure is one in which the response is binomial, i.e., yes or no: are you for the road or against it? Do you think the road will result in major impacts or not?

Sequential selection procedures can save valuable time and resources. In a sequential sampling plan, the number of individuals selected is not predetermined, and the decision to terminate sampling depends upon previous results.

Table 1. Degrees of confidence levels relative to results for proportions (percents) from samples of size 20.

Proportion (p value) *	50 Percent Lower Limit	50 Percent Upper Limit	80 Percent Lower Limit	80 Percent Upper Limit	95 Percent Lower Limit	95 Percent Upper Limit
.10	.054	.146	.011	.189	.000	.240
.20	.139	.261	.082	.318	.014	.386
.30	.230	.370	.165	.435	.087	.513
.40	.324	.476	.254	.546	.170	.630
.50	.423	.577	.351	.649	.266	.735

* The confidence band around p is calculated as $p \pm tS_p$, where p is the sample proportion, and t is the value on the t-distribution (used for small samples) which determines the percent confidence. S_p, the standard error of estimate, is calculated as S_p = Square root (pq/n), where q = 1-p.

The sequential procedure described here is a modification of that developed by Wald (1947) and adapted by Bradley (1953).

Sequential Sampling as an Experiment. The sampling and analysis approach in a sequential framework is really posed in the form of an experiment. That is, one makes an assumption, or hypothesis, about the response of the population and then, by sampling sequentially, proceeds to test it. For example, suppose it is essential to determine during preliminary assessment whether the majority of residents in an area are opposed to new highway construction. This is equivalent to hypothesizing that over 50 percent of the target universe are opposed to the construction.

To reject the hypothesis developed for a sequential sample, the surveyor often continues sampling until the results are more than adequate to support the determination. For example, the analyst could reject the hypothesis of over 50 percent opposition at the point when the negative response rate falls below 50 percent. If the analyst continues sampling and the negative response rates fall below 40 percent, however, he could more confidently conclude that the majority is not opposed. Also, there is sampling error associated with the sequential sample. Therefore, if one is testing the "majority-opposed" hypothesis, it is probably judicious to raise the 50 percent decision-point to 65 percent. However, 50 percent will be maintained in this case for illustrative purposes.

<u>The Boundaries of Decision.</u> When one is required to make decisions about a hypothesis, there must be a defined point or boundary at which the decision, when reached, becomes clear. In the case of a sequential sampling test, the boundaries of decision come in the form of lines. These lines are shown here in Figure 4.

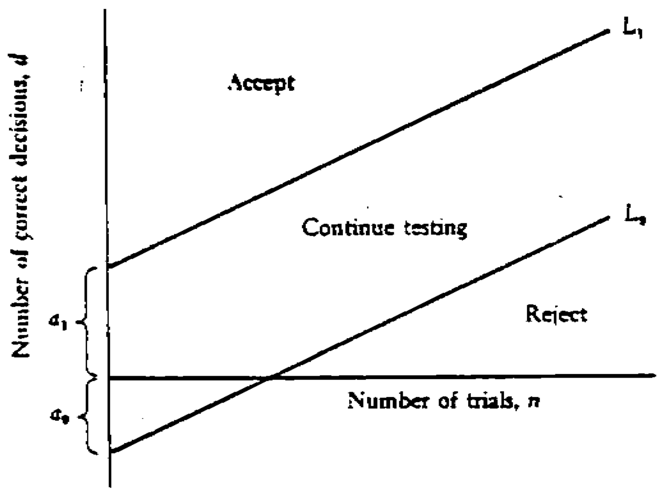

Figure 4. Sequential test chart.

This chart shows how the boundary lines are related to the sequential sample size and the number of negative responses. After each individual is sampled, the total number of negative responses (on the vertical axis) are plotted against the total sample size (on the horizontal axis) at that stage. If the plotted point goes over L_1, then the practitioner will accept the hypothesis that a majority (over 50 percent) are opposed to the construction. On the other hand, if the plotted point goes under L_0, the practitioner concludes that the majority are not opposed.

Determination of the Boundary Lines. While it is clear that the two lines in Figure 4 divide the sampling region into three decision regions, the practitioner must know exactly where the lines are located so that erroneous decisions are not made. First of all, the lines must reflect the assumptions (hypotheses) the practitioner makes about the degree of negative response in the population, e.g., he accepts the hypotheses if more than 50 percent are opposed or rejects if less than 40 percent are opposed. These two percents (p), then, are associated with two lines: for L_1, P_1 = .50; for L_o, P_o = .40.

The lines cannot be calculated using the percents alone. It is necessary to take into account the confidence to be placed in the decision. This confidence can be phrased in terms of the types of error involved when the practitioner makes a decision to accept or reject the assumption of majority opposition.

The first type of error occurs if the practitioner rejects the majority opposition hypothesis when it is really true. The second type involves accepting the majority opposition hypothesis when it is actually not true. As shown below, these errors are usually stated as probabilities:

(Type 1) A = .05

(Type 2) B = .10

This example introduces a control to test, stating that 5 percent error (.05 probability) is allowed for the first type and a 10 percent error (.10 probability) for the second type. Some individuals who use this approach believe they can reduce the error by stating beforehand that they wish the error of the first type to be 1 percent or less. This reasoning, however, is dangerous because if one error type is forced down, the other usually increases. Thus, a trade-off must be effected, and A = .05 and B = .10 is frequently selected.

The two error types discussed above are essentially the statements of confidence which the planner imposes on the sequential procedure. The planner is stating, in effect, that the error cannot exceed these probabilities. And by stating them beforehand, he controls the results. The confidence of the test is seen through the probabilities of not making an error. For example, if the planner accepts the hypothesis that the negative response rate is over 50 percent, he is 95 percent confident (1.00 - .05 = .95) that this is the correct decision. If, on the other hand, the results show that the 50 percent hypothesis should be rejected, then the confidence to be placed on that decision is 90 percent (1.00 - .10 = .90). This latter confidence is called the power of the test.

Calculation of the Lines. From the hypotheses concerning the response rates (P_1 = .50, P_0 = .40) and the pre-defined errors (A = .05, B = .10), the boundary lines can be calculated. The forms of the lines are given as:

$$L_1: d_1 = a_1 + bn, \text{ and}$$
$$L_o: d_o = a_o + bn$$

where n is the size of the sequential sample, b is the slope of the line, a_1 and a_o are the points at which the lines intersect the vertical axis, and d is the cumulative number of negative responses.

To place the lines in the positions which reflect the hypothesized response rates (P_o = .40, P_1 = .50) and the imposed errors (A = .05, B = .10), it is necessary to calculate the slope (b) and intercepts (a_o, a_1) of the lines. This can be done arithmetically through the following formulas:

$$b = K_2/(k_2 + k_1)$$
$$a_o = -e_1/(k_1 + k_2)$$
$$a_1 = e_2/(k_1 + k_2)$$

where

$$K_1 = \log (P_1/P_o)$$
$$K_2 = \log [(1 - P_o)/(1 - P_1)]$$
$$e_1 = \log [(1 - B)/A]$$
$$e_2 = \log [(1 - A/B).*$$

Using the values in the example, these formulas yield:

k_1 = .097 k_2 = .041 e_1 = 1.255 e_2 = .978

and

b = 2.971 a_o = -9.094 a_1 = 7.087.

Thus, the lines are, $L_1: d_1 = 7.087 + 2.971n$, and $L_o: d_o = -9.094 + 2.971n$.

*All logarithms are to the base 10.

To carry out the sequential sampling test of negative response to construction, a practitioner must first plot the lines on a piece of graph paper relative to the axes representing the cumulative number of negative responses and the cumulative size of the sequential sample. The next step is to randomly select residential phone numbers, interview an adult in the household, plot the response, and continue the process until one of the lines is crossed. When that occurs, one can be sure the decision is made with the stated confidence.

<u>The Expected Size of the Sample in the Sequential Process</u>. It was previously stated that the sample size in a sequential procedure is not known when the testing begins. In a strict sense this is true. However, it is possible to estimate what the expected sample size would be under the various different outcomes. For the values stated and calculated in the above discussion:

(1) If there is no negative response, the formula for the expected sample size is:

$$n = e_1/k_2,$$
$$\text{with } e_1 = 1.255 \text{ and } k_2 = .041$$
$$n = 1.255/.041$$
$$n = 30.6.$$

(2) If the negative response rate falls below the lower line (reject majority opposition), the sample size is given as:

$$n = [(1 - B)e_1 - Be_2]/[(1 - P_o)k_2 - P_o k_1]$$
$$n = 30.3.$$

(3) If a sample response exceeds the upper line (accept majority opposition) then the expected sample size is given as:

$$n = [(1 - A)e_2 - Ae_1]/[p_1 k_1 - (1 - P_1)k_2]$$
$$n = 30.9.$$

(4) Finally, if every one responds negatively, the sample size is calculated as:

$$n = e_2/k_1 \,, \quad n = 10.1.$$

As can be seen, the maximum expected sample size is about 31. The sample size can be lowered by structuring the initial values differently. For instance, changing the upper response rate from .50 to .65 would flatten the lines and reduce the size of the expected sample.

Chapter 6. SAMPLING TO SUPPORT THE DETAILED ASSESSMENT OF ALTERNATIVE ROUTES

6.1 SURVEYS OF AREA ELITES

This survey methodology is an extension of the survey of area elites described under Non-Random Samples of Area Elites (Section 5.1).

6.2 SURVEYS OF LOCAL FACILITY MANAGERS

The census sample of local facility managers does not require technical knowledge.

6.3 RANDOM SAMPLES OF AREA RESIDENTS AND BUSINESSES

Samples selected on a random -- or probabilistic -- basis can provide unbiased results from which inferences about the population can be made with known precision. The inferences will have a known precision because the random nature of the selection process permits the results to be modeled by probability distributions for which precision can be calculated in terms of percent confidence (confidence levels). The confidence levels are taken from various areas under probability curves representing amounts of precision (see Section 7.1, Sample Size and Precision).

Selecting a Random Sample. There are basically two types of random samples: simple and systematic. Other methods are extensions of these two.

The simple random approach to selecting a sample uses a table of random numbers. A reproduction of such a table is seen in Figure 5 (p. 101). To demonstrate how a sample is selected in this manner, consider the following example. Suppose there are 100 houses in the proximity strata in a corridor for an alternative ROW. To estimate the opinions from the total set of houses in that strata, suppose it has been determined that a simple random sample of 10 houses will be chosen. The first step is to list and assign to each of the 100 houses in the universe a number in the range from 1 to 100. That is:

	1	2	3	4	5	6	7	8	9	10
	03991	10461	93716	16894	98953	73231	39528	72484	82474	25593
	38555	95554	32886	59780	09958	18065	81616	18711	53342	44276
1	17546	73704	92052	46215	15917	06253	07586	16120	82641	22820
	32643	52861	95819	06831	19640	99413	90767	04235	13574	17200
	69572	68777	39510	35905	85244	35159	40188	28193	29593	88627
	24122	66591	27699	06494	03152	19121	34414	82157	86887	55087
	61196	30231	92962	61773	22109	78508	63439	75363	44989	16822
2	30532	21704	10274	12202	94205	20380	67049	09070	93399	45547
	03788	97599	75867	20717	82037	10268	79495	04146	52162	90286
	48228	63379	85783	47619	87481	37220	91704	30552	04737	21031
	88618	19161	41290	67312	71857	15957	48545	35247	18619	13674
	71299	23853	05870	01119	92784	26340	75122	11724	74627	73707
3	27954	58909	82444	99005	04921	73701	92904	13141	32392	19763
	80863	00514	20247	81759	45197	25332	69902	63742	78464	22501
	33564	60780	48460	85558	15191	18782	94972	11598	62095	36787
	90899	75754	60833	25983	01291	41349	19152	00023	12302	80783
	78038	70267	43529	06318	38384	74761	36024	00867	76378	41605
4	55986	66485	88722	56736	66164	49431	94458	74284	05041	49807
	87539	08823	94813	31900	54155	83436	54158	34243	46978	35482
	16818	60311	74457	90561	72848	11834	75051	93029	47665	64382
	34677	58300	74910	64345	19325	81549	60365	94653	35075	33949
	45305	07521	61318	31855	14413	70951	83799	42402	56623	34442
5	59747	67277	76503	34513	39663	77544	32960	07405	36409	83232
	16520	69676	11654	99893	02181	68161	19322	53845	57620	52606
	68652	27376	92852	55866	88448	03584	11220	94747	07399	37408
	79375	95220	01159	63267	10622	48391	31751	57260	68980	05339
	33521	26665	55823	47641	86225	31704	88492	99382	14454	04504
6	59589	49067	66821	41575	49767	04037	30934	47744	07481	83828
	20554	91409	96277	48257	50816	97616	22888	48893	27499	98748
	59404	72059	43947	51680	43852	59693	78212	16993	35902	91386
	42614	29297	01918	28316	25163	01889	70014	15021	68971	11403
	34994	41374	70071	14736	65251	07629	37239	33295	18477	65622
7	99385	41600	11133	07586	36815	43625	18637	37509	14707	93997
	66497	68646	78138	66559	64397	11692	05327	82162	83745	22567
	48509	23929	27482	45476	04515	25624	95096	67946	16930	33361
	15470	48355	88651	22596	83761	60873	43253	84145	20368	07126
	20094	98977	74843	93413	14387	06345	80854	09279	41196	37480
8	73788	06533	28597	20405	51321	92246	80088	77074	66919	31678
	60530	45128	74022	84617	72472	00008	80890	18002	35352	54131
	44372	15486	65741	14014	05466	55306	93128	18464	79982	68416
	18611	19241	66083	24653	84609	58232	41849	84547	46850	52326
	58319	15997	08355	60860	29735	47762	46352	33049	69248	93460
9	61199	67940	55121	29281	59076	07936	11087	96294	14013	31792
	18627	90872	00911	98936	76355	93779	52701	08337	56303	87315
	00441	58997	14060	40619	29549	69616	57275	36998	81304	48585
	32624	68691	14845	46672	61958	77100	20857	73156	70284	24326
	65961	73488	41839	55382	17267	70943	15633	84924	90415	93614
10	20288	34060	39685	23309	10061	68829	92694	48297	39904	02115
	59362	95938	74416	53166	35208	33374	77613	19019	88152	00080
	99782	93478	53152	67433	35663	52972	38688	32486	45134	63545

Figure 5. Random numbers table.

No.	House
1	417 Oak Ave.
2	419 Oak Ave.
3	421 Oak Ave.
4	423 Oak Ave.
5	425 Oak Ave.
:	:
:	:
100	947 Green Way

To choose a simple random sample, the surveyor can enter the random table (in Figure 5) at any point, i.e., any row or column. If he enters the table in a row, then he should move across the row to its completion. If one row is insufficient, he moves to the next row above or below the original, and continues in the same direction until a sufficient number of usable random digits is found.*

The random numbers in the table are displayed in groups of five digits each. Since it is only necessary to choose from a list of 100 houses -- each represented by a random number -- just the random digits up to 100 are used. If the digits 00 are allowed to stand for 100, then two-digit groups will be sufficient for the selection. Since random numbers are considered random no matter how they are grouped, the digits in the table can be regrouped by two's. Thus in the first row, starting at the left of the table, the first two groups of five numbers, i.e., 03991, 10461, can be regrouped as five groups of two, i.e., 03, 99, 11, 04, 61. If this row is the one chosen to generate the sample, then the first 10 groups of two will designate a simple random sample: 03, 99, 11, 04, 61, 93, 71, 61, 68, 94.

By returning to the numbered list of houses, the random sample of 10 houses is identified by matching the random numbers with those on the list. Number 3 on the list is included, number 99 on the list, number 11 on the list, and so on.

If a duplicate pair of digits comes up, one of two things can be done. The simplest solution is to skip the duplicate number and move on until 10 different random numbers are chosen. The more desirable approach, the one that

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*The same procedure applies when the surveyor enters the table in a column.

insures randomness, requires the surveyor to enter a new row (or column) until 10 different random numbers are drawn.

A systematic random sample is selected using a random component and a systematic component where every x^{th} house is selected. Following the example used above, a list of the 100 houses is again made, although this time the list need not be enumerated. Next, the surveyor makes a determination as to whether there is a systematic arrangement in the way the houses are listed, e.g., that every tenth house is on a corner lot and has a much higher value than the previous nine. If this turns out to be the case, the list must be randomly rearranged before a systematic method can be applied. In this way, the surveyor avoids selecting an unrepresentative sample.

The systematic component is the sampling interval. This value determines the pattern with which houses are chosen from the list. The sampling interval is obtained by dividing the total universe by the sample size. In this case, the interval is calculated as:

$$10 = 100 \text{ (total houses on list)} \div 10 \text{ (number in sample)}$$

This indicates that after some initial choice, every 10th house on the list is chosen.

The random component has to do with the selection of the initial house. Given that one out of every 10 houses is selected, it makes sense to begin with a random number between 1 and 10. This number can be chosen by consulting a table of random numbers, entering the table from any direction, and selecting the first number, between 1 and 10 inclusive.

Suppose the randomly selected number is 4. Then the first house included in the sample is the fourth on the list. The next, the 14^{th}, is identified by adding the sampling interval to 4. The next is the 24^{th} (14 + 10). The survey proceeds in this systematic manner until 10 houses are chosen. The last house chosen will be 4 + (9 x 10), or the 94^{th}.

While this method of selection is easier to implement than the simple random method, there is no direct way to calculate the sampling error associated with the estimates made from the sample as there is for simple random samples.

There are methods available for making approximations of the sampling variance of systematic samples (Jessen, 1978). Unfortunately, these do not give exact values and often overestimate the sampling error.

6.3.1 Stratification

Stratification is a method for controlling the behavior of random samples. It involves certain restrictions or constraints on the ordinary randomization procedure to avoid getting unrepresentative samples. When conditions are right and the constraints are imposed properly, a significant gain in precision can be obtained -- usually with little or no additional cost.

Stratification can ensure that data for population subgroups of interest are represented. This is particularly useful if the surveyor, hypothesizing that a particular subgroup will have unique and significant reactions to the proposed road, for example, wants to make certain the group is represented in the sample. Suppose it is important to know the attitudes towards a highway project of residents in various types of dwellings: single family homes, duplexes, townhouses, garden apartments, and mid- or high-rise apartments. Then dwelling type is used as "the stratifying variable" to divide the population so that members of each subgroup can be included in the sample.*

Stratification is thus a technique for increasing the efficiency of a sampling procedure by incorporating into the procedure one's knowledge of a population. For example, if one hypothesizes that a variable such as automobile ownership is related to opinions about accessibility, then it may be judicious to stratify on categories of that variable. (Of course, it is possible to use this plan only if the ownership status of each member of the universe is known.) Two strata are created: (1) those who own an automobile, and (2) those who do not own an automobile. Allotting portions of the sample to the two strata on the basis of prior knowledge will insure that sufficient observations are made

*Other examples of stratifying variables are location (e.g., corridor, neighborhood, proximity to proposed ROW's) ethnicity, and income level.

to test the hypothesis that there is a relationship between automobile ownership and accessibility.

Allocation of Interviews to the Strata. Increasing the efficiency and representativeness of the sample through stratification is usually carried out by the judicious allocation of the total planned sample numbers to the various strata. The allocation policy chosen for a particular stratified sample would depend not only on the sizes of the strata, but also on the degree of variability among the elements of each stratum. Proportional allocation ensures that each stratum is "weighted" by the number of elements it contains, i.e., each element has the same chance of being selected. These features are only realized, however, when the degrees of variability in each of the strata are roughly the same.

When the "within strata diversity" is not the same across the strata, a more efficient procedure is to take a disproportionate stratified sample. Using relative degrees of dispersion as the basis for allocation, this policy collects more than a proportionate amount of observations in those strata with the most variability. In other words, by allocating a disproportionate amount of effort (time, money, etc.) to those groups whose opinions are most varied, the surveyor can often obtain a maximum amount of information for a given cost.

For instance, suppose a residential survey is designed to determine public acceptance of a proposed project for which three alternative routes are being considered. Residences in the study area are stratified by location in relation to the routes. For each route there are three strata: those dwellings abutting the ROW, those proximate to the ROW (one-quarter to one mile away), and those more than one mile from the ROW. The prior experience of the practitioners suggests that those residents in dwellings abutting the road tend to be against the proposed project, while those over a mile away tend to favor it. Since, in this instance, it is the opinions of those proximate to the ROW that are most important, a disproportionately high number of observations might be taken from this stratum.

This type of allocation plan, which minimizes sampling error, is accomplished by assigning observations to the strata in proportion to:

$$N_h S_h / \sum_h N_h S_h$$

N_h is the number of houses in Stratum h, and S_h is the square root of the within-strata variance, i.e., the standard deviation.* In addition to the measure above, an optimal allocation policy should take into consideration the costs of obtaining interviews within each stratum. If the costs are the same in all strata, then the measure above is appropriate. However, a different measure must be used if they are not.

The policy outlined above suffers from a serious difficulty since, in most instances, the populations are not known beforehand. When this is the case, one is left with the possibility of trying to estimate these variances. If prior information is available in any reasonable form, this is sometimes possible. When it is not, one must turn to another approach or revert to using the original policy of allocation proportional to the number of elements (houses) in each stratum.

The only other straightforward allocation policy which attempts to utilize the concept of within strata dispersion involves using a known characteristic which is assumed to be associated with the value to be measured. For example, if it is believed that the income level of a household is related to attitudes about road construction, then the diversity of household incomes can be used as a basis for allocating the observations across strata. When this relationship has any strength at all, and allocation is made as a function of it, more efficiency can be obtained than is possible with the proportional-to-size method.

Cluster and Multistage Sampling. When designing a sample, a complete list of individuals or other units comprising the target universe is sometimes not available. However, these individuals are often conveniently grouped in some readily identifiable manner. When the target universe is structured into such groups, the surveyor should consider cluster sampling. This technique avoids

*See Chapter 7, Sample Size, for a discussion of standard deviation.

the need to compile and enumerate a complete listing, and often has other advantages.

Cluster sampling involves selecting the ultimate observational unit (individuals) through a series of stages. The partial listings of the population -- which, when combined, represent the total population -- are the clusters. In the first stage, a set of clusters is selected, preferably by random method, for inclusion in the sample. In the second stage, all elements in each cluster can be selected for the final sample. This sampling design is called cluster sampling. Alternatively, random subsets can be drawn, from all elements in each cluster, to develop the final sample. The drawing of a sub-sample from each cluster is called multistage sampling because there is an additional selection stage.

Cluster sampling is particularly efficient when clusters can be chosen that have high internal variability, i.e., are representative of the population, and have little variability among them. Ideally, all clusters have the same characteristics as the parent population. The characteristics, opinions, etc. of this population can be estimated by randomly picking one of the clusters and then observing all of the units in the cluster. However, in the more common situation, the clusters are not miniature replicas of the universe of interest, and there are some that are more representative than others. In these cases, several clusters are randomly selected for sampling and normal probability will determine whether the most representative ones are selected.

An alternative plan is to select clusters that are known to have the highest variability. This is a serious departure from randomness, however, and although the clusters will be accurate for measuring accessibility, they may not provide representative opinions regarding overall receptivity to the proposed road and other issues. The most judicious method is to attempt to develop clusters that are as like the universe as possible and to select a random sample of them.

The issue of interclass correlation, as it is referred to in statistical texts, can also determine the value of multistage sampling. As an example, suppose a planner wishes to interview workers in local industries to determine the impact of new road construction on accessibility to work. Since it is probable that only a small number of workers live in immediate proximity to the proposed ROW, a residential survey may well miss these individuals. In such instances, a complete list of all workers in the impact area is often not available in a single source, and construction of such a list is generally time-consuming and costly. However, a list of the individual companies in the area is nearly always available, and most companies are willing to provide a list of employees. Either all of the employees, or a random sample drawn from each company, can be interviewed.

Multistage Versus Simple Random Sampling Designs. Multistage sampling does not have to be used only when there is a lack of prior information about the universe of individuals to be interviewed. It sometimes turns out to be a more efficient way (in the sense of smaller error) to select individuals. This usually is the case when the behavior to be examined is quite diverse within the first (or earlier) stage grouping. For example, suppose that the surveyor wants to know about employee access to work locations, and that each of the local businesses or industries employs individuals who come from geographically diverse areas. In this case, it will probably be more efficient to use a multistage approach than a simple random one, even if a list of all relevant employees in the area is available.

The criterion which determines the most efficient approach is based on the degree of similarity within the cluster (or first stage group, in this case) of the thing being measured. The more similarity there is among target measures within the clusters, the more efficient a simple random selection design will be. Substantial differences suggest the use of multistaging. Extreme differences suggest cluster sampling. This diversity (or similarity) is measured by a statistic called the interclass correlation coefficient -- high positive values indicate similarity, low or negative values indicate diversity. The reader interested in a discussion of this measure and the decision suggested by it is referred to Jessen (1978) for a thorough treatment.

The Staging of Samples and the Probability of Selection. In the example of multistage sampling, random selection occurred in two stages: (1) selection of businesses, and (2) selection of individual workers.

Multistage sampling is carried out in more than two stages. The number of stages is usually dictated by the way the target universe, or ultimate set of observational units, is structured. The essential point is that the randomness of the sample is developed in stages. The number of stages and the degree of randomness at each stage determine the ultimate probability of selecting each individual, i.e., the likelihood of getting a representative sample.

The ultimate probability of selection is, in most cases, the product of the probability at each stage. That is, if the probability of selecting business D is .10 and the probability of selecting John Smith in business D is .05, then the ultimate probability of the selection of John Smith is (.10)(.05), or .005.

The accurate calculation of ultimate probabilities of selection is crucial in multistage sampling because, due to the structure of the selection procedure, individuals who are ultimately interviewed frequently have different chances of being selected, especially those in different clusters or businesses. The probabilities can be equalized only if information is known beforehand. Given that this may not be possible, each individual's probability of selection must be accurately calculated so that the total sample can be put on an equal basis. This equalization is carried out by weighing the individual responses in relation to the probabilities of selection and allowing inferences to be performed on the sample. As one would suspect, many combinations of selection could occur. The reader is referred to two basic works in sampling: Cochran (1967) and Kish (1962).

6.3.2 Multiphase Sampling

In some sampling situations, crucial information is lacking when the sample is taken. For example, the number of individuals comprising pertinent subgroups may not be known. Consider a planned highway which will separate residential areas from a large shopping center. To measure accessibility in this instance, the practitioner may want to know how individuals get to the center, how often they go there, and what their opinions are concerning the road. A sample could be taken in the potentially impacted areas, but these areas are difficult to identify. Further, if the areas are widely separated, survey costs could be excessive.

A reasonable alternative to sampling residential areas is to sample individuals at the shopping center itself. However, since it is likely that little or no information about the people who frequent the shopping center is available, a potentially difficult sampling problem may be created.

Multiphase sampling provides a cost-effective technique for selecting an acceptable sample in such situations.

Multiphase sampling, or double sampling as it is sometimes called, allows quantities to be estimated from the sample itself. Estimates made from information obtained in the sample can be used, in the absence of external information, to make inferences about the total target population when it has not actually been defined prior to sampling. This is achieved by judiciously structuring the sample, obtaining multiple types of information, and using the relationships among them to obtain estimates. The approach involves taking a sample within a sample and comparing the results.

The shopping center example is extended to illustrate the principle of multiphase sampling. In the first stage, the surveyor must first decide on which days in the week (or month) the shopping center attracts the most customers. If this is not clear, then days and hours of observation can be randomly selected. Samples of people at the shopping center are taken at random time intervals (from probability distributions of time); the first person interviewed is the first encountered after each random period is chosen. These individuals are asked simple questions, such as area of residence (this can be identified on a map) or number of trips per month to the center.

Before the sample is chosen, it is decided that a subset of that sample will be asked more indepth questions regarding perceived impacts of the proposed road and expected change in their attraction to the shopping center. This subset of people to be re-interviewed is randomly selected from those originally sampled. Indepth interviews are conducted with approximately 10 percent of the shopping center sample.

When the interviewing is completed, the two types of data can be used to obtain estimates of quantities relating to all those who live in the residential area to be separated from the shopping center by a new road. Of course, estimates are obtained for those on the non-separated side also, but the following discussion will be limited to those residents separated from the center.

Suppose the desire is to estimate the average summated rating of impacts given by those in potentially separated residential areas. This can be done as follows:

p^{1} = the percent of individuals in the overall (i.e., big) sample from the "other" side.

p^{11} = the percent of individuals from the "other" side in the subsample.

y^{11} = the average summated rating of impacts obtained from the individuals in the subsample.

Then the average summated rating of impact for all residents from the "other" side can be estimated as:

$$y = p^{1} (y^{11}/p^{11}).$$

This formula, known as the ratio estimator when it is applied to multiphase sampling, is known to be biased. Nevertheless, if samples of reasonable size are taken, the bias becomes negligible. In the above example, it would probably be less expensive to interview 300 people at the shopping center than to try to identify all residential areas affected and sample within them. For a further discussion of this approach, the reader is referred to Jessen (1978).

Chapter 7. SAMPLE SIZE

The size of a sample (i.e., the number of units observed in a sample survey), has a direct bearing on the precision of the estimates derived from the sample. Generally, if the surveyor knows the desired precision surrounding an estimate from the sample, then he can estimate how large a sample is required to produce that precision. Precision (as related to sampling variance) increases with sample size.

It is normally possible to connect precision and sample size only when the sample is selected randomly. Ordinarily, measures of precision are not available from samples obtained by judgment selection. This diminishes the value of judgment sampling.

7.1 SAMPLE SIZE AND PRECISION

The framework for tying sample size to precision through randomization is described by the normal probability curve (sometimes called the bell-shaped curve). The normal curve has interesting features which make it a flexible tool in sampling situations. For example, if a sample is selected randomly and the average of the observed characteristic is calculated (say, the average length of trips to a shopping center as a measure of accessibility), it is known that the distribution of all such averages taken on all possible samples (of the same size) is normal in shape.

This is the result of a well-documented work in statistics called the Central Limit Theorem. This statement has been shown to be true no matter what the actual population distribution of the characteristic may be. For example, the distribution of the lengths of trips to a shopping center by a population subgroup may contain only a few elements in the larger numbers, but be clumped together in the smaller numbers around one or two miles. This distribution is hardly normal in shape. Yet, if one were to look at the average number of trips in all samples of forty individuals, this collection of averages would have a normal curve. This would not be the case if the sample were not randomly selected.

Why is it so important for one to feel confident that a distribution of averages is normal in shape? The answer is that if one uses the standard deviation as a unit of measure, then the same areas under the curve are always associated with the same units. That is, if one were to calculate the area under the curve which was one unit above the center and one unit below the center (i.e., one standard deviation), then this area would always be 68.26 percent of the total area under the curve. Similarly, if the area bounded by two units above and below were calculated, it would always be 95.44 percent of the total area; three units above and below the center would always constitute 99.72 percent of the total area. Figure 6 (p. 114) visually depicts these normal distributions.

7.2 USE OF THE NORMAL PROBABILITY CURVE TO DETERMINE SAMPLE SIZE

The normal probability curve and area under it can provide a framework for determining the size of a sample which will produce known levels of precision in the information collected by a sample survey. For example, suppose the surveyor wants to estimate the average number of trips to a specific shopping center from a specified neighborhood. Suppose he also wants the sample average to have a tolerable error of no more than plus or minus 4 trips. Moreover, it is imperative that he can be 95 percent confident about the estimate.

The problem at hand is to find the size of the sample which will produce the required precision. It can be found using the desired confidence, the tolerable error, and the population variance.

In the simplest case, suppose one knows (or has a pretty good idea) that the variance of the population describing the number of trips is 100, i.e., Var(y) = 100, where Var stands for variance and y is representative of the random value of the number of trips an individual makes, i.e., is thought of as random because a random sample is planned. Thus, if Var(y) = 100, then the variance, or error surrounding the estimated average, from a sample will be:

$$\mathrm{Var}(\bar{y}) = \mathrm{Var}(y)/n,$$

where $\bar{y}$ stands for the sample average and n is the size of the sample.

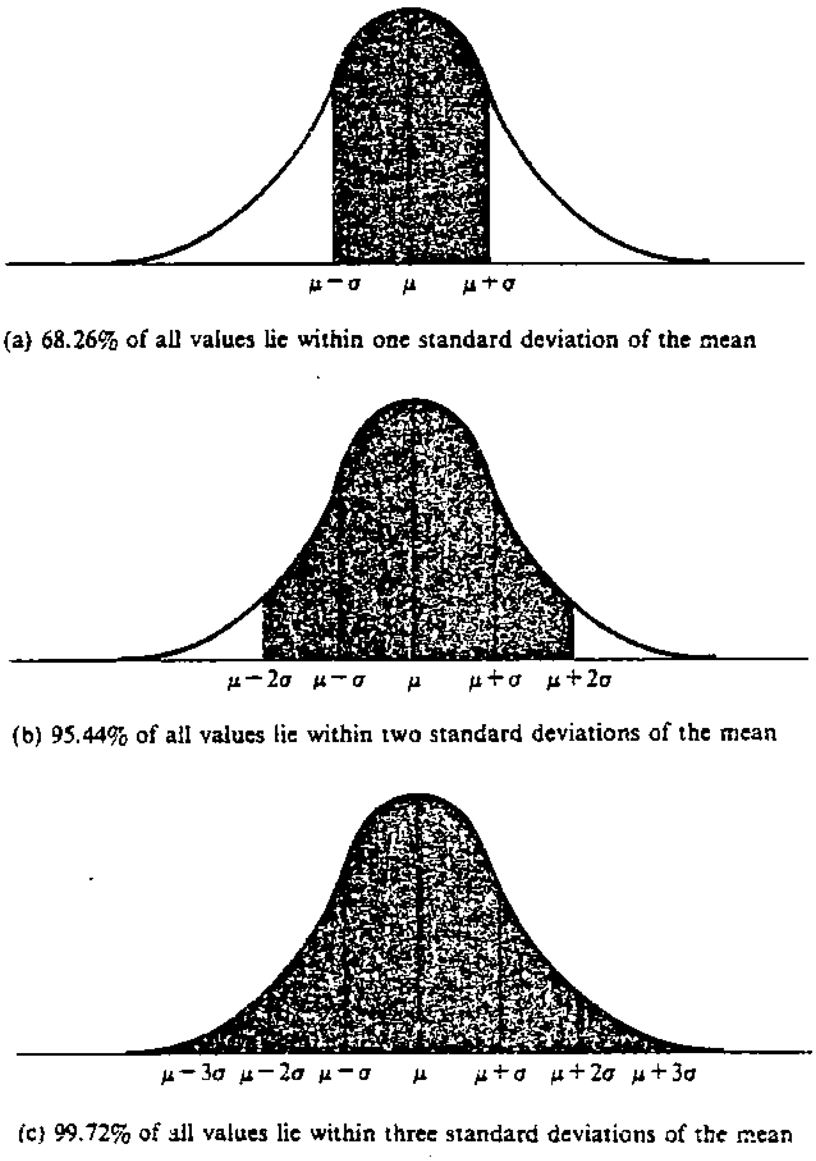

Figure 6. The normal distribution.

It is known that the units (standard deviations) on the normal curve, which between them cover 95 percent of the values, are +1.96 and -1.96, or 1.96 standard deviations above and below the center (or point were the average is) of the curve. If the tolerable error is 4 with 95 percent confidence, then 4 must represent 1.96 standard deviations above and below the center of the curve. That means that the standard deviation associated with the average estimated from the sample is 4 ÷ 1.96 or 2.04. But the variance of the mean was given as $Var(\overline{y})/n$ and its square root is the standard deviation associated with the estimate of the mean. Thus:

$$2.04 = \text{square root of } Var(y)/n$$

$$\text{or,} \quad (2.04)^2 = 4.16 = Var(y)/n$$

$$\text{then,} \quad n = Var(y)/4.16.$$

But as was stated previously, Var(y) = 100, so

$$n = 100/4.16$$

$$n = 24.$$

Under the conditions stated above, it turns out that a sample of 24 individuals will produce an estimated average number of trips in which a 95 percent confidence can be placed that the error is no more than plus or minus 4 trips. The general formula for this procedure is:

$$n = Var(y)(d/t)^2,$$

where t is the tolerable error and d is the number of units on the normal curve to produce a certain percent of confidence.

7.3 LIMITATIONS

The preceding procedure appears to be quite straightforward and simple. And in truth it is, except that only rarely is the populaton variance known beforehand. Of course, the surveyor could guess the amount of variance and use it to estimate the size of the sample to produce certain precision. There are procedures for producing estimates of the population variance from some supposed knowledge of the largest and smallest values in the population, but these approaches are crude. If possible, the surveyor should use information from previous surveys to approximate the population variance. If such information is unavailable, he can resort to other approaches to determine the required sample size.

7.4 DETERMINATION OF SAMPLE SIZE IN THE ABSENCE OF KNOWLEDGE OF POPULATION VARIANCE

Alternative approaches to sample size determination can be simple even when advance knowledge of the population variance is not available. For example, suppose the surveyor needs to estimate the percent of individuals in the corridor who are opposed to the construction of a new road. The simplicity of sample size determination in this case rests on the form of variance for a population percent. If P represents the percent of the population opposed to the highway, then Var(P) = PQ, when Q = 1-P. If P is estimated from the sample, this estimate can be called small p, and the Var(p) = pq/n. As in the first example, the sample size can be estimated as:

$$n = pq(t/d)^2,$$

where t is again the number of units on the normal curve which designate a confidence level and d is the tolerable error.

Even though PQ, the variance of P, is not known, the calculation can be carried out by assuming the worst case. The worst case occurs when P = .50 and, of course, Q = .50. In this case, PQ takes on its maximum value of .25, i.e., the maximum population variance. If P is more or less than .50, say .7, then PQ will always be smaller, i.e., PQ = (.7)(.3) = .21.

Suppose there is no previous information about P and it is necessary to assume P = .50. The required sample size can be estimated in the following manner. Assume that 95 percent confidence is required and that the tolerable error in estimating P is no more than 5 percentage points, i.e., plus or minus .05. Using the above formula, where t is the number of units on the normal curve to give a confidence interval: t = 1.95 and d is the tolerable error, d = .05. Then, assuming the sample p (p = .50) is used in place of the population P, the sample size will be:

$$n = (.5)(.5)(1.95/.05)^2$$

$$n = 380.$$

Thus, a sample of 380 will produce an estimate upon which a 95 percent confidence can be so placed that the error is no more than 5 percentage points. If the estimated P is more or less than .50, the surveyor can be 95 percent confident that the error will be something less than plus or minus .05.

Table 2 (p. 117) gives 95 percent confidence intervals for different values and sample sizes ranging from 20 to 1000.

Table 2. Ninety-five percent confidence band.

Sample Size (n)	95% Confidence Bands for the Population Portion p for Various Sample Sizes and Values of X/n								
	X/n = .50			X/n = .25			X/n = .00		
	Lower Limit	Higher Limit	Range	Lower Limit	Higher Limit	Range	Lower Limit	Higher Limit	Range
20	.275	.725	.450	.09	.49	.41	.00	.17	.17
25	.300	.700	.400	.10	.46	.36	.00	.14	.14
30	.318	.682	.364	.11	.44	.33	.00	.12	.12
40	.343	.657	.314	.13	.41	.29	.00	.09	.09
60	.372	.628	.255	.15	.38	.23	.00	.06	.06
80	.390	.610	.221	.16	.36	.20	.00	.05	.05
100	.402	.598	.197	.17	.35	.18	.00	.04	.04
200	.431	.569	.139	.19	.32	.13	.00	.02	.02
400	.451	.549	.098	.21	.30	.08	.00	.01	.01
1000	.469	.531	.062	.22	.28	.05	.00	.005	.005

Source: The confidence bands for X/n = .50 were computed using the formula $.50 \pm 1.96\ \underline{(.5)(1.0 - .5)}$. The confidence bands for X/n = .25 and X/n = .00 may contain errors of $\pm$ .01.

7.5 SAMPLING AND THE DEVELOPMENT OF CONTINUOUS MEASURES

The foregoing discussion revolved around estimating the required sample size for a percent (P) when the population variance is not known. This was not too difficult for percents, because the worst case situation is clearly defined, i.e., when P = .5. This situation is not so clear when one does not know the population variance of a characteristic, such as the number of trips to a shopping center. When this lack of information occurs, and the surveyor must estimate the size of a sample to produce certain precision, a slightly different approach must be used.

For characteristics which are continuous or somewhat continuous measures, such as number of trips, one can talk about the population variance in relative terms. This introduces a concept called the coefficient of variation. The coefficient of variation is defined as the population standard deviation (the square root of the variance) divided by the population average. In symbolic terms, this is:

$$CV = S/Y,$$

where CV stands for coefficient of variation, S for the standard deviation and Y for the population average. For sample values, the same concept can be applied, that is:

$$cv = s/y,$$

where the lower case letters stand for the sample values.

In relation to estimates, i.e., the estimated average or sample average, a similar concept called the relative standard error of an estimator is used. In this case, the sample average (the estimator of the population average) is divided into the standard error of estimate. The standard error of estimate is defined as the sample standard deviation, s, divided by the square root of the sample size. Symbolically this is:

$$RSE(\overline{y}) = (s/\text{sq. root } n)/\overline{y} \; ,$$

where RSE stands for the relative standard error; s is the sample standard deviation; sq. root means square root; n is sample size; $\overline{y}$ is sample average.

Using these concepts, it is possible to estimate the size of a sample to produce relatively tolerable error with a certain degree of confidence. For example, suppose the surveyor must estimate the average number of trips with a tolerable error of plus or minus 5 percent of the average regardless of its size.

It has been noted that the tolerable error, d, is the result of multiplying the standard error estimate, s/sq. root n, by the number of units on the normal curve (or t-curve) to produce an interval confidence:

$$d = (s/\text{sq. root } n)t.$$

Dividing both sides by the sample, or estimated average, $\overline{y}$, the framework for finding the sample size is established:

$$d/\overline{y} = (s/\overline{y})t/\text{sq. root } n.$$

The factor $s/\overline{y}$ is the coefficient of variation. It can now be used to estimate n, the sample size. The coefficient of variation is used here because, if the population variance is not known, it is easier to guess the coefficient of variation than it is to guess the variance. Coefficients of variation tend to be stable and are frequently found to be around 1.00.

If it is assumed that the coefficient of variation is about 1.00 and it is designed to estimate the average number of trips to a shopping center with an accuracy of 20 percent and do it with 95 percent confidence, then the formula given above can be used to estimate the required sample size. First, the formula is rearranged in terms of n:

$$n = [cv\ t/(d/\bar{y})]^2,$$

where cv is the coefficient of variation, t is the number of units on a t-curve to produce a 95 percent confidence interval, $\bar{y}$ is the sample average, and d is the tolerable error.

The tolerable error, 20 percent of the population average, is substituted in the following manner:

$$d = (.20)y.$$

If the sample average, y, replaces the population average, y, and is then placed in the formula for n, then:

$$\begin{aligned} n &= [cv\ t/(.20y/y)]^2 \\ &= [1.00 \times 2/.20]^2 \\ &= 100, \end{aligned}$$

where cv = 100, and t = 2. A sample of 100 will produce the desired precision with the desired confidence.

Chapter 8. ERRORS (VARIANCE) ASSOCIATED WITH ESTIMATES MADE IN A SAMPLE SURVEY

When estimates of population characteristics are made from the data obtained in a sample survey, it is expected that there will be error associated with each estimate. This error exists even under the best of circumstances because the information is obtained on less than a census, i.e., less than a 100 percent sample. Given that this error exists, it is the role of the sample design to minimize the error as much as possible. This can be done by (1) determining the appropriate sample size, (2) structuring how the sample will be chosen, (3) analyzing nonresponse, and (4) investigating measurement error.

The error associated with an estimate has several components. The components can be conveniently grouped into four components:

- Sampling variance which arises because a sample is drawn. This is the error which is expected in sampling.
- Measurement variance, sometimes called response variance, which arises because the measurements obtained for a particular individual are not always the same for repeated trials of the measurement process. This component is the error which has direct influence on the reliability or the precision of the data.
- Bias which is present if there are any systematic errors in the measurement process.
- Interaction variance which results from a relationship between sampling errors and measurement errors. It is present if the measurement for a particular individual in the sample depends upon the other individuals in the sample. In randomly chosen samples, this source of error is commonly assumed to be absent.

These components of estimation error are influenced by various aspects of the sampling and measurement process which occur in a survey.

8.1 SAMPLING VARIANCE

The first component of estimation error, sampling variance, is influenced by three potential sources of error: (1) the sampling variance of the true values, (2) the sampling variance of the bias associated with individuals around the overall net bias, and (3) the interaction between the individual bias terms and the true values.

Sampling Variance of True Values. The first source, the sampling variance of the true values, is unavoidable. It is the error which results from taking a sample. This variance can be reduced by increasing the sample size.

Sampling Variance of Individual Biases. The second source, the variation of individual biases, can be caused by errors resulting from the manner in which the sample is weighted. The sample is weighted based on the knowledge of how many individuals are in the universe or strata of the universe. If this information is missing or out of date (as often happens when intercensal population data are used), then individual bias terms can be present in the estimates of population characteristics.

Interactions Between Individual Bias Terms and True Values. The third source of error in the sampling variance results from a relationship between the individual bias terms and the true values. This could occur if, for example, the true values of the population characteristic, e.g., opinions about new roads, are different in various strata, and there are different weighting errors (bias) across those strata. This can be controlled by having accurate information concerning the size of the universe within each of the strata included in the sample design.

8.2 MEASUREMENT VARIANCE

The second component of error, measurement variance, has two sources: (1) the sample measurement error, and (2) correlation of the individual measurement errors.

Sample Measurement Error. This source of error is the result of a faulty measurement process which is usually associated with the questionnaire itself. For example, suppose one wished to measure opinions regarding the overall impact of a proposed highway using a five-point rating scale (strongly agree ... strongly disagree) and a series of statements describing individual impacts: e.g., (1) a lot of homes will go up for sale, (2) more high-rise buildings will be constructed, (3) property will be bought up by people with lots of money. If the items on this scale are poorly worded, or they inadvertently measure more than one dimension of impact, then measurement error could ensue. This measurement error can be controlled by investigating the psychometric properties of the questionnaire in relation to measurement reliability and validity, or by using questionnaire items which have proven qualities. Simple measurement variance can also be controlled by the size of the sample. That is, an increase in sample size will tend to play down the effect of sample measurement error.

Correlation of Individual Measurement Errors. The second source of error associated with measurement variance, the correlation of individual errors, is thought to be introduced by the presence of interviewers, abstractors, data coders, etc. This source can be controlled by training interviewers and imposing strong data quality control measures on the abstracting, coding, and general data-handling procedures.

8.3 BIAS

The third component of estimation error, bias or systematic error, is usually the result of nonresponse. The nonresponse rate is the number of uncompleted interviews from those in the sample who are legitimately in the universe, divided by the number of potential respondents in the sample from the universe.

Although the foregoing definition is simple, what actually constitutes an uncompleted questionnaire is not always clear. For example, questions arise as to when a sampled individual, household, business, etc., should be considered a non-sample element or a nonrespondent. When a house is vacant, should it be considered as having no one at home? What is the classification of people in hospitals, on extended vacations, or who are mentally incapacitated? For some studies, if critical information is missing on an otherwise completed survey, it is considered a non-response instead of a partially complete survey. Missing data usually stem from the following events:

- Not covered (cannot locate, overlooked, no telephone, not listed, wrong address, letter returned undelivered);

- Respondent not at home (away at work, vacation, no answer to phone);
- Respondent not available (too busy, sick, line busy); and
- Refusal.

Typically, the group of respondents "not covered" is disregarded; the remaining three groups are used to calculate the nonresponse rate.

The nonresponse rate becomes an important indicator of the quality of a survey operation. A high rate increases the danger of bias in the survey, because nonrespondents are likely to differ from those who do respond in ways important to the investigation. Although the rate of nonresponse should not be considered the sole indicator of a survey's quality, it can threaten the reliability of the results.

Nonresponse can be controlled in various ways. For example, if respondents are not available or not at home, a schedule of callbacks (by phone, revisit, or repeated mailings) can be used to obtain completed questionnaires. Refusals can be lessened by providing the interviewer with adequate training to handle hard-core cases. It has been suggested that information can be obtained from hard-core refusals through the use of money, i.e., inducements or honoraria. However, care should be exercised in this instance since the results of this strategy are inconclusive and the number of responses may not warrant the amount of money spent.

Nonresponse can also be handled in ways which utilize analytic methodologies. For example, an energetic attempt can be made to sample the pool of nonrespondents and use the estimated characteristics from both respondents and nonrespondents in a scheme to obtain unbiased results. This method also requires a lot of effort, so its value depends on the effort the surveyor can spend on minimizing nonresponse. Additionally, the extent of nonresponse bias can be investigated without sampling nonrespondents. A variety of complex statistical techniques can be used to estimate and adjust for the existence of bias. These techniques require the use of a large amount of resources.

In making a decision about controlling nonresponse, the surveyor must determine if it is better to employ resources during the survey to minimize nonresponse, or use them later in an analytic activity. Both approaches can be effective. No matter which is used, the surveyor should remember that nonresponse bias is a threat to both the reliability and the accuracy of the data. And this bias, if it exists, is almost always unaffected by the size of the sample.

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Part 4. ANALYTIC TECHNIQUES

This part focuses on analytic techniques which can be used to combine socio-economic data and statistically examine their relationships. The presentation supplements materials in Volume I, Part 3, Display and Analysis of Data.

Part 3 of Volume I discusses the use of maps, tables, graphs, and narratives to organize and display findings. These are the formats used to display the basic outputs of socio-economic impact assessments. They serve to document the fact that the area subject to impacts has been examined and the results have been organized into a profile of pertinent characteristics. These simple organizing mechanisms allow practitioners, and other interested parties, to review the data and draw inferences concerning how the people and the economic activities in the impacted area(s) will be affected by a proposed project. Part 4 of this volume focuses on supplementary analytic techniques which can be used to draw additional meaning out of the available information.

Chapter 9 provides a description of three additional techniques frequently used in preliminary stages of assessment -- the analogous case approach, content analysis, and the delphi approach.

Chapter 10 presents a set of simple algorithms for synthesizing core socio-economic data, collected during preliminary and detailed assessments, into indices which can be used as measures of potential impacts.

Chapter 11 describes how more sophisticated statistical techniques can be applied in the impact assessment process to explore and quantify the significance of relationships among data. The use of these techniques requires a degree of expertise in statistical methods; some are practical only if computer resources are available.

The presentation is intended to provide practitioners with access to state-of-the-art statistical approaches which can be used to draw out the meaning of data which they have collected and arrayed. It can also be viewed as offering a point of departure, and a reference, for practitioners who want to make effective use of specialized outside expertise to assist in the statistical analysis of socio-economic data.

Chapter 9. PRELIMINARY ANALYSIS TECHNIQUES

9.1 THE ANALOGOUS CASE METHOD

In the initial phase of impact assessment, the analyst should seek out and evaluate impact studies where the type of project and study area are similar in meaningful ways to the project and study area he will be working with. Materials which can be used for the purpose include studies and environmental documents completed by the State highway agencies, and reports published by the Federal Highway Administration (FHWA) and other organizations which summarize the literature on socio-economic impact assessments and provide descriptions of findings.*

The review of empirical studies of analogous cases should sensitize personnel responsible for conducting the assessment as to what to look for, the types of impacts to expect, and their probable magnitude. For example, previous studies concerning impacts of new freeways on property values provide some relatively clear guidelines on probable changes in property values in similar cases. These studies also show how public attitudes toward -- and potential resistance to -- new projects are often a function of proximity, and of selected socio-economic characteristics. They can also shed light on who is typically hurt and who benefits from displacement and relocation.

The analysis of similar cases provides a basis for shaping and focusing the overall assessment effort. It is often used to develop hypotheses to be tested by subsequent assessment activities. This preliminary analysis also provides a basis for predicting impacts and identifying steps to minimize harm. However the materials reviewed should be used judiciously, since each case is unique in many respects, and surface similarities may mask significant dissimilarities which make the process of reasoning by analogy misleading.

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*Several of the references at the conclusion of Chapter 11 provide information on analogous cases.

9.2 CONTENT ANALYSIS

Content analysis is similar in many respects to the analysis of analogous cases. Both focus mainly on narrative materials with an eye towards systematically extracting information which speaks to assessment problems faced by the practitioner.

However, while the analogous case method focuses on previous research studies, content analysis is directed towards source materials generated by public and private agencies in the study area: planning documents developed by local government agencies, newspaper articles, transcripts of public hearings, and other materials which describe community and area-wide goals and reflect public attitudes towards the existing transportation system and its improvement.

Because the possible goals and the materials used in content analysis are so diverse, it is important that the planner develop a clear idea of his overall purposes, and that specific criteria for abstracting information from the sources be identified. A primary purpose of content analysis is to examine planning documents of local agencies and extract data which can be used to determine whether, and to what extent, foreseeable project impacts complement or conflict with goals and objectives expressed in the documents.

In the analysis of planning documents, a listing of goals and objectives should be developed for each document examined. This listing should be supplemented by (1) the timetable established for the achievement of the stated goals, and (2) a description of actions taken and planned in support of the goals.

The analysis of planning documents can also be used to collect statistical data for the study area used to (1) test and update data in other baseline sources, and (2) provide supplemental information. Statistical presentations in planning documents (and other sources) should be reviewed for their usefulness in this area. Time-series data on variables pertinent to the seven impact areas explored are of special interest here.

A second application of content analysis focuses on back copies of local newspapers. This source can be used in the development of a chronological record of major transportation-related developments in the local area. It can also be used to identify local issues and public attitudes in this subject area, and to develop lists of local leaders and interest groups.

Content analysis can be applied to other pertinent documents, e.g., position papers produced by organizations in the area. The technique can also be applied to transcripts of all public hearings on the project. Here, statements for and against the project are often summarized at the end of the analysis and correlated with their sources, i.e., the individuals or organizations voicing the opinion. Stated preferences can also be correlated with perceptions of possible effects. Such data are often summarized in tabular formats.

9.3 THE DELPHI APPROACH

This technique can be used to reconcile disparate responses from elite groups responding to a series of questions, and to move towards a consensus through a process of iterations. The major steps in this exercise are:

(1) Select questions and a target audience, and administer the questionnaire.

(2) Analyze the results, e.g. calculate frequency distributions and mean and median scores.

(3) Summarize results, modify the questionnaire as desired, and request the same group to review the initial summary of findings and respond to the modified questionnaire. This feedback process provides respondents an opportunity to review the responses of the entire population surveyed (no names are associated with responses), rethink their own position in view of this information and answer a second time. It also provides the planner with the freedom to modify the line of questioning based on first round responses, adding, deleting, and rephrasing questions to clarify issues and probe deeper into areas of special interest.

(4) Repeat the questioning and feedback cycle as required to resolve discrepancies in responses and arrive at consensus. The number of iterations will depend on the time and resources available and the degree of dispersion in responses. Three rounds are commonly used.

Chapter 10. THE USE OF SIMPLE ALGORITHMS TO DEVELOP INDICES

A number of algorithms have been developed for combining key socio-economic indicators to produce numerical outputs which measure levels of cohesion, employment and business activity; predict displacement effects, tax revenue losses; etc. The outputs of these calculations are generally used in preliminary assessment to screen for potential negative effects. The results are often combined with mapping techniques to translate results into spatial terms.

While the algorithms presented here are a simple tool for getting more out of core socio-economic data, the results should be viewed with cauton. In general, the techniques have not been validated, and the general public may look on their use as a "black box" procedure that replaces common sense with abstraction. Other considerations concerning the currency and level of disaggregation of the data used as inputs to the algorithms are discussed in the following subsections.

Currency. The algorithms presented here are often designed to use decennial census data. Intercensal updates can also be obtained, but the estimates are usually too aggregated for small area analysis. It is possible, when currency is a problem, that more sensitive estimates could be generated through small area analysis techniques, e.g., synthetic estimates and composite estimators, so that more current data are available for impact analysis. However, the precision of the estimates becomes weaker for smaller areas since the intercensal data (themselves estimates) are given for units no smaller than urban areas or a collection of counties. Small area techniques which utilize ancillary predictor variables, e.g., ethnic composition, income, and occupation categories, could also easily introduce sizable variability into tract and sub-tract estimates. Another possible solution to the currency problem is to obtain the required data from non-census sources, e.g., State and local records.

In summary, although the algorithms presented here often employ census data which are readily available, the issue of currency introduces the need for caution when they are used in the period between censuses.

Disaggregation. The algorithms are intended as small area measures. However, from the standpoint of face validity, the application of these measures need not be limited to that unit of analysis. Many of these indicators can be measured for areas of various sizes ranging from a sub-tract collection of blocks to a study area covering several tracts.

The potential use of the algorithms on areas of different sizes is suggested for practical purposes. As noted, the data used in these measures are taken from the census. If current data are employed, then the indices can be more reliably calculated on the smaller areas in the range of application. When measures are required in the intercensal period, updates of census data can be obtained from current population statistics which describe areas usually no smaller than urban areas or counties.

As was noted in the section on currency, unwanted error could be introduced if intercensal estimates are used on small areas. Therefore, the level of disaggregation may be a function of currency and, if confidence is to be placed on the measures, then it is suggested that the unit of analysis be adjusted accordingly.

10.1 ALGORITHMS USED IN THE ASSESSMENT OF SOCIAL IMPACTS

A series of indices has been developed for combining key indicators and rating the cohesiveness, accessibility problems, and vulnerability to displacement effects of population sub-areas within the study area. Nine algorithms which generate indices of this kind are presented in the following subsections.

10.1.1 Algorithms Used to Identify Cohesive Population Groups

Use of duration of residency, owner occupancy and single unit dwellings as indicators of cohesion levels. This approach is based on the assumption that areas with low turnover rates have higher levels of cohesion among residents. These low turnover rates become proxy indicators of positive identification with place, neighborhood, mutual support activities, and membership in civic, church and fraternal groups. Stable neighborhoods are also associated with high levels of inter-generational cultural transmission. The purpose here is to identify communities with high cohesion ratings which should be avoided in defining potential routes.

(1) Mobility Index:* Used to measure the residential stability of an area. Low values indicate more stable areas which, it is believed, would suffer most from disruptions caused by road construction.

$$MI = 200 - 2R$$

Variables

MI = Mobility index.
R = Percentage of area population in dwelling five or more years.

(2) Stability Index:** This is an elaborated version of the Mobility Index. It adds two new factors which correlate positively with stability -- percent of single family and owner-occupied homes -- to the original index which is based solely on percent of families at the same address for five years or more.

$$SI = R + [(OH + SF)/2]$$

Variables

SI = Stability index.
R = Percentage of area population in dwellings five or more years.
OH = Percent of residents who own their own dwellings.
SF = Percent of single family units.

Use of housing characteristics (type and quality of dwelling unit, owner occupancy, persons per room, rooms per dwelling) as proxies for cohesion. This approach rests on the assumption that people occupying similar dwelling units are comparatively homogeneous in terms of other key socio-economic indicators.

(1) Neighborhood Index:*** This index has a range of 0-300.

$$NI = (OO + CC + NC + R/U) \times 300/400$$

Variables

NI = Neighborhood Index.
OO = Proportion of owner-occupied units.
CC = Proportion of dwelling units in good condition.

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*Stuart Hill & Bamford Franklin, "Mobility as a Measure of Neighborhood," Highway Research Record 187, 1967, p. 33.

**Ibid.

***Jon Burkhardt, Lago and Rothenburg, Highway Improvements as a Factor in Neighborhood Change, Resource Management Corporation, Bethesda, Md., 1971.

NC = Proportion of dwelling units not crowded.
R/U = Relative percentage of rooms/dwelling.

Use of duration of residency and density of residential units as proxy measures of social interaction.

(1) Neighborhood Social Interaction Index:* This index is based upon regression analysis of various variables in one community. The output is an index of relative social interaction.

$$NSII = 76.29 - 1.45M - .36R - .30Hu + u$$

Variables

NSII = Neighborhood Social Interaction Index.
M = Percent of families with tenure 2 years or less.
R = Percent of land residential.
Hu = Housing units per residential area.
u = Error term.

10.1.2 Algorithms Used to Identify Accessibility Problems

Algorithms are used here to identify areas with concentrations of persons with high levels of dependency on pedestrian access to key facilities and services, and potential accessibility problems.

(1) Social Feasibility Model:** This index can be used to identify and delineate areas where a high percentage of residents walk to and from schools, retail stores, social service centers, and other destination points. This information can also be used in route selection to avoid segmenting these areas and in design selection to determine steps to minimize harm.

The model consists of four different indicators of pedestrian dependency:

- A general indicator which makes resident dependency on pedestrian access to destination points a function of income level, size of family, and ownership of an automobile.

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*From "Neighborhood Social Interaction: Measurement and Prediction of Changes," paper by Jon E. Burkhardt, FHWA, December 1973.

**Marshall, Kaplan, and Kahn, Social Characteristics of Neighborhoods as Indicators of the Effects of Highway Improvements, Federal Highway Administration, Washington, D. C., 1972.

- An indicator showing the concentration of grammar school children in the area.

- An indicator measuring the dependency of residents on pedestrian access to local shops as a function of the percentage of elderly and carless residents in the area.

- An indicator measuring the dependency of residents on social service centers as a function of duration of residency, race, and country of birth.

$$SF = GPD + SPD + LSPD + SIPD$$

Variables

GPD = General pedestrian dependency
SPD = Pedestrian dependency on schools
LSPD = Pedestrian dependency on local shopping
SIPD = Social service dependency of pedestrians
GPD = (h x P x I)/i
SPD = S/N
LSPD = h + e/N
SIPD = (t + f + B)/N

h = Percentage of households without automobile

P = Persons per household
i = Median neighborhood income
I = Median city income
S = Number of grammar school children
N = Neighborhood population
e = Number of elderly in neighborhood
t = Number of residents for 10 years or more
B = Number of blacks in neighborhood
f = Number of foreign residents

(2) Public Transportation Submarket Index:* This index was originally designed to determine requirements for public transportation services. It can be used to identify areas with high concentrations of people with limited mobility and potential access problems. These include large families, families with low incomes, the elderly and handicapped, and households which do not own automobiles.

$$PTSI = GPD \times W \times PM$$

Variables

PTSI = Public Transportation Submarket Index
GPD = General Pedestrian Dependency
= A x P x 1/i
A = Percentage of households without autos
P = Min. value of PM in city or region

W = Relative magnitude PM/PM_{min}
PM = Potential market
= E + H - C(H)
E = Percent of population elderly
H = Percent of market handicapped
C = Percent of handicapped who are elderly

*Martin Stein, "Social-Impact Assessment Techniques and Their Application to Transportation Decisions," Traffic Quarterly 31 (April 1977).

i = Median neighborhood income PM_{min} = Average persons per household
I = Median city income

10.1.3 Algorithms Used to Identify Potential Displacement Effects

Both the algorithms discussed to this point and those presented in the next subsection on "Composite Algorithms" can be used as indicators of sensitivity to negative displacement effects. Their interchangability rests on the fact that they use many of the same indicators. These are:

- Residency at the same location for more than five years,
- Households which do not own automobiles,
- High percentages of the old, the handicapped, and the very young,
- Presence of a significant minority population, and
- High percentage of low-income families, and female-headed households with young children.

Use of selected indicators to predict the number of dwelling units taken.

(1) Household Displacement Model (HD_1):* The model uses housing density, total land in ROW, and proportion of residential land use to predict the number of households that will be displaced. It was developed for use in the initial stages of project planning when the planner has defined the potential impact area, but the actual ROW's have not been defined.

$$DU_T = DU_z/RA_z \times RA_z/TA_z \times A_{ROW}$$

Variables

DU_T = Total dwelling units taken
DU_z = Dwelling units in area
RA_z = Residential units in study area
TA_z = Acres in study area
A_{ROW} = Acres in right-of-way

10.1.4 Composite Algorithms

(1) Simple Negative Social Impact Index:** This composite index is used to identify population areas which will tend to be negatively affected by impacts associated with transportation project development. The variable

*Klein et al., Methods of Evaluation of the Effects of Transportation Systems on Community Values, U.S. Department of Housing and Urban Development, Washington, D.C., 1971.

**Martin Stein, "Social Impact Assessment Techniques."

"percentage of residents with 10+ years of tenure" is used as an indicator of cohesion. This variable, along with low income and a high incidence of female-headed households with children, is an indicator of vulnerability to displacement and proximity effects and difficulty in relocation. Low income households and female-headed households with children are also indicators of pedestrian and mass transit dependency. Density is a measure of the magnitude of these negative impacts.

$$SNSI = 1/15\ [7D + 7(A + E + 3T + FH) + \$]$$

Variables

SNSI = Simple Negative Social Impact Index
D = Density (population per acre)
A = Percentage of carless persons
E = Percentage of population over 65
T = Percentage of residents with 10+ yrs. tenure
FH = Percentage of female-headed households with own children under 18
$ = Median household income

(2) Negative Social Impact Formula:* This index uses 14 variables to identify neighborhoods with high susceptibility to negative social impacts associated with highway development.

$$NSI = NIN + NII$$

Variables

NSI = Negative Social Impact.
NII = Negative impact on individuals.
NIN = Negative impact on neighborhoods.

$$NIN = 1/30\ [6(\min NIF/\text{tract } NIF) + 3(\min V/\text{tract } V) + (\min NDF/\text{tract } NDF)]$$

$$NII = 1/30\ (10D + 9AI + RLUF)$$

Variables

NIF = R + N
R = Residents with tenure less than 10 years
N = Change in tract population
V = Percentage of tract vacant
AI = 2A + 2E2T + 2FH + C + M/2
A = Percentage of autoless households
E = Percentage of population over 65 years of age
D = Density (persons/acre)
T = Percentage of households tenured longer than 10 yrs.
NDF = SS + VR
SS = Percent of dwellings substandard
VR = Vacancy rate
FH = Percentage of female-headed households with children
C = Percentage of population less than 9 years of age
M = Percentage of population non-white or foreign
I = Median family income
RLUF = Percentage of land for residential or single family use

*Kurt Finsterbush, "Development and Application of a Systematic Methodology for Assessing the Potential Social Impact of a Prospective Highway Location," Department of Sociology, University of Maryland, 1976.

10.2 ALGORITHMS USED IN THE ASSESSMENT OF ECONOMIC IMPACTS

Similar algorithms have been developed to combine and synthesize economic data to characterize the types and level of business and residential activity in the study and surrounding area. Some of these techniques can also be used to predict the proposed project's effects on business activity, residential activity and local government finances. Algorithms are described by impact area, below.

Before using any one of these techniques, practitioners should examine the references provided to obtain a more complete understanding of its purposes and the meaning of its output.

10.2.1 Algorithms Used to Characterize Local Employment, Income, and Business Activity

Use of employment by industry to describe the structure and vitality of the local economy. This approach assumes that (1) employment by industry is an indicator of the importance of an industry to the study area economy, and (2) some industries support local economies while others support regional economies. Thus the vitality and growth potential of a local economy can be determined by examining the most active industries in the area.

(1) Major Employment Activity:* Used to identify the study area industries which are important to the economy. Industries that employ more than four percent of the total employees are considered important to the local economy.

$$III = E_{SIC}/TE$$

Variables

III = The index of the importance of an industry to the local economy.

E_{SIC} = Number of people in the local area employed in a SIC industrial category (the index should be calculated for each SIC category).

TE = Total number of people employed in the local area.

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*J.D. Meck, The Role of Economic Studies in Urban Transportation Planning, U.S. Department of Commerce, Washington, D.C., 1965.

(2) Location Quotient Method:* Uses a comparison of the level of an existing activity in a local area and in the regional area of which it is a part to determine the relative concentration (importance) of that activity in the local economy. The location quotient can be calculated for employment, retail employment, retail sales, owner-operated businesses, or almost any key indicator for which data are available. For example:

$$LQ = \frac{\dfrac{\text{Industrial workers in local area}}{\text{Industrial workers in region}}}{\dfrac{\text{All workers in local area}}{\text{All workers in region}}}$$

Variables

Employment by SIC category for local area and region.

Sales by sector for local area and region.

Businesses by type for local area and region.

Use of consumer accessibility measures to demarcate trade areas around, and the level of activity at, retail centers. This approach assumes that proximity to and size of retail centers determine their usage, and that changes in access will alter usage patterns. Areas with heavy concentrations of retail activity and proximity to many residential areas will have high accessibility indices, high levels of retail attraction, and potential for growth. Small, isolated retail centers will have limited activity and be more vulnerable to changes in access routes.

(1) Reilly's Law of Retail Gravitation:** This technique uses the distances between retail areas and the sizes of the areas to compute the area limits of retail attraction, or trade area, between the two areas. The resulting index is the mileage from the retail center to the market area border in the direction of the competing retail area. (Most users of Reilly's law have recently substituted driving time for highway mileage and square feet of retail floor space for population.) These alternatives produce a revised "break point" equation that defines a trade area in terms of travel time. By using estimated travel times associated with alternative routes, practitioners can supposedly estimate changes in consumer attraction to local trade areas, and hence the likely changes in sales and revenues in these areas.

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*Boston Transportation Planning Review, North Shore, May 1972.

**William J. Reilly, The Law of Retail Gravitation (New York: Reilly, 1931).

Original Version:

$$X_o = \frac{M_{AB}}{\sqrt{1 + \frac{P_A}{P_B}}}$$

Commonly Used Version:

$$X_c = \frac{DT_{AB}}{\sqrt{1 + \frac{RFS_A}{RFS_B}}}$$

Variables

X_o = Distance from retail center to boundary of trade area in direction of competing trade area, in miles: the "break point" between trade areas surrounding retail centers A & B.

M_{AB} = Miles between retail centers A and B.

$\frac{P_A}{P_B}$ = Population in retail area A over population in retail area B.

X_c = Distance from retail center to boundary of trade area in the direction of a competing trade area, in travel time: the "break point" between trade areas surrounding retail centers A & B.

DT = Driving time between retail centers A & B.

$\frac{RFS_A}{RFS_B}$ = Retail floor space in retail area A over retail floor space in retail area B.

(2) Accessibility Index:* Used to measure the spatial separation between predetermined zones and the attractiveness of each zone. By using residential areas and retail centers as the analysis zones, the practitioner can determine the relative degree of consumer accessibility (and attraction) to the retail areas. Travel times associated with the proposed project can be substituted for existing travel times to determine potential changes in access to, and hence, activity at, various retail centers. A similar analysis can be conducted to determine accessibility of employment opportunities.

$$A_{ij} = \sum_{j=1}^{N} R_j \, (T_i - j)$$

*U.S. Department of Transportation, Final Manual: Special Area Analysis, August 1973; Stanford Research Institute, Methods of Evaluation of the Effects of Transportation Systems on Community Values, U.S. Department of Housing and Urban Development, 1971.

Variables

A_{ij} = Accessibility of residential zone i to retail center j.
R_j = Retail establishments at zone j.
T_i = Travel time between zones i and j.
j = Travel time friction factor (as measured by road grade) associated with trips from zone i to zone j.
N = Number of analysis zones.

(3) Market Potential Model:* Used to describe the expenditures of consumers at market areas in the study area and to predict changes in expenditures resulting from altered accessibility (or spatial interaction) resulting from the highway project.

Given a description of the three components of the retail spatial structure -- demand, supply, and buyer-seller interaction space -- the model provides a measure of the probable sales levels at each center. The model can be manipulated with data on present driving times and with the projected driving times for the highway facility to estimate the change in consumer spending patterns.

This equation is specific to a pair of zones:

$$S_{ij} = C_i \frac{\frac{F_j}{d_{ij}}x}{\frac{F_i}{d_{ii}}x + \frac{F_j}{d_{ij}}x \cdots \frac{F_n}{d_{in}}x} = C_i \frac{\frac{F_j}{d_{ij}}x}{\sum_j \frac{F_j}{d_{ij}}x}$$

It can be modified to state the consumer expenditures in all zones of the region that would probably be spent in a zone, j. It implies that there is not a trade area boundary but a shopping interaction among all zones:

$$S_j = \sum_i d_i \frac{\frac{F_j}{d_{ij}}x}{\sum_j \frac{F_j}{d_{ij}}x}$$

Variables

S_j = Total sales in retail center F_j.
S_{ij} = Consumer retail expenditures of population in zone i, spent at zone j.
C_i = Total consumer retail expenditures of population in zone i as measured by the product in dollars, the population in zone i, and the per capita shopping expenditures.

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*T.R. Lakshmanan & W.G. Hansen, "Market Potential Model and its Application to a Regional Planning Problem," Highway Research Record, No. 102, 1965.

F_j = Size of retail activity in zone j as measured by number of retail establishments or, if possible, square feet of floor space devoted to the sale of consumer goods in zone j.

d_{ij} = The distance between the shopping center j and the consumers in zone i as measured by driving time between the centers of the zones.

x = Exponent applied to a distance factor, d. In practice, a friction factor is used so that:

$F = \frac{i}{d_{ij}^{x}}$ where the exponent x is variable with d_{ij}.

Use of land and accessibility data to estimate the amount of undeveloped land (including farmland) that will be developed over some future period. This approach assumes that the likelihood of development is dependent on the degree of access to available land. Judgments are still required to determine the type of development that will occur.

(1) Index of Development Pressure:* Used to estimate the strength of development forces in the impact area. This approach uses the attributes of other competitive zones, such as developed land and proximity to study area, to identify the demand for development rather than assess the way demand and supply would reach an equilibrium. It provides a relative measure, among the different zones or areas within a metropolitan region, of the extent of development which might be expected. A high IDP indicates a high likelihood of development.

$$IDP_i = \frac{U_i \sum_{j=1}^{n} D_j/T_{ij}}{\sum_{k=1}^{n} U_k \sum_{j=1}^{n} D_j/T_{kj}}$$

Variables

IDP_i = Index of development pressure for zone i.
U_i = Undeveloped acreage which is available for development in zone i.
D_j = Developed acreage in zone j.
T_{ij} = Travel time from i to j.

(2) Land Development Model:** Used to predict the amount of development that will take place on any given parcel of land in the impact area. This model integrates the concepts of land development, modal choice and ac-

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*Klein et al., Methods of Evaluation.

**John R. Hamburg, Geoffrey J. H. Brown, & Morton Schneider, "Impact of Transportation Facilities on Land Developmen," Highway Research Record #305.

cessibility into a comprehensive model based on the premise that the amount of development that will occur at a particular location is related to the relative attractiveness and the relative accessibility of the site in comparison to all other sites in a region. Specified inputs are the total amount of development expected in the region, the amount of land in the region described in terms of its relative attractiveness, the transportation networks serving the region, and certain constants related to model choice. The model then allocates urban development to each zone until land development and accessibility in the region are in equilibrium. The impacts of speed, differential accessibility, magnitude of growth, central location, and density can be measured.

$$R_f = R_F \frac{R_a I}{J - R_F I}$$

R_f = Equilibrium floor area at a site (i.e., existing development).
R_F = Total floor area in the region.
R_a = Relative attractiveness of the site (e.g., proportion of developable land, flat topography, utility systems).
I = Accessibility of the site.

J = Access integral ($\int$ IdR of the region).

10.2.2 Algorithms Used to Determine the Impact of Displacement on Residential Activity

Use of aggregate data on housing in the study area and ROW requirements to estimate the number of dwellings to be removed from the housing stock. These techniques are used early in the assessment process when the location of the proposed project is unknown.

(1) Housing Displacement Model (HD_2):* This technique predicts the number of units to be displaced based upon empirical observations of typical displacement impacts. The model parameters were developed from regression analysis.

$$Y = (0.61 \times 10^{-2})(L)^{.85} \times R^{1.53}$$

$$R_N = \frac{5{,}280L(R_o - R_e)}{43{,}560} + N_M(a_1) - e_1 + N_m(a_2) - e_2$$

$$H = Y \times R_N$$

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* Frank Ventura & Rajendra Metha, "Methods of Predicting the Effect of Long-Range Transportation Plans on Residential Land Use Activities," TRR 481, 1974.

Variables

H = Number of housing units displaced.
R_N = Net right-of-way, in acres.
Y = Number of housing units displaced per acre.
L = Length of freeway section not including interchanges, in miles.
R_o = Design right-of-way.
R_e = Existing right-of-way, in feet.
N_M = Number of major interchanges.
N_m = Number of minor interchanges.
a_1 = Average right-of-way required for major interchanges, in acres.
a_2 = Average right-of-way required for minor interchanges, in acres.
e_1 = Existing right-of-way for major interchanges, in acres.
e_2 = Existing right-of-way for minor interchanges, in acres.

(2) Housing Displacement Model (SAA):* In this technique, an estimate of the dwelling units displaced is calculated by multiplying the expected number of acres taken by the ROW, times dwelling units, and dividing it by residential acreage in that zone. These estimates are summed across all zones to get total dwelling units displaced.

$$DUD_z(X_i) = ROW_z \times \frac{DU_z(X_i)}{RACRES_z} \quad \text{where } RACRES = PCTR_z \times TACRES_z$$

$$\text{i.e., } \left(\frac{DU}{ACRE}\right) \times \left(\begin{matrix}\#ACRE \\ FACILITY\end{matrix}\right) \times \left(\begin{matrix}\%\ RESIDENTIAL \\ LAND\ USE\ IN\ ZONE\end{matrix}\right)$$

Variables

DUD_z = Dwelling units of X_i type dislocated in zone.
ROW_z = Number of acres of ROW acquisition in zone.
$DU_z(X_1)$ = Dwelling units of X_i type in zone.
RACRES = ROW acreage which will come from residential land use.
$PCTR_z$ = % residential land use in zone.
$TACRES_z$ = Total acres in zones.
Z = Number of zones.
X_i = Cost of dwelling unit.
n = Number of housing cost groups.

10.2.3 Algorithms Used to Quantify Fiscal Impacts

Use of data on the proposed ROW and tax assessment to estimate property tax losses due to ROW acquisition. These techniques, which are especially useful early in the assessment process, are based on assumptions about the amount, types, and values of land required for the ROW. Based on these assumptions,

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*Skidmore, Owings and Merrill, Environmental Assessment Notebook Series, Notebook 3, "Economic Impacts," Department of Transportation, 1975; Department of Transportation, Final Manual: Special Area Analysis (Washington, 1973).

average tax rates are used to calculate tax losses associated with the required acreage.

(1) Proportional Acreage Method:* This technique is based on the premise that the ROW acreage of each land use type taken for the construction of new facilities is proportional to existing uses in the affected zones. It requires the identification of the amount of property to be taken in the ROW acquisition, the estimation of proportions of different land uses in the study area, and the application of these proportions to the affected property. The resulting estimates of acres of each use to be taken are multiplied by the average assessed value of property devoted to that use to get total assessed value by usage. The summation of these is multiplied by an average tax rate to get a rough approximation of the direct tax loss.

Total Residential Tax Base Affected in Each Zone	=	Total Number of Acres to be Acquired in that Zone	x	Percent of Land in Zone Which is Residential	x	Average Assessed Value per Residential Acre in that Zone
Total Business Tax Base Affected in Each Zone	=	Total Number of Acres to be Acquired in that Zone	x	Percent of Land in Zone Which is Commercial	x	Average Assessed Value per Business Acre in that Zone
Total XXX[†] Tax Base Affected in Each Zone	=	Total Number of Acres to be Acquired in that Zone	x	Percent of Land in Zone Which is XXX	x	Average Assessed Value per XXX Acre in that Zone

[†]XXX = any other significant use.

(2) Right-of-Way Cost Ratio:** The model estimates the tax revenues lost by using estimates of the ROW acquisition cost as a reasonable approximation of fair market value. These figures are adjusted to reflect the fact that assessed values are often only a fraction of fair market values. The per parcel assessment value is multiplied by an average tax rate for the area to obtain annual tax revenue lost.

$$TL = AC \times (AV/MV) \times TR$$

Variables

TL = Total tax revenue lost.
AC = Acquisition cost.
AV = Assessed value.
MV = Market value.
TR = Average tax rate per dollar of assessed value.

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*Ibid.

**Klein, et al., Methods of Evaluation.

Use of data on individual parcels of land to determine property tax losses due to ROW acquisition. This approach uses detailed tax assessment data on all affected parcels and sums the losses accruing to each one. It is most useful during detailed assessment when a limited number of alternatives are under consideration.

(1) Parcel-by-parcel Method:*

$$TR = \underline{r}\ (AV)$$

Variables

TR = Local property tax revenues from parcels in question.
$\underline{r}$ = Tax rate.
AV = Assessed value of parcels in question.

*Ibid.

Chapter 11. TECHNIQUES FOR TESTING THE SIGNIFICANCE OF RELATIONSHIPS AMONG DATA

11.1 TESTS OF SIGNIFICANT RELATIONSHIPS IN BIVARIATE TABLES

When categorical data are cross-tabulated, or arranged in a bivariate table, it is often desirable to summarize the array with a measure of association or a test of significance. A measure of association indicates how strongly two variables are related. From another viewpoint, a measure of association indicates to what extent one's prior knowledge of a category (or value) of one variable facilitates the prediction of categories for the other variable. However, a measure of association only indicates how strongly the two variables are related among the individuals in the sample. This does not mean the relationship holds for all possible individuals in the universe.

A test of significance, then, determines whether the surveyor can make statements about all individuals in the universe using the results from the sample. Through tests of significance one can infer, from the results of the sample, the presence or absence of a relationship among variables in the universe. The inference is based upon the chance (probability) that the results occur. Therefore, there is nothing certain about the inference. If a different sample is taken, it is possible that significance tests could produce completely different results.

The surveyor can rely on inferences developed as described above (inductive) only if the test is performed many times and the same result (either significance or insignificance) occurs in 95 out of 100 trials. This is the basis for significance testing.

Significance depends both on the strength of the relationship and on the size of the sample. In large samples even weak relationships may prove to be statistically significant. Tests of statistical significance indicate only the likelihood that an observed relationship exits in the universe; they do not tell how strong it is. Consequently, a relationship can be statistically significant while not being substantively important.

The Chi-Square Test of Significance

Suppose after a sample of residents is taken in a proposed ROW, it is important to determine whether there is a relationship between home ownership and route preference for all residents in the ROW. To do this, it will be necessary to perform a test of significance on the cross-tabulated sample data. The results of this test will permit inferences to be made to all residents as to whether or not a relationship exists. The cross-tabulated data which provide the basis for the test have the following appearance:

Route Preference

		Route A	Route B	Route C	"No Build" Option	ROW Total
Ownership	Own or Buying	10	10	10	30	60
	Rent	10	20	5	5	40
Column Total		20	30	15	35	100

The statistical procedure generally used to perform a test of significance on categorical data of the type above is a Chi-square test. The Chi-square test test suggested here is predicated on the hypothesis that the two variables (ownership and route preference) are unrelated. The hypothesis of no relationship in a statistical test is called the null hypothesis. To prove that a relationship does exists, the null hypothesis has to be rejected when the Chi-square test is applied to the data.

The null hypothesis is accepted or rejected based on the value of the Chi-square statistic. The Chi-square statistic is calculated as follows:

$$X^2 = \sum_{j}^{2} \sum_{j}^{4} (O - E)^2/E$$

= the sum over all cells in the table of squared difference between the observed count and the expected count, divided by the expected count.

In this calculation, "O" stands for the frequency counts which are actually observed in the cells of the cross-tabulation. The "E" represents the expected frequency counts under the null hypothesis. Thus, if the disparity between the actual observations and the expectation of no relationship is significantly large, one can reject the null hypothesis and state that the data support the existence of a relationship.

Since one is not required to calculate the observed frequency counts -- they are merely observed from survey results and arranged in the cells describing the joint occurrence of ownership and route preference -- the discussion can focus on the calculation of the frequencies expected under no relationship. These calculations are shown below.

The expected cell frequency for those who own or are buying a home and choose route A is calculated from the marginal row percent for owning or buying a home, and the column percent for choosing route A.

Marginal for:

(Row) Own or buying = 60/100
(Col.) Route A = 20/100

Expected frequency for that cell:

$$
\begin{aligned}
E &= 100\ (60/100)\ (20/100) \\
&= (\text{Table Total}) \times (\text{Row Rate}) \times (\text{Column Rate}) \\
&= 60 \times 20/100 \\
&= 12
\end{aligned}
$$

The other expected frequencies are:

- Own and Route B:

$$
\begin{aligned}
E &= 100\ (60/100)\ (30/100) \\
&= 18
\end{aligned}
$$

- Own and Route C:

$$
\begin{aligned}
E &= 100\ (60/100)\ (15/100) \\
&= 9
\end{aligned}
$$

- Own and "No Build":

$$
\begin{aligned}
E &= 100\ (60/100)\ (35/100) \\
&= 21
\end{aligned}
$$

- Rent and Route A:

$$E = 100\ (40/100)\ (20/100) = 8$$

- Rent and Route B:

$$E = 100\ (40/100)\ (30/100) = 12$$

- Rent and Route C:

$$E = 100\ (40/100)\ (15/100) = 6$$

- Rent and "No Build":

$$E = 100\ (40/100)\ (35/100) = 14$$

The Chi-square statistic is then calculated as:

$$X^2 = (10-12)^2/12 + (10-18)^2/18 + (10-9)^2/9 + (30-21)^2/21 + (10-8)^2/8 + (20-12)^2/12 + (5-6)^2/6 + (5-14)^2/14 = 29.643$$

To test the significance of the value of the Chi-square statistic for this type of cross-tabulation, i.e., 2 x 4 = 8 cells, a table of theoretical Chi-square values is consulted (see Table 3, p. 149). To find the appropriate test value for deciding whether a relationship exists or not, it is necessary to enter the table in the specific row and column which fits the problem at hand. Specifically, the Chi-square test depends on the number of cells in the cross-tabulation and the practitioners' willingness to assume that a large Chi-square value does not really signal a relationship, but just happens as a rarity due to an extreme sample (which can happen in random sampling).

The number of rows and columns determines a value called the degrees of freedom and each Chi-square value in the table is dependent on that value. The degrees of freedom merely relate to the constraints placed on the data by the way the analyst groups the data.

In the ownership/route preference example, there are two categories of ownership and four categories of preference; these categories are the constraints.

Table 3. The Chi-square distribution.

p	0.10	0.05	0.025	0.01	0.005	df
	2.71	3.84	5.02	6.63	7.88	1
	4.61	5.99	7.38	9.21	10.60	2
	6.25	7.81	9.35	11.34	12.84	3
	7.78	9.49	11.14	13.28	14.86	4
	9.24	11.07	12.83	15.09	16.75	5
	10.64	12.59	14.45	16.81	18.55	6
	12.02	14.07	16.01	18.48	20.3	7
	13.36	15.51	17.53	20.1	22.0	8
	14.68	16.92	19.02	21.7	23.6	9
	15.99	18.31	20.5	23.2	25.2	10
	17.28	19.68	21.9	24.7	26.8	11
	18.55	21.0	23.3	26.2	28.3	12
	19.81	22.4	24.7	27.7	29.8	13
	21.1	23.7	26.1	29.1	31.3	14
	22.3	25.0	27.5	30.6	32.8	15
	23.5	26.3	28.8	32.0	34.3	16
	24.8	27.6	30.2	33.4	35.7	17
	26.0	28.9	31.5	34.8	37.2	18
	27.2	30.1	32.9	36.2	38.6	19
	28.4	31.4	34.2	37.6	40.0	20
	29.6	32.7	35.5	38.9	41.4	21
	30.8	33.9	36.8	40.3	42.8	22
	32.0	35.2	38.1	41.6	44.2	23
	33.2	36.4	39.4	43.0	45.6	24
	34.4	37.7	40.6	44.3	46.9	25
	35.6	38.9	41.9	45.6	48.3	26
	36.7	40.1	43.2	47.0	49.6	27
	37.9	41.3	44.5	48.3	51.0	28
	39.1	42.6	45.7	49.6	52.3	29
	40.3	43.8	47.0	50.9	53.7	30
	51.8	55.8	59.3	63.7	66.8	40
	63.2	67.5	71.4	76.2	79.5	50
	74.4	79.1	83.3	88.4	92.0	60
	85.5	90.5	95.0	100.4	104.2	70
	96.6	101.9	106.6	112.3	116.3	80
	107.6	113.1	118.1	124.1	128.3	90
	118.5	124.3	129.6	135.8	140.2	100

Source: K.J. Meier and J.L. Brudney, Applied Statistics for Public Administration (Boston: Duxbury Press, 1981), p. 444.

With these constraints, the rows have 4 - 1, or 3 degrees of freedom, i.e., if the row total is known and three categories freely vary in their counts, once they are known, the fourth must be set to make the row total. Similarly, for columns, there is 2 - 1, or 1 degree of freedom. Since the data array is bivariate, or two dimensional, the total degrees of freedom are 3 x 1 = 3. Thus the table is entered in the row under "df" (for degrees of freedom) which is numbered 3.

The allowable decision error in rejecting the hypothesis about "no relationship," between ownership and preference, is commonly set at the 5 percent confidence level. That is, whatever value cuts off the extreme upper 5 percent of the Chi-square distribution is acceptable as a critical value for the test.

If the value of the Chi-square statistic calculated from the actual data exceeds the five percent critical value in the table (for three degrees of freedom), then the null hypothesis can be rejected with the understanding that this decision can be in error five percent of the time. This merely means that if a set of residents are sampled over and over again ad infinitum, and there is no actual relationship between ownership and choice, five percent of those samples will produce results in that five percent extreme end of the distribution. This is what is meant by "extreme results happening by chance."

Because random sampling allows all residents an equal chance of being interviewed, extreme results indicating a relationship can occur even though in the total population it does not, in fact, exist. Because of the way the test is structured, this can only happen five percent of the time as an error. If extreme results do occur, the chances are really much larger that they come, by sampling, from a set of residents in which a relationship between ownership and preference is actually present. The 5 percent error set in the test is the price one must pay for using a sample and not having all the information.

Using the degrees of freedom (df = 3) and the acceptable error level (A =.05), the critical value can be found in Table 3. It was already stated that the appropriate row to enter the table was under df = 3. The appropriate column is determined by 1 - A or (since A = .05) 1 - A = .950. Thus the critical value of Chi-square for 3 degrees of freedom and A = .05 is 7.81. Since the

Chi-square statistic calculated from the data, 29.643, is more extreme than 7.81, the results are significant, i.e., a relationship does exist in the sample and can be inferred to all residents.

* * * * *

As was mentioned earlier, tests of significance, such as Chi-square, indicate the possibility of a relationship which can be inferred to all residents in the ROW, but they do not indicate the strength of the relationship. It was also mentioned that tests of significance can indicate the existence of a relationship when it is quite weak because the test depends, in part, on the size of the sample. To determine the strength of a relationship, it is often necessary to use the size of the sample to adjust the results of a test. For example, if the cross-tabulated table were two categories by two categories (i.e., a 2 x 2 table), then a measure of association called the Phi-coefficient ($\emptyset$) can be calculated:

$$\emptyset = (X^2/N)^{1/2},$$

where X^2 is the value of a Chi-square statistic on the two-by-two table and N is the size of the sample. This coefficient takes on values which range from 0 to 1, with 0 meaning no relationship and 1 meaning a perfect relationship.

Cramer's V

The Phi-coefficient is used to assess the strength of relationships for 2 x 2 tables, but different adjustments must be carried out for cross-tabulations of other dimensions. One such measure is Cramer's V, which is given as:

$$V = (\emptyset^2/[\min(r - 1), (c - 1)])^{1/2},$$

where $\emptyset$ is the value of the Phi-coefficient and min (r - 1), (c - 1) means the minimum value of (r - 1) and (c - 1), r and c being the number of rows and columns respectively. V, like Phi, ranges from 0 to 1 when the dimensions of the cross-tabulation are larger than 2 x 2. In the example involving the cross-tabulation of ownership with preference, a 2 x 4 table, the value of V is calculated as:

$$X^2 = 29.643$$
$$N = 100$$

$$\phi = (29.643/100)^{1/2}$$
$$= .544$$
$$r - 1 = 2 - 1 = 1$$
$$c - 1 = 4 - 1 = 3$$
$$\min(r - 1), (c - 1) = 1$$
$$V = (\phi^2/1)^{1/2}$$
$$= .544$$

V is the same as Phi because there were two rows in the cross-tabulation and $r - 1 = 1$ was the minimum value.

The Contingency Coefficient

Another measure of association based on Chi-square values is the Contingency coefficient, C. The formula is:

$$C = [X^2/(X^2 + N)]^{1/2}$$

For the original example, C = .478. C can be used for tables of any size. But, if the minimum value is zero, like V, the maximum value depends on the size of the table. For this reason it should be used only to compare tables having the same number of rows and columns.

* * * * *

Measures of association such as the Phi-coefficient, Cramer's V, or the Contingency coefficient will signify the strength of association. However, they reveal nothing about the manner in which the variables are associated. That is, they say nothing about which variable is the predictor and which is predicted. The distinction between non-directional association and prediction in cross-tabulated tables can be seen by recalling the example about the relationship between home ownership and route preference.

Route Preference

		A	B	C	"No Build" Option	Row Totals
Ownership	Buy	.10	.10	.10	.30	.60
	Rent	.10	.20	.05	.05	.40
Column Totals		.20	.30	.15	.35	1.00

If the frequency counts in the cells of the original cross-tabulation are divided by the table total (100), the resulting decimal values represent the joint probability of the two variables. The joint distribution describes the nondirectional relationship between the two variables. This is the distribution which is tested by the Chi-square procedure and related measures. A relationship exists if cell probabilities are not uniformly spread over the cells as in the table above, e.g., 30, or 30 percent, own or are buying a residence and choose the "no build" option.

In the data situation described in the ownership/preference table, the highway planning question is: Can route preference be predicted by residence ownership? To array the data to fit that question, it is necessary to rearrange the joint distribution so that it becomes a conditional or predictive distribution. This is accomplished by calculating separate distributions for each category of the predictor, or independent variable, across the categories of the predicted, or dependent variable. In relation to the ownership/preference table, this means that separate distributions will be calculated for the "Owns or Is Buying" category and the "Renting" category across the choice categories. This is done as follows:

- For "Owns or Is Buying":

  Row total = 60

  Distribution for Choice Categories:

Choice A	Choice B	Choice C	No Build
10/60	10/60	10/60	30/60

For both categories of the independent variable, these distributions (as decimals) are:

		Route Choice				
		A	B	C	"No Build" Option	Row Totals
Ownership	Owns	.167	.167	.167	.500	1.00
	Rents	.250	.500	.125	.125	1.00
	Marginal	.200	.300	.150	.350	1.00

This arrangement shows more clearly how the analyst could predict route preference if the category of ownership is known. For example, if a resident owns or is buying a residence, then the highest likelihood is that he prefers the no-build option (.500). If a resident rents, then the highest likelihood is Route B (.500).

The Uncertainty Coefficient: A Measure of Association Which Takes Prediction into Consideration

The Uncertainty coefficient is a measure of association which has the asymmetric quality of allowing one variable to be an independent variable and the other to be dependent. It measures the reduction in uncertainty in prediction which can be gained by knowing the categories of the independent variables. In essence, this type of measure fits the data arrangement with the conditional distributions in the previous section. The uncertainty coefficient is given as:

$$U.C. = \frac{U(Y) - U(Y/X)}{U(Y)},$$

where U(Y) and U(Y/X) are information functions, with U(Y) being the marginal information across the route preference categories (now called Y). They are calculated as:

$$\begin{aligned} U(Y) &= - \sum_{j}^{4} P_j \log P_j \\ &= - (.200 \log .200 \\ &\quad + .300 \log .300 \\ &\quad + .150 \log .150 \\ &\quad + .350 \log .350) \\ &= .580 \end{aligned}$$

U(Y/X) is the information function of the route preference (Y), given the different ownership categories (X). This function is calculated as:

$$U(Y/X) = - \sum_{i}^{2} \sum_{j}^{4} p(Y,X) \log p\,(Y/X),$$

where p(Y,X) are the joint probabilities and p(Y/X) are the conditional probabilities.

$$\begin{aligned} U(Y/X) = &- (.10 \log .167 \\ &+ .10 \log .167 \\ &+ .10 \log .167 \\ &+ .30 \log .500 \\ &+ .10 \log .250 \\ &+ .20 \log .500 \\ &+ .05 \log .125 \\ &+ .05 \log .125) \\ = &\ .534. \end{aligned}$$

The Uncertainty coefficient then has the value:

$$\begin{aligned} U.C. &= [U(Y) - U(Y/X)] \;/\; U(Y) \\ &= (.580 - .534) \;/ .580 \\ &= .793. \end{aligned}$$

The value of .793 eliminates uncertainty by identifying the category of ownership in which an individual falls. The maximum value of the uncertainty coefficient is 1. A value of 1 would indicate the complete elimination of uncertainty, i.e., perfect prediction from the knowledge of the categories of the independent variable. Therefore, the value of .793 indicates a high degree of predictability.

The foregoing example of predicting route preference from home ownership shows clearly the difference between association as a nondirectional joint distribution and association as a conditional predictive distribution. When cross-tabulations are used to display the relationship between categorical (nominal-level data) variables, the predictive shape of the data can always be shown by constructing distributions conditioned on the categories of the independent variable. Of course, the choice of the independent variable is made because the practitioner believes that a particular variable should be the predictor.

* * * * *

There is no guarantee that a variable is a predictor or independent variable, even if the data show that it does discriminate the outcomes of variables. The nature of prediction is often in the mind of the researcher, and sometimes that insight is not shared by others. Thus, one must be careful about choosing a predictor variable because, in the context of the survey, it may not always be clear which variables can be labeled as such. Sometimes it is safe to consider certain variables as predictors because they are antecedent in time. Variables such as sex, ethnicity, education, and in this case resident ownership, occur before the road is built. But when two measures occur more or less simultaneously, it is not always clear which is the predictor. Instead of a predictive relationship, the variables could be subject to reciprocal causality which hardly clarifies the information provided by the data. In light of this, a researcher is well-advised to employ background variables, such as those mentioned above, to develop predictions.

There are a number of other measures of association and tests of significance for categorical data. Some use different ways of combining data and are based on different assumptions about the type of data (nominal, ordinal, etc.). In applying the techniques, care should be exercised concerning their appropriateness. If the survey data, for example, are cross-tabulated and analyzed using the Statistical Package for the Social Sciences (SPSS), then the tests and measures described earlier, plus several more, can be printed with the tables as part of the output. Since the computer will calculate all of the measures, regardless of the type of data, one should be sure that the uses are appropriate.

11.2 INDICES AND SCALES

Attitude or opinion data are often collected in the form of ranked or ordinal data. An example of a set of questions which attempt to collect this type of data appears below:

> When a road is built it usually causes changes in the community through which it runs. Using the rating form below, tell us how you would feel if the following changes were to occur in your area as a result of road construction.

The respondent is then asked to complete a series of statements about how he would feel about possible changes. The statements in the following example are designed to show the significance of selected accessibility questions.

a) If driving to work becomes easier, I would feel . . .
b) If driving to shopping centers becomes easier, I would feel . . .
c) If driving to school becomes easier, I would feel . . .

Respondents are provided a 5- or 7-point scale and asked to give a numerical response -- for example:

Extremely Unhappy	Very Unhappy	Somewhat Unhappy	Neutral	Somewhat Happy	Very Happy	Extremely Happy
7	6	5	4	3	2	1

The planner may wish to combine responses to all questions in a subject area to obtain an overall measure of the importance of increasing accessibility. This is done by aggregating the rankings of the statements by each respondent.

Then $d^2 = 30$, and:

$$r = 1 - 6(30) / (125 - 5)$$
$$= 1 - 180 / 120$$
$$= -0.5$$

A coefficient of −0.5 indicates that respondent attitudes about these two changes are somewhat inversely associated where, for example, a respondent who was unhappy with increasing business property values, would tend to be happy with increasing residential property values. [The significance of r can be tested with a t-test as $t = r(N - 2)^{1/2} / (1 - r^2)^{1/2}$, with N − 2 degrees of freedom (see Hayes, 1973).]

11.4 THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENT: MEASURE OF ASSOCIATION FOR INTERVAL (CONTINUOUS) DATA

Interval data is not normally collected in surveys which measure opinions and attitudes. In survey data for highway planning this generally applies, except where non-opinion, information data are involved. Here the continuous information measures are usually categorized in a manner similar to the following:

Monthly Payroll

1. Less than $5,000
2. $5,000 - $9,000
3. $9,001 - $10,000
4. Over $10,000

However, the definition of interval data can be stretched a bit so that the Pearson product moment correlation coefficient can be used to assess the degree of association between two measures obtained in the survey. For example, a practitioner may be interested in the relationship between the manner in which goods are received by businesses in the area and the preference between two routes. The data collected for these two variables can be considered interval measures. For example, the following question can be viewed as eliciting a response on an interval scale of 0 to 100:

What percentage of your goods is received by motor vehicle?

Similarly, the question shown below applies an interval measure to route preference:

Please indicate, on a scale of 0 to 100, your preference for the two routes. (Points assigned to the two routes should, when combined, total 100.)

Route A________

Route B________

The response to this question calls for 100 points to be distributed over alternative routes A and B as a measure of preference. While this response is subjective, it is an interval measure on a scale from 0 to 100.

To see how the Pearson coefficient is calculated, suppose that five businesses interviewed respond to the two questions in the following manner:

Respondent	% of Goods Carried by Motor Vehicle	Focus on Route A (points)
1	20	10
2	80	60
3	50	60
4	70	20
5	90	100

The Pearson product moment correlation coefficient as a measure of association between two variables is defined as the co-variance between the two variables divided by the product at the standard deviation of each. The mathematical formula is:

$$r = S_{xy}/(S_x S_y),$$

where S_{xy} = the co-variance of x and y, and the co-variance of x and y = $\sum (x-\bar{x})(y-\bar{y})/n$ [$\bar{x}$, $\bar{y}$ are the respective means, n is the size of the sample]. S_x is the standard deviation of x, represented by the following formula:

$$S_x = [\sum (x - \bar{x})^2/n]^{1/2}$$

S_y is the standard deviation of y, represented by the following formula:

$$S_y = [\sum (y - \bar{y})^2/n]^{1/2}$$

In the example cited above, x is the % motor transport and y is the total number of preference points for route A. Thus, x = 50 and y = 50, and the correlation in terms of the data is calculated as follows:

	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	$(x - \bar{x})(y - \bar{y})$
	20	10	900	1600	1200
	80	60	900	100	300
	50	60	0	100	0
	10	20	1600	1600	1600
	90	100	1600	2500	2000
Total			5000	5900	5100

$$Sx = (5000/5)^{1/2} = 31.623 \qquad Sy = (5900/5)^{1/2} = 34.351$$

$$Sxy = 1020 \qquad r = 1020/(31.623)(34.351) = .939$$

For example, an individual might respond to the three statements as follows:

Statement	Response (Rank)
a	6
b	3
c	7

The summated rank for this respondent would be 16 (6 + 3 + 7), although the possible range of scores for any given respondent is from 3 to 21. It would seem reasonable to assume that the combined measure of concern over increased accessibility is better than any of the individual measures. There is obviously more information in the combined measure than in the ranking of a single statement. Unfortunately, however, there are some potential pitfalls in combined measures.

When the responses to multiple statements are combined as they are above, the tacit assumption is made that each response has the same weight. This assumption is equivalent to stating that each statement is measuring the same variable, i.e., accessibility. While this appears to be true from an analytic standpoint, it may not be. This possibility requires a distinction in the meaning of combined data.

A combined measure such as the summated rating shown above can be called an index or a scale. An index is a number, usually a combination of individual measures, which is said to measure an attitude, opinion, etc., because it is believed to do so; it has face validity. A scale on the other hand has been shown to measure something because it has been validated through quantitative analysis.

In most cases the statements whose ratings are to be summed are newly assembled with each survey. When the summated ratings are used in further analysis -- in comparing alternative routes, for example -- one should be aware that an index is being used. If it is desirable to claim that the summated ratings are more than an index, they should be investigated to determine whether the statements, in fact, form a single scale.

This can be done by correlating all possible pairs of statements across the respondents and using factor analysis to determine if one or more dimensions are being measured. If the results of this analysis show that some statements do not measure the dimension -- in this instance, accessibility -- they can be eliminated from the sum. To insure that the elimination of statements does not leave too few to be summed, a relatively large number of statements should be included in the questionnaire when this type of analysis is attempted.

11.3 THE SPEARMAN RANK CORRELATION COEFFICIENT: A MEASURE OF ASSOCIATION FOR RANKED DATA

As noted above, opinion data are frequently collected in the form of ordinal data. To measure attitudes toward property value, for instance, the practitioner might ask respondents to rank the following statements on an index of 1 (extremely happy) to 7 (extremely unhappy):

a) If residential property values increased, I would feel ....
b) If business property values increased, I would feel ....

The analyst may wish to determine whether the rankings of the two statements, a and b, are associated. A measure of association which can be used on this type of data is the Spearman rank correlation coefficient.

To calculate this coefficient, it is necessary to have responses to both categories across a set of survey respondents. Suppose five individuals ranked the two categories in the following manner:

Individual	Category (a)	Category (b)
1	5	3
2	7	2
3	6	6
4	5	5
5	1	2

The Spearman coefficient is calculated on these data as:

$$r = 1 - 6 \sum d^2 / (N^3 - N),$$

where d is the difference in ranks across an individual and N is the total number of individuals (N = 5). The calculation would proceed as follows:

Individual	Rank (a)	Rank (b)	d [=(a)-(b)]	d^2
1	5	3	2	4
2	7	2	5	25
3	6	6	0	0
4	5	5	0	0
5	1	2	-1	1
				30

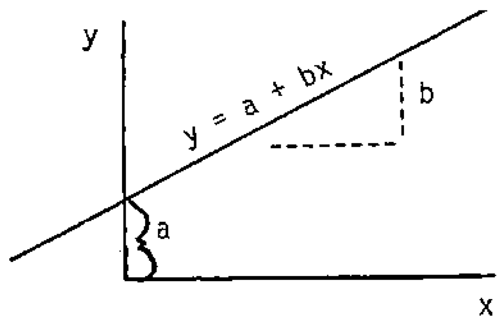
Since the Pearson coefficient ranges from -1 to +1, a value of .939 indicates a large amount of association (to test significance with a t-test as $t = r[(n - 2)/(1 - r^2)]^{1/2}$, with n - 2 degrees of freedom, see Hayes, 1973). If these data were real, one could assume that the choice of the route for the sampled businessmen was related to the mode of access by which they receive goods by motor vehicle.

Simple Regression: Prediction with Interval Measures

As noted, the Pearson product moment correlation coefficient is a measure of association. It does not give an indication of how the measured variables are related. With interval measures, this type of question is usually answered by using regression analysis. Regression analysis is exemplified in the form of the equation:

$$y = a + bx,$$

where y is a function of x, or y is predicted from x. That is, y is the dependent variable and x is the independent variable. The a and b in the equation are constant values; a is called the intercept and b is called the slope. Graphically, the sample regression equation is described by a line on a two-dimensional surface describing the variables x and y:



The intercept, a, is the value of y where the line intercepts the y axis. The slope, b, is the degree of incline exhibited by the line.

The constants a and b are estimated from the data. In fact, the slope b is related to the correlation coefficient in a straightforward manner. If y is the dependent variable:

$$b = rS_y/S_x,$$

r being the correlation coefficient, Sy, the standard deviation of y, and Sx, the standard deviation of x.

Using the data in the example of the correlation coefficient, where x is the percent of goods received by motor vehicle and y is the preference points for route A, the equation for predicting y from x is calculated as follows:

$$r = .939$$
$$Sx = 31.623 \qquad b = (.939)(34.351)/(31.623)$$
$$Sy = 34.351 \qquad = 1.02.$$

The intercept, a, is calculated using the form of the equation and the means of x and y:

$$a = \overline{y} - b\overline{x}$$

From the example:

$$\overline{y} = 50 \qquad \overline{x} = 50$$
$$a = 50-(1.02)50 = -1.$$

Thus, the equation for predicting the preference for Route A from the percent of goods received by motor vehicles is:

$$y = -1 + 1.02x.$$

For simple regression, i.e., one predictor, the test which determines the significance of the equation is the same as the test for the Pearson product moment correlation coefficient (the t-test).

The utility of the regression equation in the planning process is to estimate, by adjustment, the expected attitude toward a particular route, route A in this example. For instance, if it is known from secondary data sources that the average receipt of goods to businesses in the affected area by motor vehicle is 65 percent, then this value and the equation can be used to estimate the overall attitude toward route A. This is done by substituting 65 for x in the equation:

$$\overline{y} = -1 + 1.02\overline{x}, \text{ where}$$

$\overline{x}$ is the average percent receipt of goods by motor vehicle in the area, and $\overline{y}$ is the unknown average preference points for Route A for all businessmen.

$$\text{If } \overline{x} = 65, \text{ then } \overline{y} = -1 + 1.02(65) = 65.3 \text{ points.}$$

The researcher could then assume that the average preference points for the alternative route (Route B) would be 100 - 65.3 = 34.7. This can, of course, be verified by an independent analysis on route B. The results will probably differ slightly due to sampling variation, but they should be close.

11.5 MULTIVARIATE ANALYSIS OF SURVEY DATA: THE CATEGORICAL CASE

In the analysis of opinion survey data, the practitioner may wish to investigate the simultaneous influence of a number of residents' characteristics on their expressed opinions about highway construction. This type of investigation, which uses multiple variables, is called a multivariate analysis. In the present context, multivariate analysis refers to the use of three or more variables. The variables considered here are measured by categorical data.

Suppose the planner wishes to determine which resident characteristics have an influence on the choice of design features for a planned freeway. More specifically, suppose the planner wishes to investigate the effect, if any, which household composition and home ownership have on grade preference. These three variables might be examined using the following questions and response categories.

Grade Preference. If a freeway had to go through your community, which of the following grades would your prefer?

1 Depressed
2 At grade
3 Elevated
4 No Difference
5 Don't Know

Composition of Household. What is the relationship of persons comprising your household?

1 One Person
2 Married Couple Only
3 Married Couple with Children under 18
4 Married Couple with Some Children over 18
5 Divorced Person with Children
6 Other Adult-Children
7 Other Adult Only

Home Ownership. Do you own this house/apartment, or do you rent?

1 Own or is Buying
2 Rent

If these three variables are considered simultaneously, a three-way cross-tabulation of the data is required to describe the multivariate behavior. If a three-dimensional table is to be displayed on a two-dimensional page, it is necessary to show two-way tables for each category of the third variable. In this example, composition of household can be arrayed against grade choice within each category of home ownership. The data might appear as shown on page 164. To assess whether choice is related to ownership, to household composition or to both would be an arduous task if done using pencil and paper.

Home Owners' Grade Choice

		1	2	3	4	5	Row Total
Household Composition	1	2	8	7	5	6	28
	2	5	1	9	0	2	17
	3	1	0	0	4	3	8
	4	10	8	13	5	6	2
	5	6	17	6	3	9	41
	6	4	18	15	1	2	40
	7	2	4	16	1	11	34
Column Total		30	56	66	19	39	210

Renters' Grade Choice

		1	2	3	4	5	Row Total
Household Composition	1	10	1	3	5	7	26
	2	9	2	0	0	1	12
	3	15	5	1	2	1	24
	4	0	1	9	3	8	21
	5	5	0	0	1	0	6
	6	10	11	20	1	1	43
	7	9	3	1	5	2	20
Column Total		58	23	34	17	20	152

Fortunately, there are analytic techniques available in packaged computer programs which can quickly analyze the data and provide output for tests of significance. In relation to categorical data, two such techniques will be discussed in the following text. There are others, but these two offer quick, intuitive, and relatively inexpensive results. For a guide to the many other techniques the reader is referred to Andrews, et al.(1981).

Log-Linear Models

The use of log-linear models is a method for analyzing all possible relationships which could arise from the three-way cross-tabulation of variables. The main problem which is encountered with this type of multivariate data has been the manner in which all the possible relationships can be represented (or modeled) in relation to the observed data. It has been found that if this modeling is attempted in the same fashion as was done with two-way or bivariate tables, the representation of the interactions (or relationships) between variables is not consistent in all situations. To remedy this, a model has been developed in which the natural logarithm of the cell frequencies in the cross-tabulated tables is set as a function of the interactions explicitly exhibited by the table.

In the case of the three-way table above, the representation would have the appearance:

$$\log n(123) = u + u(1) + u(2) + u(3) + u(12) + u(13) + u(23) + u(123),$$

where u is the count shared by all cells in the table; u(1), u(2), u(3) are the marginal counts of the three variables; and u(12), u(13), u(23) are equal to all pair-wise interactions.

This representation (model) is very similar to the typical analysis of variance model used in experimental designs. The existence (or absence) of interactions (relationships) can be tested by including or dropping terms from the model and determining how well the resulting model fits the data. Dropping terms from the model is tantamount to collapsing the total cross-tabulation into various tables which fit the model to be tested. For example, if the term representing the three-way interaction were dropped, then the configuration of the data would be three two-way tables for:

- Grade choice by household composition,
- Grade choice by ownership, and
- Household composition by ownership.

The test for this configuration involves determining whether marginal values of these tables fit the original three-way table. The test statistic is a weighted sum of the logarithm of the ratio of observed to expected frequency counts, summed over the cells of the three-way tables. This statistic is distributed as a Chi-Square variable with degrees of freedom appropriate to the tabular configuration. A significant departure of the observed frequency from the expected frequency would suggest a rejection of the model. The tests for other configurations are carried out in a similar manner.

Computer capabilities are required to perform these analyses. A canned program that can carry out this type of analysis is available from the University of California Press. The program is the Biomedical Computer Programs P-Series (BMDP-79), edited by W.J. Dixon and M.B. Brown. This program organizes the cross-tabulations from the data tape into frequency counts upon which the log-linear analyses can be performed. Once this is done, the actual analysis of the counts is relatively inexpensive.

Chi-Square Automatic Interaction Detection (CHAID)

In analyzing opinion survey data, it is often important to search the results for significant relationships in relation to a specific dependent variable. To a certain extent this is done with log-linear models, but in that technique no variable is actually designated as a dependent variable. Of course, if one has a particular variable in mind as a dependent variable and it is a part of a significant interaction, it can be viewed as a dependent variable, provided that the data in the results are arranged in conditional distributions.

In some instances, the analyst may be interested in focusing immediately on a particular variable as being dependent and analyzing the other variables in order of importance. A technique which can effect this is called CHAID. This technique partitions the data into mutually exclusive, exhaustive subsets that best describe the dependent variable. The analysis, unlike log-linear analysis, is performed without any preconceived notion of what variables may be related.

CHAID proceeds in steps, analyzing each predictor separately in relation to the dependent variable. In the example discussed previously, in the section on log-linear models, the dependent variable would be choice of grade and the independent variables are household composition and home ownership.

The first step in the analysis is to determine the best partition for each predictor. The predictors are compared and the best one chosen. The data are then subdivided according to the partition of the best predictor, and the sub-subgroups are re-analyzed independently to produce further subdivisions in the data. The resulting partitions are grouped in relation to the dependent variable, which is portrayed in the last step as a dendogram.

The grade choice example can be used to show these steps. Suppose household composition is found to be the best predictor of grade choice. As a result of this analysis, the seven categories of household composition are partitioned to a reduced set which has only three categories:

I. One Person
Married Couples Only
Other Adult Only.

II. Married Couple with All Children under 18
Married Couple with Some Children over 18.

III. Divorced Person with Children
Other Adult - Children.

In effect the predictor, household composition, now has only three categories. Next, the second predictor, home ownership (Buy, Rent) is analyzed within each partition (new category) to determine if it contributes significantly to prediction. Suppose this is found to be the case only within Partition I. The results of this analysis would appear as follows:

Household Composition

I Grade Choice	II Grade Choice	III Grade Choice
1. 40%	1. 10%	1. 30%
2. 10%	2. 20%	2. 5%
3. 5%	3. 5%	3. 40%
4. 20%	4. 60%	4. 10%
5. 25%	5. 5%	5. 15%

Home Ownership

Buy Grade Choice	Rent Grade Choice
1. 60%	1. 15%
2. 10%	2. 10%
3. 5%	3. 10%
4. 5%	4. 50%
5. 20%	5. 15%

These results show the significant relationship which best recapitulates the data in a hierarchical sense. That is, the data have been searched to find where the differences in the categories of the dependent variable lie in relation to the predictors. This technique offers a fast way to search the data from a survey and extract essential information.

11.6 INDIRECT MEASURES: SUMMATED INSTRUMENTALITIES

In comparing alternative routes, it is often helpful to use indirect measures to assess attitudes towards different alternatives. These measures can be generated by a judicious combination of different types of questions. For example, suppose data are collected using the following question and response forms:

> When a road is build it usually causes changes to occur in the community through which it runs. Using the rating form below, tell us how you would feel if the following changes were to occur in (SPECIFY TOWN OR CITY) as a result of road construction.

	Extremely Unhappy 7	Very Happy 6	Somewhat Unhappy 5	Neutral 4	Somewhat Happy 3	Very Happy 2	Extremely Happy 1
If residential property values increased, I would feel							
If homes had to be moved, I would feel							
.							
.							
.							

These data, according to Gordon (1974), measure secondary outcomes resulting from the primary outcome; the primary outcome is highway construction.

The perceived or subjective correlation between the primary and secondary outcome is called an instrumentality. This can be assessed by measuring the subjective likelihood, or probability, that the secondary outcomes will occur if a particular alternative route is constructed. A question such as the following will collect the type of data required to use as instrumentalities:

> Rate the likelihood that each of the changes listed above will occur if <u>Alternative A</u> is chosen for the new route. Use the rating form below to tell us what you think the chances are that each of the changes will occur if <u>Alternative A</u> is constructed.

	Surely Will Not	Probably Will Not	May or May not	Probably Will	Surely Will	
Construction of Alternative A						Increase residential property values
Construction of Alternative A						Cause homes to be moved
.						.
.						.
.						.

Suppose the responses to these questions for an individual are as follows:

Secondary Outcome	Desirability of Secondary Outcome [Item]	Instrumentalities Route A	Route B
1	5	4	2
2	6	1	5
3	3	2	3

The attitude toward Route A across the outcomes is calculated as:

$$\text{Att (A)} = (5)(4) + (6)(1) + (3)(2)$$
$$= 32$$

For B, it would be:

$$\text{Att (B)} = (5)(2) + (6)(5) + (3)(3)$$
$$= 49$$

If only this individual were used to compare routes, Route B would be more desirable since it has a higher positive attitude rating, 49 to 32.

It is obviously not defensible to use only one individual to assess the summated instrumentalities of different routes when the intent is to infer survey results to all residents from the sample. It is, therefore, necessary to obtain a measure of the summated instrumentalities for all individuals in the sample. This can be accomplished by calculating the summated instrumentalities for each individual and averaging them across all individuals in the sample. In symbolic terms, the summated instrumentality for individual i, with respect to Route A, is given as:

$$SI_i(A) = \sum I_j D_j,$$

where I_j is the instrumentality of the jth statement of outcome, and D_j is the desirability of the jth statement of outcome.

To obtain the average summated instrumentality for Route A across the sample, the $SI_i(A)$ for all individuals in the sample are added and the total is divided by the sample size (n), or:

$$SI(A) = \sum_i SI_i(A)/n,$$

where SI(A) is the average summated instrumentality for the whole sample for Route A.

Use of summated instrumentalities is a systematic way of combining attitudes about outcomes of highway construction with the likelihood that they will occur. It is an indirect method of obtaining overall attitudes concerning alternative routes, and it affords a procedure for comparing those routes based on the subjective perceptions of the individuals who will be affected. Because it is subjective and uses data similar to that in summated ratings, this method is subject to the same caveats about validity as discussed in Section 11.2 on indices and scales.

For summated instrumentalities to be considered a valid demonstration of residents' attitudes in relation to a general impact area, e.g., accessibility, cohesion, etc., the researcher should verify that the statements of desirability measure a single dimension of that area. This can be done either by knowing that the statements have been validated through previous use, or by doing so with the present survey data and discarding statements with poor measurement qualities. This type of validation was carried out by Gordon (1974) in his Tennessee study and his psychometric methodology can be used for each new set of outcome statements. One can also consult an article on summated ratings by Napior (1972) which discusses the assessment of dimensionality when this type of data is used.

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Yerushalmi, Deena CTR (FHWA)

From:	Azizi, Max (FHWA)
Sent:	Monday, June 1, 2015 3:33 PM
To:	Canada, Carol
Cc:	Adelman, Deena CTR (FHWA); Crichton, Ross (FHWA); Rose, Heather
Subject:	RE: LC/CRS request: The costs of complying with federal aid highway regulations, 2008/Battelle
Attachments:	8-12-08 Master-FHWA Cost of Compliance Final Draft Report.pdf

Ms. Canada;
We completed our review of the *"Cost of Complying with Federal-aid Highway Regulations"* report. Our review indicates that there were some technical issues with the report that were not resolved. In addition, this report was not reviewed by different offices within the Federal Highway Administration (FHWA) and has not been formally adopted by FHWA. As a result, this report cannot be considered a Final FHWA document. I am not sure if the Library of Congress is interested in obtaining draft reports. However, for your convenience, I have attached a draft copy of the report with this e-mail. If you have any questions, please feel free to contact me.
Best Regard;

Max Azizi
Transportation Policy Analysis Team Leader
FHWA

From: Adelman, Deena CTR (FHWA)
Sent: Thursday, May 21, 2015 9:18 AM
To: Canada, Carol
Cc: Azizi, Max (FHWA)
Subject: RE: LC/CRS request: The costs of complying with federal aid highway regulations, 2008/Battelle

Dear Ms. Canada,

As I mentioned on the phone, FHWA's Office of Policy is reviewing the document to see if it can be released. If you have any further questions, please contact Max Azizi at Max.Azizi@dot.gov or (202) 366-9237.

Thank you,
Deena

Deena Adelman (MacroSys, LLC)
Supervisory/Reference Librarian
Federal Highway Administration Research Library
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McLean, VA 22101-2296
Phone: 202-493-3058
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deena.adelman.ctr@dot.gov

From: Canada, Carol [mailto:CCANADA@crs.loc.gov]
Sent: Wednesday, May 06, 2015 8:13 AM
To: Adelman, Deena CTR (FHWA)

Cc: Gagnon, Stuart CTR (FHWA)
Subject: RE: LC/CRS request: The costs of complying with federal aid highway regulations, 2008/Battelle

Ms. Adelman,

I am checking on the status of the request for “The costs of complying with federal aid highway regulations.” If possible, could you provide me with an update by C.O.B. today.

Thank you,

Carol Canada
Information Research Specialist
Congressional Research Service
101 Independence Ave SE
Washington, DC 20540-7000
(202) 707-7619 Phone

The Costs of Complying with Federal-aid Highway Regulations

Final Report

Prepared for

Office of Policy

Federal Highway Administration

Washington, D.C.

August 2008

Battelle
The Business *of* Innovation

Table of Contents

Page

Table of Contents

List of Tables **Page**

List of Figures **Page**

1.0 INTRODUCTION

Since 1916, the Federal Government has supported surface transportation through the Federal-aid program, a cost reimbursement funding strategy. Since 1957, revenues generated by the Federal gas tax and other Federal use taxes have been credited to the Highway Trust Fund (HTF). These revenues are allocated to States based on formulas relating to highway usage and roadway characteristics. Under this approach, the United States Department of Transportation (US DOT) reimburses State expenditures on transportation infrastructure at prescribed rates (historically, 80 or 90 percent), with the remainder of the project costs being covered by the States. States rely heavily on Federal-aid funding to construct, rehabilitate and maintain their highway and road systems. In 2002, roughly 29 percent of total State highway funding was received from Federal highway user taxes and fees (Figure 1).

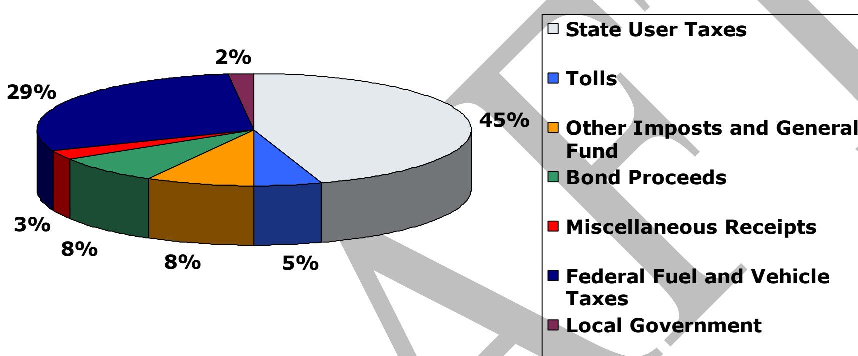

Figure 1. State Highway Funding Sources[1]

The continued growth of the U.S. economy will depend in the coming years in part on the soundness and adequacy of the nation's transportation system. The increase in both travel and shipping demands are straining the capacity of the existing system. The Federal-aid cost reimbursement program has enabled construction of an extensive national highway system; however, project sponsors and construction industry representatives argue that the many regulations tied to Federal-aid funding (e.g., Davis-Bacon, National Environmental Policy Act (NEPA), and Buy America) are limiting the productivity of Federal highway funding, and that the program's limitations are becoming evident in the face of growing investment needs and the lack of available funding to meet those needs.

These Federal regulations are designed to achieve various Federal social, economic, and environmental objectives, but these goals are met with a price. To date, there are a number of studies that have been completed which estimate the compliance costs associated with Federal regulations in the labor, transportation, energy, and environmental sectors. These estimates vary widely based on the methods used to compute the costs, the assumptions used to support the analysis and the intentions of the group producing the analysis. These estimates are further

[1] Federal Highway Administration. 2003. Federal Highway Statistics, Table SF-21. Washington, D.C.

complicated by the presence of State regulations that are similar to those imposed by the Federal Government.

The lack of consensus concerning the success of these Federal regulations in terms of meeting policy objectives, the absence of reliable estimates of the benefits and costs that they impose on society, the range of benefit-cost estimates published to date, and the presence of State regulations that are increasingly resembling those imposed by the Federal Government necessitates a more thorough examination of the issues related to Federal-aid requirements.

In order to gain a better understanding of these issues, the research team made initial contact with representatives of Federal, State and local transportation agencies and compiled an initial list of regulations that were thought to have significant cost implications for transportation construction projects. A matrix was then prepared, which outlined roughly 30 regulations, aligning the various major Federal-aid requirements with corresponding policy objectives, general benefits and costs, and relevant issues concerning the computation of benefits and costs (Appendix A). Though there are numerous requirements placed on Federal-aid highway projects, the following eight Federal-aid regulations were selected for this study through preliminary research and input from FHWA:

- National Environmental Policy Act (NEPA)
- Section 4(f) of the Department of Transportation Act
- Section 404 of the Clean Water Act
- Section 7 of the Endangered Species Act (ESA)
- Davis-Bacon Act
- Buy America
- Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970
- Section 106 of the National Historic Preservation Act

Environmental elements included in this study (NEPA, Section 4(f), Section 404, and Section 7 of the ESA) were combined with other environmental regulations and examined under the umbrella of "environmental regulations."

The research team conducted a literature review that examined and documented existing literature detailing the marginal benefits and costs of Federal highway regulations selected for examination in this study. That marginal benefits and costs are the focus of this research effort is an important distinction as several States have adopted regulations and programs that are similar in terms of overall cost to current Federal-aid requirements. Studies of State regulations assist in determining the marginal impact of Federal-aid requirements on project costs. Thus, studies of both Federal and State regulations were identified and examined.

The literature review focused on the following elements:

- The magnitude of the compliance costs associated with Federal and State highway regulations and the elements that drive these costs.
- The benefits associated with these regulations and their ability to achieve stated policy objectives.

- An assessment of the methods used to estimate the costs and benefits associated with Federal and State highway regulations.
- The similarities and differences in the methods used to estimate these costs and benefits.
- The assessment of the costs and benefits associated with complying with non-highway Federal regulations.

To gain a better understanding of the benefits and costs associated with complying with Federal-aid regulations, the research team also interviewed and collected information from Federal, State and local DOT representatives; private industry representatives; and other stakeholders. In support of this study, interviews were conducted with representatives of the following organizations:

- Federal Highway Administration,
  - Office of Program Administration
  - Office of Real Estate Services
  - Pennsylvania Division
  - Georgia Division
  - Minnesota Division
  - Central Federal Lands Highway Division
- United States Office of Management and Budget,
- Florida Department of Transportation,
- Federal Transit Administration,
- Maryland Department of Transportation,
- Washington State Department of Transportation,
- California Department of Transportation (Caltrans),
- Advisory Council on Historic Preservation,
- George Harms Construction Company, Inc.,
- United States Department of Labor,
- Ohio Department of Transportation,
- Arizona Department of Transportation,
- Kentucky Transportation Cabinet,
- Oregon Department of Transportation,
- Utah Department of Transportation,
- Wisconsin Department of Transportation,
- Jesse Engineering Company,
- Alaska Department of Transportation,
- Center for Transportation and Environment,
- Environmental Defense Fund,
- Environmental Council of States,
- Sierra Club, and
- United States Environmental Protection Agency.

These interviews in combination with previous research examined in the literature review were used to identify and outline the compliance costs typically associated with Federal and State highway regulations. Interview guides are presented in Appendix B. Note that the interview guides on the non-environmental regulations were very similar and, therefore, only the Davis-

Bacon interview guide is supplied. Furthermore, this study examines the factors that influence the extent to which these regulations achieve benefits from a policy perspective. In certain cases, project and program-related data are highlighted in order to demonstrate the magnitude of the costs associated with these regulations. Factors that are perceived to drive compliance costs are examined and the extent to which Federal regulations impose costs above and beyond those incurred when complying with State regulations are studied.

This report is divided into six sections with the first being this introduction. The second section examines environmental regulations. The third section examines the Buy America provisions. The fourth section covers the Davis-Bacon Act. The Uniform Act is examined in the fifth section of this report. The sixth, and final, section of the report analyzes Section 106 of the National Historic Preservation Act.

2.0 ENVIRONMENTAL REGULATIONS

2.1 Introduction

Transportation projects that include Federal involvement (e.g., funding support or permitting) generally must follow environmental review procedures prescribed in the National Environmental Policy Act (NEPA). This law also provides an umbrella framework for guiding compliance with many other Federal environmental laws, such as the Clean Water Act, and the Endangered Species Act. In its most recent annual report to Congress on progress in environmental streamlining, FHWA lists eight major Federal laws affecting the transportation project development process, and another 58 Federal laws and executive orders that are occasionally applied on a case-by-case basis.[2] Federal-level environmental regulations are complemented by an array of State-level environmental regulations that may also influence the cost and benefits of completing Federal-aid transportation projects. The extent of State regulations and their overlap with Federal regulations varies from State to State and by environmental impact area. In some instances, State regulations may be more stringent than Federal regulations; more often they mirror Federal requirements or are less stringent.

Compliance with Federal environmental regulations is perceived by many practitioners and stakeholders in the transportation community to add significant costs to the transportation project development process for Federal-aid projects. Federal environmental regulations are also acknowledged to generate important societal benefits. Statistical analysis of national highway expenditure data confirms that Federal environmental regulations have significant positive influences on construction costs for Federal-aid projects when compared to similar projects financed exclusively with State funds.[3]

2.2 Literature Review

This review of the literature on the costs and benefits of environmental compliance activities for transportation projects gives priority to consideration of impacts caused by the National Environmental Policy Act, Section 4f of the Department of Transportation Act, Section 404 of the Clean Water Act, and Section 7 of the Endangered Species Act. These four major regulations are consistently cited by transportation practitioners as having the greatest impact on transportation projects.[4]

2.2.1 Literature Relating to the Benefits Associated with Environmental Regulations

Transportation projects are frequently perceived to have primarily negative environmental impacts. For example, Transport Canada's guide to conducting cost benefit analysis, which is

[2] Federal Highway Administration (FHWA). 2003. "Evaluating the Performance of Environmental Streamlining: Phase II." Washington, D.C.
[3] Smith, V.K.; Von Haefen, R; and Zhu, Wei; 1999. "Do Environmental Regulations Increase Construction Costs for Federal-Aid Highways? A Statistical Experiment." *Journal of Transportation and Statistics*. Washington, D.C.
[4] National Cooperative Highway Research Program (NCHRP). 2003. "Improving Project Costing and Incorporation of New Attributes – Highways and Transit." NCHRP Report 20-24 (25). Washington, D.C.

used as a guide for assessing the benefits of Canadian transportation projects, assumes that environmental effects are negative.[5] Federal environmental regulations, however, also can create opportunities for transportation projects to protect, remediate, or enhance environmental quality. A recent NCHRP study found that environmental benefits from transportation investments generally fit into six categories:[6]

- Improved air quality and energy efficiency,
- Reduced noise pollution,
- Protection of wetlands and water supplies,
- Reduced light pollution,
- Reclamation of "brownfield" land and recycled materials, and
- Historic and ecological preservation benefits.

Quantification of these benefits in the literature is not common. Two approaches found in the literature that may have particular promise for assessing transportation benefits include:

1) **Inventories of selected environmental resources affected by transportation projects.** Two examples of inventories that may be helpful in quantifying environmental benefits of transportation projects are data collected on wetlands and historic bridges.

    - Wetlands are regulated under Section 404 of the Clean Water Act. FHWA monitors annual wetland loss and gain under the Federal-aid highway program nationwide. Monitoring began in Fiscal Year 1996. Data collected over the last nine years indicate that nationwide, the Federal-aid highway program has achieved a 160 percent gain in wetland acreage (2.6:1 gain/loss ratio). In terms of acres, the Federal-aid highway program produced a total net gain of 23,283 acres of wetlands nationwide in Fiscal Year 1996 through Fiscal Year 2004 (FHWA, 2004a). The quality of newly created wetlands relative to the wetlands they replace remains a subject of debate.[7]

    - Historic bridges may be subject to regulation under Section 106 of the National Historic Preservation Act. Under language included in the Intermodal Surface Transportation Efficiency Act (ISTEA), the Highway Bridge Replacement and Rehabilitation Program ensures that State DOTs create and maintain inventories of their historic bridges.

2) **Studies of best practices and innovative policies driven by environmental compliance requirements.** Numerous studies and reviews exist that provide assessments of best practices or innovative approaches by State DOTs to compliance with environmental requirements. For example, FHWA's *Successes in Streamlining*

[5] Transport Canada. (1994). "Guide to Benefit-Cost Analysis in Transport Canada." Ottawa, ON
[6] National Cooperative Highway Research Program (NCHRP). 2003. "Improving Project Costing and Incorporation of New Attributes – Highways and Transit." NCHRP Report 20-24 (25). Washington, D.C.
[7] Federal Highway Administration (FHWA). 1995. "Results of Wetlands Mitigation Associated with Highway Projects, Conference presentation." New Orleans, LA

electronic newsletter documents dozens of successful practices from State DOTs around the country.

2.2.2 Challenges to Calculating the Costs of Environmental Regulations

No quantification of environmental costs specific to delivery of Federal-aid transportation projects was found in the literature prior to the mid-1990s. A 1994 study by the United States General Accounting Office (GAO) observes that the total amount of Highway Trust Fund (HTF) money that States spent on mitigating environmental impacts could not be calculated because of incomplete data.[8] The introduction to a widely cited 1997 study on the environmental costs of transportation projects cites anecdotal judgments from selected State DOT practitioners that environmental costs are about eight to ten percent of total construction costs for a typical project.[9] As the report notes, however, these estimates are not based on any specific records of environmental costs. Even the most recent literature makes clear that efforts to account for the environmental costs of delivering Federal-aid transportation projects face major hurdles:

1) **Categories of Environmental Costs Are Not Well Understood.** Despite widespread concern about the impacts of Federal environmental regulation, the literature offers scant insight on the fabric of environmental costs. The GAO finds that FHWA has not defined what constitutes an environmental cost.[10] Environmental regulations affect public expenditures to support staff and equipment of State DOTs and public expenditures for private contractors involved in specific projects.[11] Wetlands, historic sites, archeological sites, public involvement, and endangered species are ranked the most important environmental factors by State transportation officials.[12]

   A report prepared by staff at the Washington State Department of Transportation (WSDOT) offers a framework for categorizing the components of environmental costs that may have broader application among States.[13] The report suggests that most environmental costs can be ascribed to "mitigation" planning and implementation. According to the report, mitigation includes the expense of preparing necessary environmental documents and permit applications, and carrying out mitigation, which may include special features, such as noise walls, or avoidance of environmental impacts, such as placement of bridge abutments in a floodplain. In Washington State, according to the report, storm water facilities, wetlands restoration, noise walls, and stream protection are the four leading categories where greatest mitigation costs are incurred. The WSDOT report describes six cost components for mitigation features:

[8] U.S. General Accounting Office (USGAO). 1994. "Highway Planning: Agencies are Attempting to Expedite Environmental Reviews, But Barriers Remain" Report to the chairman, Subcommittee on Transportation, Committee on Appropriations, U.S. House of Representatives. GAO/RCED 94 211. Washington, D.C.
[9] Smith, V.K.; Von Haefen, R; and Zhu, Wei; 1997. "Environmental Compliance Costs: Where the Rubber Meets the Road. Center for Transportation and the Environment." North Carolina State University. Raleigh, NC
[10] US GAO (1994)
[11] Smith (1997)
[12] Ibid.
[13] Washington State Department of Transportation (WSDOT). 2003. "WSDOT Project Mitigation Costs Case Studies." Olympia, WA

- Construction cost (actual cost from bid document or engineer's estimate);
- Allocated share of State sales tax;
- Right of way acquisition costs;
- Allocated share of contractor's mobilization, usually estimated to be approximately 10 percent of the overall construction amount;
- Allocated share of WSDOT cost for construction engineering and administration usually estimated to be approximately 6 to 14 percent of construction contract amount; and
- Allocated share of WSDOT planning and design; usually estimated to be approximately 5 to 15 percent of the overall project costs.

The WSDOT report notes that environmental costs also may be incurred as a result of project delays due to environmental requirements, but these costs are not quantified as part of the report.

2) **No Data on Environmental Costs is Routinely Collected.** Evidence from the literature demonstrates conclusively that neither the U.S. Department of Transportation (USDOT) nor individual State departments of transportation (DOTs) routinely collect data on environmental costs associated with delivering Federal-aid transportation projects to construction completion.

- **Federal-Level Environmental Cost and Benefit Tracking.** Federal-level efforts to track environmental costs associated with transportation project development are evolving but remain limited. Historically, Federal agencies have not identified the environmental costs of transportation project development. Smith finds that "all past economic analyses of the costs of environmental regulations have completely overlooked their impacts on the construction and repair of highways".[14] The GAO finds that FHWA with limited exceptions does not routinely track how much States spend to mitigate environmental impacts.[15] The National Cooperative Highway Research Program (NCHRP) finds that neither FHWA's Fiscal Management Information System (FMIS) or the Federal Transit Administration (FTA)'s Transportation Electronic Award Management (TEAM) contain enough information to allow estimation of environmental costs.[16]

  FHWA is undertaking efforts to strengthen its environmental cost tracking capabilities. In 2001, the agency completed phase one of a comprehensive study of the impacts of the NEPA process on the total time and cost involved in delivering a Federal-aid highway or bridge project to construction completion.[17] The phase one report provides a baseline against which to assess future environmental streamlining efforts, including detailed analysis of the time required to complete FHWA's Environmental Impact Statement (EIS) documents. The phase two report expands the

[14] Smith (1997)
[15] GAO (1994)
[16] NCHRP (2003)
[17] Federal Highway Administration (FHWA). 2001. "Evaluating the Performance of Environmental Streamlining: Development of a NEPA Baseline for Measuring Continuous Performance." Washington, D.C.

analysis of delays and identifies continuing trends.[18] As the phase two report acknowledges, however, scrutiny of costs associated with NEPA compliance activities was not feasible because of limitations in the data.

- **State-Level Environmental Cost and Benefit Tracking**. NCHRP report 20-24 (25) finds that no complete and consistent data on environmental costs are available at the State level.[19] None of the 32 State DOT environmental officials that responded to the project survey associated with this report indicated they have engaged in any study or compilation of planning, design, and environmental (PD&E) costs related to environment and planning activities. In a similar earlier survey of the designated environmental officials for each of the 50 State DOTs to determine their estimates of increases in costs due to environmental regulations, nineteen States responded and only six indicated they kept records of staff time and added costs of compliance.[20] The GAO found that none of 11 States it contacted in 1994 routinely tracked data on environmental costs.[21]

  Washington State DOT has attempted to examine environmental costs for selected projects on a case-by-case basis.[22] NCHRP Report 20-24 (25) indicates that Florida DOT has developed a detailed classification system to assist project managers in developing staff-hour estimates of various tasks related to PD&E.[23] In addition, according to this study, Florida has for about a decade included man-hour estimates for defining project-related environmental costs within its construction contracts.

2.2.3 Literature Estimating Environmental Regulation Costs and Benefits

Since neither Federal nor State-level agencies collect data on costs or benefits associated with environmental compliance, several studies have attempted to estimate environmental costs associated with delivering Federal-aid transportation projects to construction completion using various analytic techniques. Three key studies include:

1) **NCHRP Report 20-24 (25) Improving Project Costing and Incorporation of New Attributes – Highways and Transit (2003).** This study provides two approaches for generating what are characterized as "preliminary estimates" of environmental costs. The first approach uses the judgments of a 21-person expert panel assembled by the research team to gauge typical environmental costs for hypothetical projects by impact area. The second approach identifies 60 actual projects completed by individual DOTs and relies on judgments by staff associated with the projects to estimate mitigation costs as a percentage of overall construction costs.

[18] FHWA (2003)
[19] NCHRP (2003)
[20] Smith (1997)
[21] GAO (1994)
[22] WSDOT (2003)
[23] NCHRP (2003)

The "expert panel" approach generated a matrix that depicts typical project-level costs in the areas of public involvement, cultural resources, wetlands, water resources, endangered species, community cohesion, land use, socio-economic factors, hazardous materials, noise, air quality, and construction impacts. Costs for each impact area are reported on a "per project" or "per lane-mile" basis as applicable. The study methodology attempts to account for variation in the magnitude of environmental costs at the project-level by providing a breakout of cost estimates for urban and non-urban projects that are processed under NEPA as Categorical Exclusions or Environmental Assessments (with low or medium impacts), or EISs (with medium or high impacts).

The "mitigation costs" approach generated a matrix that shows low, medium, and high mitigation costs for projects processed as CEs, EAs, or EISs. Average mitigation costs for CE projects reviewed were $181,000 per project, or 1.1 percent of overall construction costs. Average mitigation costs for EA projects reviewed were $827,650 per project, or 1.4 percent of overall construction costs. Average mitigation costs for EIS projects reviewed were $2.8 million per project, or 2.3 percent of overall construction costs. Neither approach attempts to account for project costs associated with delay caused by environmental mitigation requirements, nor do they separate the influence of Federal and State environmental requirements on costs.

2) **WSDOT Project Mitigation Costs Case Studies (2003).** This short study examines the mitigation costs associated with 14 recently constructed transportation projects in Washington State. The projects include five new interchanges, seven highway widenings, and two preservation projects. The projects vary in cost from $280,000 to $82 million and are located in different geographic regions of the State. The case studies describe the mitigation undertaken for each project, why it was undertaken, and its cost relative to overall project costs. The percentage of project costs spent on mitigation ranges from four percent to 34 percent; the average is 15 percent. The report concludes that environmental costs tend to be higher for projects in Washington State that are located west of the Cascades. The study does not separate costs for compliance with State and Federal regulations.

3) **Center for Transportation and the Environment, Environmental Compliance Costs - Where the Rubber Meets the Road (1997)**. Two data sets were reported in this study. First the study reports on the results of a survey of State DOTs to request their estimates of the increases in costs due to environmental regulations and their evaluations of the primary factors leading to these costs. This component of the study determined that few States keep useful records about environmental costs. Second, the study reports on a "natural experiment" that compares costs for Federal-aid highway projects and State-funded projects. The study methodology assumes that measures of the presence of environmental resources regulated under Federal law (e.g., historic sites or wetlands) are a proxy for the likelihood of greater Federal regulation. The study finds a positive correlation between measures of regulated environmental resources and Federal-aid project costs, but no effect on construction expenditure for State projects. This finding suggests that Federal environmental regulations do increase project costs.

2.3 Environmental Regulations Benefits

2.3.1 Introduction

Federal environmental regulations create measurable benefits when adverse impacts to the natural and human environment are avoided, minimized, or compensated. Examples of the types of benefits that accrue from Federal environmental regulations include, but are not limited to fewer air pollutant emissions or acres of wetlands preserved or restored. Measurement of the magnitude of benefits is often undertaken, such as State air quality agencies' State Implementation Plan-related estimates of air pollutants reduced or State Department of Transportation (DOT)/Federal Highway Administration (FHWA) sponsored National Environmental Policy Act (NEPA) document estimates acres of wetlands preserved. Benefits, however, are rarely valued in economic terms that allow direct comparison with the cost of achieving them.

The remainder of Section 2.3 reports on a set of five phone interviews with selected non-DOT stakeholders. The interviews address their perspectives on the range of benefits generated by Federal environmental laws that affect transportation projects, their knowledge about efforts to value these benefits in economic terms, and their opinions on how such information should be used. The interviews suggest that valuation of the environmental benefits of transportation projects in economic terms is in its infancy.

For this report, staff in five non-State DOT stakeholder groups with a policy interest in transportation and the environment were interviewed by telephone, including the Environmental Council of States (www.ecos.org); the Environmental Protection Agency (www.epa.gov) Office of Transportation and Air Quality; the Environmental Defense Fund (www.ed.org), the Center for Transportation and the Environment (http://itre.ncsu.edu/cte/); and the Sierra Club (www.sierraclub.org). These stakeholders were identified by the project team in coordination with FHWA staff.

A short interview guide was used for each interview. Questions in the guide covered stakeholders' opinions about the benefits of environmental regulations, their knowledge of studies that quantify environmental benefits, their understanding of hurdles to better quantification of environmental benefits, and their suggestions for steps to improve knowledge on this topic. The interviews took place in July and September 2005.

2.3.2 Summary of Major Findings

Key findings derived from the interviews include:

- Stakeholders identify a diverse range of benefits created by environmental regulations that affect transportation projects,
- Stakeholders think measuring benefits in economic terms is extremely difficult and that decision-making should not focus strictly on comparison of costs versus benefits,

- Stakeholders think governmental agencies lack mandates to measure benefits in economic terms, but are ambiguous about the value of such mandates,

- Stakeholders support greater consideration of benefits during decision-making, particularly via improved inter-agency coordination

- Stakeholders view better public participation as a catalyst for optimizing benefits, and

- Stakeholders think other sectors can provide lessons for transportation.

Each of these findings is discussed in more detail in the following sections.

2.3.3 Stakeholders identify a diverse range of benefits created by environmental regulation

Non-DOT stakeholders generally agree that stronger environmental regulations introduced over the last several decades have created an array of benefits, some of which they perceive are more easily measurable than others. In particular, conversations with stakeholders focused on two types of benefits:

- Protection of Natural and Human Environment. Stakeholders agree that fewer adverse impacts to the human and natural environment are the most visible and quantifiable benefit of Federal environmental laws, which generally require avoidance of, minimization of, or compensation for negative impacts. These benefits include but are not limited to better air and water quality; preservation of wetlands and streams; protection of biological resources; and preservation of historic, cultural, and park resources. Some stakeholders note that for individual projects these benefits are quantified in NEPA documents, while benefits in some categories may be quantified at a regional, State-wide, or national level in documents prepared by State and Federal agencies. Working Paper Two: Environmental Benefits of Transportation Investment, NCHRP Project 8-36, Task 22, January 2002 provides a detailed summary of these types of benefits.

- Lower Transportation Project Costs. Some non-DOT stakeholders also suggested that environmental compliance may in some instances reduce the cost of transportation solutions, particularly if travel demand management is used in place of added supply. Lower transportation project costs are not easily measurable, according to stakeholders, since “the road not taken” is hard to detail.

According to non-DOT stakeholders, the range of benefits associated with environmental regulation varies widely from project to project and may be most easily measured on a case-by-case basis. All non-DOT stakeholders expressed caution about appropriate use of data on environmental benefits during the transportation project decision-making process. They support informed decision-making that is based on understanding of benefits, but they are critical of efforts to directly compare costs and benefits.

2.3.4 Measuring benefits in economic terms is extremely difficult and decision-making should not rely only on a comparison of costs versus benefits

All non-DOT stakeholders interviewed perceive that laws to protect natural and cultural resources during the transportation project development process have great intrinsic value. They observe, however, that this value is hard, if not impossible, to measure in dollars because valuation of environmental benefits is often highly subjective.

> *"It is difficult to tally up the benefits [of NEPA] and enumerate them. No one tallies the savings of going through the [NEPA] checklist"*

Some non-DOT stakeholders are concerned about efforts to quantify environmental benefits in economic terms. They suggest that comparison of monetary costs versus monetized benefits is an inappropriate tool for making decisions about transportation projects.

Stakeholders were unable to identify any specific efforts to quantify the economic value of human and/or natural resources-related regulations for transportation projects. Several stakeholders described selected efforts within the field of environmental economics that involve valuation of environmental quality and which they think could provide insight for this project:

- **Sustainability Indices.** An organization called Redefining Progress (www.rprogress.org) has developed sustainability indicators and a technique called "Ecological Footprinting" that quantify the positive and negative impacts of economic activity on environmental resources. The Genuine Progress Indicator, for example, subtracts destructive costs to the environment and adds in social and economic benefits ignored by the Gross Domestic Product. The Ecological Footprint tracks the consumption and waste patterns of individuals, communities, businesses, and nations and observes the portion of Earth's resources used in that consumption. The current consumption of humanity is 25 percent beyond Earth's ability to renew resources or remain sustainable. In each case natural and social capital as well as fiscal capital is factored into the economic modeling.
- **Environmental Regulation and Economic Growth.** A 1996 report, *The Positive Relationship Between Jobs, Environment and the Economy* (Louisiana State University) summarizes several studies that correlate economic vitality with a healthy environment, strong environmental regulations, and spending on environmental initiatives. The report suggests that states with good environmental programs have better employment, productivity and economic growth than poor environmental states.

2.3.5 Governmental Agencies Lack Mandates to Value Benefits of Environmental Regulations

Non-DOT stakeholders agreed that the absence of data on the economic value of the benefits of environmental regulation is explainable, in part, because transportation agencies have no mandatory requirements to prepare such data. They acknowledge that such a mandate could involve added costs and would likely require additional coordination among multiple agencies.

Stakeholders were unclear about the need to calculate the value of environmental benefits, particularly given the complexity of trying to do so.

2.3.6 Improved Public Participation is View by Stakeholders as a Catalyst for Optimizing Benefits

Non-DOT stakeholders emphasize the value of good public participation in decision-making, which helps ensure any natural and human environmental resource-related benefits are optimized. As one stakeholder noted:

> "*There is a lot of value in engaging communities in transportation projects. The more the community can be involved early on, the better the transportation project.*"

According to another stakeholder, public participation helps to ensure:

- Adequate opportunities for comment on significant decisions about cultural and natural resources;
- A framework for considering alternatives to avoid/minimize adverse impacts;
- Consideration of not only primary impacts, but secondary and cumulative impacts;
- Interagency cooperation and consultation and effective consideration of how transportation supports or undermines other societal programs, e.g., natural resource preservation, public health protection and the protection of historic and cultural resources; and
- Consideration of equity.

2.3.7 Stakeholders support greater consideration of benefits during decision-making, particularly via improved inter-agency coordination

Non-DOT stakeholders acknowledge and support coordination between transportation agencies and other agencies that have oversight for natural and human environmental resources throughout the environmental review process. They also recognize that extensive efforts to collect data on environmental impacts are a part of this process, but some non-DOT stakeholders think that transportation agencies may not always use the data appropriately in decision-making, thus hampering achievement of environmental benefits.

> "*DOTs sometimes seem to follow the path of least resistance by conforming to the request of a permitting regulatory agency rather than working to develop a balanced solution. Therefore, the benefits to society as a whole have been compromised.*"

Stakeholders view better consideration of benefits as part of the solution to improved coordination. One stakeholder notes that coordinated development of transportation and environmental models and data sets would allow for better quantification of environmental benefits. Without sufficient funding and leadership on this topic, however, progress will not be made according to stakeholders.

2.3.8 Other sectors can provide lessons for transportation

Other sectors offer lessons learned on quantification of benefits associated with environmental regulation. The utility industry, for example, has quantified energy savings associated with conservation efforts. This has helped the utility industry emphasize management of demand rather than focusing on increasing supply. By contrast, transportation practitioners have focused on managing supply because the benefits of demand management are not as easily quantified.

In the public health field, risk management is often used to support decision making, and may offer lessons learned for transportation decision-makers. Risk assessment helps decision-makers understand the likelihood of certain events over time under different scenarios.

2.3.9 Conclusions

Non-DOT stakeholders share a general interest in better quantification of benefits associated with environmental requirements for transportation projects. They recognize, however, that major hurdles must still be overcome to achieve objective valuation of environmental benefits in economic terms. Non-DOT stakeholders see greatest promise in efforts to encourage more collaborative approaches to full quantification of environmental benefits and appropriate use of this information in evaluation and implementation of transportation projects. Such efforts may, or may not require economic valuation of environmental benefits.

2.4 Environmental Regulations Costs

2.4.1 Introduction

Delivery of Federally-funded transportation infrastructure projects by State DOTs has the potential to impose adverse impacts on the environment. Compliance with Federal, State, and local environmental requirements, including those of the National Environmental Policy Act (NEPA) and many other laws, regulations, and policies helps State DOTs mitigate for many of the significant environmental impacts that can be caused by projects. Environmental mitigation activities may, however, affect overall Federal-aid highway project costs (as well as generating benefits).

Information about environmental costs has a range of benefits for State DOTs and their partners. For example, it can be used to ensure projected project and program costs are more realistic, or it may help agencies assure greater fiscal responsibility for the actions they undertake.

Review of relevant research indicates that neither the Federal Highway Administration (FHWA) nor most State departments of transportation (DOTs) have the ability to measure the cost of mitigation activities associated with addressing the environmental impacts of transportation projects. Highlighted findings from the limited national-level literature on this topic include:

- **United States General Accounting Office (GAO) -** A 1994 study by the GAO observes that the total amount of HTF money that States spent on mitigating environmental impacts could not be calculated because of incomplete data.[24]
- **Center for Transportation and the Environment (CTE), North Carolina State University –** A 1997 study by CTE finds that "all past economic analyses of the costs of environmental regulations have completely overlooked their impacts on the construction and repair of highways."[25]
- **National Research Council, National Cooperative Highway Research Program (NCHRP) -** A 2003 NCHRP-sponsored study concluded that "a majority of States do not track environmental costs separately" from overall project costs. None of the 32 State DOT environmental officials that responded to the project survey associated with this report indicated they have engaged in any study or compilation of planning, design, and environmental costs related to environment and planning activities.[26]

At the State level, Montana, Oregon, Washington, and Wisconsin appear to be among a small group of pioneers that are making greater efforts to report on quantification environmental costs associated with transportation project delivery:

- **Montana DOT Project Cost Case Study – Environmental Mitigation and Context Sensitive Design. (October 2004)** Montana DOT (MDT) does not as standard practice track environmental costs; however, a 2004 study prepared by the MDT examined these costs for a set of 14 recently completed or almost completed projects. For the 14 projects studied, median mitigation and document preparation costs were 1.7 percent of total project costs.
- **Oregon DOT Environmental Cost Study for State Fiscal Year 2004. (December 2004)** Oregon DOT (ODOT) may well be unique among State DOTs in producing a detailed annual report on its program-wide environmental costs. ODOT's report responds to a 1999 requirement passed by the Oregon State Legislature that the DOT must provide regular summaries of costs related to State and Federal mandates and environmental regulations. ODOT estimates that environmental costs were 4.8 percent of total agency costs for FY 2004, or $33.0 million.

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[24] Government Accounting Office. "Highway Planning: Agencies are attempting to Expedite Environmental Reviews, But Barriers Remain." Report to the Chairman, Subcommittee on Transportation, Committee on Appropriations, U.S. House of Representatives. GAO/RCED 94 211. Washington, DC. 1994).

[25] Center for Transportation and the Environment, North Carolina State University "Environmental Compliance Costs: Where the Rubber Meets the Road." Raleigh, NC. 1997)

[26] NCHRP 20-24 (25) "Improving Project Costing and Incorporation of New Attributes – Highways and Transit." Washington, DC. 2003)

- **Washington State DOT Project Mitigation Costs Case Studies. (May 2003)** Washington State DOT (WSDOT) has published a set of *WSDOT Project Mitigation Costs Case Studies* that provides a detailed review of mitigation costs associated with 14 completed projects around the State. The WSDOT report is conceived as a one-time "snapshot" of a few sample projects. The report has helped WSDOT respond to concerns among legislators and the public, particularly about excessive expenditures by WSDOT to meet environmental mandates. For the 14 projects studied, median mitigation cost was 12 percent of total project costs.
- **Wisconsin Legislative Audit Bureau, An Evaluation of Major Highway Program. (November 2003)** According to a comprehensive analysis prepared by the Wisconsin State Legislature in coordination with Wisconsin DOT (WisDOT), WisDOT's FY2001 environmental expenditures totaled $29.1 million.

Comparisons between each State's efforts are inappropriate because each State used a different methodology to calculate its costs. The experiences of Montana DOT, Washington DOT, Wisconsin DOT, and Oregon DOT in measuring environmental costs, however, provide some important caveats that hold true for this study: 1) collecting data is labor intensive — WSDOT reports that its efforts to collect data took the equivalent of one FTE working full time on the project for a year, and WisDOT reports a year-long process to gather data on one fiscal year's costs; and 2) data are weak in some places — ODOT and Montana DOT report that the quality of their estimates is speculative at best, despite considerable efforts by staff to develop thorough measurement techniques.

These caveats were reiterated during the American Association of State Highway and Transportation Officials' (AASHTO) 2005 Standing Committee on Environment meeting when the research team for this project informally questioned several State DOT environmental managers about their agencies' environmental cost measuring capabilities. Most suggested that environmental cost data is buried within information their agencies collect on overall project cost. Off-the-record opinions offered by State DOT staff suggest that many State DOTs perceive the complexity of separating environmental cost components from the overall cost of delivering transportation projects presently outweighs the benefits of having better environmental costs information.

2.4.2 Interviews with State DOT Representatives

This section reports on the results of the phone interviews conducted with staff at eight State DOTs including agencies in Arizona, Florida, Kentucky, Maryland, Oregon, Utah, Washington, and Wisconsin. Prior to the interviews, contacts at each of these States verbally verified that comprehensive efforts to measure environmental costs are underway in their agency. The purpose of the interviews was to learn about each State's efforts to measure environmental costs.

Interview Process

Candidate States for interview were suggested by the research team and approved by FHWA. Information used to select States included an informal polling of 23 States (see Table 1 below) by the research team to identify whether they measure environmental costs; review of recent NCHRP report 20-24 (25), which describes the extent of efforts to track environmental costs at 32 State DOTs; and discussions with knowledgeable AASHTO and FHWA staff.

Table 1. States Contacted about their Environmental Cost Measurement Efforts

Arizona	Kansas	Maine	New Hampshire	Texas
California	Kentucky	Minnesota	New York	Utah
Florida	North Carolina	Mississippi	Ohio	Washington
Illinois	Maryland	Missouri	Oregon	West Virginia
		Montana	Pennsylvania	Wisconsin

State DOT directors at each of the selected States were formally invited to participate in the interviews via a letter signed by Ms. Cindy Burbank, Associate Administrator for Planning, Environment, and Realty at FHWA. An interview guide developed by the contractor and approved by FHWA was used to ensure comprehensive coverage of key issues and comparability of interview results. This guide is included in Appendix B.

Overview of Interview Results

The interview results suggest that the ability of State DOTs to measure environmental mitigation costs falls into one of three groups:

- **States that routinely measure all environmental costs –** In this group, States have methodologies in place specifically for measuring environmental costs. Of the States interviewed, only ODOT has a comprehensive methodology in place for collecting reliable environmental mitigation cost data on a regular basis. No other States in the country are thought to have similar methodologies in place. WSDOT has established a rigorous measurement methodology, but has used it only to measure costs associated with a handful of projects on a one-time basis.
- **States that can measure some environmental costs, if needed –** In this group, States express confidence in their abilities to track environmental mitigation cost data as needed. Of the States interviewed, Maryland State Highway Administration (SHA) and Utah DOT (UDOT) do not routinely measure all environmental costs but are confident that their existing cost and project management systems are sufficient to support collection of detailed cost information on an as needed basis. Maryland SHA uses selected components of overall environmental costs to estimate future project costs. Arizona DOT (ADOT) is capable of tracking selected components of environmental costs.
- **States that are learning to measure environmental costs –** In this group, States have experienced significant hurdles despite efforts to measure environmental costs. Of the States interviewed, Florida DOT (FDOT), Kentucky Transportation Cabinet (KTC), and WisDOT are not yet able to track environmental costs in detail. KTC and WisDOT are working on improvements to cost accounting and project management systems that will enable them to track environmental costs with greater accuracy in the future. FDOT has not pursued additional efforts to measure its environmental costs.

The spectrum of environmental cost measurement capabilities observed among the State DOTs interviewed suggests that measurement of environmental mitigation costs is an emerging issue that most States have yet to fully address. Nonetheless, the interview results provide useful insights on both good practices and lessons learned.

An October 2006 FHWA Report to Congress, Costs Associated with the Environmental Process: Impacts of Federal Environmental Requirements on Federal-aid Highway Projects Costs, identified several reasons why efforts to identify and track environmental costs are so limited:

- Insufficient labor and financial resources are available to develop, implement, and maintain appropriate financial management information systems.
- There is inconsistency among existing State financial management information systems protocols for breaking down project costs and coding them. The methods for collecting and categorizing costs differ greatly from State to State.
- Separating environmental costs from non-environmental costs is quite difficult, especially in the avoidance costs category. Multiple project or program needs often underlie particular expenditures of time or money.
- There is no reliable means to identify the costs of "the path not taken" when design changes are made, or when other actions are taken, or not taken, for environmental reasons.
- Unique geographic, demographic, and other conditions affect each highway project. Even though the variables may fall into generally identifiable categories, such as habitat impacts, community impacts, or level of public controversy, it is difficult to extrapolate what can be considered "typical" in terms of time, costs, or impacts.

For these reasons, the report concluded, "many States still question the benefits of tracking environmental costs. However, FHWA and the States that are working to track environmental costs believe that there are benefits to doing so. Greater program accountability, better data to support policy-level decisions, and improved project cost estimating and project decisionmaking are among the perceived benefits. While cost tracking efforts continue to expand, the challenges are significant and impede progress."

A Working Definition of Environmental Mitigation Costs

This section introduces a working definition of environmental mitigation costs. The definition is based on information drawn from interview States that were pre-selected on the basis of their experience in measuring environmental costs. In the interviews, however, even these States uniformly emphasized that environmental mitigation costs are hard to define and measure. At each State, staff highly familiar with the environmental process for transportation projects struggled to delineate which costs should be attributed to environmental mitigation activities:

> "*Some environmental mitigation practices are really just the "right thing to do," and would happen regardless of laws and regulations.*" – Maryland SHA

> "*Environmental mitigation expertise and responsibilities are spread across our agency and across the entire project delivery process.*" – UDOT

"*The same activity sometimes serves both environmental and non-environmental objectives.*" – ODOT

A clear definition of environmental mitigation costs provides the start point for understanding State DOTs' mitigation cost information. The interviews revealed two distinct varieties of mitigation costs that form the foundation of the definition established in this section:

- Mitigation costs may be incurred for actual **"compensation"** or enhancement of environmental impacts by restoring, replacing, substituting, or enhancing affected resources; and
- Mitigation costs may be incurred for **"avoidance"** or minimization of environmental impacts by not taking an action, or parts of an action, or by limiting its magnitude.

Costs related to environmental requirements also include costs associated with generating information for informed decision-making or addressing public concerns. In some cases "mitigation" activities are undertaken not because of environmental requirements, but as the perceived cost of garnering community support and expediting project development. Thus there is some ambiguity concerning exactly what costs should be classified as mitigation costs.

State DOTs' perspectives on compensation and avoidance mitigation costs are discussed in the remainder of this section.

Compensation-Related Environmental Mitigation Costs

Mitigation costs are incurred whenever activities are undertaken by a DOT to compensate for unavoidable environmental impacts and/or to improve the environment during project delivery. Compensation means that the DOT may repair the affected environment or replace it with substitute resources. Most of these activities are the result of compliance requirements associated with Federal and/or State and local environmental laws.

Compensation activities are difficult to generalize since every project is different. As Washington and Montana DOTs found when they compared mitigation needs for individual projects, no rules of thumb exist for the amount or type of compensation required; some projects require extensive compensation activities while others require few or none. The primary range of compensation activities, according to the DOTs interviewed, might include some or all of the following:

- **Wetland and stream restoration –** Adverse impacts to wetlands or streams may be unavoidable during construction of project elements such as roadway fills, approaches to bridges, or culvert installations. To preserve the valuable functions wetlands and streams perform in ecological systems, Section 404 of the Clean Water Act (CWA) may require DOT to consult with the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency, study affected natural resources, complete permits, and restore or replace any losses. If replacement wetlands are required, additional right-of-way (ROW) or an off-site location may be needed. Re-vegetation of riparian areas and repairs to streambeds may also be required. In 1995, FHWA estimated average wetland mitigation costs at $16,000 per acre.

- **Stormwater treatment –** Depending on factors such as soil quality, water table levels, and proximity to bodies of water, control of polluted stormwater runoff during and after project construction may be required under the National Pollution Discharge Elimination System of the CWA and the Coastal Zone Management Act. Common controls include silt fencing during construction and creation of permanent storm water detention ponds, sewers, and runoff swales. Ponds or other features may require acquisition of additional right-of-way (ROW). A WSDOT study completed in 2003 found that the average cost of stormwater treatment was $1.81 per square foot of impervious surface.
- **Biology –** Construction of highway projects can cause impacts to important natural upland ecosystems and landscapes. Under the Endangered Species Act, mitigation activities may include investigative studies and consultation with resource agencies. If necessary, land acquisition and other measures to establish mitigation, such as re-vegetation, site preparation, fencing, pest management, access control, fire control, and mitigation performance monitoring may be required. Special sensitive construction techniques may also be required to protect natural resources and communities. Since 2000, FHWA has asked DOTs to report their threatened and endangered species mitigation-related costs annually.
- **Noise reduction –** Construction noise and on-going traffic noise are a nuisance to humans and wildlife. FHWA has in place noise abatement standards and if certain criteria are met a project may require construction of linear concrete, block, brick, metal, or earth barriers to help reduce noise in adjacent areas. Noise walls can sometimes be accommodated within the existing ROW, or they may require additional ROW. WSDOT found that the average cost per square foot to build a noise wall is $32.31. An FHWA study based on data from 44 States suggests that the average noise wall cost per square foot is $19. ODOT estimates that noise accounts for about 19 percent of its total environmental compliance costs. UDOT requires that noise walls should not cost more than $20,000 to $25,000 per affected resident. During construction, job practices may include noise mitigation.
- **Documentation and other handling of historic and cultural resources –** Construction of highway projects may have adverse impacts on historic and cultural resources. Under section 106 of the National Historic Preservation Act, activities may include consultation with resource agencies, identification of resources, assessment of impacts, and efforts to minimize or mitigate impacts, which most commonly includes documentation.

Of the categories described above, the States interviewed uniformly indicated that wetlands and stormwater are responsible for the largest share of costs. In addition to the cost categories described above, DOTs suggested that a range of other categorizable mitigation activities may take place on a less regular basis, including hazardous materials clean up, land use protection, indirect and cumulative impact mitigation, and environmental justice mitigation.

According to the States interviewed, compensation mitigation is usually easily distinguishable from other project activities because it involves discrete "environmental" activities that go beyond the core scope of a project. Replacement of wetlands, for example, is not undertaken for any reason other than to preserve environmental quality. Contracting for these activities may be conducted separately from the overall project because they often require specialist expertise and equipment, and can be timed to occur separately. Compensatory and enhancement costs can generally be identified in an objective manner and are reasonably straightforward to compile. At Maryland SHA, for example, most mitigation costs except those for stormwater and erosion control-related activities are contracted separately from other project components.

Avoidance-Related Environmental Mitigation Costs

Mitigation costs are also incurred wherever a DOT undertakes mitigation activities to avoid and/or minimize significant environmental impacts. For a transportation project this might include special project location, design, and or construction elements that would not otherwise be required to meet the project's transportation function. As with compensatory mitigation, most of these activities are the result of compliance requirements associated with Federal and/or State and local environmental laws. In contrast, however, avoidance activities are not necessarily considered "environmental" activities, but might involve changes in the way non-environmental activities are carried out.

Typical Avoidance-related Activities

As with compensation activities, avoidance-related activities are difficult to generalize since every project is different. The primary range of avoidance activities, according to the DOTs interviewed, might include some, or all of the following:

- **Preparation of environmental documentation –** Preparation of documents required under NEPA and/or other laws that describe the purpose and need for proposed projects, potential alternatives, and any environmental consequences. Document preparation activities may include preliminary project design work, public involvement, environmental resource studies, and coordination with stakeholders. The cost of environmental documents is partially avoidance-related because they involve consideration of project alternatives; however, some agencies might also consider these costs to be compensation-related.
- **Project design and alignment changes –** Sometimes a project design or alignment may be altered to avoid or minimize environmental impacts. A bridge design, for example, may feature longer spans to avoid placing piers in a water channel, but which are not required from a hydraulic design perspective, or a road alignment may be specially located to avoid a sensitive habitat or some historic resources. These project elements may require additional design time. Project scope may also decrease as a result of avoidance activities. State DOTs interviewed, however, had mixed opinions about the likelihood of decreased costs associated with a change in project scope.

  Section 4(f) of the Department of Transportation Act deserves special mention as a unique factor that often leads to project design and alignment changes and construction-related avoidance costs. The Section 4(f) process requires that a special effort must be made to preserve public parks, wildlife and waterfowl refuges, and historic sites. Any project that affects Section 4(f) land must include a Section 4(f) evaluation. Use of

Section 4(f) lands is only granted if no feasible and prudent alternative can be found and all possible planning to minimize harm to the land or resources is taken. Section 4(f) impacts may require purchase of additional ROW and design/construction-related costs if measures to minimize harm are needed. Under SAFETEA-LU, the Secretary of Transportation can comply with Section 4(f) in a streamlined manner if the program or project will have a "de minimis" impact on the area – i.e., there are no adverse effects of the project and the relevant State Historic Preservation Officer or other official with jurisdiction over a property concurs.

- **Project construction changes.** The construction cost of projects may increase as a result of design and alignment changes to avoid or minimize environmental impacts. In Washington State, several projects reviewed as part of the 2003 environmental costs study were found to require bridge crossings in place of box culverts as part of the conditions for permitting, e.g. SR 18 at an additional estimated project cost of $3.33 million, and SR 202 at an additional cost of $1.05 million. Project construction practices may be also modified to avoid environmental impacts. At Maryland SHA and UDOT, for example, "environmental monitors" are required on-site during construction of large projects to ensure quality assurance / quality control (QA/QC) of environmental procedures.

Activities to avoid or minimize environmental impacts can be hard to distinguish from overall project activities because they are not discrete efforts that are readily separable from the core scope of the project. The States interviewed raised numerous concerns about attempting to quantify avoidance and minimization costs:

> "*The preferred project alignment from an environmental perspective may also be supported by the local community so we would do it this way regardless of environmental laws.*" – Maryland SHA

> "*If a project alignment is extended to avoid a wetland, is the added cost of a longer route or structure an environmental cost, or would the additional hurdle of building on unstable wetland soils have been equally expensive?*" – WisDOT

> "*These types of costs and savings lie in the realm of the "road not taken" and are extremely subjective to measure.*" – ODOT

In contrast to compensation-related costs, avoidance-related costs often require subjective judgments and are harder to compile. Only one of the States interviewed has made any previous attempt to quantify avoidance-related costs. Initial efforts to measure environmental costs may be best focused on compensation-related costs and the fraction of avoidance costs that is most easily quantifiable.

2.4.3 When and How State DOTs Incur Environmental Related Costs

The costs associated with complying with Federal-aid environmental regulations include both compensation and avoidance costs incurred by DOTs during all phases of the project delivery process, including in-house staff costs, consultant costs, and contractor costs. This section discusses State DOTs' perspectives on: (1) the phases of project delivery where environmental mitigation costs are incurred, and (2) how different types of environmental mitigation costs are incurred.

Where Do State DOTs Incur Environmental Mitigation Costs?

Compensatory- or avoidance-related environmental mitigation costs may be incurred by a DOT throughout the project delivery process, which includes four distinct and sequential phases. According to the DOTs interviewed, mitigation costs for any project are generally lowest during planning and maintenance, and highest during construction, with moderate costs incurred during design:

- Planning (low mitigation costs),
- Preliminary engineering/environmental review (moderate mitigation costs),
- Final design/ROW/permitting (moderate mitigation costs),
- Construction (high mitigation costs), and
- Maintenance (low mitigation costs)

Consideration of costs in each phase helps make measurement more manageable. For example, a State seeking the most efficient way to get a reliable sense of overall environmental costs may choose to spend the greatest effort on quantifying construction-related mitigation costs.

Planning

The extent of project-level planning varies widely among projects and among DOTs. Maryland SHA, for example, conducts all planning activities with an eye towards subsequent NEPA requirements. In general, planning efforts are most extensive for major projects with potential for significant environmental impacts; minor projects, such as roadway rehabilitation, may involve little or no planning activity. Broadly stated, the purpose of planning is to help identify project needs, community concerns, and potential solutions. Early consideration of environmental issues is increasingly common as part of project planning.

A fraction of total project-related planning activity may be attributable to environmental mitigation, such as early identification of environmental resources during corridor studies, or public involvement. Mitigation costs at this phase are primarily associated with avoidance or minimization of environmental impacts and they are hard to separate from overall planning activity, which is likely to include public involvement and consideration of issues such as possible project alignments.

- The scope of public involvement that a State chooses to use on a project often is driven by factors other than NEPA requirements, particularly the State's own view of how important public support may be or how to best communicate with its citizens and institutions. Consequently, all costs and time requirements for public involvement cannot be attributed environmental requirements.

- **Compensation Costs –** No compensation costs for mitigation of impacts are likely to be incurred during planning.
- **Avoidance Costs –** Avoidance costs may include State DOT staff time and other direct costs, and the cost of external consultants to prepare studies or conduct public involvement. The DOTs interviewed for this project had mixed opinions about ascribing any costs during planning specifically to environmental mitigation. Several suggested that almost all planning costs are part of a general "good government" ethic that is required to win support for projects regardless of environmental compliance requirements.

Preliminary Engineering/Environmental Review

Preparation of NEPA documentation, which can include coordination with other agencies, detailed review of project alternatives, public outreach, and studies of environmental resources, is a primary and potentially significant activity at this phase. Other Federal environmental laws, such as the Clean Water Act or the National Historic Preservation Act, may also require consultations, outreach, or mitigation studies during the preliminary engineering phase.

Some preliminary design work is required to support NEPA activities. According to the DOTs interviewed, however, most project activities undertaken during this phase are directly attributable to environmental mitigation and would not be needed without Federal and State environmental requirements. For complex or high profile projects, environmental review and preliminary engineering can be time-consuming efforts that may take several years to complete. Wisconsin DOT estimates that the average cost of an EIS is $2 million. For small projects, however, compliance with environmental requirements is minimal and usually takes only a few days or weeks to complete. Maryland SHA notes that a project developed in a single EIS may subsequently be designed and constructed in several phases.

- **Compensation Costs –** Compensation costs for mitigation of impacts incurred during preliminary engineering may include staff or consultant time to coordinate with resource agencies and work during preparation of a NEPA document to plan mitigation strategies.
- **Avoidance Costs -** Avoidance costs may include State DOT staff time and other direct costs incurred during management of environmental review activities. External consultant costs associated with preparation of studies, NEPA documents, and public involvement are common.

Final Design, ROW, and Permitting

Once the NEPA process is complete and a horizontal and vertical alignment for the project is agreed upon, detailed engineering plans can be finalized. Most final design work is unrelated to environmental mitigation; however, design of environmental compensation or enhancement features, such as storm water control facilities, wetland mitigation, or noise walls may add to overall final design costs. UDOT estimates that less than 10 percent of its final design costs are related to environmental mitigation.

If avoidance or minimization of environmental impacts requires a more complex design, additional costs may also be incurred because plans may take more time in design. Several of the

DOTs interviewed for this project including Maryland, Oregon, Kentucky, and Florida observe, however, that distinguishing between the most practicable design solution from an engineering perspective and the environmentally preferred solution is difficult.

Where needed, right-of-way is acquired once final design plans provide sufficient detail to identify specific parcels. Most ROW costs are unrelated to environmental mitigation; however, sometimes additional land may be required, for example to accommodate wetland restoration or a storm water control facility. Washington State DOT reports that stormwater facilities and wetlands mitigation, particularly, can require additional ROW. Maryland SHA reports that additional ROW required for these facilities is usually a small proportion of total ROW needs on a large project, but may be significant on small storm water retrofit projects.

Permits from natural resources agencies may also be required at this phase during project delivery and require time to prepare and approve. Permits may be required for wetland restoration, storm water runoff control, conservation of historic resources, or special construction management techniques.

- **Compensation Costs –** Compensation costs during final design may include DOT staff time, consultant time for design of mitigation features, and costs associated with any additional ROW including staff or consultant time needed to follow the ROW acquisition process, actual land costs, and any costs associated with investigation and clean up of hazardous materials found on properties acquired for the project.
- **Avoidance Costs –** Avoidance costs may include additional State DOT staff or consultant time and other direct costs associated with development of a more costly project design.

Construction

Once a final design is complete, a project may begin construction. DOTs use contractors to complete most projects, but they retain an overall project management and oversight role. Environmental mitigation costs are incurred at this phase if the design requires construction of environmental compensation or enhancement-related elements. Furthermore, if the project design is more complex as a result of efforts to avoid or minimize environmental impacts, construction costs may increase. In addition, parts of construction engineering related to environmental mitigation features (e.g. construction management, inspections) add costs.

- **Compensation Costs –** Compensation costs during construction may include DOT staff time to manage contractors, and contractor costs for construction of mitigation features, or adherence to special construction procedures.
- **Avoidance Costs -** Avoidance costs may include additional State DOT staff or contractor costs associated with construction of a more costly project design.

Maintenance

Environmental mitigation-related maintenance costs are generally perceived by the States interviewed to be much smaller than project development costs and difficult to estimate. Costs are most frequently incurred for activities such as National Pollutant Discharge Elimination

System (NPDES) permit requirements for storm water run-off at maintenance facilities, solid waste disposal, hazardous materials, and control of vegetation and weed pests. ODOT has found that most environmental costs incurred during maintenance are for Endangered Species Act, Clean Water Act, Resource Conservation and Recovery Act (RCRA) and Noxious Weed Act. Maryland SHA notes that culvert and drainage pipe repair fall under maintenance activities.

How Do State DOTs Incur Environmental Mitigation Costs?

State DOTs commonly track four components of project cost data that have relevance to measurement of environmental costs:

- In-house staff time and other direct costs,
- Consultant services costs,
- Right-of-way acquisition costs, and
- Construction contractor costs.

In each instance, however, DOTs' tracking systems for these cost components sometimes combine environmental and non-environmental elements. The degree to which the environmental element can be identified varies from State to State. Compensatory mitigation costs are frequently easier to extract than avoidance mitigation costs. At WisDOT, where costs were broken out in these categories for costs incurred by the DOT for FY01, construction contractors accounted for 66 percent of environmental costs, consultants accounted for 21 percent of environmental costs, and in-house staff accounted for 4 percent of environmental costs. (In-lieu type fees and other miscellaneous costs accounted for the remainder of environmental costs at WisDOT.)

In-House Staff Time and Other Direct Costs (ODCs)

During project delivery, most DOTs conduct a proportion of environmental mitigation-related activities in-house using their own staff, and staff also oversees the work of consultants and contractors. All the DOTs interviewed for this project describe a trend towards outsourcing of environmental mitigation activities that suggests DOT staff costs may be decreasing as a proportion of overall costs.

Costs are incurred whenever DOT staff spends time or incurs other direct costs (e.g., for travel or supplies) while working on project-related environmental mitigation activities. The extent of in-house staff involvement in environmental mitigation-related activities varies from project to project and is not always significant; some projects may require little or no environmental mitigation component, while on other projects consultants may handle all or some environmental mitigation.

Tracking Staff Time and Other Direct Costs. Actual in-house staff costs are a simple function of time spent on environmental activities multiplied by a combined hourly labor/overhead rate. Most DOTs have in place a potentially helpful resource for calculating in-house staff environmental mitigation costs – well-established financial accounting systems are used to monitor how staff allocates time and other costs among projects. These systems use unique alpha-numeric identifiers, often called “object codes” or “activity codes” to distinguish costs associated with different categories of activities, such as traffic, project management, pavement, or bridge design.

Information about two types of staff activity should be obtained to ensure a reasonably complete assessment of in-house DOT staff time costs:

- **Stand-Alone Environmental Activities.** Some State DOTs’ systems have specific object codes for monitoring stand-alone environmental mitigation activities. As more codes are used, the accuracy of cost tracking capabilities improves; however, a tradeoff is exists between the value added of better cost data and the additional reporting burden imposed on staff.

Arizona DOT’s financial accounting system has 40 environmental activity codes used by its staff, which are reproduced in Table 2. Oregon DOT’s TEAMS financial accounting system includes 11 specific environmental object codes that are used by environmental staff to report time.

Other State DOTs are working on developing better specificity in their environmental activity codes. In April 2005, for example, KTC introduced a set of 22 environmental activity codes for use in time reporting by its Division of Environmental Analysis staff. Utah DOT is developing a set of about 25 environmental codes for inclusion in its brand new electronic Project Management (ePM) system, which will enhance project cost tracking.

Many DOTs’ systems, however, lack a comprehensive array of environmental mitigation-related object codes. As a result, many DOTs struggle to extract reliable data about staff costs. Wisconsin DOT’s financial accounting system, for example, was initially created in the 1950s and despite modifications over time, it is not able to track staff time dedicated to environmental mitigation.

Activities that Include Environmental Elements. Not all environmental mitigation activities can be tracked using stand-alone environmental object codes. For some activities, only a fraction of staff time may be directed to environmental mitigation, such as project management, roadway or bridge design, right-of-way acquisition, or construction engineering activities. In these instances, the DOT must estimate the fraction of activity for which is associated with environmental mitigation.

At ODOT, methodologies have been developed for ascribing the fraction of selected non-environmental object codes, such as geotechnical work, hydraulics, roadway design, or bridge design, that are attributable to environmental mitigation activities. Different fractions are applied for different project types, such as bridge replacements, modernization projects, or repaving projects. In most instances, however, combined activities are likely to be easily missed unless a manual review of data for individual projects is conducted

Table 2. Arizona DOT Environmental Activity Codes

General environmental activity	Hazardous material prelim. assessments
Prepare categorical exclusion	Hazardous material initial site assessments
Prepare draft environmental document	Hazardous material site investigations
Prepare final environmental document	Hazardous material remediation
Review consultant-prepared document	Section 7 consultation
Environmental project scoping activity	General cultural resource activity
Environmental agency coordination	Cultural resource surveys
Environmental field review	Cultural resource testing
Environmental project travel	Cultural resource data recovery
Preparation of public involvement	Cultural resource agency coordination
Conduct public involvement	Section 106 consultation
Prepare material source environmental documents	Cultural resource permit/maintenance
Review consultant/contractor material source docs	Environmental mitigation post const. Review
Prepare noise reports	Public noise involvement
Review consultant noise reports	Environmental committees
Prepare air quality reports	Partnering
Review consultant air quality reports	Training
National Pollutant Discharge Elimination System	Project administration
Process 404 permits	Monitoring on-call consultants
Process 401 permits	

.**Practical Considerations.** Interest, willingness, and ability to use financial information systems to track in-house staff time costs varies among the DOTs interviewed.

Wisconsin DOT, for example, has historically used only a few environment-related activity codes, and despite great interest in quantifying environmental costs, WisDOT has struggled to gain approval for use of new codes that would improve estimates. Florida DOT has not experienced pressure to provide better accounting for in-house staff environmental costs and their financial information system provides only a rudimentary breakdown of selected environmental mitigation activities. Arizona DOT uses environmental activity codes, but these are never analyzed for the purpose of estimating environmental costs. Washington State DOT reports that mining information from its staff time tracking system is too time consuming to merit its use. Oregon DOT has been using its TEAMS system for this purpose since 2001, but reports that recent changes to reporting requirements may stymie its ability to provide such tracking capabilities in the future.

A simpler approach for estimating in-house costs may be to assume a percentage of overall project costs that is attributable to in-house costs. This number can be based on a combination of professional judgment and review of sample case studies, and might vary by type of project.

Consultant Services Costs

State DOTs may rely on support from consultants to conduct some environmental mitigation activities during the pre-construction phases of project delivery. Consultants supplement in-house staff time or expertise and enable DOTs to implement a larger program of projects and tackle projects where specialist expertise is required. Arizona DOT, for example, estimates that about 80 percent of all environmental work is completed by its consultants rather than in-house. Wisconsin DOT estimates that they outsource about 60 percent of their pre-construction project work. WisDOT paid consultants $6.164 million in FY01 for environmental services, or 21 percent of its total budget for environmental costs.

Costs for consultant services are incurred whenever a consultant works on environmental mitigation-related activities. Consultants are frequently used by DOTs during the NEPA/preliminary engineering and final design/ROW phases of project delivery. Common environmental mitigation-related activities performed by consultants include: NEPA document preparation services, public involvement services, mitigation study preparation (e.g., for air quality, biology, historic resources, noise, water quality, and wetlands), preliminary design to support NEPA analysis, parts of project design related to environmental mitigation features (e.g. noise walls or storm water ponds), and parts of right-of-way acquisition related to environmental features (e.g. land for wetlands).

Consultant costs in each of these areas include staff time, overhead, and other direct costs for items such as equipment, travel, and supplies. Costs for consultants used during NEPA and preliminary engineering are almost exclusively associated with environmental mitigation, and they are often therefore easily identifiable. Costs for consultants involved in final design and right of way are usually only fractionally related to environmental mitigation and may be harder to identify.

Practices for using consultants vary from agency to agency and project to project. At Arizona DOT, for example, the agency relies on an on-call roster of five environmental consultants for most environmental mitigation activities, particularly during NEPA and preliminary engineering. On midsize or large projects, however, many DOTs rely on consultant teams that include sub-consultants with environmental expertise and in these instances costs attributable to sub-contractors may be hard to identify. At Maryland SHA, for example, environmental work incurred during design is sometimes part of an overall design consultant contract. In such instances, SHA's consultant design team includes specialist sub-contractors and their costs can only be identified via review of original contract documents.

Tracking Consultant Costs. In some instances, individual DOT staff specialists keep their own records of consultant costs used for their area of expertise using simple spreadsheets. Wisconsin DOT's historian, for example, tracks all consultant expenditures related to historic and cultural resources. Such records can be useful, but obviously provide only a partial record of overall consultant costs. Wisconsin DOT has had great difficulty in gathering complete information about consultant costs.

Some DOTs' financial reporting systems track all consultant costs by project and by object codes that give details about environmental activities. Alternatively, a review of individual consultant contracts and actual invoices can provide a similar level of detail. As with in-house staff time costs, consultants' costs fall into two categories:

- **Stand-alone Environmental Activities.** Some consultant contract costs are for stand-alone environmental mitigation activities where all consultant costs are environmental-related. On-call consultant costs are often entirely in this category. For example, Arizona DOT's on-call consultant costs are tracked and reported. Utah DOT reports that most of its Section 106-related work is conducted using stand-alone contracts that can easily be tracked.

- **Activities that Include Environmental Elements.** Some consultant contract costs are for other activities (e.g., design), which include an environmental component. Oregon DOT uses a multiplier to estimate the share of overall consultant costs that include an environmental component.

As with in-house costs, some DOTs may prefer to use professional judgment based on prior experience to apply a percentage share of pre-construction or overall project costs to consultant costs. WSDOT used this approach in its 2003 study.

Right-of-Way Acquisition Costs

In some instances, additional ROW may be required as part of compensatory mitigation or avoidance mitigation. For example, in Washington State, widening of Interstate 5 from four to six lanes for two miles required additional right-of-way for a 1.2 acre stormwater detention pond. ROW costs include actual land acquisition costs as well as in-house staff costs or consultant services costs. In general, a percentage of ROW costs may be attributed to environmental mitigation based on the ratio between total ROW required and additional ROW needed for mitigation purposes.

Contractor Costs

DOTs rely exclusively on private contractors to build projects designed in-house or by consultants. Major elements of contractors' costs include earthwork, drainage, base courses, pavements, structures, and traffic control. Common project features that may be constructed by contractors include wetland restoration, storm water control facilities to control runoff from new impervious surface, conservation of historic properties, and noise walls. In addition, permitting requirements may stipulate the use of special construction techniques. Environmental mitigation costs become a fraction of total costs if a contractor is required to build one or more environmental mitigation-related project features. Environmental mitigation costs vary from project to project, and the magnitude of environmental mitigation-related costs incurred by contractors depends on specifications that are agreed to during a project's pre-construction phase. Some projects may require no environmental mitigation-related construction.

Tracking Contractor Costs. Environmental mitigation-related construction costs must be disaggregated from total construction costs, unless the whole purpose of a project is environmental, e.g., a noise wall project, or a stormwater retrofit.) Some bid items are almost never environmental-related, e.g., asphalt, concrete, and striping, while some bid items are exclusively environmental, such as erosion control. Still others are harder to separate out, e.g. facilities to remove stormwater from roadways (required for any project) and treat it (required for environmental purposes).

Sometimes a separate contractor may be used for environmental mitigation, in which case costs are easily separated. Where the same contractor is used for environmental and non-environmental elements, DOTs are able to use detailed, standardized systems for estimating and tracking construction costs as a tool for disaggregating costs. Several data sources may be used to verify contractors' environmental mitigation-related costs:

- **The engineer's estimate.** This document is used by the DOT for soliciting and awarding construction contracts. The engineer's estimate provides a detailed breakdown of fair and reasonable project costs using unit prices for provision of specific bid items such as Portland cement concrete pavement, structural concrete, structural steel, asphalt concrete pavement, or embankments. The engineer's unit prices are based on his or her knowledge about labor and materials costs, industry overhead costs, and profit margins, and other items. The integrity of States' contracting processes depend on preparation of accurate engineers' estimates, therefore this information is likely to be acceptable for use in estimating environmental mitigation costs. Washington State, for example, has used engineers' estimates for estimating construction-related environmental costs.

- **The contractor's bid document.** In response to a bid advertisement issued by the DOT, contractors will submit a bid document that lists their price for all bid items specified by the DOT. The successful bidder's price establishes the overall cost of the project and the cost of individual units. Sometimes the successful bidder's price for the project may diverge from the engineer's estimate.

- **The record of invoices paid,** which shows what the DOT ultimately paid for actual units of bid items used. Discrepancies between the engineer's estimate or contractor's bid document may occur; for example, a contractor may find that more or less materials are required to complete the job than specified in their original bid. Change orders are used to make the design a better fit for the actual field conditions, sometimes a change order may result in an increase in project cost. The invoices paid provide the greatest degree of accuracy in estimating costs. Tracking change orders can be complex.

2.4.4 State-by-State Interview Reports

Following is a summary of detailed interviews with staff at DOTs in eight States including Arizona, Florida, Kentucky, Maryland, Oregon, Utah, Washington, and Wisconsin. An interview guide was used to ensure information collected from States was as generally comparable as possible. The eight States, however, varied considerably in their degree of expertise with collection of environmental cost data. A few of the States interviewed have developed detailed methodologies for collecting cost data and were able to provide extensive information such as reports and other documentation of methodologies. Other States have only just begun to address this issue and were limited to talking primarily in generalities about desired approaches or initiatives underway.

Arizona DOT

Background. Arizona DOT's Environmental and Enhancement Group (EEG) has a limited but expanding capacity to track some environmental mitigation costs incurred by the agency during project delivery. The focus of ADOT's efforts at present is on collection of cost data for biological resource documentation and mitigation. Cost tracking in other areas is sporadic. The general approach ADOT uses to track biology-related costs, however, appears applicable to other environmental resources for which ADOT has responsibility. ADOT's resource-based tracking system has great potential as a project management and cost measurement tool.

Motivation for Cost Measurement. Impacts to biological resources are often a concern for transportation projects in Arizona, where a rapidly growing population and an expanding transportation program necessitate considerable efforts to preserve the State's unique ecosystems. ADOT staff explains the primary motivation for developing its cost tracking capabilities has been to enable accurate responses to regular questions from sources outside the agency, including legislators and Federal agencies, about expenditures for mitigation of impacts to threatened and endangered species. ADOT does not publicly publish cost data, but it is available on request.

Tracking Systems. ADOT's biological cost tracking effort is part of a broader electronic environmental information management system that is maintained by EEG staff and was developed by in-house ADOT information technology support staff. Running on a Microsoft Standard Query Language (SQL) platform, the database enables staff to efficiently track every element of the NEPA process on a project-by-project basis from their PCs. Information in the system is easily navigable and is updated on a regular basis. ADOT environmental staff uses the database for a range of functions such as tracking project staffing and workloads, monitoring important environmental study milestones, analyzing key concerns, and reporting the current status of individual projects for each specialty (e.g., air, water, hazardous materials, etc.).

ADOT began its efforts to track biological costs on a comprehensive basis in 2003. Almost all ADOT's biological mitigation costs are linked to use of consultants and contractors whose work includes biology documentation and any specific actions required as a result of studies. Almost all biology-related work (about 90 percent) is conducted by one of ADOT's pre-approved, on call consultants. Biological costs are broken into the following fields, based on information collected from these consultants on a project-by-project basis:

- **Biological Documentation Cost:** This includes pre-construction activities such as coordination with agencies, review of relevant literature, field studies, and preparation of reports. Cost information is collected from consultant task order documentation, which includes detailed standards for reporting hours and costs by activity type that enable costs to be broken out.

- **Bio-mitigation Cost, Pre-Construction:** This includes mitigation efforts required before construction begins, such as species surveys, or exclusionary netting on bridges. Cost information is collected from consultant task order documentation.

- **Bio-mitigation Cost, Construction:** This includes mitigation conducted during construction. Cost information is collected from ADOT project managers who generally provide numbers based on bid item documentation.

Using the database, ADOT staff can report biology-related mitigation costs program-wide, project by project, or even species by species. Not included in EEG's database is in-house staff time, however, this information is tracked via bi-weekly employee timesheets that use 40 environmental codes. EEG has not made an attempt to integrate staff time costs with the consultant and contractor cost tracking capabilities of the database. Staff perceives that staff costs are a small share of total biological costs borne by ADOT and that the effort required to track this information would exceed the value of having it.

State Funded Projects and Mitigation Requirements. Arizona's State environmental laws are not as broad ranging as Federal environmental laws. ADOT does conduct some projects with State funds only, but it uses the same environmental procedures regardless of funding sources. (An exception is the Section 4(f) process, which is not required if State funding is used.) Staff cite several reasons for following Federal-style procedures including the presence of Federal lands throughout Arizona, which necessitates Federal participation in decision-making, and the clarity that Federal regulations assure for working with affected stakeholders and resource agencies.

Environmental Requirements and Project Scope. ADOT staff provided two examples of projects where scopes were scaled back to accommodate environmental concerns:

- **Organ Pipe National Monument –** The project footprint of a scenic road improvement was reduced by reducing the number of rest areas from three to two, which reduced project costs.
- **Highway 82 (Bridge Replacement), Santa Cruz, Arizona –** The original detour during bridge construction ran through a dry river bed, however, environmental concerns led to a solution that maintained traffic on the bridge during construction. This solution was also cheaper than building the detour would have been.

Florida DOT

Background. Environmental cost measurement is a lower priority at Florida DOT than it is at any of the other DOTs that participated in this study. Staff at FDOT describes a decentralized organization where practices for collecting information such as environmental costs vary from district to district. While FDOT staff provided helpful perspectives on the challenges and value of measuring environmental costs, few specifics about methodologies and approaches were forthcoming from this interview.

Motivation for Cost Measurement. Florida DOT reports limited internal or external motivation for greater measurement of environmental costs. Primary drivers appear to be Federal reporting requirements and ease of access to data.

Tracking Systems. Florida DOT has no comprehensive environmental cost measurement system. The Department tracks selected environmental costs on a regular basis:

- **Biology.** Since 2001, consultant costs associated with determination of endangered species impacts and any required mitigation have been reported annually to FHWA. Data is broken out by species using a format requested by FHWA. In-house staff costs are not tracked. Data for this report is collected from District staff by an e-mail survey
- **Wetlands.** Since 1997, the Department has tracked annual in-lieu fee costs paid to the State's wetlands agency for wetlands mitigation. For 85 to 90 percent of wetlands affected by transportation projects, FDOT pays a flat in-lieu fee of $90,000 per acre to the appropriate Water Management District in Florida. Districts coordinate closely with Water Management Districts who are responsible for conducting wetland restoration either on-site or at a bank and maintaining wetlands. FDOT views this approach favorably because it enables holistic wetland mitigation efforts that ensure best value is achieved for funds spent by considering long-term watershed implications. Cost data is easily collected for these payments. Remaining wetland impacts (primarily for saltwater wetlands) are mitigated by FDOT and its contractors, but no comprehensive cost tracking exists for these efforts.

Florida DOT has not considered a broader effort to identify in-house staff costs, consultant costs, or construction contractor costs associated with environmental mitigation. Environmental and permitting staff use unique time codes, so their time could easily be identified, but tracking environmental-related time for design engineers or construction engineers would be difficult. Consultant costs are tracked, but environmental costs are not broken out. Florida DOT expressed great concern about the amount of time required to extract environmental cost data from contractor costs. They indicated it would probably be possible on a project-by-project basis using bid item lists or pay item data.

Florida DOT was skeptical about the ability to accurately compare the cost of avoided alternatives to the selected alternative. Staff also questioned whether additional costs could be fairly attributed to environmental requirements, since many factors often influence the selection of a preferred alternative.

Kentucky Transportation Cabinet

Background. In the last several years, Kentucky Transportation Cabinet has undergone a significant transformation in its commitment to environmental stewardship. Efforts such as the agency's innovative "Communicate All Promises" program to ensure all environmental commitments are kept, and its nationally recognized Context Sensitive Solutions initiative are making the agency much more sensitive to environmental considerations. As part of this philosophy, KTC also acknowledges it must also practice responsible management of environmental costs. The agency emphasizes strongly that while work is underway in this area, staff understanding of environmental costs has yet to reach maturity. Given the infancy of KTC's efforts, this interview was most valuable in providing the perspectives of a practitioner at the outset of measuring environmental costs.

Motivation for Cost Measurement. KTC would like to be able to improve its project cost estimates, understand how costs are changing over time, and demonstrate responsible cost management practices. One use for cost information cited by KTC is "benchmark" costs for typical environmental activities that can be used in project development.

Cost Tracking Systems. KTC does not have a comprehensive tracking system in place, but the agency recently undertook a labor-intensive review of all 2000 to 2005 environmental costs. The study was reportedly based on data from design contracts and contractor bids. The study focused on basic compensatory costs and did not include consideration of many avoidance costs. The agency is not ready to share the results of its study; however, staff indicated that although costs appear to be steady over time, archaeology costs in particular are a major issue. The study appears to have led to creation of 22 new activity codes for use by environmental staff and a comparable set of 22 codes for tracking consultant activity, which were implemented in late Spring 2005. Specific comments from KTC about environmental costs incurred during project development include:

- **Planning.** Some environmental costs are incurred during planning, but these numbers were not included in KTC's study. A limited Environmental Overview may be prepared for some projects. It usually includes brief field reviews to "raise a flag over showstopper issues."
- **Preliminary Engineering.** This includes NEPA document preparation, which may be done in-house, but is often done by consultants. In-house staff time spent on NEPA documents or review of consultants' work is not tracked, but consultant costs could be tracked. Sub-contractors on a design team often conduct environmental work, but work scopes include costs for environmental components.
- **Final Design.** A few environmental costs may be incurred at this phase, but not many according to KTC staff.
- **ROW Acquisition.** Additional ROW may be required for wetlands and stormwater treatment facilities. Costs include staff time for negotiations as well as land costs.
- **In-Lieu Fees.** KTC pays an in-lieu fee to the Kentucky Department of Natural Resources for wetland and stream mitigation.
- **Construction.** Some bid items are unique and clearly environmental such as noise walls, but others such as earth moving may include an environmental component. KTC has no methodology for determining environmental costs in this instance.

KTC has recently introduced two new sets of 22 environmental staff activity codes and 22 consultant activity codes (See Table 3) that are expected to improve the agency's cost tracking capabilities. KTC believes that avoidance costs are not easily estimated.

Table 3. KTC Staff and Consultant Activity Codes

Adv. stream mitigation dev.	Env. project manager	Permitting
Adv. wetland mitigation dev.	Facilities	Permitting in-lieu fees
Air quality	General geological	Permitting mitigation
Aquatic ecology	Historic	Socioeconomic
Aquatic mitigation	Historic mitigation	Socioeconomic mitigation
Archaeology	Noise	Terrestrial ecology
Archaeology mitigation	Noise mitigation	Terrestrial mitigation
		UST/HZM

Maryland SHA

Background. Maryland SHA has a decade-long track record of collecting selected environmental cost information for internal use. The agency has not, however, routinely used this information to prepare comprehensive estimates of environmental costs.

Maryland SHA estimates that most of its environmental costs are incurred for mitigation related to reforestation (a State-level requirement), stormwater, wetlands, stream restoration, noise walls, and historic and cultural resources. Staff indicates that comprehensive project-level measurement of environmental costs could be achieved via careful review of existing systems, but would be extremely labor-intensive without major overhaul of the way cost information is collected.

Motivation for Cost Measurement. SHA's primary motivation for environmental cost measurement is internally driven. SHA uses environmental cost data from old projects to help develop estimates of environmental costs for new projects. Project managers, however, use past data only as a guide to projecting new project costs, since every project is different. This use of cost data occurs on an informal basis, with project managers self-selecting comparative projects and reviewing any data independently. Unlike Washington State DOT and Oregon DOT, Maryland SHA has not received strong external pressure to provide accounting for its environmental costs.

Cost Tracking Systems. All SHA staff time and pre-construction consultant activities are tracked using SHA's Financial Management Information System (FMIS). This system assigns a specific alphanumeric code to each project and consultants and in-house staff use project-specific charge codes for different activities. A single EIS document, however, may subsequently be designed and constructed in several phases each with an independent project code. As a result, FMIS data may not provide a straightforward way to track total environmental costs for a project. SHA does not use FMIS data for review of environmental costs.

At SHA, most mitigation activities such as wetland restoration, noise walls, and stream restoration are almost always designed and constructed under separate contracts from overall design and construction, which ensures data are easily available. By contrast, stormwater and erosion control features are usually conducted as part of overall project design and construction and are therefore harder to track separately.

During construction, Maryland SHA employs environmental inspectors to monitor environmental components of construction.

State Funded Projects and Mitigation Requirements. In Maryland, few if any environmental costs can be avoided by using only State funds on projects. Maryland's State environmental regulations closely mirror Federal regulations. For example, the Maryland Environmental Protection Act is the same as NEPA. Maryland's water quality, reforestation, and endangered species requirements are more stringent than Federal regulations.

Environmental Requirements and Project Scope. Maryland SHA staff is skeptical that project costs are ever reduced as a result of environmental regulations, except in instances where a project is not pursued. SHA staff interviewed could identify no examples of scope reductions with cost savings. As an example, staff described a project where the footprint was narrower, but since the median was eliminated, crash barriers and other safety devices added to the project costs.

Oregon DOT

Background. Oregon DOT is the only State DOT interviewed that prepares a comprehensive annual estimate of its environmental costs; therefore, this interview was a particularly valuable source of detailed information. Despite developing detailed methodologies for estimating its environmental costs, ODOT staff recognizes that data included in its annual reports is only an estimate. Since 1999, Oregon DOT has been required by State statute (Oregon revised Statute 184.666) to estimate the cost incurred in response to new mandates and legislation relating to environmental concerns:

> "*The Department shall develop a summary that shows, to the extent it can be determined, how the department's costs for maintenance, preservation, and modernization are affected by state and federal mandates, environmental regulations, or other factors that have a significant impact on cost.*"

ODOT estimates that 70 mandates, laws, regulations, and ordinances affect its environmental compliance costs. (47 Federal, 22 State, 1 local) For fiscal year 2004, the Department spent $33.0 million on environmental compliance activities, or 4.8 percent of ODOT's budget for its Transportation Operations Division and Transportation Development Division combined. Biology, wetlands and water quality account for more than half ODOT's environmental costs.

Motivation for Cost Measurement. ODOT has responded to legislative pressure as an opportunity to account for the costs of all environmental regulations.

Cost Tracking Systems. Oregon DOT has developed detailed methodologies for measuring costs. Some costs are derived from actual costs as reported in ODOT's financial accounting systems, such as costs of personnel engaged wholly in environmental compliance. Other costs are estimated based on past experience, such as environmental costs for personnel engaged in a primary activity such as design where the response to environmental mandates is diffused within the overall work effort is more difficult. Specific elements of ODOT's cost tracking methodology include:

- **Planning Costs.** Budget allocations for activities that address environmental mandates are identified and then a level of effort applicable to the mandate is estimated and finally calculated against the budget for the appropriate activity.

- **Preliminary Engineering/Environmental Costs.** This is largely a summary of true costs since all environmental personnel are engaged full time in applying environmental mandates. Since environmental staff is also specialized, there is a very good match between costs and each category, such as wetlands.

- **Right-of-Way Costs.** The largest cost factor in right of way is the purchase of property for mitigation sites, usually for wetlands and noise walls. These are true costs. In addition there are some estimated costs that relate to personnel costs of compliance.

- **Design Costs.** Differentiating design work between normal design and design for environmental mandates is very difficult. Managers were asked to estimate the percentage of time spent by their crews on environmental design issues. This percentage was then applied against the aggregate personnel costs expended by each design unit. For some design functions, namely those dealing with water quality, erosion control, and hydraulic design, the costs were more directly discernable.

- **Construction.** Environmental cost items are most readily discernable in the bid items rather than the progress payments. The item is accounted for in the year that it is bid. This cost grouping experiences significant variability year to year.

- **Maintenance.** There are some maintenance personnel assigned to environmental issues where true costs could be captured. There are also some activities that are tracked on a true cost basis. However, some costs are estimates and include labor, equipment, supplies, and services as well as contract work. Maintenance activities are not performed at the same level, consistently, year after year. This is primarily due to weather influences such as flooding, severe snow, etc. The applicability of environmental requirements varies throughout the State resulting in environmental costs varying from maintenance district to maintenance district.

ODOT does not report what it calls "indirect costs," such as the cost of providing a small bridge rather than a culvert to enable fish passage, that vary with each individual situation. Nor does the Department calculate costs or savings due to avoidance of impacts to resources calculated. These types of costs and savings, according to ODOT staff, lie in the realm of the "road not taken" and are extremely subjective to measure and arguable as to outcome.

State Funded Projects and Mitigation Requirements. In Oregon, as with several other States interviewed, few if any environmental costs can be avoided by using only State funds on projects. Oregon's State environmental regulations closely mirror or even exceed Federal regulations.

Environmental Requirements and Project Scope. ODOT staff were unwilling to speculate about whether environmental requirements might reduce a project's scope without a detailed review of projects. They noted that in general, "the path not taken" is highly subjective and almost impossible to quantify in terms of either added costs or savings.

Utah DOT

Background. Utah DOT tracks some components of overall environmental costs, but the Department anticipates that it may be able to provide a more comprehensive estimate of environmental costs in the future as part of a broader effort to improve efficiency and accountability at UDOT via creation of an electronic project management system called "ePM."

Motivation for Cost Measurement. Utah DOT's primary motivations for measuring environmental costs are to provide information to FHWA and to use for internal project cost estimating processes, particularly for wetlands and noise walls. The Department also seeks to ensure that its environmental practices are fiscally responsible. The State Legislature is likely to start requiring UDOT to report its archaeology costs.

Cost Tracking Systems. At present, UDOT does not have a comprehensive environmental cost tracking system in place. The Department is developing an electronic project management (ePM) system using an Oracle database platform. The system is almost complete and it will enable much better tracking of environmental costs. The ePM will include about 25 environmental-related activity codes that will allow better tracking of staff time and consultant costs. The ePM will also allow project managers to predict environmental costs based on standard defaults for different types of activities. The system will be improved as more information is gathered over time.

At present, Utah DOT tracks several elements of overall environmental costs on a fairly informal basis, including:

- Noise abatement construction costs per linear foot by height, based on past year's projects and reported to FHWA;
- Threatened and endangered species – reported to FHWA;
- Wetlands monitoring costs – based on Statewide Transportation Improvement plan (STIP) data, typically about $100,000 per year Statewide;
- Wetlands mitigation costs – $50,000 to $75,000 per acre usually;
- In-lieu fees for wetlands mitigation – $100,000 per acre

Specific comments from UDOT about environmental costs incurred during project development include:

- **Planning.** Staff time will be tracked by the new ePM system. Most costs incurred during planning are not environmentally related. Activities may include a general scan of sensitive resources in the proposed corridor and some public involvement.

- **Preliminary engineering and NEPA.** UDOT staff is always involved at this phase, but consultants may be used to prepare an environmental document, particularly if an Environmental Assessment or EIS is required.

- **Final design.** At this stage, a final project alignment is known and UDOT estimates that less than 10 percent of final design costs are related to environmental mitigation.

- **Right of way.** According to UDOT, costs may include additional land for stormwater retention ponds or wetlands, and clean up of contamination. UDOT has no simple way to identify these costs other than to pull up each parcel and examine its use in the project. UDOT staff thinks that environmental mitigation-related ROW costs are a small proportion of total project costs.

- **Construction.** Large UDOT projects include an Environmental Control Supervisor for the contractor and a UDOT environmental monitor. UDOT has not tracked its construction-related environmental costs, but staff thinks that bid item lists could be used to collect this information. Some bid items are exclusively environmentally related, but others would have to be subdivided, such as erosion control and earthwork. Likewise construction engineers' time would have to be subdivided.

State Funded Projects and Mitigation Requirements. In Utah, as with several other States interviewed, few if any environmental costs can be avoided by using only State funds on projects. Utah's State environmental regulations are similar to Federal regulations and a lot of land in Utah is Federally controlled. One exception is use of State funds would avoid Section 4(f) requirements, which UDOT staff estimate could save about $10,000 to $30,000 on a typical project where 4(f) issues occur.

Environmental Requirements and Project Scope. UDOT staff acknowledges that environmental requirements might reduce a project's scope. They cited an instance during Purpose and Need development where a smaller interchange was chosen with consequent money savings.

Washington State DOT

Background. Washington State is one of only two States interviewed in this study that has examined the environmental cost of its projects in detail. In May 2003, Washington State DOT (WSDOT) investigated the environmental mitigation costs associated with 14 projects that have recently been constructed or are planned for construction in the near future. The projects included five interchanges, seven widenings or lane additions, and two preservation projects. Based on the findings reported by Washington State, environmental mitigation costs for WSDOT projects are most commonly attributable to stormwater, wetlands/streams, or noise-related requirements.

For the projects studied, the percent of project costs spent on environmental mitigation ranged from 4 percent to 34 percent and the absolute value of mitigation costs ranged from $55,000 to $27.93 million. The median share of costs attributable to environmental mitigation was 12 percent. According to WSDOT, there is no clear pattern for the scale of mitigation costs in relation to project size. The setting of projects in relation to neighborhoods, streams, and wetlands were more critical factors.

Motivation for Cost Measurement. WSDOT's 2003 report was intended to provide information to the State Legislature about WSDOT's environmental costs. According to WSDOT staff, a considerable amount of "misinformation" was circulating about how much WSDOT spends on environmental mitigation. The study helped alleviate these concerns. WSDOT has since incorporated the results of the study into its cost-estimating procedures. WSDOT may periodically update the study with a fresh sample set of projects, but because this requires considerable effort, no comprehensive cost measurement effort is planned.

Cost Tracking Systems. For each project, the cost components included in the WSDOT estimates include:

- Environmental component of construction cost (taken either from contractor's bid document or engineer's estimate),
- Share of total right of way acquisition cost (based on discussion with project team),
- Allocated share of contractor's mobilization (based on discussion with project team, usually assumed to be 10 percent of overall construction amount),
- Allocated share of WSDOT's cost for construction engineering and administration (based on discussion with project team),
- Allocated share of WSDOT cost for planning, NEPA, and design (based on discussion with project team, usually assumed to be 5 to 15 percent of overall project costs).

Data for each of these elements is tracked in WSDOT's electronic Program Delivery System, which provides a comprehensive accounting system for the Department.

WSDOT estimates that the project required approximately 150 person hours per project for compilation of information. For each project, the contractors bid item list had to be reviewed item by item by the project team since WSDOT's bid item categories often blend environmental and non-environmental activities that must be correctly apportioned. As an example, 15 bid items address stormwater which must be removed from the road regardless of environmental concerns and costs to do this should not be counted as environmental costs. Once removed from the road, however, stormwater becomes primarily an environmental concern. Contractor's bid item estimates were generally found to be within 1 or 2 percent of actual costs, so bid estimates were used.

Wisconsin DOT

Background. Going back to the late 1990s, the Wisconsin State Legislature has repeatedly asked WisDOT to provide a complete accounting for its environmental costs, but the Department has struggled to respond fully. In 2002, WisDOT prepared a highly labor-intensive estimate of its complete FY01 environmental costs. Unsatisfied by this response, the State Legislature directed the State's Legislative Audit Bureau to conduct an additional study in FY02 using WisDOT's data. The LAB study reported that WisDOT's FY01 environmental costs were $29.1 million for construction bid items, consultant contracts, and staffing related to safeguarding the environment. Stormwater and erosion control are WisDOT's largest environmental cost categories.

Motivation for Cost Measurement. WisDOT's primary motivation for attempting to measure environmental costs is direct requests from its State Legislature; however, the Department also sees value in using the data internally to improve project management can cost estimating processes.

Cost Tracking Systems. WisDOT's ability to modify its outdated Financial Management System (FMS) has been a big hurdle to better cost management. The FMS was originally developed in the 1950s, according to WisDOT staff, and it includes only a handful of environmental-related activity codes. WisDOT has had great trouble extracting reliable cost information about staff time and consultants' activities from the FMS. WisDOT's initial FY01 estimate of its environmental costs was literally based on review of thousands of hand printed pages of data from FMS and consultant contracts and is not reproducible on an annual basis. Likewise, Wisconsin has also had great difficulty in breaking out bid items that include environmental and non-environmental components. A task force that involves contractors is now attempting to reach general rules of thumbs for attempting this activity.

One result of the 2003 LAB report is a requirement that WisDOT must develop a new project management system that is capable of tracking environmental costs project by project. WisDOT is now in the process of developing such a system and it is about to be started on a pilot basis.

State Funded Projects and Mitigation Requirements. WisDOT does not use State funds to avoid Federal environmental regulations because, according to WisDOT staff, Wisconsin's State environmental regulations are similar to Federal regulations and more stringent in places.

Environmental Requirements and Project Scope. WisDOT staff doubts that project costs are reduced on a regular basis because of the fact that environmental requirements might reduce a project's scope. They cited an instance on a highway geometrics project (eliminating bumps, curves, widening shoulders, etc.) where issues related to Native American cultural artifacts led to a reduced footprint with narrow shoulders. While the costs of this alternative were probably lower, the time taken to arrive at this solution was considerable.

3.0 BUY AMERICA

3.1 Background

It is widely known that the use of Federal-aid funding for highway transportation projects is associated with additional regulatory requirements. Buy America is among these regulations and affects contracting agency procurements by giving preferential treatment to domestically produced steel and iron products. The FHWA's Buy America policy requires that all Federal-aid construction projects use steel and iron that was manufactured in the United States if these materials are permanently incorporated into the project.

The primary intent of Buy America requirements was to protect the U.S. steel industry in order to support the domestic economy. This protection of the steel industry may provide positive economic benefits through stimulated domestic economic activity and reduced risk of failing to meet resource needs during times of war, but in some cases could have negative consequences such as higher domestic steel prices, increased highway construction project costs, and market inefficiency.

Whether or not Buy America provides a net benefit or a net cost to society is far from being resolved. To date, there have been no studies identified that actually estimate the costs and/or the benefits of the Buy America requirements as they relate to Federal-aid highway projects. Furthermore, the economic impacts of protectionism in general are still not fully understood and are still an issue of great debate. The purpose of this examination is to explore the potential benefits and costs of Buy America requirements on Federal-aid highway construction projects and to further identify the compliance factors perceived to create the greatest costs to project sponsors.

All Federal-aid construction projects must require that all iron and steel materials permanently incorporated into the project be manufactured in the United States. This domestic requirement applies to the manufacturing process; from the initial mixing and melting process all the way to the coating process. Exceptions to Buy America requirements are permitted in the following circumstances: (1) the amount of foreign steel and iron materials is minimal, meaning it does not exceed 0.1 percent of the total contract value, or $2,500, whichever is greater; (2) the State permits alternate bids for foreign versus domestic steel and iron materials and the total bid for the contract using domestic steel and iron materials is higher than the total bid for the contract using foreign steel and iron materials by more than 25 percent of the total bid using foreign source materials; and (3) the State requested waiver to permit use of foreign steel and/or iron materials is approved by the FHWA. Additionally, two nationwide waivers to Buy America have been approved by the FHWA, thus exempting specific ferryboat parts and exempting covered pig iron, scrap, raw alloy materials, and processed, pelletized or reduced iron ore.

America has had a long history of protectionist economic policies. Tariffs, import quotas, exchange controls, and subsidies represent the most common forms of protectionist policy. Buy America requirements are a form of protectionism because they give preferential treatment to domestic industry in government projects and procurements. The first instance of this type of protectionism was congressionally mandated in 1875 and was applied to purchasing by the U.S.

Department of War. This was then superseded by the Buy American Act of 1933, which expanded the procurement requirements to all manufactured goods and raw materials and covered all Federal government agencies and departments. This act was only applicable to purchases made by the Federal government, not to grants made by Federal agencies.[27]

Protectionist requirements of this nature were first applied to the Federal-aid highway program by the Surface Transportation Assistance Act of 1978. Buy America requirements, as they are now applied to Federal-aid highways, were created by Section 165 of the Surface Transportation Assistance Act (STAA) in 1982.[28] In this Act, congress specified that all highway projects receiving Federal-aid had to use steel, cement, and other manufactured products that were produced in the United States. Cement was removed as one of the product requirements of Buy America in 1984. [29] The final rule published by FHWA implementing this Act had waived the requirement for all manufactured products and only applied the Buy America rules to steel products. This act was last modified by Sections 1041(a) and 1048 of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 which expanded the Buy America requirements to include iron products. It should be noted that Buy America requirements for Federal-aid highway projects are different from the Buy American requirements that still apply to other sectors. While Buy America only applies to steel and iron, Buy American requirements apply to the Federal procurement of roughly 100 programs.

3.2 Literature Review

Buy America requirements have been criticized as being burdensome and costly to Federal-aid highway projects and government procurements.[30] There are, however, few studies relating to the specific costs and benefits of Buy America, as applied to Federal-aid highways. To obtain a general sense of the costs and benefits of Buy America as it is implemented by FHWA, this review will explore related literature on the costs and benefits of protectionism in general and as it relates to the steel industry and Buy American as it is instituted by other Federal agencies.

3.2.1 Literature Relating to the Benefit of Buy America

There are no studies that attempt to quantify the benefits of the Buy America compliance on Federal-aid highway projects. However, the potential benefits can be seen by addressing the broad arguments for protectionism (e.g., protection against unfair competition, national security interests and protection of domestic jobs).

[27] McDaniel, James B and Jaye Pershing Johnson. September 2001. *Guide to Federal Buy America Requirements.* Report prepared for the Transit Cooperative Research Program of the Federal Transit Administration. No. 17

[28] Federal Highway Administration (FHWA). 2001. *Contract* Administration Core Curriculum: Participant's Manual and Reference Guide. Washington, D.C.

[29] Section 10 of Public Law 98-229

[30] Poole, Robert W. Jr. October 1996. Defederalizing Transportation Funding. Reason Public Policy Institute. http://www.rppi.org/ps216.html and Roth, Gabriel. April 2003. Federal-Free Highways. Cato Institute. Washington, D.C.

The original intent of Buy America as applied to the Federal-aid highway program was to help protect American industry from what was seen at the time as unfair competition as a result of protectionist policies such as government subsidies enacted by European countries and Japan. Congressional reports have noted that the harm to American business as a result of foreign policies "adds to the trade deficit, fuels inflation and leads to unemployment and reduced productivity."[31] The American Iron and Steel Institute (AISI), an advocacy group for the domestic steel industry, has taken the position that Buy America benefits the U.S. economy since money invested domestically spurs economic activity, citing U.S. DOT claims that every $1 billion invested nationally in infrastructure improvements stimulates economic activity by $2.6 billion and creates roughly 42,100 jobs.[32] While protection of jobs, economic productivity and the stability of the economy are the assumed benefits that collectively formed the justification of the Buy America act, there have been no studies that provide evidence correlating Buy America to these benefits. Further, whether or not protectionist policies in general protect or are detrimental to the national economy has been a subject of persistent and impassioned debate among academics, politicians, activists and other segments of society.

A benefit claimed by advocates of protectionist policies in general is the reduced risk to national security through the continued development of certain industries (e.g., steel and iron manufacturers) within the U.S. economy. Some key industries, it is argued, are necessary to maintain in case of a serious national security threat that cuts off trade for essential materials from other countries. This reasoning is easily applied to the domestic steel industry since much of the machinery and equipment used in defense are largely made of iron and steel. In 2001 the U.S. Department of Commerce investigated whether imports of iron and semi-finished steel could threaten or impair national security.[33] It was determined that while iron ore and semi-finished steel are necessary for national security and over dependence on foreign sources of these goods is a threat to national security, there is no evidence to suggest that imports of these products threaten the ability of domestic producers to meet the needs of national security. These conclusions were based on information from public comments, public hearings, industry surveys, industry site visits, and consultation with government agencies. It is important to note that: (1) these conclusions were based on current factors affecting defense and industry and because these factors can change, these conclusions are not timeless; and (2) if it was actually determined that steel and iron imports were a current threat to national security, the benefits associated with averting potential risk to national security through protectionist policies like Buy America would be extremely difficult to quantify due to the complexity of the issue and the numerous uncertainties in gauging national security risk.

[31] Quoted in McDaniel, James B and Jaye Pershing Johnson. September 2001. *Guide to Federal Buy America Requirements.* Report prepared for the Transit Cooperative Research Program of the Federal Transit Administration. No. 17

[32] AISI (American Iron and Steel Institute) *Policy Positions Environment: Infrastructure/ Buy America.* No Date.

[33] U.S. Department of Commerce Bureau of Export Administration. October 2001. The Effect of Imports of Iron Ore and Semi-Finished Steel on the National Security. An Investigation Conducted Under Section 232 of the Trade Expansion Act of 1962, as amended. Washington, D.C.

3.2.2 Literature Related to the Costs Associated with Buy America

This section of the report highlights the potential costs of the Buy America act. In view of the fact that literature identifying the costs of the Federal-aid highway Buy America has not been fully investigated and we have found no studies that attempt to quantify these costs, literature relating to the costs of similar programs can be used to identify the types of costs associated with these provisions and the potential magnitude of these costs.

In general, one of the main criticisms of protectionist policies such as Buy America has been that they lead to higher domestic prices. Economic theory would hold that restriction of imports decreases competition, thus leading to reduced supply and higher prices. To date, there has been no study correlating Buy America specific provisions with increased domestic steel prices.

Even if no significant correlation exists between Buy America and higher domestic steel and iron prices, any price differential between domestic and foreign produced steel at the time of project construction will impact project costs. Although no study exists that evaluates the impact of Buy America due to higher domestic steel and iron prices on highway projects, this topic could be explored by analyzing the historical differences between foreign and domestic product prices for these goods and relating them to highway projects that receive Federal-aid, after accounting for several factors including transport costs.

Another criticism of protectionism is that these policies breed inefficiency within the protected industries. Observations of the U.S. steel industry indicate that during the time that the steel industry has received protection, a greater share of profits were being divested, new technologies were slow to be adopted relative to foreign steel companies and the industry has had very high wages compared to the rest of the domestic manufacturing sector.[34] The magnitude of the costs associated with these inefficiencies and how much Buy America protections have added to that inefficiency has not been analyzed.

There are also costs associated with administering and enforcing Buy America requirements. These costs include: the time spent by industry to provide the documentation regarding the origin of materials, agency administration of the materials certification process and any project delays as a result of Buy America compliance. These costs have not been explored with respect to Federal-aid highway projects. However, in a report exploring Federal and State requirements imposing the greatest compliance burden on Federal Transit Administration (FTA) program administration, program officials cited Buy America as causing the most delays in FTA funded procurements and projects.[35] However, even though the Buy America requirements are similar

[34] Carbaugh, Robert and John Olienyk. February 2004. *U.S. Steelmakers in Continuing Crisis. Challenge* vol. 47, no. 1. pp. 86–106 and Tornell, Aaron. 1997. *Rational Atrophy: The US Steel Industry*. National Bureau of Economic Research Working Paper Series, NBER Working Paper #6084. Cambridge MA

[35] Sheys, Kevin M., Robert L. Gunter and James B. McDaniel. December 1996. Requirements that Impact the Acquisition of Capital-Intensive Long-Lead Items, Rights of Way, and Land for Transit. Legal Research Digest No. 6

between the FHWA and FTA, the experiences between the agencies will not be identical because the scope and administration of the programs by these two agencies are dissimilar.

3.3 Benefits of Buy America

No studies have been identified that attempt to quantify the benefits of the Buy America compliance on Federal-aid highway projects. However, the potential benefits can be seen by addressing the broad arguments for protectionism (e.g., protection against unfair competition, national security interests and protection of domestic jobs).

3.3.1 Support for the Domestic Economy

The assumed benefits of Buy America are protection of U.S. steel and iron manufacturing jobs, improved economic productivity and stability for the U.S. economy. However, these benefits have not been critically analyzed or confirmed. Furthermore, as previously mentioned, great debate exists over whether protectionist policies are actually beneficial to a domestic economy or in fact are a net detriment. The net affects of protectionist policy in general, and the Buy America Act specifically, are difficult to decipher because they are wide-ranging and occur in a massive and dynamic economy.

One perspective on the economic benefit of protections for the steel industry is that Buy America may benefit certain regional economies while harming others. For instance, the steel industry has traditionally been located in the eastern and mid-western regions of the United States. These regions may benefit from Buy America related steel purchases – steel purchased in the U.S. that would have otherwise been purchased by a foreign source – through sustain or increased jobs and increased economic activity. However, States and regions requiring steel and iron for Federally funded transportation projects that do not have a major steel industry may be paying more for steel and have to absorb the administrative costs for Buy America compliance while not receiving any of the regional economic benefits. From this point of view, Buy America is effectively a transfer payment, when domestic product prices are higher than foreign prices, from States that do not have major iron and steel industries to States that do have these industries.

3.3.2 Strategic Protectionism for National Security

It is often argued that the U.S. iron and steel industries are essential to national defense and, in the past, have played a key role for providing the U.S. with defense goods in times of war. If this industry is threatened with competition from other countries, it may decline to the point where it would not be able to security needs in a timely manner in case of future conflict.

Several questions arise when evaluating this argument as a rational for the Buy America requirements and finding ways for addressing each poses great methodological difficulties. The first question is whether foreign competition threatens the ability the U.S. iron and steel industry to meet the needs of national security. This question was addressed by the U.S. Department of Commerce study "The Effect of Imports of Iron Ore and Semi-Finished Steel on the National Security" discussed earlier, which concluded that imports of iron ore and semi-finished steel products do not threaten the ability of domestic producers to meet the needs of national security.[36]

However, if the conclusions of this study are incorrect and the ability of the U.S. iron and steel industry to provide goods in times of war is indeed threatened, the next question that needs to be answered would be whether or not Buy America, as a policy tool, is effective at providing the needed protection. To date, there have been no efforts to critically evaluate the extent that Buy America, as applied to highway projects, has helped to sustain the steel and iron industry, if at all. Even if research had confirmed that Buy America has helped to support the iron and steel industry, the evaluation of whether or not it is a beneficial policy tool would still require further analysis of the risk to national security averted and the benefits of that averted risk. The benefits associated with this would be extremely difficult to quantify due to the complexity of the issue and the numerous uncertainties in gauging national security risk.

3.4 Costs of Buy America

The major costs items that could be imposed on Federally funded transportation construction projects by compliance with Buy America are higher iron and steel prices, higher overall project costs, reduced bidding competition and project delays. These costs may be absorbed by State transportation programs and Federal-aid funds. Contractors may potentially also bare these costs depending on how much they are able to pass on these costs to their customers. Additionally, costs imposed by project delays and market inefficiency occur at a societal level as well.

Aggregating Buy America project compliance costs on a national level would be a difficult task due to two factors. First, the compliance costs will vary significantly depending on the nature and size of the construction project. Projects most affected by Buy America compliance are bridge construction projects and ferry terminal construction projects. This is primarily because of the size and immense quantity of the iron and steel products required for these projects. On these projects, project designers occasionally have trouble finding the materials in sufficient enough quantity domestically to fulfill the needs of the project and, therefore, must commit extra effort towards applying for a Buy America waiver or finding other solutions. The marginal costs that Buy America imposes on projects will also depend on State statutes. Some States may adopt regulations that mirror Federal Buy America requirements. In these States, the Federal Buy America requirement would not impose additional costs for some compliance activities since they are already required by the State. Many States do not have equivalent Buy America statutes and therefore any Buy America compliance activity represents an additional cost.

The following sections identify the major Buy America compliance cost items. Wherever possible, case examples are given and a range of costs are presented for these cost elements.

[36] U.S. Department of Commerce Bureau of Export Administration. October 2001. The Effect of Imports of Iron Ore and Semi-Finished Steel on the National Security. An Investigation Conducted Under Section 232 of the Trade Expansion Act of 1962, as amended. Washington, D.C.

3.4.1 Material Origin Inspection

On the part of State transportation administrators, the minimum level of effort that must be expended in order to ensure that steel and iron used on Federal-aid transportation projects was manufactured in the U.S. is tracking product origin documentation. This task can be performed in-house or contracted out. In either case, the time needed to obtain and inspect documentation on the materials origin and to complete any additional paperwork that may be required represents an additional cost to a project.

The scale of this cost is not easily identified because it will likely vary significantly depending on the size and type of project. Further, because it is often performed in-house, the costs specifically linked to this activity are not often tracked. One identified example of the costs of this activity is provided by Alaska DOT representatives. On Federal-aid construction projects in Alaska, an outside consultant is hired to inspect the materials and certify the domestic origin on Federal-aid highway projects. The total fee for these tasks was estimated to range from between $30,000 to $120,000, 10 to 15 percent of which was estimated to be attributed towards Buy America compliance. This gives a range of $3,000 to $18,000 per project for material certification.

3.4.2 Steel Prices

A major concern of Buy America as applied to Federal-aid highway projects is the affect of iron and steel prices on overall project costs. When there is a significant differential between foreign and domestic iron and steel prices, projects required to comply with Buy America may cost significantly more than they would have if foreign steel could be used instead.

In 2004, the entire market for steel experienced sharp price increases squeezing steel consumers such as transportation projects. The following graphs show the recent trends in prices for hot rolled coil (HRC) and rebar. U.S. prices for these products were consistently higher than of equivalent products in Europe and Asia until 2003. U.S. prices for rebar briefly outpaced European prices during the steel price boom of 2004 but remained significantly higher than Asia prices for that period. U.S. HRC prices remained higher than Europe and Asia for that period. When US steel prices surpass world steel prices, transportation project managers do not have the option of importing cheaper steel.

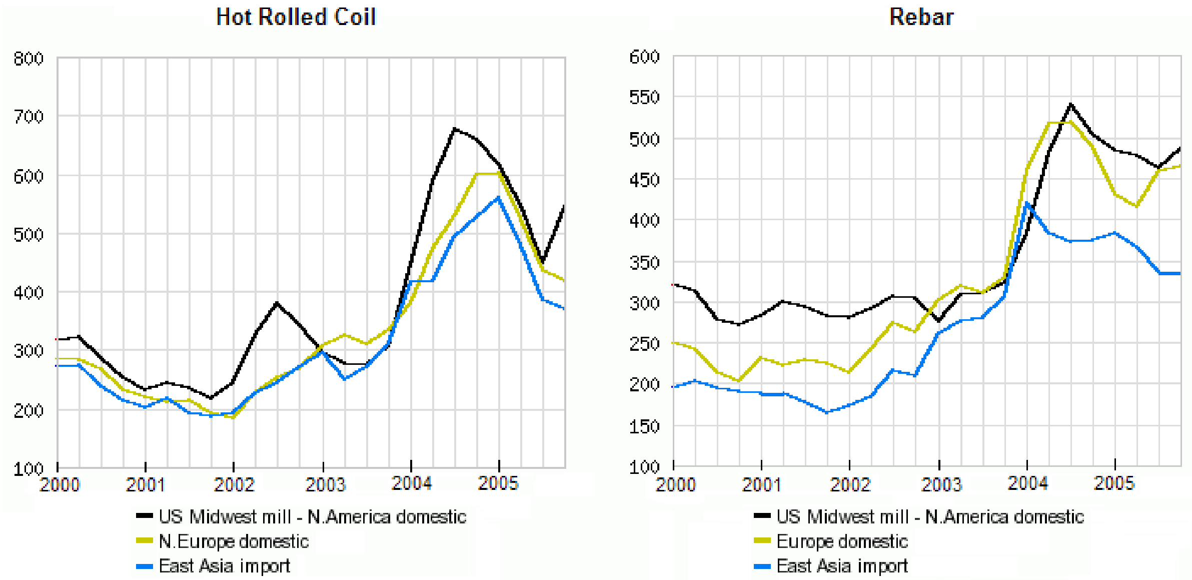

Figure 2. U.S., Europe and Asia Steel Prices for HRC and Rebar $US/ton[37]

To keep project costs from escalating too high, an exception to the Buy America requirement is granted when the total bid for a contract using domestic steel and iron products is greater than an alternative bid using foreign materials by more than 25 percent of the total project bid. Therefore, it is possible that Buy America can cost a transportation project up to 25 percent more than one that does not have to comply with Buy America provisions.

One recent case demonstrating the effects of domestic and foreign steel prices on project costs is the California San Francisco-Oakland Bay Bridge Seismic Retrofit Project. California does not have a State law equivalent to Buy America. However, in January of 2000, Governor Gray Davis ordered Federal funds to be used on the Bay Bridge project enacting the Buy America requirements. In May 2004, California Department of Transportation (Caltrans) received a bid from a single contractor to build the self-anchored suspension (SAS) segment of the east span of the bridge. The contractor submitted two bids; one came in at $1.8 billion proposing the use of domestic iron and steel products and another came in at $1.4 billion proposing the use of foreign iron and steel products.[38] This $400 million difference was 28.6 percent of the total project cost using foreign steel, great enough to trigger the Buy America 25 percent foreign/domestic price differential exception. However, Caltrans eventually rejected this bid as being excessive as it was well over the engineer's estimate and the bid expired in September 2004 without award. In response to recommendation by the Toll Bridge Project Oversight Committee, a new bid package was released for the SAS portion of the bridge project which included a number of revisions meant to increase competition and minimize costs.[39] Among those revisions was a provision de-

[37] International Steel Review U.S. Steel Prices Outperform MEPS World Index
[38] Pollak, Daniel. December 2004. Timeline of the San Francisco-Oakland Bay Bridge Seismic Retrofit: Milestones in Decision Making, Financing and Construction California Research Bureau. Sacramento CA. http://www.library.ca.gov/crb/04/13/04-013.pdf
[39] Bay Bridge East Span Update: Signature Tower Will Be Rebid; Work on Foundations to Resume July 27, 2005. Metropolitan Transportation Commission http://www.mtc.ca.gov/legislation/seismic_update.htm

Federalizing the contract by removing all Federal funding from the project. Caltrans revised the contract documents and re-advertised the project as a state-funded contract (without Buy America provisions) on August 1, 2005. Caltrans received two bids in response to the re-advertisement and awarded a $1.43 billion contract to the American Bridge Company.

Another recent bridge project, the Washington State Tacoma Narrow Bridge, demonstrates the affect of the differential between domestic and foreign steel prices on project costs. In 1998, the voters of Washington State approved a referendum to modify the Tacoma Narrows Bridge, funded partially by tolls, to increase traffic capacity. Project planners decided to use foreign steel for this project for two stated reasons. The first reason was that, since the project was not receiving Federal funding, they did not have to comply with domestic steel and iron procurement restrictions mandated by Buy America. The cost of materials was the second element of the decision to use foreign steel. During the preliminary design phase, a project cost analysis revealed that using foreign steel for the fabricated bridge deck sections of the bridge and foreign cable wire would save the project approximately $30 million. These cost savings resulted from the types of available foreign facilities for deck fabrication and lower foreign labor costs.[40]

In addition to the direct affect of higher domestic steel prices – during periods when U.S. steel is more expensive than foreign alternatives – there is also a concern that the requirements of Buy America actually lead to higher U.S. prices. The notion that Buy America provisions would lead to higher domestic steel prices emanates from general economic theory regarding protectionism. Buy America is a protectionist policy as it shields the steel and iron industry from foreign competition for purchases made on Federally funded transportation projects. Economic theory would hold that the restriction of imports decreases competition leading to greater monopolistic power over prices. In other words, the domestic steel and iron industry has the freedom and even incentive to increase product prices because Federally-funded transportation projects requiring iron and steel are captive consumers. However, the question of whether Buy America has led to higher domestic steel prices is not settled. To date, there have been no studies correlating specific provisions of Buy America to changes in domestic steel prices.

3.4.3 Project Delays

Compliance with Buy America requirements can instigate project delays leading to higher project costs. The Buy America waiver process is one potential source of schedule interruption. The delay may not cause significant costs or may not exist at all if it is identified that a Buy America waiver is needed early in the project during the design process. However, if it is identified after the project has commenced, the waiver process could delay the project for one to two months. Further, because Buy America requires that all iron and steel incorporated into Federally funding transportation projects be domestic, the lack of the availability of domestic iron and steel materials or the lack of the ability of domestic industry to supply these materials in a timely manner can cause delays.

[40] Tacoma Narrows Bridge Steel Procurement October 2005. Washington State Department of Transportation http://www1.leg.wa.gov/documents/Joint/SCTF/10-26_DOT.pdf

Project delays can potentially be very costly contributing to overall project costs in the form of wages paid during down time, overhead and cost escalation. Even the risk of project delays will affect project costs; contractors evaluate the risk of project delays and incorporate the cost of the risk into their project bids. Further, project delays also have economic consequences on a societal level resulting from the impediment of traffic. It is critical that contracting agencies verify the availability of domestic steel and iron products during the design phase of the project. If this is done correctly, the need for waivers would be reduced considerably.

3.4.4 Reduced Competition

One potential result of Buy America compliance is the potential for reduced competition for certain types of structural steel on large projects. In an analysis of the cost increases of the San Francisco-Oakland Bay Bridge Seismic Retrofit Project performed by The Results Group, it was concluded that the fact that contractors were made to submit a domestic bid as well as a foreign bid was a significant factor in why only one bid was submitted for the SAS portion of the bridge. [41] This was because of the limited domestic market capacity to provide the steel required for this portion of the bridge. No one domestic steel fabricator was able to provide steel that would comply with Caltrans unique specifications and satisfy the contract delivery requirements. Caltrans identified that the materials would only be able to be provided domestically by a consortium of companies who would need to build new facilities and hire on additional staff just for this project.

3.4.5 Industry Inefficiency

The magnitude of the costs associated with inefficiencies resulting from Buy America protections has not been previously analyzed. Industry inefficiency caused by Buy America would be a societal-level cost. One criticism of protectionist policies in general is that they breed inefficiency within the protected industries. Observations of the U.S. steel industry indicate that during the time that the steel industry has received protection, a greater share of profits were being divested, new technologies were slow to be adopted relative to foreign steel companies and the industry has had very high wages compared to the rest of the domestic manufacturing sector.[42]

[41] The Results Group. January 2005. Historical Review of San Francisco-Oakland Bay Bridge East Span Seismic Retrofit Cost Increases. http://www.dot.ca.gov/baybridge/Focused-Review-Final-Report-(Amended)-to-BTH-1-28-05.pdf

[42] Carbaugh, Robert and John Olienyk. February 2004. U.S. Steelmakers in Continuing Crisis. Challenge vol. 47, no. 1. pp. 86–106 and Tornell, Aaron. 1997. Rational Atrophy: The US Steel Industry. National Bureau of Economic Research Working Paper Series, NBER Working Paper #6084. Cambridge MA

3.5 Interview Report

3.5.1 Compliance Process

State DOTs and other Federal-aid recipients have responsibility for contract compliance on any Federal-aid construction project. As it relates to Buy America requirements, this involves a review of the certifications and material documentation provided by the contractors and material suppliers for each step of the manufacturing process. FHWA has limited engineering staff in each of its 52 Division Offices to provide oversight for all Federal-aid requirements (including Buy America); however, given FHWA's staff resource limitations, compliance with Buy America requirements is limited to spot checks on certain projects and process reviews of recipient procedures.

The FHWA's Buy America regulation provides a process for waivers of Buy America requirements in 23 CFR 635.410 (c). In addition, the FHWA's July 3, 2003 memo delegated the approval authority for Buy America waivers to Division Administrators (with prior Headquarters concurrence for items greater than $50,000). FHWA processes an average of seven Buy America waiver requests per year (See FHWA's Buy America Waiver List). This represents a relatively small fraction of the approximate 12,000 to 14,000 construction projects authorized annually by the FHWA.

All of the interview respondents stated that the Buy America compliance process is not very complex as long as issues do not arise such as domestic steel and iron product scarcity or foreign products intentionally or unintentionally being incorporated into a project. Bridge construction projects were cited as being the most affected by Buy America because of the considerable quantity and size of the iron and steel products usually required for these projects. For States with a significant amount of ferry transportation, ferry terminals are also projects that require more effort towards compliance with Buy America.

For State transportation agencies receiving Federal-aid for transportation projects, compliance with Buy America means that, at a minimum, proof of the domestic origin of steel and iron used on a project needs to be obtained and documented. This task can either be conducted by in-house transportation officials or outsourced to a consultant. Some States may also hold the construction contractor responsible for collecting material origin certificates which the State will monitor.

Another part of the compliance process for States designing a construction project may involve an investigation to find out whether the materials required are available in sufficient quantities domestically. This way, projects can either be redesigned, when possible, to accommodate for domestically available materials or if that is not possible, the need to file a request with FHWA for a Buy America waiver is identified early in the process.

Another piece in the compliance process comes from the fact that States may allow two bids to be submitted for a project per contractor: a bid using domestic steel and iron products and a bid using foreign steel and iron products. Buy America requirements are waived if the total domestic bid exceeds the total foreign bid by more than 25 percent. This compliance burden primarily falls on the contractor for putting together the additional bid but this additional work is likely reflected in the overall bid price.

When product issues arise such as the lack of a domestic source for a particular material, the State DOT has the option of requesting a waiver from FHWA, which could grant an exception to the Buy America requirements. The waiver documentation can either be prepared by the State or in cooperation between the State and a contractor.

In some cases, the need for a waiver is identified in the design phase of the project. If the need for a waiver is identified in the later stages of a project, the waiver process can entail greater costs to the project such as from project delays. The time to complete the waiver request documentation takes approximately two weeks to a month according to the State DOTs interviewed. After the request is submitted to the FHWA, it takes approximately 2 weeks to a month to process according to the FHWA. Therefore, the total Buy America waiver process can take one to two months. During the process of evaluating the waiver request, the FHWA must contact the appropriate steel or iron industry associations to verify that there are no domestic manufacturers of the material as claimed by the contractor. If a domestic supplier contends that it has the ability to manufacture the material, the waiver review process can take a significant amount of time to review the differences of opinion regarding the acceptability and availability a certain product.

3.5.2 Buy America Compliance Costs

Preparing and tracking material origin documentation is one compliance cost of Buy America on Federally funded construction projects. The costs that this activity imposes on project costs likely vary significantly depending on the size and nature of the construction project. Additionally, these costs would be difficult to identify on a per-project basis unless the hours of employee time expended on this particular task are tracked well for tasks performed in-house, or unless private contractors itemize this activity on their bills. These costs were not tracked for any of the stakeholders interviewed.

The Alaska DOT estimated the costs for this activity although they did not perform rigorous cost tracking. Alaska DOT tracks the material origin certificates completed by an outside consultant and checks off a box stating that all iron and steel incorporated into a project were produced domestically by a project manager. The consultant, in addition to checking the materials compliance with Buy America, inspects product quality. Depending on the project, the total contractor fee for this inspection of the materials and material origin certificates can range from $30,000 to $120,000. The portion of this cost due to efforts expended for Buy America compliance is not exactly known since it is not itemized on the bills. However, it was thought that this might be 10 to 15 percent of the total inspection costs.

There are also costs resulting from the research that has to be conducted to ensure that iron and steel products are available in sufficient enough quantities from domestic sources. This activity can be done by the design contractor or conducted in-house if it is an in-house State designed project. Caltrans stated that it can take two to four weeks of staff time for a design firm to put together these data, however, it should be noted that project designers should be reviewing cost and material availability information for any design (with or without Buy America requirements) as the project design proceeds.

Another cost of Buy America mentioned is that competition for the bidding of bridge projects is difficult to generate because of the scarcity of certain domestically produced steel projects. The costs associated with the mandate to use U.S. steel even if foreign steel is less expensive can also be significant and will be discussed in the example of the California Bay Bridge project below.

The major costs associated with Buy America compliance arise when domestic product scarcity or domestic product time delivery issues develop. One issue that can arise is that a particular part or product required for the construction project cannot be obtained from a domestic source in a timely manner because of the capacity of domestic manufacturers. This not only produces costs from project delays; contractors also consider time restraints and the risk associated with the timeliness of steel deliveries and increase their project bids accordingly. The direct costs of higher bid prices are absorbed by the project sponsors. Additionally, scarcity can also drive up the product price.

Another Buy America compliance issue occurs when a required material is simply not available domestically. In this case, either a Buy America waiver must be obtained so that the product could be bought from foreign sources or the project has to be redesigned to compensate for the lack of materials. When one of the aforementioned issues arise, significant management and employee time is expended. If the need for a Buy America waiver is identified during the design process, the costs are minimal compared to the costs resulting from project delays should the need be identified further into the project. Alaska DOT estimated that a project design has to be modified once every five years due to Buy America compliance. It was estimated that, on average, this redesign process takes two to four additional months of employee time redesigning the project and has, in some cases, doubled the costs for project design.

3.5.3 Buy America Benefits

Questionnaire responses regarding the benefits of Buy America from a contractor, project sponsor, and societal level were sparse. Many respondents felt that they did not have enough information in order to make an assessment of the benefits of Buy America. Buy America as applied by the FHWA was intended to protect the iron and steel industries in order to safeguard the level of iron and steel produced domestically for national strategic and defense reasons. Whether or not Buy America has been effective at this protection is contentious. One perspective is that the domestic steel industry has been in decline and that protectionist policies such as Buy America do not appear to be helping much. Another perspective is that Buy America has been very successful and has helped to curb the decline of the industry resulting from competitive pressures from oversees manufacturers.

Another perspective on the benefits of Buy America is that it supports the economy by creating jobs and economic activity. One respondent felt that on a State-by-State basis, some States benefit from Buy America while others do not. In this regard, States that do not have major iron and steel industry are simply making a transfer payment to States that do.

4.0 DAVIS-BACON WAGE REQUIREMENTS

4.1 Introduction

The 1931 Davis-Bacon Act, also known as the prevailing wage law, requires the payment of locally established prevailing wages and fringe benefits to workers employed on Federal-aid highway construction contracts.[43] The Davis-Bacon Act requires that workers, when employed on Federal construction contracts valued at more than $2,000 be paid, at a minimum, wages and fringe benefits that the Secretary of Labor determines to be prevailing for corresponding classes of workers employed on projects that are similar in character to the contract work in the geographic area where the construction takes place.[44] At the Federal level, the Department of Labor's Wage and Hour Division sets prevailing wages. In some instances, these wages may be significantly higher than market wages.[45] The Davis-Bacon Act precludes contractors from hiring low-cost labor contractors from outside local areas. The policy objectives of the act are to improve wages for laborers working on Federal Government contracts and to increase the distribution of income and capital throughout the U.S.

The benefits attributed to the Davis-Bacon Act identified in the studies reviewed for this report include: encouraging the recruitment and training of skilled labor, promoting high construction quality, developing local economies, reducing local unemployment, and increasing local household's income levels. The costs attributed to the Act include: costs associated with program administration for both the public and private sector; in certain States, costs associated with higher contract prices may result from published prevailing wages being higher than free-market wages. Davis-Bacon imposes costs on contractors in the form of higher wages than they would pay on a non-government contract job. The costs of the Davis-Bacon Act, as measured in previous studies, are commonly measured in terms of the transfers to labor from taxpayers in the form of higher wages paid on government contracts.

Many States have enacted their own version of the Davis-Bacon Act. Most States have prevailing wage laws which require private contractors bidding for State or local public works projects, or private projects that are financed in part by public funds, to pay a minimum package of wages and benefits to their workers. Although details of the laws differ from State to State, the effects of these laws on construction labor costs, and on construction labor markets more generally, have been the focus of continuous and very extensive policy debate.

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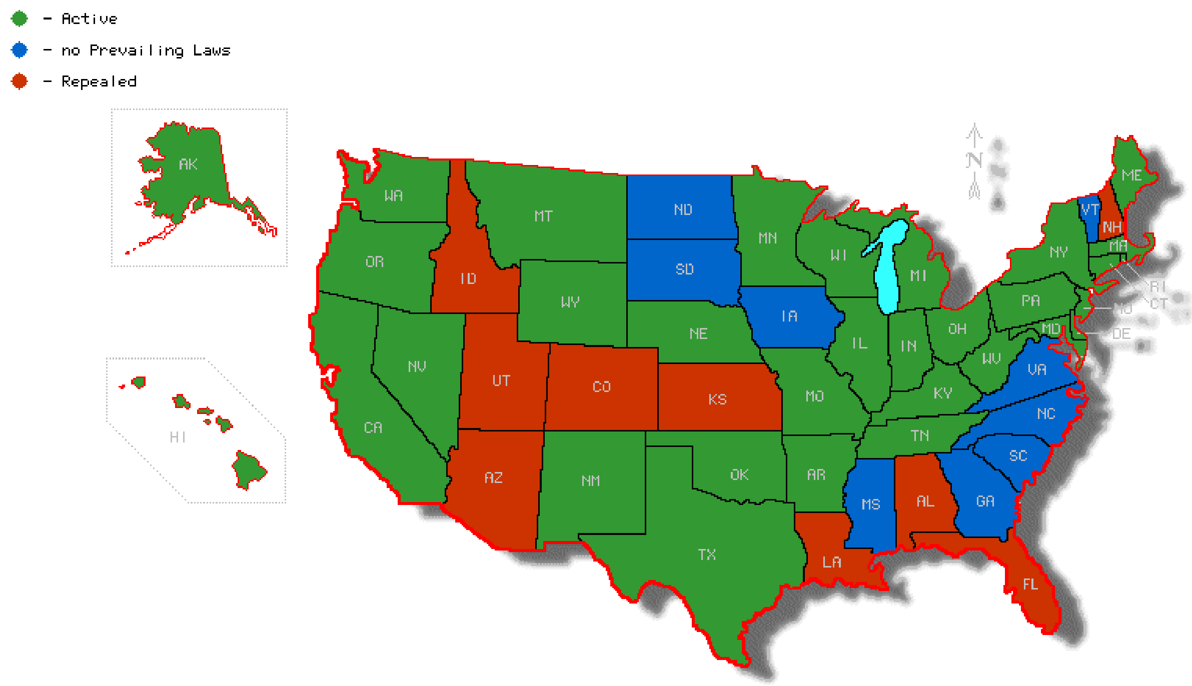
[43] As noted on the U.S. Department of Labor website: "In addition to the Davis-Bacon Act itself, Congress has added prevailing wage provisions to approximately 60 statutes which assist construction projects through grants, loans, loan guarantees, and insurance. These related acts involve construction in such areas as transportation, housing, air and water pollution reduction, and health. If a construction project is funded or assisted under more than one Federal statute, the Davis-Bacon prevailing wage provisions may apply to the project if any of the applicable statutes requires payment of Davis-Bacon wage rates" http://www.dol.gov/esa/programs/dbra/whatdbra.htm.

[44] General Accounting Office (GAO) 1999. Davis-Bacon Act: Labor's Actions Have Potential to Improve Wage Determinations. GAO/HEHS-99-97. Washington, D.C.

[45] Johnson, Joseph. 2001. "A Review and Synthesis of the Cost of Workplace Regulations." Regulatory Studies Program Mercatus Center George Mason University. Working Paper.

Figure 3 highlights the breakdown of prevailing State wage laws at the end of 2004. In 2004, there were 9 States had never had a prevailing wage law (Georgia, Iowa, Mississippi, North Carolina, North Dakota, South Carolina, South Dakota, Vermont, and Virginia); nine States that had repealed their laws between 1979 and 1988 (Alabama, Arizona, Colorado, Florida, Idaho, Kansas, Louisiana, New Hampshire and Utah); and 32 States plus the District of Columbia that have active laws. Roughly half of these States specifically or effectively use union rates as prevailing, and the rest take Davis-Bacon or some industry mean wage rate as prevailing. Additional prevailing wage laws exist in U.S. Territories and at the local level in a number of States.



Note: Oklahoma's law was invalidated by a 1995 court decision.

Figure 3. States Active, Repealed, or Without Prevailing Wage Laws

4.2 Literature Examining the Benefits and Costs Associated with Davis-Bacon Regulations

The benefits and costs of the 1931 Davis-Bacon Act have been the focus of several studies. The methods used to assess the impact of Davis-Bacon have varied widely from qualitative comparisons, simple statistical approaches and regression and econometric analysis to complex economy-wide multiplier effect models, such as the regional input-output models. This report examines selected studies examining the Davis-Bacon Act that were published during the past two decades. These studies were selected due to their technical soundness and clear and understandable methodology.

Kelsay et al. (2004) used an input-output model to study and estimate the economic impact of the prevailing wage statute – including Davis-Bacon Act – on the construction industry in the State of Missouri.[46] The authors in Kelsay et al. study used the input-output model approach and RIMS II modeling system to quantify the interdependence among industries in a regional or State economy in order to reach a conclusion with respect to the impact that a change in incomes or expenditures in one industry might have upon the total regional economy. The regional input-output models provide a valuable tool for examining the impact of prevailing wage laws on a region's economy.

Kelsay et al. (2004) concluded that attempts to repeal the prevailing wage law in Missouri were based upon the claim that the repeal would lower total construction costs to the State and bolster State and local budgets. On the contrary, the study found that the repeal of the prevailing wage statute in Missouri would not reap the State construction cost savings sufficient to counterbalance the negative economic impact such a repeal would have on the State economy. At the State-level, the study's major conclusions are:

- The mean cost per square foot for construction projects examined in several States did not yield a statistically significant difference between States with prevailing wage laws and those without.

- The repeal of the prevailing wage law would cost Missouri residents between $294.4 million and $356.0 million in annual lost income.

- The repeal of the prevailing wage law would cost the State of Missouri between $17.7 and $21.4 million in lost income tax revenue on an annual basis.

- The total economic loss due to repeal of the prevailing wage law in Missouri in 2004 would be a loss of income and revenue between $317.8 million and $384.2 million annually.

Johnson reviewed and synthesized studies on the cost of workplace regulations, including the Davis-Bacon Act.[47] The estimates produced by Johnson are not limited to highway projects. Further, Johnson discussed the methodology used in determining regulatory compliance costs and raised the issue of what type of costs to consider. He found that previous research into the impact of prevailing wages and the Davis-Bacon Act focused on direct costs only, which could be identified as engineering, labor and compliance costs. Johnson concluded that while direct cost estimation had the virtue of being directly measurable, the economic costs, which can alternatively be called opportunity costs or efficiency costs, are the legitimate approximation of the "true" economic impact of the regulation on society. While noting the difficulty in accurately measuring real societal economic costs, he suggested the use of direct costs measured in previous studies as a proxy or baseline for estimating full economic costs. Johnson reasoned that approximately two-thirds of total payments represent transfer payments, which are cash

[46] Kelsay, Michael P., Randall Wray, and Kelly D. Pinkham, 2004. *The Adverse Economic Impact from Repeal of the Prevailing Wage Law in Missouri.* Prepared for the Council for Promoting American Business. University of Missouri at Kansas City. Kansas City, Missouri.
[47] Johnson (2001)

flows paid by one group to the other. Since the losses of one group are completely offset by the benefits accruing to another, transfer payments are not viewed by economists as imposing net costs to society as a whole. The remaining one-third of total costs, or roughly 50 percent of the transfer payment, were determined to be the social costs of the regulation. Note that this "rule of thumb" approximation was not based on a systematically designed procedure to estimate social costs.

Johnson (2001) reported lower bound revenue transfers at approximately $1.17 billion, which implies a social cost of $567 million. The upper bound of $2.85 billion implies a social cost of $950 million.

Table 4. Davis-Bacon Regulatory Social Costs

Regulation	**Cost[a] (millions)**		
	Low	Best	High
Fair Labor Standards Act Social Cost	NA	NA	NA
Davis-Bacon Act Transfer Payments	**$1,170**	**NA**	**$2,850**
Davis-Bacon Act Social Cost	**$567**	**$950**	**$950**
Service Contract Act Social Cost	$243	$291	$291
Walsh-Healey Act Social Cost	$0	$0	$0
Migrant and Seasonal Agricultural and Workers Protection Act Social Cost	$4.30	$4.30	$4.30
Total	$814	$1,245	$1,245

Adopted from Johnson (2001)

[a] All figures presented in 2000 dollars.

Kessler and Katz (1999) examined the consequences of several States' repeal of prevailing wage laws in the 1970s and 1980s.[48] The authors compared trends in construction labor markets in repeal States to trends in labor markets within States that did not change their laws. Kessler and Katz basic specification compares time trends in blue-collar construction and non-construction labor markets across both States that had repealed prevailing wage laws and those that had not. The authors modeled wages and unionization rates as nonparametric functions of worker characteristics, State-fixed-effects, time-fixed-effects, and prevailing wage laws. Thus, they controlled for fixed differences across States over time. The data sources on Kessler and Katz study included the census and Current Population Survey (CPS), which enabled them to control for changes in workforce composition. The authors estimated the impact of prevailing wage law repeal as the difference between the change over time in the relative blue-collar construction / non-construction wage in repeal States and non-repeal States, to control for other, unobserved

[48] Kessler, Daniel P. Lawrence Katz (1999) "Prevailing Wage Laws and Construction Labor Markets" National Bureau of Economic Research (NBER) Working Paper No. w7454.

time-varying factors that affect all blue-collar labor markets and may be correlated with the status of labor market regulation.

Kessler and Katz (1999), by comparing trends in construction labor markets in "repeal" States to trends in labor markets in States that did not change their laws, found that the average wages of construction workers (in repeal States) decline slightly after repeal -- by about 2 to 4 percent. However, they also found that the small overall impact that repealing the law had on construction costs masked substantial differences in outcomes for different segments of the construction worker population. For example, white and unionized workers largely bore the negative effects of the repeal on wages, while repealing the prevailing wage law actually raised the construction industry premium for black workers by approximately 4 percentage points, relative to other workers.

Kessler and Katz found that the repeal of the prevailing wage law generates a 10 percent point decline in the long-run union wage premium earned by workers in the construction industries, an amount representing roughly half the total wage premium earned by unionized construction workers. The resultant decline in the union wage premium of 10 percentage points accounts for nearly the entire decline in construction workers' wages.

Prus (1996) used multivariate analysis to study the impact of State prevailing wage laws on total construction costs.[49] Prus' findings indicate that, in contrast to earlier academic analyses as well as some casual statements, he found no measurable cost difference between similar structures as a result of prevailing wage requirements. Therefore, reforming or repealing these laws did not appear to lead to the kinds of substantial savings promised by proponents of repeal. At the same time, Prus found no significant measurable cost differences between public and private projects of a similar nature.

Thiebolt (1996) used multiple regression analysis on a data sample of 27,778 observations to predict construction wage rates in various States.[50] The author selected 17 variables for his study. These variables included:

- region of the country;
- number of years after an arbitrary starting point of 1975 (the "secular trend");
- the Statewide unemployment rate for private, nonagricultural workers;
- the nationwide rate of inflation as measured by the consumer price index; and
- the status of the State's prevailing wage law—whether the State has ever had one, had one but repealed it sometime between 1979 and 1988, had one during some or all of the entire period that covered public works contracts only in excess of $500,000, or had an active one.

[49] Prus, Mark J. (1996) "The Effect of State Prevailing Wage Laws on Total Construction Costs." Department of Economics. SUNY, Cortland, Cortland, NY
[50] Thieblot, A.J. 1996. A New Evaluation of Impacts of Prevailing Wage Law Repeal, Journal of Labor Research 17(2):297-322. Washington, D.C.

Thieblot (1996) estimates the costs of Davis-Bacon at $1.62 billion per year in wage inflation with the number climbing to $1.85 billion per year when administrative costs were included.

A study conducted by the National Alliance for Fair Contracting (NAFC) (1995) that examined productivity and costs for highway construction in the 50 States over a 13 year period from 1980-1993 found an inverse empirical relationship between higher hourly wage rates paid to labor and the cost of a mile of highway construction—higher wage rates result in lower highway cost per mile. Bob Gasperow, Director of the Construction Labor Research Council (CLRC) summarized NAFC data and, in support of Davis-Bacon Act, concluded the evidence suggested that the data show no basis to support the claim that lower wage rates results in reduced construction costs to States.

Philips (1995) applied linear regression analysis and used U.S. Department of Labor (US DOL) employment and earnings data for construction workers broken down by States for 1975-91 to re-estimate the construction earnings loss resulting from State repeals of prevailing wage laws.[51] The analysis controls for long-term trends in wages, variations in unemployment, and variation in wages by region of the country, and then focuses on the effect of: (1) never having a prevailing wage law, (2) the repeal of a prevailing wage law, and (3) raising the cost threshold triggering the implementation of the State prevailing wage law to contracts in excess of $500,000.

Philips et al. (1995) studied the impact of the repeal of nine State prevailing wage laws and concluded that at the Federal level, construction cost savings must be substantially higher to generate any budget benefit from a repeal of the Davis-Bacon Act due to the Federal income tax structure. Phillips concluded that repealing the Davis-Bacon Act would reduce construction costs by 3 percent but that at a 20 percent marginal tax rates and at the 1991 level of Federal construction spending (in 1994 dollars), the Federal government would lose approximately $838 million annually in lost income tax revenue as a result of repealing the Davis-Bacon Act.

Allen (1983) in a study titled "Much ado about Davis-Bacon: a critical review and new evidence" used maximum likelihood regression analysis to measure the U.S. DOL behavior when determining the prevailing wages and the impact of DOL behavior on the public projects costs.[52] Data sources for performing this study included Standard Metropolitan Area –SMAs issued 1979 and 1980 in the Federal register for residential, highway, heavy and building constructions among other sources to collect relevant wage data. Allen concluded that the main policy implication of his study's results is that the goal of efficiently constructing public projects does not seem to be as seriously compromised by the Davis-Bacon Act as indicated by previous studies (e.g., Goldfarb and Morall 1978 and 1981). Allen (1983) found that the most reasonable estimate of the increase in public construction costs, resulting from inaccurate wage determination process to comply with Davis-Bacon and other prevailing wage laws, are between $41 million and $224 million per year.

[51] Philips, Peter Garth Mangum Norm Waitzman, and Anne Yeagle. 1995. "Losing Ground: Lessons from the Repeal of Nine "Little Davis-Bacon Acts." Working Paper Economics Department University of Utah.
[52] Allen, S.G. 1983. "Much Ado about Davis-Bacon: A Critical Review and New Evidence." Journal of Law and Economics. Vol. 25, 707-736.

Goldfarb and Morall (1981) reviewed the evidence presented in the literature presented in the 1970s on several aspects of the Davis-Bacon act, including the methodologies used to estimate the costs of compliance.[53] Goldfarb and Morall identified four categories covered in previous studies of Davis-Bacon Act effects (cost, real quantity, spillover effects, and administrative effects). The first category is the economic cost effect because the act may alter the mix of union versus non-union projects and so affect the overall labor cost-ignoring the fact that the act may affect the total volume of construction projects as well. The second category is Davis-Bacon Act real quantity effects which is relative quantity of labor versus capital within the projects. The third type of effects is the spillover effects. This is the spillover by altering market structure and effecting other private construction sectors. The fourth category is the administrative cost. A significant question raised by the authors analyzing this category (administrative) is whether there are "lags in the Davis-Bacon wage determination process and if so, how do they influence the project's cost?" The authors conclude that although the cost studies in the 1970s have been faulty in several aspects – including the lags in the Davis-Bacon wage determination process – it is reasonably clear that Davis-Bacon is unattractive on ground of economic efficiency alone. Goldfarb conclude that the question remains whether the Davis-Bacon costs are offset, partially or wholly, by the possible equity benefits of the act. Based on their review of previous research, Goldfarber and Morral (1981) estimated the annual costs of the Davis Bacon Act at $1.2 to $2.2 billion annually.

The Mackinac Center (1999) examined the Michigan economy during the 30 months that the State's prevailing wage statute was suspended and compares it to the 30 months prior to the law's repealed.[54] The study concluded that the State's prevailing wage law increased costs by at least $275 million annually, an amount equal to 5 percent of the State's income tax revenue. The study also concluded that prevailing wage laws reduced employment in construction and particularly disadvantaged minority employment.

4.2.1 Methods used to Estimate Benefits and Costs in Previous Literature

The studies examined in the previous section use a number of methods to assess the costs and benefits of Davis-Bacon Act compliance, including experts' survey, statistical analysis, simple linear or multiple regression analysis, econometric analysis, and regional input-output modeling. Previous studies rarely examined the net present value of the costs and benefits of Davis-Bacon and the wage prevailing acts. In other words, no single study took a neutral position and assessed both the discounted benefits and costs of the act throughout the last seven decades since 1931 when Davis-Bacon enacted. Thus, no true benefit-cost analysis has yet been conducted.

Another major gap in previous studies is the lack of discussion concerning the market failure of labor supply in highway projects that is claimed to be the reason behind enacting Davis-Bacon Act. Highway construction projects are complex, thus requiring specialty skilled labor in many of the projects – that might not be transferable from other segments of the construction industry. Very few studies considered the wages comparison between public (such as highway

[53] Goldfarb, Robert S. and John F. Morrall III. 1981. *The Davis-Bacon Act: An Appraisal of Recent Studies.* Industrial and Labor Relations Review, Vol. 34 (January), pp. 191-206.
[54] Mackinac Center. September, 1999. Michigan's Prevailing Wage Law and Its Effects on Government Spending and Construction Employment. Midland, Michigan.

construction projects) and private sectors projects labor costs to better understand the labor market failure in highway construction industry.

To date, there has been no study that examined and empirically proved that market failure exists in the highway construction labor market. If market failure were determined to exist within the framework of Davis-Bacon, the costs and benefit of compliance evaluation would take into consideration the public good nature of the jobs in the highway projects. Such a framework should consider project's benefits and costs discounting from the society point of view, rather than from the perspective of a private company or a public agency alone.

There are very few studies that have discussed alternative methods to increasing the Davis-Bacon Act efficiency without the need to repeal the act. However, the GAO (1979) suggested increasing the threshold or applying a flexible index of the volume of the construction project to account for inflation. The original rationale for establishing a threshold was to exclude contracts considered too small to disrupt a community's wage structure or living standards (see Appendix A for the current threshold by the States laws). The GAO (1979) report also discussed allowing more exemptions to the prevailing wage laws within the heavy construction industry.

4.3 Benefits of the Davis Bacon Act

4.3.1 Davis-Bacon Supports Local Economic Development

The Davis Bacon Act was signed into law in 1931. Enacted in an era of high unemployment, it was originally designed to promote economic development and to protect local labor from imported, lower paid work crews. The State officials interviewed for this study indicated that in their view, Davis Bacon had achieved that goal by ensuring that skilled labor be paid wages that prevail in their communities and ensuring that predatory contracting practices not be used to undercut local contractors. Though the benefits associated with local economic development are significant, these are not the only benefits that can be attributed to the Davis Bacon Act. Other benefits include leveling the playing field for honest contractors, promoting more training and benefits for labor and enhancing productivity on Federal highway projects.

4.3.2 Davis-Bacon Promotes a Level Playing Field for Contractors

Labor unions, State representatives interviewed for this study and other organizations that support Davis-Bacon and State prevailing wage laws argue that honest contractors could find it difficult to compete in the absence of prevailing wages because predatory contractors from outside an area where Federal projects are undertaken could import labor into the region and underbid the local contractors. Because labor costs represent the element over which contractors can exert the most short-term control, there is temptation to drive down costs through the use of unskilled, low-cost labor.

In principle, low-cost labor would result in enhanced efficiency and lower project costs. However, labor advocates argue that low-cost labor equates to unskilled labor, thus resulting in cost overruns that in the long run result in higher project costs. Other potential negative consequences associated with unskilled labor include: poor quality of workmanship, more injuries on the job site, higher maintenance costs post-construction, and early replacement costs.

4.3.3 Davis-Bacon Results in Enhanced Employee Benefits

Labor union representatives interviewed for this study indicated that prevailing wage laws have significant impacts on employee fringe benefits, in addition to the positive impact on wages. These representatives argued further that because there are over 40 million Americans without health insurance, the prevailing wage laws ensure that workers and their families are covered by health insurance. Without such insurance, these families would potentially be a burden on State Medicaid and other assistance programs.

These assertions were confirmed in a study conducted by Petersen (2000) that found that in States that repealed prevailing wage laws, wage rates and fringe benefits for construction workers declined. While the decline in wage rates was small, the cut in benefits was dramatic.[55]

4.3.4 Higher Wages Promote the Use of Skilled Labor with Positive Impacts on Productivity

An analysis of FHWA data recently compiled by the Construction Labor Research Council found that the wages paid to highway construction workers did not correlate with high costs per mile of highway construction. The argument supporting this seemingly counterintuitive result is that the use of high quality, highly skilled labor attracted with higher wage rates enhances productivity, thus offsetting any labor cost savings realized by offering low wages.[56] The report points to cost data reported by FHWA from 1994 through 2002, highlighting the average hourly wage, labor, and total cost per mile (Table 5).

Table 5. The Impact of Prevailing Wages on Highway Construction Costs

Measure	Low Wage	High Wage
Average Hourly Wage	$15.68	$26.34
Hours per Mile	10,276	6,991
Labor Costs per Mile	$161,128	$184,138
Total Costs per Mile	$857,965	$826,509

High wage States were those with average transportation construction labor rates in excess of $25 per hour, with rates in low wages State ranging from $12 to $25 per hour and rates in high wage States ranging from $25 to $30 per hour. Table 5 shows that although the average hourly rates in the high cost States exceed the average wage in the low wage States by 68 percent, these

[55] Petersen, J. "Health Care and Pension Benefits for Construction Workers: The Role of Prevailing Wage Laws." Industrial Relations, Vol. 39, No. 2. Oxford, UK. April 2000.

[56] The Construction Labor Research Council. "The Impact of Wages on Highway Construction Costs: Updated analysis." Prepared for the Construction Industry Labor-Management Trust and the National Heavy and Highway Alliance. 2004. Washington, D.C.

costs are counterbalanced by the higher number of hours required per mile to complete construction, with the total cost per mile in high wage States coming in at 3.7 percent below the costs per mile incurred in low tax States.

4.4 Davis Bacon Costs

Many studies and some of the interviewees for this study have noted the peculiarity of the Davis Bacon Act. While many State DOTs purchase computers, IT services, janitorial services, automotive services and research services in a competitive environment without consideration for the wages set by those contractors, Federal and State governments have chosen to establish wage rates for highway construction contractors.

A study published by the Commonwealth Foundation by Eleanor Craig of the University of Delaware noted:

> *"Pennsylvania believes in competitive bidding when it comes to most of the products and services it purchases – but not to construction."*

Craig compared average wages for four categories of workers on prevailing-wage and non-prevailing-wage jobs and found a 141 percent to -9.3 percent difference in wage rates, with a median cost of prevailing wages of 30 percent.[57]

The Davis Bacon Act has significant implications for sectors other than transportation. A study conducted by Oregon State University examined the costs associated with Davis Bacon by conducting interviews with 215 contractors who had constructed non-residential buildings across the country. The study examined wage, price, project characteristic and other data to isolate the costs associated with Davis-Bacon. In doing so, the authors concluded that the impact of the Davis Bacon Act was to add 26 percent to 38 percent to project costs.[58]

The General Accounting Office (GAO) also recently examined the budgetary implications of the Davis Bacon act. Citing estimates provided by the Congressional Budget Office (CBO), the GAO reported that in FY 2005, the Federal Government could have saved roughly $1.2 billion as a direct result of repealing Davis Bacon.[59]

Construction industry representatives interviewed for this study noted that although Davis Bacon and State prevailing wage laws drive up labor costs – inflating them by roughly 20 percent – the larger contracting operations are union shops and the impact of repealing Davis-Bacon would be negligible due to the presence of union wage rates.[60] In fact, these representatives argued that repealing Davis Bacon could hurt their bottom line to the extent that they are undercut by non-union shops.

[57] Washington Research Council. "Prevailing Wage Laws Mandate Excessive Costs." November, 1999. Seattle, Washington.
[58] IBID.
[59] Government Accounting Office. "Budgetary Implications of Selected GAO Work for Fiscal Year 2001." GAO/OCG-00-8. March 2000. Washington, D.C.
[60] Hardell, T. and Nyland, E. Personal Interview. June, 2005.

4.4.1 The Incremental Cost of Davis Bacon is Significantly Impacted by the Presence of State Prevailing Wage Laws

The impact of the costs associated with prevailing wage laws and Davis Bacon are significant; however, information obtained through interviews conducted with several State DOT representatives suggests that with the exception of the small number of State's where prevailing wage laws have been repealed, the incremental impact of the Davis Bacon Act is negligible – generally less than 4 percent of total labor costs. For instance, in the State of California, the State prevailing wage law requirements generally exceed those of the Federal act with more labor categories and higher wage rates. This sentiment was echoed by representatives in Ohio and New Jersey.

In a survey completed by States agency representatives and published by the American Association of State Highway and Transportation Officials (AASHTO), the impact of Davis Bacon in States with prevailing wage laws was considered minimal.[61] In Illinois the impact of Davis Bacon was thought to be slight while Michigan estimated the cost at $1 per hour on Federal projects. Davis Bacon was thought to have no impact in Pennsylvania and Nebraska.

In the absence of State prevailing wage laws, the Federal act can drive up wages. For example, the State of Arizona compared labor wage rates for a small number of labor categories on non-Davis Bacon projects to those paid on Davis Bacon projects and estimated the incremental impact of the Federal law on wage rates at 39 percent (Table 6).

Table 6. Market Wage vs. Davis-Bacon Wage Comparison

Project Date	Classification	Non Davis-Bacon Rate	Davis-Bacon Rate	$ Difference	% Difference
Oct-94	Laborers	$6.00	$12.78	$6.78	113%
	Operators	$10.50	$16.53	$6.03	57%
Jan-94	Operators	$13.00	$16.00	$3.00	23%
	Teamster	$13.00	$10.49	-$2.51	-19%
	Carpenter	$11.50	$18.15	$6.65	58%
	Operator 2	$14.00	$18.83	$4.83	35%
	Teamster 2	$12.00	$13.69	$1.69	14%
May-94	Carpenter	$11.56	$18.30	$6.74	58%
	Cement Mason	$12.14	$19.05	$6.91	57%
Aug-93	Laborer 4	$12.28	$15.66	$3.38	28%
	laborer 5	$13.53	$15.66	$2.13	16%
	Carpenter	$18.31	$18.15	-$0.16	-1%
Oct-93	Laborer	$13.77	$12.78	-$0.99	-7%
	Operator	$12.00	$16.00	$4.00	33%
	Electrician	$8.65	$19.19	$10.54	122%
Average					**39%**

[61] American Association of State Highway and Transportation Officials. "Results of AASHTO Survey on Costs Associated with Sec. 13 (c), Davis-Bacon Law, Clean Water Act, and Federal-Aid vs. State Only Projects." April, 1995.

4.4.2 Davis Bacon Administration Complexity and Cost

The administrators interviewed in connection with this study all rated the Davis Bacon Act at least and 8 out of 10 on a degree of complexity on a scale of one to ten, with ten being the most difficult. Most noted that it is a system that can be manipulated by contractors (e.g., purposely mis-categorizing an employee in a lower wage position) and that the compliance requirements with respect to ensuring proper wages, auditing records and coordinating with contractors is expensive.

In order to improve compliance, States include FHWA-1273: Required Contract Provisions with Federal-aid Construction Contracts with Federal contracts, post EEO posters on job sites, review wage schedules to ensure that employees are properly categorized and receiving appropriate wage rates, audit wage records and penalize contractors who are not in compliance. In California, the State penalties exceed those of the Federal Government. State penalties are $50 per day for a straight time violation and $25 per day for overtime violations. State administrators also take on a more collaborative role when responding to questions concerning the application of Davis Bacon to specific jobs. In the State of Ohio, for example, a contractor may not know whether a job such as cable splicing falls under the act and, in turn, requires guidance. To assist in making these determinations and assist in implementation of the regulations, the Ohio DOT has assembled a manual in a three-inch binder, which it uses to educate staff and conduct bi-annual meeting with coordinators who work directly in the education of contractors and enforcement of the Davis Bacon Act.

State representatives also noted during recent interviews that the staffing requirements associated with Davis Bacon compliance and enforcement are significant. Caltrans staff interviewed for this study indicated that there are 32 employees dedicated to prevailing wages in the field and four dedicated to program operation at the central offices.[62] In Ohio, there are 15 field coordinators in three districts enforcing Davis Bacon.

[62] Alston, S., Sanborn, T., and Ferguson, G. Interview

5.0 UNIFORM RELOCATION ASSISTANCE AND REAL PROPERTY ACQUISITION POLICIES ACT OF 1970

5.1 Background

Public transportation projects often require the acquisition of land. All transportation projects that receive Federal funds are subject to the rules, policies and procedures established by the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as Amended by the Uniform Relocation Act Amendments of 1987 (Public Law 91-646).

This Act, commonly called the Uniform Act, was intended to ensure payment of just compensation for real property acquisition and provision of relocation services and payments to individuals and entities displaced by public project development. In order to accomplish this, Federal, State, and local agencies comply with a certain and specific set of acquisition and relocation requirements set out in the Code of Federal Regulations (CFRs). These requirements both impose costs to agencies and transportation projects and provide benefits to property owners, displaced entities and society at large. The purpose of this examination is to explore the potential benefits and costs of Uniform Act requirements on Federally funded highway projects.

5.2 Regulation Overview

The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 was passed by Congress to ensure that persons who are displaced or whose property is acquired because of Federally funded public projects are fairly and equitably treated and receive assistance in moving from the property they occupy. After this act was enacted in 1971, Federal agencies including the FHWA commenced rulemaking separately. In 1987, after a GAO report suggested that treatment be uniform across agencies, Congress mandated in the Surface Transportation and Uniform Relocation Assistance Act of 1987 that the FHWA issue a unified rule which other agencies could follow. Revised rules for this Act were most recently published in January of 2005.

Federal real estate acquisition statutes and regulations applicable to the Federal-aid Highway program include:

Code of Federal Regulations

- 23 Part 710
- 49 Part 24 (government-wide)

United States Code

- Title 23 – Highways
- Title 42 – Chapter 61: Uniform Relocation Assistance and Real Property Acquisition Policies for Federal and Federally Assisted Programs (government-wide)
- Title 49 - Transportation

The Uniform Act prescribes certain benefits and protections for persons displaced by Federally funded public projects. Among the benefits, the Uniform Act provides relocation payments for persons displaced from their residences, businesses, farms, or non-profit organizations. These payments include moving expenses and certain supplements for increased costs at a replacement location. In addition, the Act provides protections for persons displaced from residences by requiring the availability of replacement housing, minimum standards for such housing, and requirements for notices and informational materials. Additionally, the Uniform Act entitles displaced persons including businesses to certain "advisory services" to help them move successfully.

In addition to guidelines regarding how real property is to be purchased and how individuals and businesses are to be fairly compensated, the Uniform Act as administered by the FHWA also requires States to report on their acquisition and relocation activities. All U.S. States, as well as the District of Columbia and Puerto Rico, submit periodic reports (generally annually) to the FHWA Division Offices.

5.3 Literature Review

No prior analysis has been identified that quantifies the costs and benefits of the rules, policies and procedures established by the Uniform Act for Federal-aid highway projects or other Federal-aid projects. This literature review will: (1) discuss the benefits of the Uniform Act as they have been presented in other literature; (2) supplement this discussion by conjecture of the potential costs of the Uniform Act; and (3) review available and relevant data sources with respect to the costs associated with the Uniform Act.

5.3.1 Benefits of the Uniform Act

The protections that the Uniform Act provides are derived from requirements set forth in the United States Constitution. The Fifth Amendment states that private property can not be taken without just compensation and that "No person shall be deprived of life, liberty, or property without due process of the law…." Further, the Fourteenth Amendment declares that private property cannot be taken by the State without due process.

Benefits provided by the Uniform Act include: 1) fair and equitable treatment of land-owners and tenants displaced by direct Federal and Federal-aid projects, 2) establishment of standards for advising affected persons of their rights and benefits, and reimbursing displaced persons, and 3) reduced negative impact on local economy.

5.3.2 Costs of the Uniform Act

State and local acquisition and relocation processes associated with non-Federal projects may vary from those that would be used on Federal projects. To the extent that Federal processes require additional or more rigorous procedures, real estate procurements on Federally funded highway projects may impose greater costs compared to non-Federally funded projects in terms of administrative and management costs.

Another potential cost associated with the Uniform Act is the cost associated with assisting displaced tenants and businesses. State and local real estate and right of way laws vary. In some cases, State and local laws may not mandate compensation for relocation expenses not related to acquisition (e.g. moving related expenses, relocation advisory services, and business reestablishment expenses, etc.). For State and local governments that provide less compensation and services to displaced individuals, the costs of complying with the Uniform Act for Federally funded projects may be greater than State and local requirements on non-Federally funded projects.

Under 23 CFR 710.203(b), the Federal-aid Highway Program generally treats as eligible for federal participation all usual costs that are provided for by State law. The FHWA is the only Uniform Act agency with this type of provision, which permits States to provide benefits beyond the levels specified in the Uniform Act and its implementing regulations. Many States have created such "enhanced" benefit levels, and any consideration of the costs of Federal-aid Highway Program acquisitions and relocations needs to differentiate between costs required under the Uniform Act and those that States elect to impose on their program.

There have been no studies identified that have attempted to quantify these or overall project costs of the Uniform Act. There is, however, literature resulting from ongoing efforts to streamline acquisition and relocation processes and minimize costs. One example of such an initiative was an experimental tenant relocation incentive program that the Virginia Department of Transportation (VDOT) in cooperation with FHWA used on the relocation process of tenants of large apartment buildings in the path of a road alignment of the Woodrow Wilson Bridge. This initiative was known as the Early Move Incentive Program and gave a $4,000 incentive to those residents who moved within 30 days of receiving a replacement housing offer and a $2,000 incentive for tenants moving between 31 and 60 days of receiving the offer. VDOT estimated that $4.8 million was saved by using this program taking into account seven months of project schedule savings and the added costs related to the incentive program. VDOT also stated that, in addition to these cost savings, there were reduced overhead costs resulting from the program that would have otherwise been spent to manage the condemned properties for the seven months of schedule delay.[63] Such incentive programs, both for acquisition and relocation, are not precluded by the Uniform Act, and permitted in accordance with April 2006 guidance issued by the FHWA Office of Real Estate Services (http://www.fhwa.dot.gov/realestate/acqincentguid.htm).

5.3.3 Data Sources relating to the Uniform Act and State Acquisition

The Uniform Act, besides setting forth rules for property acquisition and relocation, also requires States to provide statistical information on acquisition and relocation activities. All of the States as well as Puerto Rico and the District of Columbia submit reports which provide information for both Federally and non-Federally funded projects. State and local spending is differentiated for Federal-aid and non-Federal-aid acquisitions. Relocation statistics include funds spent for displacements, moving payments, 180-day owner benefits and tenant benefits. Business

[63] Richard Moeller et al. August 2002 European Right-Of-Way and Utilities Best Practices. FHWA Office of International Programs. Washington DC

relocation statistics are presented for the number of businesses, farms or nonprofit organizations displaced, actual expenses, reestablishment expenses and advisory services. These statistics are presented on the FHWA website.[64]

These data, however, if used to analyze the differences between State, local and Federal acquisition and relocation costs may not provide accurate results. Some of the data gathered is voluntary and not all States have consistently made contributions. Further, this data may not just reflect variation in costs specifically relating to differing relocation and acquisition laws. It also may reflect differing State and Local practices about cost accounting measures.[65]

Individual States may have databases that track right-of-way expenses and could be used to differentiate costs of Uniform Act compliance with compliance of State right-of-way statutes. For this to be feasible, State statutes would have to be different in at least some respects from the Uniform Act and the State would have to have non-Federally funded projects in which property acquisitions and relocations are made. Even if these conditions are met, databases may not track all costs associated with Uniform Act compliance.

5.4 Benefits of the Uniform Act

5.4.1 Rights and Protections

There are benefits associated with the rights and protections intended to be ensured by the Uniform Act. However, it may not be feasible or even appropriate to monetize these benefits because they are, to a large extent, ensuing from basic rights conferred to all citizens in the U.S. by the United States Constitution.

5.4.2 Reduced Impact on Local Economies

Without adequate relocation support, displacement of businesses can adversely affect local economies when these businesses are placed under additional hardship and increased risk of failure. The Uniform Act provisions are intended to ensure that businesses do not suffer disproportionately and to help them recover from their displacement to the extent possible. The success of Uniform Act compliance in minimizing the impact to businesses has been recently evaluated by the National Business Relocation Study.[66] This report found that reestablishment payments were considered almost universally inadequate. Further, businesses felt that they did not receive adequate relocation assistance and compensation for relocation expenses. Common concerns among businesses over relocation costs were the loss of income during downtime, loss of visibility, loss of customer base and the exclusion of certain costs from reimbursement eligibility. A review of Uniform Act provision relative to business relocation payments was completed and certain changes were made to the regulations in January 2005. The FHWA is

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64 Annual Right of Way Statistics. http://www.fhwa.dot.gov/realestate/stats/

65 Janet Myers. February 2005. Personal Communication

66 FHWA. April 2002. National Business Relocation Study. Report No. FHWA-EP-02-030. FHWA. Washington DC

continuing to assess the impact to business relocations as a result of reimbursement levels imposed by the Uniform Act that could not be addressed through the 2005 Rulemaking.[67]

The Uniform Act's real impact to local economies and the potential benefits in terms of reduced impacts to local economies have not been previously analyzed or monetized. These benefits would be the marginal impact of the Uniform Act over and above current State and local regulations. For instance, these benefits would not accrue in States with identical relocation benefits. An analysis of these incremental benefits would have to consider the economic impacts of relocation on Federally funded projects compared to non-Federally funded projects and properly attribute the economic impacts to the Uniform Act on Federally funded projects.

5.5 Costs of the Uniform Act

5.5.1 Real Estate Appraisal Process

The Uniform Act specifies the conditions under which the appraisal process must proceed. The Uniform Act requires that an agency appraise a property prior to negotiations to acquire it and make an offer based on the appraisal of the property. The Uniform Act provides minimum standards and specific requirements for the qualifications of the appraiser and how the appraisal is conducted and documented. Additionally, the appraisal must undergo an appraisal review process. It is this process on which just compensation to property owners is built. The appraisal process would occur in most States regardless of whether or not the Uniform Act applies; however, specific activities may be unique to the Uniform Act in certain States. For States that have statutes that do not mirror the Federal Uniform Act requirements and have to comply with additional requirements due to the Uniform Act, these additional requirements represent additional compliance costs of the Uniform Act.

One example of the incremental cost of the Federal Uniform Act revolves around the appraisal review process. In the Federal Uniform Act requirements, an initial appraisal must go through an additional appraisal review process in order to be approved and accepted. Florida does not have such a State requirement and right-of-way officials stated that they believed that the industry standards for appraisal have increased to the extent that the review process is redundant. Currently, both Florida State employees and consultants are used for the appraisal review. Florida officials estimated they would save approximately $3.1 million in project funds if the appraisal review process were to be eliminated. This was a best estimate based on the additional staff time required for appraisal reviews.

[67] See also GAO report Eminent Domain Information about Its Uses and Effect on Property Owners and Communities Is Limited (GAO-07-28 November 2006)

Streamlining of this process has occurred. For example, low-value acquisitions ($10,000 or less) can use an alternative valuation process. This $10,000 limit may be increased up to $25,000 in certain instances. Also, certain types of transactions do not require an appraisal. Also, the FHWA has undertaken several pilot projects to experiment with revised appraisal and appraisal review requirements.

The Uniform Act has several requirements regarding the acquisition of real property. One requirement is that the agency acquiring the property must make a reasonable effort to contact the property owner to explain the negotiation process. Another requirement of the acquisition process is that, once the amount of just compensation is determined, a written offer must be made to the property owner in a prompt manner. The owner is then allowed a reasonable opportunity, by mandate, to consider the offer and to make any proposed modifications. In some instances, owners will accept the offer or the acquisition is settled through negotiations. The process becomes more encumbered when the two parties are not able to come to an agreement through the initial offer or negotiation process and have to turn to administrative settlements or mediation. If these options have failed, the acquiring agency can seek legal counsel and begin condemnation proceedings as a last resort.

The Uniform Act only imposes acquisition compliance costs to the extent that similar compliance requirements are not mandated by State statutes. For States that have less extensive acquisition requirements, the Uniform Act acquisition compliance process may impose additional costs. For those States that have adopted the Federally regulations completely, Uniform Act acquisition requirements entail no additional costs.

In situations where condemnation proceedings are commenced, litigation and attorney fees can be very costly. One case example of Federal regulations imposing additional acquisition costs occurred in Florida. Florida has one of the highest rates of acquisition by condemnation in the U.S. – 46 percent in 2002 – and requires the acquiring agency to pay for all litigation costs for those affected by right-of-way. Thus, Florida spends an incredible sum on litigation-related costs. On average, Florida currently spends $50 to $60 million annually in court fees out of a total right-of-way program of $350 to $400 million annually. The Uniform Act requires that an offer made for real property must represent the fair market value, or appraisal value. Florida officials believe that the high costs of the litigation process might be curbed if they had more flexibility to make larger initial offers. Florida officials estimate that 10 percent of the total litigation costs could be saved if they had additional flexibility in making the initial offer. This example may only be relevant to Florida; however, it exhibits one way that differing Federal and State acquisition regulations can represent additional Uniform Act compliance burden. Florida's laws are not representative of the norm, especially because of its unusually pro-landowner provisions with respect to payment of attorneys' fees.

5.5.2 Relocation Assistance

The final major compliance item mandated by the Uniform Act is relocation assistance for displaced persons. Among the relocation benefits that might be received from dislocated individuals, families, businesses and other entities are relocation payments; relocation advisory services; replacement housing and standards for housing; and requirements for informational materials and notices. Relocation assistance payments and advisory services were claimed to be the most significant costs resulting from the Uniform Act. In 2001, both residential relocation expenses and business relocation expenses and advisory services each totaled approximately $61 million. As noted above assessing the cost of Federal-aid Highway program acquisitions and relocations should differentiate between costs required under the Uniform Act and those that States elect to impose on their program since many States have created enhanced benefit levels beyond those specified in the Uniform Act.

5.6 Interview Report

5.6.1 Compliance Process

The Uniform Act compliance process generally involves the following activities for agencies seeking to acquire real property: personal meetings with property owners and tenants; appraisal and appraisal review; acquisition negotiations, potential condemnation proceedings or alternative means of property acquisition; property payment; relocation planning; relocation advisory services; and relocation assistance payments. Increasingly, State real estate offices are contracting out some of these activities. Florida representatives estimated that 90 percent of appraisal activities were contracted out to consultants.

When asked about the level of complexity of the Uniform Act compliance process, most interviewees rated the process complexity moderate to high. However, a few of the State DOT representatives rated the acquisition and relocation processes separately stating that the acquisition process was moderately complex while the relocation process could be highly complex.

FHWA oversight plays a significant role in the Uniform Act compliance process. FHWA headquarters disseminates policy and advisory services. The Division offices ensure that States are in compliance and provide training to State and local agencies. FHWA headquarters, by congressional mandate, is the lead agency for the Uniform Act and provides technical and assistance and guidance to 18 other Federal agencies.

All of the State DOT representatives interviewed stated that if the Federal Uniform Act and its implementing regulations were to be rescinded, the States would keep their right-of-way laws. However, it was also stated that some changes to the right-of-way process may be considered for implementation. Florida representatives stated that although the State right-of-way laws would mostly remain unchanged, it would be likely that the relocation benefits would decrease and the appraisal review process would be more flexible.

5.6.2 Compliance Cost Items

Many States have adopted similar or mirror laws to the Uniform Act. Because of this fact, it is difficult to differentiate between the impact of Federal and State compliance costs. The compliance process identified in terms of imposing the greatest costs is the relocation and reestablishment of businesses. This cost can vary significantly depending on whether the business is in an urban or rural setting.

Many interviewees stated that residential owners were, for the most part, treated fairly under the Uniform Act but business relocatees were not properly compensated for the interruption of their business and the loss of established customers from changing locations.

5.6.3 Compliance Benefit Items

Among the benefits mentioned by those interviewed for this study is that it ensures rights, protections and equal treatment. Another benefit is that the Uniform Act helped to streamline the compliance process and make the compliance process consistent across jurisdictions. There is also an additional benefit of minimizing the impact on local communities and economies through planning and advisory services.

Another benefit of the Uniform Act is that it relieves the political pressures that would otherwise affect projects. Without the act, many argued that individuals with the right connections or those who are otherwise in positions of power would receive better treatment. In this way, the Uniform Act depoliticizes the process.

6.0 SECTION 106 OF THE NATIONAL HISTORIC PRESERVATION ACT

6.1 Introduction

Section 106 of the National Historic Preservation Act requires that "the head of any Federal agency having direct or indirect jurisdiction over a proposed Federal or Federally assisted undertaking in any State and the head of any Federal department or independent agency having authority to license any undertaking shall, prior to the approval of the expenditure of any Federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register."[68] Further, it requires that the aforementioned Federal agency head provide the Advisory Council on Historic Preservation (ACHP) with a reasonable opportunity to review and comment on any relevant project.

Section 106 requires each Federal agency to perform two actions prior to carrying out, approving financial assistance to, or issuing a permit for a project that may affect properties listed or eligible for listing in the National Register of Historic Places. First, the agency must recognize and consider the project's impact on historic properties. Second, the agency must afford the ACHP an opportunity to comment on the project if it would have adverse effects on historic resources.

6.1.1 Literature Relating to the Economic Impact of Historic Preservation

Benefits due to the compliance with the historic preservation act are recognized and attributed to be a preservation of a public good. Previous studies argued for the public nature of the historic properties because the market is expected to fail in recognizing and capturing the benefits of protecting such property. Kling (2004) argued that estimating the benefits generated by complying with the historic monuments preservation regulations action was tied to the recognition of the value of a historic building or monument as the protection of a public good. When contacted by the project team, Kling added that "there has been a major impediment to the consistent application of efficiency criteria to decisions about public projects, particularly when the benefits extend beyond 'use values' and also include option prices[69] and so-called bequest and existence values[70]. Because of the importance of such non-use values in the case of the historical preservation, these areas have been the most frequent contexts for application of stated-preference valuation (SPV) and related approaches.

The costs associated with complying with Section 106 the National Historic Preservation Act include:

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[68] Source: FEMA http://www.fema.gov/pdf/ehp/deskrefd.pdf

[69] Option Price is the amount that individuals are willing to pay for policies prior to the realization of contingencies.

[70] Existence Value is the individuals willing to pay for existence of good that they will never "consume" because they believe the good has intrinsic value apart from its use. They could be driven by the desire for others to enjoy its existence.

- The cost of agency coordination and environmental studies to determine the presence of historic resources & potential for adverse affect.
- The cost of project delays (if any).
- The added cost (if any) of project alternatives that avoid historic sites.
- Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and administration, construction costs.

The economic impact of historic preservation has been the topic of many State studies over the past 15 years. The results of these studies has generally been very positive suggesting that the economic benefits associated with tourism, income generated through preservation activities and rising housing prices have exceeded the costs of historic preservation. Though these studies are not directly related to Section 106 restoration activities tied to transportation projects, they are certainly relevant when considering the tradeoffs between project costs and the economic benefits of restoration activities.

The Center for Urban Policy Research at Rutgers University in cooperation with Texas Perspectives and the LBJ School of Public Affairs at the University of Texas prepared a report on the economic impact of historic preservation in Texas. The study found that incentives for historic preservation results in reinvestment, which generates thousands of in-State jobs. Private property owners invest more than $172 million annually to support historic building rehabilitation activities. The investment in historic rehabilitation generated 4,200 jobs in 1997. Finally, the study also found that Texas heritage tourism generates roughly $1.43 billion annually.[71]

The Center for Urban Policy Research at Rutgers (2001) also studied the economic impacts of historic preservation in Missouri concluding that historic preservation activity generated in excess of $1 billion in annual economic activity supporting 42,353 jobs.[72] This estimate includes both the direct effects and indirect and induced effects of historic preservation activities.

In Florida, the Center of Urban Policy Research at Rutgers and the Center for Government Responsibility at Florida (2002) examined the economic impacts of historic preservation in Florida.[73] The study examined both the direct and indirect and induced economic impact of historic preservation. Thus, the study included the impact of the multiplier effect as the impact of initial construction and the income generated through these activities rippled through the economy. The authors used an input-output (I-O) model to examine the specific economic effects of historic preservation generating the following conclusions:

- In 2000, $5.4 billion was spent on rehabilitation projects in Florida and 6.5 percent of the total amount ($350 million) was tied to historic projects.

[71] The Center for Urban Policy Research at Rutgers University in cooperation with Texas Perspectives and the LBJ School of Public Affairs at the University of Texas. "Economic Impacts of Historic Preservation in Texas." New Brunswick, New Jersey. 1999.

[72] Center of Urban Policy Research at Rutgers University. "Economic Impacts of Historic Preservation in Missouri." December 2001. New Brunswick, New Jersey.

[73] The Center for Urban Policy Research at Rutgers University and Center for Governmental Responsibility at the University of Florida. September 2002. New Brunswick, New Jersey.

- The total economic impact of the money spent on historic rehabilitation resulted in 15,258 new jobs, income of $465 million, $729 million in Gross Domestic Product (GDP) and $111 million in tax revenue.
- In 2000, heritage tourism accounted for $3.7 billion in spending in Florida and generated 140,789 jobs, $3.4 billion in income, $6.5 billion in GDP, and $1.4 billion in tax collections.

Lennox and Revels (2000) studied the economic impact of historic preservation activities in South Carolina. The authors found that historic preservation activities created 400 jobs annually, that historic preservation drives heritage tourism bringing in $325.6 million in annual direct spending in South Carolina and that historic preservation spurs the revitalization of downtown areas.[74]

Clarion Associates in association with BBC Research and Consulting measured the economic benefit of historic preservation in Colorado. This study found that since 1981, historic preservation activities had generated in excess of $2 billion in economic activity and almost 29,000 jobs. Heritage tourism was found to create more than $3 billion annually in direct and indirect economic impacts supporting 60,964 jobs.[75]

Leithe and Tigue studied the economic impact of historic preservation in Georgia. The authors found that from 1992 to 1996, historic rehabilitation generated 7,550 jobs, $201 million in earnings and $559 million in total economic activity. The study also found that historic preservation correlated positively with growth in property values. Finally, the study attributed roughly half of Georgia's nearly $15 billion annual tourist industry to visitors drawn to historic attractions.[76]

Leichenko, Coulson and Listokin studied the impact of designations of historic districts on housing prices in nine Texas cities and found that a historic designation of a neighborhood correlated with average property value increases of 5 to 20 percent. Among the nine cities studies, the percentage change in value from a historic designation was greatest in Nacogdoches (+20.1 percent) and lowest in Dallas (+4.9 percent).[77]

A study of the impact of historic districts on housing prices in South Carolina found that houses in historic districts sold for between 11 percent (Georgetown) and 36 percent (Anderson) more than comparable houses not located in historic districts. Furthermore, the study found that in Columbia, housing prices in historic districts grew 26 percent faster than the entire housing market.[78]

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[74] Lennox, C. and Revels, J. "Smiling Faces Historic Places: The Economic Benefits of Historic Preservation in South Carolina." Columbia, South Carolina. January 2000.
[75] Clarion Associates in association with BBC Research and Consulting. "The Economic Benefits of Historic Preservation in Colorado. July 2005. Denver, Colorado.
[76] Leithe, J. and Tigue, P. "Profiting from the Past: The Economic Impact of Historic Preservation in Georgia." Government Finance Review. April 2000. Chicago, Illinois.
[77] Leichenko, R., Coulson, N, and Listokin, D. "Historic Preservation and Residential Property Values: An Analysis of Texas Cities." Urban Studies, Vol. 38, No. 11, 1973-1987. 2001.
[78] South Carolina Department of Archives and History. "Historic Districts Are Good for Your Pocketbook: The Impact of Local Historic Districts on House Prices in South Carolina." Columbia, South Carolina. January 2000.

The studies outlined in this section generally rely on I-O modeling to measure the economic impacts of historic preservation activities on job, income and tax revenue growth. To the extent that historic preservation activities enhance property values or result in heritage tourism, these benefits are unique to historic preservation. To examine the full impact of historic preservation, a study would need to measure non-use or indirect benefits associated with the value citizens place on historic assets, measurable through an analysis of their willingness to pay in order to preserve them.

6.1.2 Qualitative Impact of Higher Compliance with Section 106 of the National Historic Preservation Act

It is difficult to evaluate the benefits and costs of compliance with section 106 Historic Preservation Act because historic preservation derives its significance from the values that living people attribute to it. These values are heritage tourism, intrinsic, cultural, subjective, and judgmental values rather than monetary values. That is, individuals have a willingness to pay to capture the various direct use values (e.g., site visits, education) as well as non-use values (e.g., option to visit, desire to bequest asset on future generations, benevolence motive) they derive from historic sites. The remainder of this section is devoted to examining research that investigates the qualitative impact of Section 106 of the National Historic Preservation Act and the value that individuals place on the presentation of historic sites.

Slattery and Jacobitz (2004) found that the FHWA, often working through State DOTs was effectively accounting for the effects of road projects on historic properties. In their report, the authors describe the recent work of two State agencies: the Nebraska Department of Roads (NDOR) and FDOT, which are collectively leading the way by adopting proactive approaches toward preserving and revitalizing sites of historic significance. The authors emphasize that these two agencies have used thoughtful planning, interagency cooperation, context-sensitive design solutions, and strong partnerships with the FHWA in their approaches to recent projects. The authors describe the NDOR's comprehensive Statewide survey of historic properties along five of the State's earliest automobile routes and the FDOT's work in Ybor City (an historic section near Tampa that is divided by Interstate Route 4). The authors conclude that Section 106 regulations represent an opportunity to incorporate historic preservation into the planning of future transportation infrastructure.

Kling (2004) applies the Contingent Valuation Method (CVM) to estimate the public good values of preservation and restoration of a local historic landmark in Fort Collins, Colorado. The survey device entailed a referendum-style dichotomous-choice question designed to evaluate the participation on the part of the city in the restoration of a historic hotel in Fort Collins' downtown to its 1930s appearance. The project was estimated to cost $10 million with financing coming from the State of Colorado Historic Fund and the City of Fort Collins. The cost to city residents has amounted to approximately $670,000 or $17 per household.

Kling (2004) findings raised the question of who benefits from the historic preservation and found that the public interest is the driver behind such restoration.[79] The authors of this study concluded that the level of public involvement appeared to be economically rational because the willingness to pay (WTP) survey results showed a consistency between the people's desire (valued through the CVM exercise) and the funds contributed by the State and the city.

On the benefits side of the compliance with Section 106, Barrett (1999) claimed that there is an indirect and as yet unrecognized benefit associated with Section 106 compliance. The benefit in question is the information that project management gathers at the historic sites. Barrett argued for this information to become publicly available:

> *" the public benefit provisions are a major step forward in sharing with the public the information gained through Section 106 compliance. Many times significant dollars are spent on researching, recording, or excavating a historic property and then the results are simply filed away and are not accessible to those with an interest in history or archeology, let alone regular citizens. Increasingly, agencies are recognizing that it is critical to build public support and to show results".*

Barrett (1999) continued on within the same report to further examine the significant educational benefits associated with Section 106 compliance.

6.2 Section 106 Benefits

The benefits associated with Section 106 are extensive and well documented. The literature review and interviews conducted in support of this study identified numerous benefits associated with historic preservation. These benefits are tied to the economic activity resulting from historic preservation activities, to the tourism generated by the presence of historical places, to enhanced property values near historic monuments and neighborhoods and the non-use values tied to the education and maintaining the Nation's cultural legacy.

Section 106 is designed to identify historic resources, assess the adverse effects of transportation projects and provide for a process for addressing these adverse effects. In doing so, mitigation measures are developed. These measures may include data recovery in archeological sites, signage, restoration and rehabilitation of historic properties, documentation of historic properties, relocation of historic buildings and creation of educational videos. When adverse effects cannot be appropriately mitigated, Section 106 may result in project design changes.

Why protect our cultural heritage? The answer to that question underlies the benefits of Section 106 of the National Historic Preservation Act.

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[79] Kling, Robert W. Charles F. Revier and Karin Sable. 2004 "Estimating the Public Good Value of Preserving a Local Historic Landmark: The Role of Non-substitutability and Citizen Information." Urban Studies, Volume 41, No. 10, pp 2025-2041

Heritage tourism involves visits by tourists to historical sites, museums, monuments, parks, districts and other historical sites. Historic preservation enhances tourism opportunities and numerous studies site the economic benefits of heritage tourism. In Georgia, for example, tourism generated $15 billion in spending in 1996 and of the tourists surveyed, nearly half indicated that they planned to visit a historically significant site during their stay.[80] Historical national parks in Georgia entertained nearly four million visitors in 1996.

Heritage travelers account for more than 11 percent of visitors to Texas, spending roughly $1.43 billion annually.[81] Studies conducted in Florida, Missouri, South Carolina, Maryland and New York all confirm that heritage tourism represents a major source of economic activity.

Historic preservation projects have also been shown to enhance property values in numerous studies. Historic preservation is viewed as an important tool for community development and is used to enhance livability by identifying, maintaining and enhancing historic resources. In States across the U.S. (e.g., Maryland, Texas, Florida, Missouri, New Jersey, New York), studies show that the value of property located within historic districts or near historic resources is higher and has experienced historic growth rates that exceed those for property not located near historic properties. For example, historic designations in Texas were reported to increase property values by approximately 20 percent.[82]

Numerous studies highlight the impact of historic preservation activities on economic activity and job creation. These studies find that preservation activities create jobs, rebuild communities, promote reinvestment in aged infrastructure, generate income and enhance tax collections. Many of these studies were highlighted previously in this report.

The principle benefit of Section 106 expressed by the experts interviewed for this study is also the most difficult to measure. It involves the maintenance of our cultural legacy. Section 106 requires that DOTs assess the negative impacts of transportation construction on historic resources and investigate alternatives in order to protect national historic places. Section 106 also requires the documentation of history by requiring archeological and historical analysis of our nation's historic resources. This requirement maintains our connection to the past.

6.3 Section 106 Costs

Section 106 limits the destructive effects of Federal transportation projects on historic sites through the application of a system process designed to ensure that historic properties are identified and alternatives are considered in order to preserve the Nation's cultural legacy. The Section 106 process includes numerous steps:

- Identify whether or not the project impacts historic resources,

[80] Leithe and Tigue (2000).
[81] The Center for Urban Policy Research at Rutgers University in cooperation with Texas Perspectives and the LBJ School of Public Affairs at the University of Texas. (1999).
[82] Leichenko, R., Coulson, N, and Listokin, D. (2001).

- Identify the effected properties,
- Determine impacts of the project on the properties, and
- Report the properties and any adverse effects to the State Historic Preservation Officer and/or Tribal Historic Preservation Officer, as appropriate, and provide for ACHP comment if there are adverse effects from the project,
- Determine how to address these impacts through mitigation and design solutions.

The seemingly simple process outlined above can be time consuming and expensive depending on the historical significance of properties impacted by transportation projects. Provided that historical properties are identified early in the project development process, mitigation costs are generally reasonably low compared to the costs associated with complying with other Federal regulations. When the historical significance of properties effected by a transportation project is not identified early, however, agencies may be required to undergo expensive redesign and realignment procedures.

Those interviewed for this study indicated that in nearly all cases, the costs associated with Section 106 compliance are less than two percent of total project costs. When historically significant sites are involved and mitigation measures are identified early on in the project development process, compliance costs increase but would not be expected to exceed four percent of project costs. The State of California tracks and manages environmental costs through the department's Capital Outlay Support (COS) Standard Work Breakdown Structure (WBS). The WBS enables project managers to maintain control over work content and manage budgets. The WBS includes codes associated with performing environmental studies and developing draft environmental documents (WBS 165) and codes tied to conducting historic studies (WBS 165.2020). A Caltrans representative interviewed for this study indicated that an analysis of the WBS system demonstrated that environmental costs were roughly seven percent of project costs and that the costs associated with conducting historic studies in California represented less than one percent of project costs.[83] These costs, however, are not necessarily absolutely attributable to Section 106 compliance. For example, the California Environmental Quality Act (CEQA) contains some provisions that are similar to Federal standards. Even in the event that Section 106 was repealed, Caltrans would continue on with its preservation activities.

6.3.1 Historic Preservation Requires Close Coordination With a Diverse Set of Stakeholders

The experts interviewed for this study conclude that historic preservation costs are most significant when Section 106 is not included in the early phases of the project design and communication between the stakeholders is inadequate. The coordination of historic studies is a complicated process due in large part to the nature of the interested parties, which includes a diverse set of interests. Participants in the Section 106 process include:

- Federal agencies,
- ACHP,

[83]

- State Historic Preservation Officer (SHPO) and/or Tribal Historic Preservation Officer (THPO),
- State agencies,
- Local agencies,
- Tribes and native Hawaiian organizations,
- Preservation advocacy groups, and
- General public.

To coordinate Section 106 activities States employ archeologists, historians and planners, who are dedicated to historic preservation activities. In California, there is roughly 100 staff located in 12 district offices across the State principally dedicated to Section 106 compliance.[84] In Pennsylvania, there are roughly 14 archeologists and historic structure specialists dedicated to Section 106.[85] The Minnesota DOT has established a cultural resources unit where six members are charged with implementing Section 106 activities.

6.3.2 Section 106 Streamlining Activities

Many of the individuals interviewed for this study highlighted streamlining efforts designed to reduce the complexity and cost associated with Section 106 compliance. Among these activities, programmatic agreements (PAs) designed to make the process more systematic and improve coordination are perhaps the most significant. In Minnesota, a PA between Minnesota DOT, the SHPO, FHWA, ACHP and the U.S. Army Corps of Engineers specifies that there is no need to wait for SHPO concurrence on most projects and information is filed electronically. Due in large part to a similar PA, roughly 80 percent to 85 percent of all projects are screened by Caltrans and do not require extensive SHPO review. In Vermont, PAs have been developed around bridge projects. The Vermont DOT has entered into a PA with the ACHP, SHPO and the FHWA.

Further streamlining activities include historic property surveys, GIS mapping of historic properties and bundling of Section 106 compliance with other environmental regulation compliance activities.

[84] Buss (2005).
[85] Martin, Cheryl. Personal Interview. June 2005.

APPENDIX A: REGULATION MATRIX

Environment

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
National Environmental Policy Act	23 CFR 771-772 40 CFR 1500-1508 Executive Order 11514 as amended by Executive Order 11991 on NEPA responsibilities	Umbrella legislation for considering environmental factors during project development. Project sponsors must demonstrate informed consideration of impacts to reasonable project alternatives (including a no-build alternative).	Consider environmental factors through systemic interdisciplinary approach before committing to a course of action.	1. Generates and organizes information needed for informed decision-making. 2. Promotes "open" and "transparent" decision-making for publicly-funded actions. Clearly defined decision-making process during project planning & design. 2. Reduces the negative human and natural environmental impacts associated with Federal-aid construction projects. 3. Enhances direct (e.g., consumption of natural resources, recreational opportunities, presence of habitat, protection or enhancement of social and economic structures) and indirect (bequest, existence) benefits to humans.	1. Cost of agency coordination & preparation of environmental documents (CE, EA, or EIS). 2. Elements of NEPA (e.g., the decision to not file an impact statement) open states and local agencies up to environmental litigation. 3. Marginal added cost to project associated with the selection of a higher cost but less environmentally damaging alternative. 4. Mitigation costs. 5. Costs associated with the time required to complete environmental studies and documentation, which in some cases exceeds the time required for other project functions.	Many States have NEPA-like laws. If eliminated, NEPA decision-making would be replaced in part by other processes. Some NEPA document preparation costs are part of overall project design phase. NEPA impacts/costs vary widely on individual projects. Variety of data on number & timeframe of documents collected by FHWA.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 4(f) of The Department of Transportation Act	23 CFR 771.135	The 1966 Act that requires specific analysis of potential effects on public park and recreation lands, wildlife and waterfowl refuges, and historic sites. Affected projects must demonstrate no prudent and feasible alternative to using that land; and include all possible planning to minimize harm.	Preserve publicly owned parklands, waterfowl and wildlife refuges, and significant historic sites.	1. Preservation of States' 4(f) properties e.g. parklands, etc.	1. Cost of agency coordination & preparation of 4(f) evaluations - may involve studies similar to Section 106. 2. Cost of delays (if any). 3. Marginal added cost of alternative that avoids 4(f) impacts. 4. Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and admin, construction costs 5. Cost of maintaining mitigation sites (if any).	Section 4(f) impacts/costs vary widely on individual projects. States may have laws that protect parkland and historic sites. Variety of data on number & timeframe of documents collected by FHWA.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 404 of the Clean Water Act	DOT Order 5660.1A 23 CFR 650 Subpart B, 771 33 CFR 209, 320-323, 325, 328, 329 40 CFR 121-125, 129-131, 133, 135-136, 230-231	Section 404 of the Clean Water Act (CWA) is overseen by the US Army Corps of Engineers (USACE), which issues permits, with additional oversight from the US Environmental Protection Agency (EPA). It operates according to the principle of no net loss of wetlands; requiring a sequence of avoid, minimize, enhance and compensate for impacts on wetlands. For major transportation projects, an individual Section 404 permit may be required. Individual permits require extensive scrutiny, the preparation of reports and the completion of an alternatives analysis.	To prevent, reduce, and eliminate water pollution by regulating dredge and fill activities in navigable waters of the U.S. This includes avoiding direct or indirect support of new construction in wetlands wherever there is a practicable alternative.	1. Protection and preservation of States' wetlands and waterways, including water quality and habitat. 2. Direct (e.g., recreational opportunities in wetland areas, hunting), and indirect (e.g., preservation of animal habitat, existence values) environmental values. 3. Health benefits.	1. Cost of agency coordination and environmental studies/permit application. 2. Cost of delays (if any). 3. Marginal added cost of preferred project alternative. 4. Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and admin, construction costs. 5. Cost of maintaining mitigation sites (if any).	Section 404 impacts/costs vary widely on individual projects. Many States have laws protecting wetlands. FHWA tracks annual acreage of wetlands mitigated.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 10: Rivers and Harbors Act	23 CFR 650, Subparts D & H 33 CFR 114-115	Section 10 of the Rivers and Harbors Act covers construction, excavation, or deposition of materials in, over, or under such waters, or any work which would affect the course, location, condition, or capacity of those waters. Activities requiring Section 10 permits include structures (e.g., piers, wharfs, breakwaters, bulkheads, jetties, weirs, transmission lines) and work such as dredging or disposal of dredged material, or excavation, filling, or other modifications to the navigable waters of the United States.	Protects wetlands and waterways and ensures no obstructions occur to navigable waters as a result of dredging, fill, or construction of structures.	1. Preservation of waterways. 2. Benefits to maritime operations associated with maintaining a clear channel.	1. Cost of environmental studies/permitting. 2. Cost of delays (if any). 3. Marginal added cost of preferred project alternative. 4. Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and admin, construction costs. 5. Cost of maintaining mitigation sites (if any).	Section 10 impacts vary on individual projects. Usually bridge projects have biggest impacts.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 402: Clean Water Act	DOT Order 5660.1A 23 CFR 650 Subpart B, 771 33 CFR 209, 320-323, 325, 328, 329 40 CFR 121-125, 129-131, 133, 135-136, 230-231	The National Pollutant Discharge Elimination System (NPDES) program—required by Section 402 of the CWA—regulates discharges from point sources to waters of the United States. Point source is defined by the CWA as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or floating craft, from which pollutants are or may be discharged." This includes storm water discharges. Such discharges are regulated through permits, which are a license for a facility to discharge a specific amount of a pollutant into a water body, under certain conditions.	To prevent, reduce, and eliminate water pollution by regulating discharges from point sources, including construction sites, maintenance facilities, etc. to U.S. waterways.	1. Better erosion control and protection of water quality. 2. Health benefits. 3. Other direct (e.g., improved fish runs) and indirect (e.g., sustained waterway habitat) environmental benefits.	1. Cost of agency coordination and environmental studies/permits 2. Implementation of Best Management Plans 3. Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and admin, construction costs. 4. Compliance costs for industry.	NPDES requirements vary by project. Because highways are "receptors" of discharges from other sources (abutting properties, etc.), and States operate sites such as maintenance yards, this statute has consequences in the maintenance and operations areas as well.
Coastal Zone Management Act + Amendments	15 CFR 923, 926, 930 23 CFR 771	Broad ranging legislation that creates a partnership among Federal, State, and local governments to address problems caused by competing coastal pressures.	Protects coastal natural resources as well as broader ecological and geological functions of coastal areas. Manage non-point source pollution of activities located in coastal zones.	1. Improved coastal habitat. 2. Reduced damage to coastal environments. 3. Enhanced recreational opportunities due to improved sustainability of coastal areas. 4. Economic benefits associated with coastal tourism.	1. Cost of agency coordination and environmental studies. 2. Marginal added cost of preferred project alternative. 3. Cost of delays (if any).	States often have similar laws.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 7 of the Endangered Species Act	7 CFR 355 50 CFR 17, 23, 81, 222, 225-227, 402, 424, 450-453	Under the ESA of 1973, Federally authorized or funded projects must not jeopardize the existence of threatened or endangered species. The consultation process established by Section 7 of the ESA requires all Federal agencies to coordinate with US Fish and Wildlife Service (FWS) to determine potential project-level impacts on listed species and to develop project alternative measures to minimize impacts.	Conserve species of fish, wildlife and plants facing extinction.	Support for preservation of endangered species. Maintain healthy ecosystems and biodiversity	1. Cost of agency coordination and environmental studies (Biological Assessment & FWS/NMFS consultation, Biological Opinion, if necessary) 2. Cost of delays (if any) 3. Marginal cost of preferred project alternative	Section 7 impacts vary widely on individual projects.
Executive Order 12898: Environmental Justice	59 CFR 7629, 62 CFR 18377, 60 CFR 33896	A 1994 Presidential Executive Order directed every Federal agency to make environmental justice part of its mission by identifying and addressing the effects of all programs, policies, and activities on "minority populations and low-income populations."	Avoid Federal actions which cause disproportionately high and adverse impacts on minority and low income populations with respect to human health and the environment.	1. Reduction in disproportionate adverse impacts on minority and low income populations and communities at the project level.	1. Cost of agency coordination and environmental studies. 2. Marginal added cost of preferred project alternative. 3. Cost of delays (if any).	
Noise Standards: 23 U.S.C. 109(i)	23 CFR 772	The FHWA noise regulations require that abatement measures be considered when highway traffic noise impacts are identified and that the abatement measures be implemented when they are determined to be reasonable and feasible.	Promulgate noise standards for highway traffic.	1. Address noise pollution. 2. Health impacts.	1. Cost of environmental studies. 2. Cost of delays (if any). 3. Marginal cost of preferred project alternative. 4. Mitigation costs (if any) including some or all of: ROW acquisition, planning and design, construct engineering, admin, construction costs.	Noise impacts vary widely on individual projects. FHWA tracks costs and mileage of noise barriers constructed.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Conformity Rule of Clean Air Act	40 CFR 51 and 93	The transportation conformity process is intended to ensure that transportation plans, programs, and projects will not create new violations of the National Ambient Air Quality Standards (NAAQS); increase the frequency or severity of existing NAAQS violations; or delay the attainment of the NAAQS in designated nonattainment (or maintenance) areas.	To restrict Federal funding and approvals for highway projects in States that fail to submit or implement an adequate State Implementation Plan (SIP).	1. Control of mobile source emissions that contribute to air quality problems. 2. Health impacts	1. Cost of agency coordination & environmental studies.	
Labor						
1931 Davis Bacon Act, as amended by 1991 Intermodal Surface Transportation Efficiency Act. *Payment of Predetermined Minimum Wages.*	23 USC 113, 40 USC 276 (a) & (c)	Requires the payment of locally established prevailing wages and fringe benefits to laborers and mechanics employed on Federal-aid highway construction contracts located on a Federal-aid highway.	Davis Bacon precludes contractors from hiring low-cost labor contractors from outside local areas and increases the distribution of income and capital throughout the U.S.	1. Encouraging the recruitment and training of skilled labor. 2. Promotes high construction quality. 3. Local economic development. 4. Local employment. 5. Increased local income levels.	1. Costs associated with program administration for both the public and private sector. 2. In certain states, costs associated with higher contract prices may result from published prevailing wages being higher than free-market wages.	Many States have enacted their own version of the Davis Bacon Act. Higher contracting costs could be measured by comparing equivalent Federal-aid and non Federal-aid State highway programs.
Copeland Act *Statements and Payrolls*	40 USC 276 (a) & (c), 18 USC 874	Prohibits any contractor from encouraging or forcing an employee to give up any part of the compensation entitled under the employment contract. Requires the filing of weekly payroll statements.	To protect employees from paying kickbacks and to ensure compliance with the Davis Bacon Act.	1. Increased local income levels. 2. Increased compliance with prevailing current wage laws. 3. Reduced incentives for corruption.	1. Costs associated with program administration and compliance for both the public and private sector. 2. Costs associated with higher than free-market wages.	

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Federal-Aid Highway Act of 1968 Federal-Aid Highway Act of 1970 23 USC 140*On the Job Training (OJT)*	23 CFR 230 (A) 23 U.S.C. 140(a) 23 U.S.C. 140(b)	Allows apprentices to work at a lower than the journeyman established wage rate for a State Transportation Agency (STA) registered apprenticeship program or an approved training program of the US Department of Labor.	The main objective of this legislation is to train and give upward mobility to women, minorities and those on welfare.	1. Encouraging the recruitment and training of skilled labor. 2. Increased opportunities for women and minorities. 3. Economic rehabilitation for those on public assistance.	1. Administrative costs for both the STA and the construction contractor associated with the registration and monitoring process for OJT programs.	
ISTEA of 1991 Convict Labor and Convict Produced Material 23 USC 114(b)*Use of Convict Labor*	23 U.S.C. 114(b) 23 CFR 635.117	Prohibits the use of convict labor or convict produced material on any Federal-aid construction site located on a Federal-aid highway..	To ensure fair competition in the bidding process for Federal-aid contracts.	1. Ensures greater equity in the contracting process as defined by the law. 2. Increases local income and employment levels.	1. Reduces competition slightly for selected products and work types. 2. Eliminates a potential source of low cost labor.	
Drug-Free Workplace Act of 1988 *Drug - Free Workplace*	49 CFR 29 23 CFR 630.307(c)(3)	Requires grantees from direct recipients who receive assistance directly from a Federal agency to verify that they will maintain a drug free workplace and impose sanctions. This does not apply to Federal-aid contractors.	To reduce drug related activities.	1. Decreased incidence of drug related activities in Federal-aid recipients' workplaces. 2. Improved productivity and enhanced operational safety.	1. Costs incurred by STAs for guaranteeing, maintaining and enforcing a drug-free workplace.	

Civil Rights						
Legislative Reference	**Regulatory Reference**	**General Overview**	**Purpose/Goals of Regulation**	**Major Benefits**	**Major Costs**	**Other Issues**
The Civil Rights Act of 1964 The Age Discrimination and Employment Act of 1967 The Age Discrimination Act of 1975 The Americans with Disabilities Act of 1990 Federal-Aid Highway Act of 1973. 23 USC 140*Nondiscrimination*	23 U.S.C. 140 23 U.S.C. 324 23 CFR 200 23 CFR 230A and D 28 CFR 35 29 CFR 1630 41 CFR 60 49 CFR 21 49 CFR 23	Requires State assurance that no person shall be excluded on the grounds of race, color, or national origin from participation or be subjected to discrimination under any program or activity which receives Federal-aid assistance from the Department of Transportation. Federal-aid policy requires all construction contractors to have an Equal Employment Opportunity policy.	The main objectives are to ensure that Federal assistance will not be used to discriminate and to increase participation of minorities and women in the work force.	1. Encourages fair competition in the labor force. 2. Enhances income and opportunity to minority and otherwise disadvantaged individuals.	1. Costs associated with monitoring contractor compliance of nondiscrimination requirements. 2. Costs associated with implementing Federal nondiscrimination policies (e.g. periodic reviews, paper costs, EEO officer labor costs).	
STURAA of 1987 ISTEA of 1991 23 USC 140(d)*Indian Preference*	23 U.S.C. 140 23 CFR 635.117	Permits States to use hiring preferences towards Native Americans on Federal-aid projects located on or near Native American Reservations.	To extend employment opportunities for Native Americans on all eligible Federal-aid highway projects.	1. Economic development and increased income levels for Native American communities. 2. Builds local Native American economies.	1. Costs of contracts potentially awarded to less competitive (i.e. price or quality) firms. 2. Potential negative impacts on competition.	

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Civil Rights Act of 1964 STAA of 1982 STURAA of 1987 ISTEA 1991 *Disadvantaged Business Enterprises*	49 CFR Part 26 (DBE Regulations) 49 CFR Part 21 (Title VI Regulations) 23 USC 140(c) 23 CFR 200 & 230	As a national goal, this requires no lower than 10% participation of disadvantaged business enterprises (DBE) in Federal-aid funded projects.	The main objective of the DBE Program is to ensure that enterprises owned by minorities, women and otherwise disadvantaged businesses are provided an opportunity to participate in DOT funded contracts.	1. Increased income and economic opportunities for minorities, women and otherwise disadvantaged individuals.	1. Costs incurred by the FHWA with the approval process for State DBE programs. 2. Costs incurred by the State in administering the DBE program (e.g. certifying and monitoring DBEs). 3. Costs incurred by businesses receiving DBE certification. 4. Costs of contracts potentially awarded to less competitive (i.e. price and quality) firms.	Many States have enacted their own version of this rule.
Executive Order 11246 *Nonsegregated facilities*	23 CFR 633A	All Federal-aid construction contractor facilities must be non-segregated.	To ensure the elimination of past discriminatory practices of providing separate facilities or prohibiting minorities access to facilities.	1. Improves social equity. 2. Enhances minority employment opportunities.	1. Costs incurred by contractors in attaining guarantee that subcontractor facilities are not segregated.	
Material Standards and Documentation						
STAA of 1982 and ISTEA of 1991 *Buy America*	23 CFR 635.410	A mandate for all Federally funded construction projects to purchase steel and iron domestically.	To support the US economy and the domestic steel industry.	1. Economic support for the domestic economy. 2. Increased domestic income, GDP and employment. 3. Advancement of the U.S. steel industry.	1. Costs from possible above-market prices resulting from decreased competition and restrictions on the use of potential lower-cost foreign suppliers.	

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
No legislative reference *Record of Materials, Supplies, and Labor*	23 CFR 635.126	Federal-aid project contractors are required to submit Form FHWA-47, "Statement of Materials and Labor Used by Contractors on Highway Construction Involving Federal Funds."	To support a database on usage of various construction materials.	1. More knowledge in the bidding process. 2. Availability of information. 3. Potentially reduced prices due to more knowledge of industry costs.	1. Costs incurred by the FHWA from checking, coding and entering data. 2. Costs incurred by the contractor from filing forms and complying with the regulation.	
STURAA of 1987 *Convict Produced Materials*	23 U.S.C. 114(b)(2) 23 CFR 635.417	Convict produced materials not permissible on Federal-aid projects unless: 1) convicts are on parole, supervised release or on probation from prison 2) materials were produced in a qualified prison facility.	To ensure fair competition in the bidding process for Federal-aid contracts.	1. Enhanced equity in the bidding process. 2. Enhanced local income and employment for non-convict labor force.	1. Reduced access to low-cost labor.	
Competition						
No legislative reference *Noncollusion Statement*	23 U.S.C. 112 23 CFR 635.112(f)	Requiring submission of a non-collusion statement by Federal-aid construction contracts.	The goal is to deter collusion on Federal-aid contracts.	1. Decreased incentives to collude possibly resulting in lower bid prices. 2. Enhanced integrity in bidding process. 3. Increased competition.	1. Costs associated with submission of non-collusion statement. 2. Costs incurred by investigating potential collusion activities.	Actual collusion avoided would be extraordinarily difficult to identify and measure.
No legislative reference. *Public Agencies in Competition with the Private Sector.*	23 U.S.C. 112 23 CFR 635.112(e)	Unless it is proven cost effective or an emergency exists, Public agencies are disallowed from entering into competition for Federal-aid construction projects with private enterprises.	To ensure open and competitive bidding in Federal-aid construction contracts.	1. Improved competition and fewer conflicts of interest.		

Real Property Management and Preservation

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970	49 CFR (A) 42 U.S.C. 4601	This law brought a minimum standard of performance to all Federally funded projects with regard to the acquisition of real property and the relocation of persons displaced by the acquisition of such property.	The purpose of this act is to provide for uniform and equitable treatment of persons displaced from their homes, businesses, or farms by Federal and Federally assisted programs and to establish uniform and equitable land acquisition policies for Federal and Federally assisted programs.	1. Fair treatment of land-owners and tenants displaced by direct Federal and Federal-aid projects. 2. Establishment of standards for advising affected individuals of their rights and benefits, and compensating displaced individuals. 3. Reduced negative impact on local economy.	1. The costs associated with assisting displaced tenants and businesses. 2. The costs associated with fairly compensating displaced owners. 3. Litigation costs resulting from liability arising from landowners and tenants challenges.	Protections in the Uniform Act derive from requirements of the U.S. Constitution.

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
Section 106 of the National Historic Preservation Act	Executive Order 11593 23 CFR 771 36 CFR 60 36 CFR 63 36 CFR 800	Requires Federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The process includes three key steps: 1) Are any historic properties affected by the undertaking? 2) Does undertaking have an "adverse impact" on properties? 3) Develop MOA to resolve adverse effects.	Protect, rehabilitate, restore, and reuse districts, sites, buildings, structures, and objects significant in American architecture, archeology, and culture.	1. Preservation of States' historic resources and lands.	1. Cost of agency coordination & environmental studies to determine presence of historic resources & potential for adverse affect. MOA to address any adverse affects. 2. Cost of delays (if any). 3. Marginal added cost of preferred project alternative. 4. Mitigation costs (if any), including some or all of: ROW acquisition, planning and design, construction engineering and admin, construction costs. 5. Cost of maintaining mitigation sites (if any).	Section 106 impacts/costs vary widely on individual projects. Finding of "adverse effect" in Section 106 report increases costs. States may have 106-like laws.
Fraud Deterrence						
Federal-aid Road Act of 1916 18 USC 1020*False Statements Concerning Highway Projects.*	18 U.S.C. 1020 23 CFR 633 23 CFR 635.119	Prohibits the willful falsification, distortion, or misrepresentation with respect to any facts related to Federal-aid projects.	To curb fraud, waste, and abuse on Federal-aid highway projects.	1. Deter fraud in Federal-aid highway projects. 2. Improve competition. 3. Reduce project costs by reducing fraudulent claims on public funds.	1. Costs incurred by STAs from investigating allegations of fraud with respect to Federal-aid construction contracts.	

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
No legislative reference. *Certification Regarding Debarment, Suspension, Ineligibility, and Voluntary Exclusion*	49 CFR 29	Each Federal-aid highway program contractor or subcontractor is required to certify current contractor eligibility status. Contractors are not eligible for Federal-aid projects if they are presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency. They are also ineligible if they have been convicted or had civil judgment rendered within the past three years for certain types of offenses.	To curb fraud, waste, and abuse on Federal-aid highway projects.	1. Deter fraud in Federal-aid highway projects. 2. Enhance competition and lower costs by reducing fraudulent and false claims on public funds.	1. Costs incurred by the General Services Administration (GSA) for compiling, maintaining, and distributing a list of suspended and debarred parties which are excluded from all Federal projects. 2. Costs incurred by STA's from verifying eligibility status of bidding contractors. 3. Cost incurred by STAs and FHWA in administering suspension / debarment actions.	
No legislative reference. *Certification Regarding the Use of Contract Funds for Lobbying.*	23 CFR 635.112(g) 49 CFR 20	STA's and other recipients of Federal-aid funds must submit a certification to the FHWA that it has and will not use funds to pay for lobbying activities prior to receiving funds in excess of $100,000.	To prevent the use of Federal funds to influence Congress or a Federal agency in connection with the awarding of any Federal contract or grant.	1. More efficiency in the allocation of Federal-aid highway funds. 2. Reduced project costs.	1. Costs incurred by STA's to submit paperwork verifying the non-use of Federal-aid funds for lobbying purposes.	
Miscellaneous						
Occupational Safety and Health Act of 1970 *Safety: Accident Prevention*	40 U.S.C. 333 23 CFR 635.108 29 CFR 1926	Requires the contractor to comply with all applicable Federal, State, and local laws governing safety, health, and sanitation.	To ensure that Federal, State and local health and safety standards are met in all Federal-aid construction projects.	1. Aversion of costs resulting from poor safety standards and compliance. 2. Fewer costs associated with fatalities (e.g., lost income, quality of life), injuries and accidents (e.g., property damage, investigation costs).	1. Costs incurred by DOL in periodic inspections of contract sites to ensure safety requirements are met. 2. Costs incurred by STAs in fulfilling responsibilities to ensure State safety standards are met.	

Legislative Reference	Regulatory Reference	General Overview	Purpose/Goals of Regulation	Major Benefits	Major Costs	Other Issues
No legislative reference. *Subletting or Assigning the Contract*	23 CFR 633 23 CFR 635.116	Requires that the prime contractor perform not less than 30 percent of contract work (less designated specialty work) with its own organization.	To inhibit brokering of a Federal-aid highway contract by the prime broker / contractor.	1. Deter abuse on Federal-aid highway projects. 2. Improves the direct management of the project by ensuring that the prime contractor will provide proper oversight.	1. Costs incurred by STAs evaluating and approving all subcontracts or administering a certification process for subcontractors. 2. Increased costs whenever less expensive sub-contractors could have otherwise been used to defray costs.	

APPENDIX B: INTERVIEW GUIDES

Project-Level Environmental Costs

Introduction. To help structure this discussion, we are referring to the entire range of environmental expenditures for any transportation project as “mitigation” costs. Therefore, the terms “mitigation costs” and “environmental costs” are used interchangeably in this study. We have grouped mitigation costs into four broad categories: 1) avoidance costs, 2) minimization costs, 3) compensation costs, and 4) enhancement costs. We expect that costs in each category may occur during all or some phases of project delivery:

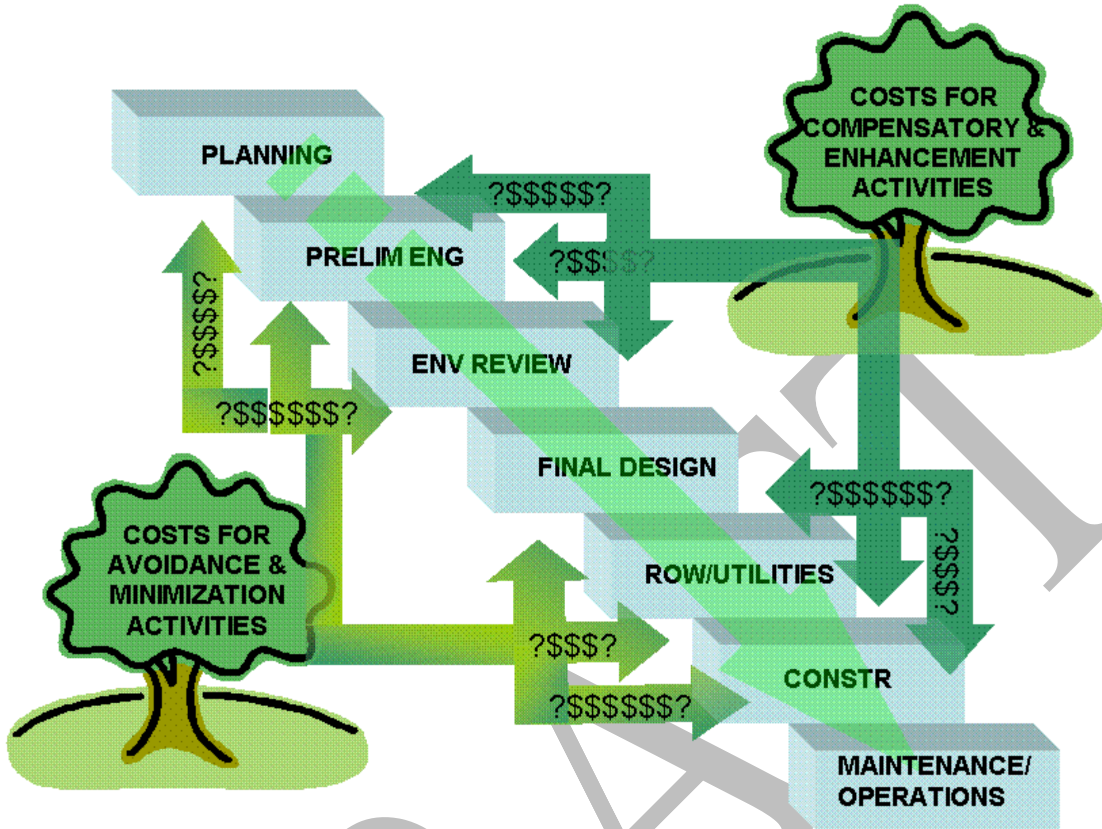
- **Avoidance and/or Minimization Costs.** Incurred when the process of planning, locating, designing, and constructing new projects and includes efforts to identify, avoid or minimize adverse environmental impacts. For example:
  - Bridge design features long spans to eliminate piers in riverbed or wetland areas;
  - Road alignment is specially located to avoid sensitive habitat, or parklands;
  - Project features storm water facilities or noise walls to minimize operating impacts; or
  - Construction activities are timed to avoid or minimize environmental impacts to threatened or endangered species.
- **Compensatory and/or Enhancement Costs.** Incurred where environmental impacts are impossible to avoid and compensatory “mitigation features” are required, such as wetlands restoration, historic resources conservation, or stream protection; or where projects add features that actually improve the environment. For example:
  - Construction of wetland/use of wetland bank;
  - Stream bed restoration;
  - Documentation of historic resource; or
  - Incorporation of environmental features in project design.

Activities in any of these categories may involve costs of different kinds, such as DOT staff time (for planning, design, NEPA, ROW, and construction), construction costs, right-of-way acquisition costs, and contractor mobilization costs. The graphic overleaf illustrates this framework for thinking about project-level environmental costs.

Part One Topic: General Background on Environmental Cost Tracking

1. Is your DOT attempting to measure any environmental mitigation costs?
2. If yes, when did you start and what was the motivation for doing so?
3. How does your agency use environmental cost data, and/or how will you use it in the future?
4. What benefits are achieved by measuring some or all project-level environmental costs?

Part Two Topic: Mitigation Costs at the Project Level



5. Following the graphic above, consider the avoidance, minimization, compensation, or enhancement activities that occur in each of the seven project delivery steps (from planning to maintenance/operations) identified, or as practiced in your state.

6. What are the types of expenditures (e.g. staff costs, contractor costs, etc.) that are incurred for each of the four mitigation categories identified in your answer above?

7. Explain which, if any, types of identified expenditures you measure. How, if at all, you are able to measure any of the mitigation-related costs you identified in Q5?.

8. For areas identified in Q5 where you are not measuring environmental costs, what are the barriers to better measurement of mitigation costs and how might measurement techniques be improved?

9. What, if any environmental activities/costs are avoided if a project does not use Federal funds, and why? Could you provide a general estimate of resultant savings?

10. Are you aware of any instances where environmental activities helped reduce overall project costs, such as if the NEPA process led to selection of a project alternative that had a more modest design scope than other alternatives? If so, please describe such case(s) and, if possible, estimate resulting cost savings.

Part Three Topic: Project Level Case Studies

11. As a separate part of the research, following the completion of these interviews FHWA would like to conduct case studies of typical projects. We are seeking a single project from your state (or projects) that you believe would be a good candidate for a detailed exploration of costs associated with mitigation, including process, avoidance, and delay costs. FHWA is seeking project(s) drawn from one of the following types:

- New roadway on new alignment (2 to 4 lanes);
- New capacity on existing roadway alignment, or major roadway reconstruction with no capacity increase but with substantial improvement/alteration of drainage or other design features including safety components;
- 3R/4R project (rehabilitation, resurfacing, minor reconstruction, relocation);
- Bridge replacement in existing location;
- Bridge replacement in new location; and
- New interchange

Additional criteria for selecting the project(s) include:

- Projects should be "typical" or "middle of the pack" in terms of the DOT's experiences with environmental compliance requirements. This means that the selected projects will not be at the highest or lowest end of the cost, time, or controversy spectrums.
- Project should be completed and open for operation.
- Project was constructed within 10 years of starting the NEPA process.

The Davis-Bacon Act

Battelle is conducting research for the Federal Highway Administration (FHWA). The research study is entitled, "*Benefits and Costs of Complying with Federal-Aid Highway Regulations.*" The research effort is designed to examine existing data, industry and project sponsor input and previous studies on the benefits and costs resulting from a small number of existing Federal highway regulations. The specific regulation that we would like to discuss with you in this interview is the Davis-Bacon Act (also known as the prevailing wage laws). This is not a survey but rather an interview aimed at gathering information concerning applied experience in complying with Davis-Bacon requirements.

A- Compliance Process

1. Please describe the key elements of the regulatory process that must be followed in order to comply with the Davis-Bacon Act.

2. How do you scale the degree of complexity associated with the compliance process with Davis-Bacon, in a scale of zero to ten relative to other State and Federal regulations (zero being relatively not complex and 10 being very complex)? What elements contribute to your rating?

3. What types of resources are deployed in the compliance with Davis-Bacon? Consider the following cost elements and discuss the burden placed on each.

    a. Project manager (s) time
    b. Employees other than the project manager involved in the Davis-Bacon compliance process
    c. Administrative, clerical and data entry time required to perform the compliance process
    d. Computer, software, bookkeeping material and other stationary material (posters, flyers and publications about prevailing wage laws) related to complying with Davis-Bacon
    e. Contract negotiation and execution
    f. Ongoing monitoring costs
    g. Efforts to conduct, search, and gather information and obtain data from the Department of Labor (DOL) related to prevailing wage requirements
    h. Other relevant Davis-Bacon Act process cost items besides the items listed above

4. Are you aware of any contradictory or duplicative requirements between Davis-Bacon and other local, State and Federal regulations?[86] If so, what are these other regulations and what are the duplicative or contradictory elements? What are the:
    a. relevant duplicative or contradictory regulations
    b. similarities and/or contradictions
    c. impacts of these similarities and contradictions
    d. which regulation(s) have a more significant impact on project costs
5. What would be the expected change in the local and State regulations if the Federal Davis-Bacon Act were to be repealed?
6. Has your agency or company been involved in any ongoing efforts to streamline compliance or to generally minimize the costs associated with Davis-Bacon compliance? Please describe such activities.
7. Regulatory action is generally viewed as a means to correct a market failure. A market failure is evident when there are factors (e.g., imperfect information, externalities) that prevent the market from achieving an efficient allocation of resources. Does Davis-Bacon properly correct a failure in the market? What is the market failure for which Davis-Bacon corrects? What is the basis of your response?
8. What would you recommend to improve efficiency in Davis-Bacon compliance, without considering the removal of the regulation?
9. Are you aware of the fact that some states have repealed State prevailing wage laws? Have you participated in projects in any of these states? How has the repeal of prevailing wage laws affected labor productivity and project costs? Has the repeal made an impact on the demographics of the labor force?
10. Do you have any further comments related to the process of complying with Davis-Bacon regulations that are specific to Federal highway projects?

B- Compliance Cost Items

1. What other types of costs (different than the compliance costs listed in question group A) are associated with the Davis-Bacon Act, including all those direct and indirect seen from the contractor, project sponsor and societal perspective? (Note to interviewer: These cost items could include higher project costs due to paying higher wages or loss of competitiveness.) Please list the cost items from most to least significant.
    a. Cost items from the **contractor's** perspective
    b. Cost items from the **project sponsor's** perspective

[86] For the purposes of this study, duplicative regulations are defined as those that achieve similar or identical regulatory goals through the application of two distinct and separate compliance processes.

a. Cost items from the **society's** perspective

2. What are the most important factors that contribute to the increase or decrease of the cost items you listed above?

    a. Factors affecting cost items from the **contractor**'s perspective

    b. Factors affecting the cost items from the **project sponsor's** perspective

    c. Factors affecting cost items from **society**'s perspectives

3. Based on your experience, estimate the marginal costs (over and above the impact of State prevailing wage laws) that Davis-Bacon imposes on projects as a percent of the total cost of the project. In what State are these exchanges occurring? What share of this cost is due to the process of compliance, and what share is due to prevailing wage requirements and other cost items?

    ☐ 0-2 percent
    ☐ 2-4 percent
    ☐ 6-8 percent
    ☐ 8-10 percent
    ☐ Greater than 10 percent

4. Are you aware of programs whereby Federal and State funds are traded between State and local project sponsors in order to minimize the compliance costs of Federal-aid highway regulations? What regulations are project sponsors hoping to avert through the funds trading? In which States are these exchange programs operated? What is the magnitude of the funds exchanges? What are the factors contributing to the exchange magnitude? Is there a discount rate applied to Federal funds during the exchange? What is that discount rate?

5. Do you have any further comments concerning the direct and indirect cost of compliance with Davis-Bacon act requirements, as specifically related to Federal highway projects?

C - Compliance Benefits Items

1. What are the major benefits resulting from the Davis-Bacon Act from the contractor, project sponsor and societal perspectives? (Please identify the benefit items from the most to the least significant.)

    a. Benefit items from the **contractor's** perspective

    b. Benefit items from the **project sponsor's** perspective

    c. Benefit items from **society's** perspectives

2. What are the most important factors that contribute to the increase or decrease of the benefit items you listed above?

a. Factors affecting benefit items from the **contractor's** perspective

b. Factors affecting the benefit items from the **project sponsor's** perspective

c. Factors affecting benefit items from **society's** perspectives

3. One of the main objectives of Davis-Bacon involves local economic development associated with keeping jobs in the areas where a Federal project is constructed. How successful is the regulation in achieving this goal, in your view?

4. Do you think the societal benefits of Davis-Bacon exceed societal costs associated with the regulation? What is the basis of your response?

5. Are you aware of any studies or datasets that could be used to better understand the benefits associated with Davis-Bacon?

6. If your State is one of the States that repealed prevailing wage regulations or do not have active prevailing wage regulations, what is your assessment of the impact of repealing (or not having prevailing wages regulations) on affected businesses? Do you think the repeal (or not having prevailing wages regulations) would have a positive or negative impact on highway construction projects? Why do you believe that to be the case?

7. Do you have any further comments concerning the direct and indirect benefits of compliance with Davis-Bacon requirements specifically related to Federal highway projects?

D- Special Cases

1. We are interested in specific case studies highlighting instances when the Davis-Bacon Act had a specific impact on Federal highway projects. Do you have project-specific information or data that would allow us to construct a case study or examine Davis-Bacon affects at the project level? Please discuss the reasons underlying the significant impact that Davis-Bacon had on the project in question.

E- Data Sources

1. Are you aware of any project data or unpublished datasets that could be used to estimate the cost impacts of Davis Bacon on projects?

2. What other data sources are available that may aid the project team in quantifying the benefits and costs associated with Davis-Bacon compliance?

3. Are you aware of studies measuring the direct and indirect impact of Davis-Bacon Act compliance? If so, will you please indicate to us the institute, project or organization that conducted the study and provide any other reference or contact information?

4. Do you have any knowledge of highway project finance data that could be used to differentiate between projects required to comply with Davis-Bacon requirements and projects that are not required to comply?

5. Are you aware of any highway construction worker wage data that could be used to differentiate between projects required to comply with Davis-Bacon versus projects that are not required to comply?

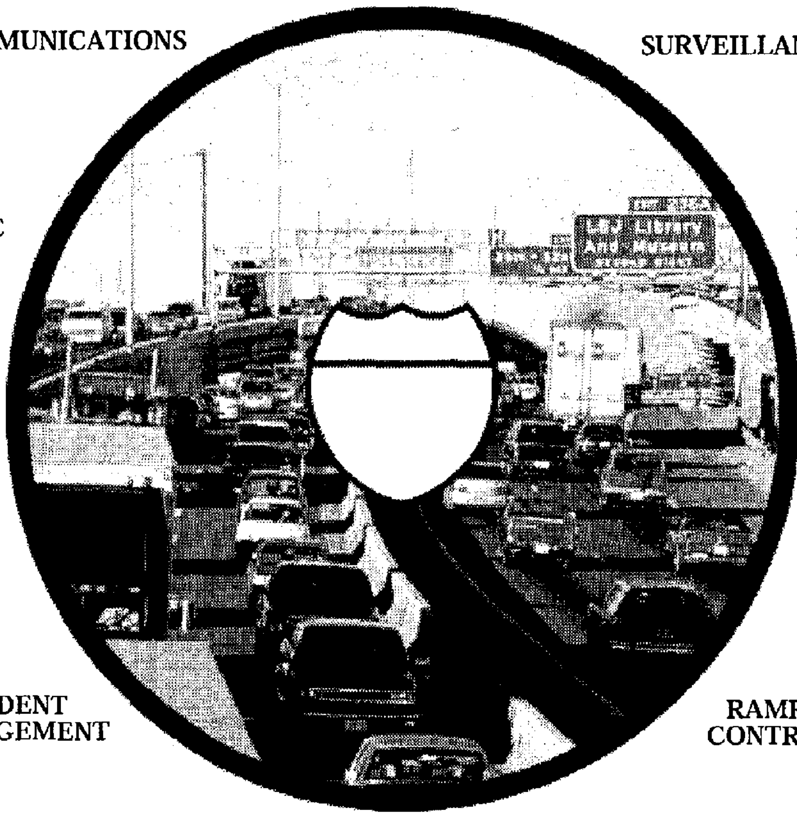
6. Are you aware of any project-level or budget data that could be used to determine the marginal costs associated with Davis Bacon compliance? If so, will you please provide the following for each set of data?
    a. The agency or the organization that collects and maintains the data
    b. The extent to which the data set is available
    c. Any information about the methodology used to collect the data
    d. Your assessment of the relative strengths and weaknesses associated with the data set.

U.S. Department of Transportation

Federal Highway Administration

FREEWAY MANAGEMENT HANDBOOK

PB98-105810



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15. Supplementary Notes
FHWA Contracting Officer's Technical Representative(COTR): Morris Oliver (HTA-30)

Abstract:
This handbook, 1997 *Freeway Management Handbook,* is an update of the 1983 *Freeway Management Handbook* and reflects the tremendous developments in computing and communications technology. It also reflects the importance of *Integrated* Transportation Management Systems and the development of the concept of Intelligent Transportation Systems (ITS). The handbook development began with a survey of current practice, including site visits and interviews, of ten Freeway Management Systems throughout the country. It was developed under the advice of a panel of freeway management practitioners' panel.

The 1997 *Freeway Management Handbook* is organized in modular fashion with each module addressing a particular aspect or technology of the freeway management task. The modules are stand-alone treatments of particular areas of freeway management but are cross-referenced to reflect their interdependence. Each module is organized as follows:
INTRODUCTION- Including Module Objective and Scope.
DECISION PROCESS- Partners and Consensus Building, Establishing Goals and Objectives, Performance Criteria, Functional. Requirements, System Architectures, Identification and Screening of Technologies, and Implementation.
TECHNIQUES AND TECHNOLOGIES - Applications specific to the module.
LESSONS LEARNED - Experiences and observations from operating systems.
REFERENCES - Comprehensive list of references used in module preparation.

Specific modules are as follows:

INTRODUCTION AND EXECUTIVE SUMMARY	6. HOV CONCEPTS
1. FREEWAY MANAGEMENT CONCEPTS	7. INFORMATION DISSEMINATION
2. DECISION PROCESS	8. INCIDENT MANAGEMENT
3. SURVEILLANCE	9. COMMUNICATIONS
4. LANE CONTROL	10. CONTROL CENTERS
5. RAMP CONTROL	11. ECONOMIC ANALYSIS

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- Mr. Morris Oliver, COTR

Office of Acquistion Management - contractual negotiations and administration.

- Ms. Lorraine Johnson

Practitioners' Panel

This panel consisted of persons who have been actively engaged in the practice of freeway management for a number of years. They provided reviews of the State of the Practice Document, the detailed outline for development of the handbook, and a review of the final draft handbook. The panel consisted of the following individuals:

- Mr. Pete Briglia, ITS Program Manager, Washington State Department of Transportation
- Mr. Glen Carlson, Manager, Traffic Management Center, Minnesota Department of Transportation
- Mr. Pat Irwin, Director of Transportation Operations, Texas Department of Transportation
- Mr. Stephen Leung, Chief, Office of Traffic Investigations, State of California Department of Transportation
- Mr. Joe McDermott, Chief, Bureau of Traffic, District 01, Illinois Department of Transportation
- Mr. Tom Werner, Director, Traffic Engineering and Safety Division, State of New York Department of Transportation

Texas Transportation Institute Internal Review Panel

This panel of TTI researchers provided periodic review and guidance during the development of the handbook in their specific fields of expertise. The panel included the following individuals:

- Mr. Charles Blumentritt, Research Scientist
- Dr. Conrad Dudek, Research Engineer
- Mr. William McCasland, Research Engineer
- Dr. Ed Seymour, Research Engineer
- Dr. Katie Turnbull, Research Scientist
- Dr. Thomas Urbanik II, Research Engineer
- Ms. Carol H. Walters, Research Engineer

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Site Visit Facilitators

As part of the development of the State of the Practice Report, the following freeway management systems were visited by the project team. These site visits were facilitated or hosted by the individuals named below.

Baltimore, Maryland

- Mr. Lee McMichael, SOC Team Manager, Maryland State Highway Administration

Phoenix, Arizona

- Mr. Jim Shea, P.E., Manager, Intermodal Transportation Division,, Arizona Department of Transportation

Atlanta, Georgia

- Mr. Bert Riddle, Assistant State Traffic Engineer, Georgia Department of Transportation
- Mr. Joe Stapleton, Assistant State Traffic Engineer, Georgia Department of Transportation

Boston, Massachusetts

- Mr. Michael J. Costa, Director, ITS Programs, Massachusetts Highway Department
- Mr. Sergiu. F. Luchian, Project Engineer, Central Artery/Tunnel, Massachusetts Highway Department

Northern Virginia

- Mr. Jimmy Chu, Transportation Center Manager, Virginia Department of Transporatation
- Mr. Pete Todd, Incident Management Team Leader, Virginia Department of Transportation

Detroit, Michigan

- Mr. Ross Bremer, Operations Manager, Michigan Intelligent Transportation Systems Center
- Mr. Ray Klucens, Operations Engineer, Michigan Intelligent Transportation Systems Center

Seattle, Washington

- Mr. Mark Leth, Transportation Management Center, Washington State Department of Transportation
- Mr. Mark Bandy, Transportation Management Center, Washington State Department of Transportation

San Francisco, California

- Mr. Jim McCrank, Traffic Systems Chief, CALTRANS District 4

New Jersey Turnpike Authority

- Mr. Robert W. Dale, P.E., Director of Operations, New Jersey Turnpike Authority
- Mr. Leo Jackson, Manager, Traffic Operations Center, New Jersey Turnpike Authority

San Antonio, Texas

- Mr. Pat Irwin, District Traffic Engineer, Texas Department of Transportation
- Mr. Mark Olson, Federal Highway Administration
- Mr. Pat McGowan, Traffic Management Engineer, Texas Department of Transportation

Houston, Texas

- Mr. Carlton Allen, Freeway Operations Supervisor, Texas Department of Transportation
- Mr. Doug Wiersig, Executive Director, Traffic Management Center, City of Houston

TRANSCOM

- Mr. Tom Batz, Manager of Technology Development, TRANSCOM
- Mr. K. R. Marshall, Manager of Traffic Engineering, Farradyne Systems, consultant to the TRANSMIT project
- Mr. Bernie Wagenblast, Operations Manager, TRANSCOM

I-95 Coalition

- Mr. Dave Gehr, Chair, I-95 Corridor Coalition Executive Board and Administrator, Virginia Department of Transportation
- Mr. Stephen R. Kuciemba, Co-Chair, Smart Routes, Boston, Massachusetts

Previous Handbook Developers

Previous freeway management related handbooks facilitated and funded by the Federal Highway Administration provided an excellent baseline for the development of the *1997 Freeway Management Handbook* and the authors would like to acknowledge those handbooks and the performing organizations that developed them.

- ***1979 Traffic Control Systems Handbook*** - Pinnell, Anderson, and Wilshire and Assoc.
- ***1983 Freeway Management Handbook*** -Allen M. Voorhees, and Assoc.
- ***1985 Traffic Control Systems Handbook*** - Pinnell, Anderson, and Wilshire and Assoc.
- ***1991 Freeway Incident Management Handbook*** - Dunn Engineering and Assoc.
- ***1993 Communications Handbook for Traffic Control Systems*** - Dunn Engineering and Assoc.
- ***1996 Traffic Control Systems Handbook*** - Dunn Engineering and Assoc.

TABLE OF CONTENTS

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MODULE 3. SURVEILLANCE

MODULE 8. INCIDENT MANAGEMENT

MODULE 9. COMMUNICATIONS

MODULE 10. CONTROL CENTER

MODULE 11. ECONOMIC ANALYSIS

LIST OF FIGURES

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LIST OF TABLES

EXECUTIVE SUMMARY

Freeways were originally conceived and designed to provide continuous, free flow, high-speed movement of traffic on a limited-access facility. In their original design, little thought was given to providing for the need of traffic management and control systems to maintain a high level of mobility on these facilities. However, as urban areas continued to grow, the freeway system became more congested. The previous approach of constructing more freeway lane-miles to relieve congestion is today often politically and socially unacceptable and economically infeasible. It is incumbent on transportation agencies planning, constructing, operating, and maintaining freeway infrastructure to make the best possible use of available capacity.

Freeway management systems are a primary means by which transportation agencies can manage traffic flow and make better use of the existing freeway system. Freeway management systems make use of control strategies and operational activities such as incident management and information dissemination to 1) keep congestion from occurring in the first place, and 2) lessen the duration and extent of congestion when it does occur.

While the term *freeway management system* was probably not applied to the tasks, early freeway management systems consisted primarily of fixed signs on the roadway providing regulatory and directional information, and police officers handling traffic following incidents. As freeway systems have matured and traffic demands have grown in urban areas over the past half century, freeway management systems have evolved and developed to provide many and varied services.

What Is Freeway Management?

The 1983 *Freeway Management Handbook* defined freeway management as the "... control, guidance and warning of traffic in order to improve the flow of people and goods on these limited access facilities."[(6)] Today, the definition of freeway management should be expanded to encompass all activities undertaken to operate a freeway facility in a manner consistent with predetermined goals and objectives of that facility, including those related to impacts on and the influence of surrounding communities and jurisdictions. Certainly, the efficient movement of goods and people continues to be one of the major goals of freeway management. However, legislative mandates, public pressure regarding environmental concerns, adjacent landowner and homeowner rights, and other issues further influence the operation of the freeway system.

In many cases, freeway management requires striking a balance between competing goals and objectives. For example, a goal to minimize recurrent congestion may not necessarily be compatible with a goal to maximize the movement of people and goods on a facility, especially if the goal to maximize people movement is accomplished through the use of high-occupancy vehicle lanes. High-occupancy vehicle lanes require a significant travel time advantage over regular-use lanes to be attractive to travelers using the freeway. In terms of this example, it may be appropriate to allow some level of congestion in the regular-use lanes in order to achieve the best overall operation of the freeway system.

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What Is a Freeway Management System?

In general terms, a system is defined as a set of components or elements that could be seen as working together for the overall objective of the whole.[7] These components or elements may include many different things, depending on the perspective of the person who defines the system. System components can be objects, concepts, processes, or even people. A system has a set of boundaries that define the interactions between system components and the environment. The environment consists of all those factors external to the system that influence the behavior of the system, and that cannot be controlled. Within the system, there are interfaces between the various components, which control how they interact with each other. Finally, the components themselves may be subsystems consisting of smaller elements or components.

A freeway management system, then, consists of the infrastructure elements utilized to accomplish the goals and objectives of freeway management. These things (elements) include field hardware (cameras, dynamic message signs, electronic toll tag readers, etc.), communications equipment, a traffic management center (with associated hardware and software), the people who staff the center, and the policies and procedures established to deal with various transportation-related events that affect the freeway system. The freeway management system comprises several infrastructure subsystems (the motorist information system, the ramp metering system, etc.) that interface with each other to accomplish specific objectives as the need arises.

It is important to recognize that each freeway management system is a unique consolidation of components and interfaces that reflect the location-specific freeway, geographic, and political characteristics and needs of the region. However, most systems can be described in terms of which of the possible functions of freeway traffic management they perform. The following section presents a brief overview of these functions.

History of Freeway Management

Pioneering efforts in "freeway surveillance and control," as systems were first generally known, took place in Detroit, Chicago, Houston, Los Angeles, Seattle, and Dallas. Highlights of some these early efforts are listed below:[9]

- **1962 Detroit** - Freeway lane control signs and variable speed signs.
- **1963 Chicago** - Demand-capacity/ occupancy metering and surveillance by freeway loop detectors.
- **1965 Houston** - Demand-capacity/ gap-acceptance metering and surveillance by closed-circuit television and freeway loops.
- **1967 Los Angeles** - Fixed time metering and ramp closure.
- **1967 Seattle** - Reversible roadway control and closed-circuit television surveillance.
- **1971 Dallas** - Corridor control integrating ramp metering, frontage road and arterial intersection control with preferential treatment for buses at ramps and intersections.

- **1972 Minneapolis** - Bus bypass ramps at metered ramps.
- **1990** - Introduction of Intelligent Vehicle/Highway System (IVHS) concept including freeway management and related systems.
- **1992** - Federal Highway Administration's introduction of concept of IntelligentVehicle/Highway Systems (IVHS)
- **1993** - Intelligent Transportation Systems (ITS) concept succeession of IVHS to broaden the scope to include other forms of surface transportation.
- **1993**-Initiation of National ITS Architecture Initiative to address common interfaces and protocols for ITS systems.

As systems were upgraded and expanded, they began to be more properly termed "Freeway Management Systems." New and upgraded systems have incorporated many of the basic techniques developed on these earlier systems. The phenomenal developments in computer and communications technology have further enhanced capabilities for various freeway management tasks.

Relationship of Freeway Management to National ITS Architecture

The freeway management concepts of this handbook follow the National ITS Architecture. Quoting from the *1996 ITS Architecture Executive Summary:*

> *The National ITS Architecture provides a common structure for the design of intelligent transportation systems.*

Agencies should seek to ensure that the design of a new or upgrade of an existing freeway management system design uses the National ITS Architecture and applicable National ITS standards.

An outgrowth of the development of the National ITS Architecture has been the concept of intelligent transportation system infrastructure. The term "infrastructure" has been in common use for a number of years to describe the supporting roadways, bridges, water and sewer lines, and other public works structural items that allow movement of persons and goods. It is not the truck or car, it is the roadway and bridge. It is not the water, it is the pipes or conduits that carry the water. A logical extension of the infrastructure concept is its application to flow and delivery of information in Intelligent Transportation Systems.

Many of the functions needed for ITS implementation are already being provided or supported by a broad variety of ITS infrastructure features, which can serve as the building blocks of a full ITS implementation. An ITS infrastructure refers to those portions of ITS-related hardware, software, etc. that today, and increasingly in the future will manage and support transportation-related activities. This is typically happening first in the metropolitan areas, but is expanding to include commercial vehicle and rural needs.

An intregrated transportation management system should contain some or all of the following applicable ITS components in a given region:

- Traffic Signal Control.
- Freeway Management.
- Transit Management.

- Incident Management.
- Electronic Fare Payment.
- Electronic Toll Collection.
- Railroad Grade Crossings.
- Emergency Services.
- Regional Multimodal Traveler Information.

Both the implementation of a given component and the integration of the components should use the National ITS Architecture and standards.

OBJECTIVES OF A FREEWAY MANAGEMENT SYSTEM

The goals and objectives of a freeway management system are specific to the social and political desires of the community; however, there are goals and objectives for freeway management systems that are universal across all systems. These include the following:

- To reduce the impacts and occurrence of recurring congestion on the freeway system.
- To minimize the duration and effects of nonrecurring congestion on the freeway system.
- To maximize the operational safety and efficiency of the traveling public while using the freeway system.
- To provide facility users with information necessary to aid them in making effective use of the freeway facilities and to reduce their mental and physical stress.
- To provide a means of aiding users who encounter problems (crashes, breakdowns, confusion, etc.) while traveling on the freeway system.

FUNCTIONS OF FREEWAY MANAGEMENT

Freeway management systems combine personnel, operational strategies, and technologies to control and manage traffic on the freeway more effectively. The following functions can be performed by a freeway management system:

- Surveillance and incident detection.
- Lane use control.
- Ramp control.
- Priority treatment and control for high-occupancy vehicles.
- Information dissemination.
- Incident management.

A brief review of each of these functions is provided below. A more detailed discussion of the pertinent issues affecting planning, design, operations, and maintenance is provided in subsequent modules.

Surveillance and Incident Detection

Traditionally, one of the primary functions of most freeway management systems is to detect traffic incidents that affect the smooth flow of traffic.[10] With surveillance, traffic conditions can be monitored and the location and causes of any operational problems that occur can be pinpointed. As traffic management systems have become increasingly multijurisdictional and multimodal, the surveillance function has expanded to include such considerations as transit and emergency fleet vehicle locations, weather and pavement conditions, and parking lot status.

Lane Use Control

The function of lane use control is to maximize the efficient use of existing pavement within the right-of-way. Mainline metering, temporary shoulder utilization, reversible lane operations, and large truck restrictions are all examples of lane use control.

Ramp Control

Managing the amount of traffic that can enter or exit the freeway is another function of freeway management systems. Both ramp metering and temporary ramp closures (during peak periods, for instance) are examples of the ramp control function. Controlling freeway access and egress reduces turbulence in freeway flow near the ramps and improves overall freeway operations.

High-Occupancy Vehicle (HOV) Priority Treatments

Another function of freeway management is to provide preferential treatment to buses, carpools, and vanpools on a freeway to generate a travel time advantage for the vehicle occupants and review the number of vehicles on the roadways. These treatments can include special lanes, priority access, and ramp controls for HOV vehicles, special surveillance of those lanes to detect and remove incidents quickly, and occupant restriction enforcement.

Information Dissemination

From a traveler's perspective, information dissemination is one of the most important functions of freeway management. Research and experience have shown that travelers want and use real-time information about traffic conditions on the freeway and alternative routes; adverse weather and driving conditions; construction and maintenance activities; and special lane use and roadway control measures that are enacted. With current and accurate information, travelers are better able to make mode, departure time, and route choice decisions. A number of existing and emerging technologies are available to facilitate information transfer to travelers.

The Freeway Management System

A freeway management system may be the common interface for multiple transportation agencies in a given region. In the such cases, it is the focal point for receiving, processing, and transferring various types of traffic and transportation data, including digital, video, and voice. Regional multiagency coordination will logically take place in the freeway management center.

Incident Management

Of all the major freeway management functions, incident management probably offers the greatest potential operational and safety benefit to freeway motorists.[5] Incident management requires the coordinated operation and preplanned use of human and technological resources to restore the freeway to full capacity quickly and efficiently after an incident occurs. Typically, incident management may include other freeway management functions such as the following:

- Control center operation.
- Surveillance.
- Information dissemination.

- Freeway service patrols.
- Ramp control.
- Decision process control strategies.
- Lane use control signals.

Integration with Other ITS Components

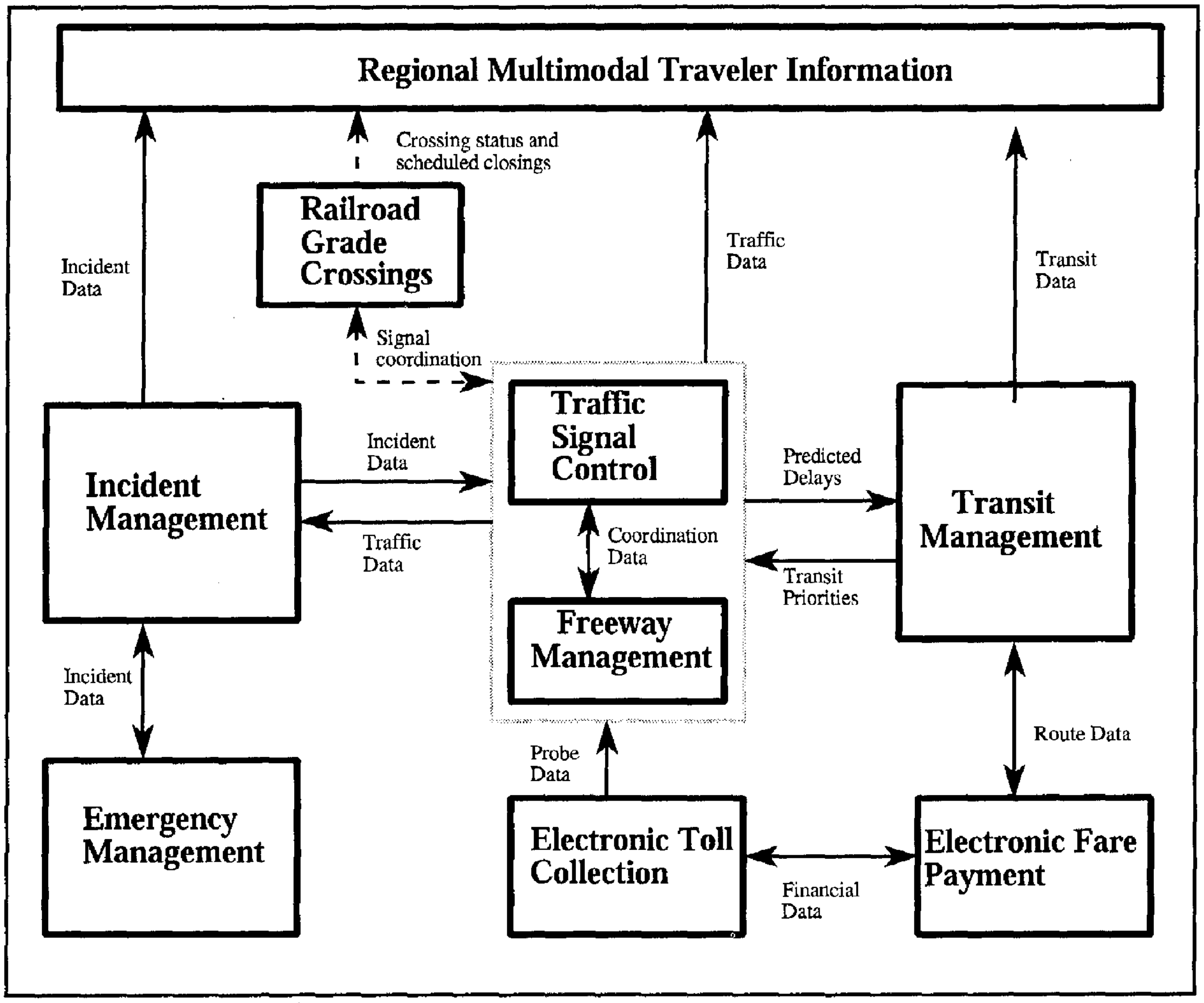
As illustrated below, freeway management is just one component of an integrated transportation management system. Freeway management, along with traffic signal control, form the hub of an integrated transportation system. The traffic signal control and freeway management components exchange data with each other, allowing the traffic management strategies on the freeways, the freeway entrance ramps, and the surface street network to act as an integrated system. These data define the actions to be taken by the system when a particular signal timing plan is in effect on the road network, and when a particular sign plan is in effect on the highways. For example, ramp meter timings and traffic signal controls can be coordinated to ensure that queues do not back into intersections. When traffic is diverted off the freeway to bypass an incident, the traffic signals timings can be adjusted to handle the increased flow on the arterials. At the same time, dynamic message signs can be updated along the arterials to give directions on how to return to the freeway beyond the incident location.

In addition, both the freeway management and traffic signal control components can provide critical information to other components of the transportation system. Both the freeway management and traffic signal control components are responsible for the surveillance, monitoring, device control, and management of the road network. These components provide information on the status of the roadway system, including link travel times, traffic volumes, and speeds currently flowing on the road and highway network. These data can be passed to the other components in the overall transportation system, such as the incident management and transit management components, and information from these other systems can be channeled through the freeway management and traffic control components. Traffic data can also be output to a regional traveler information system for dissemination to the public for trip planning and other purposes. Because the freeway management and traffic signal control components are monitoring traffic conditions on the roadways, information about predicted delays and incidents can be passed to the transit management component, which in turn can use the information to establish transit priorities and operating strategies, which are implemented by the freeway management and traffic signal control components.

Although it may be possible for some transportation management subsystems to operate in an isolated or independent manner, their operation and functions will affect and be affected by the other transportation subsystems. This will be particularly evident in an urban environment. For optimal efficiency, the various transportation subsystems must operate in a cohesive, integrated manner. Multiple agencies must maintain open communication and cooperation to achieve the goal of a truly integrated transportation system.

FREEWAY MANAGEMENT HANDBOOK

The objectives of this handbook are as follows:



Freeway Management as Part of an Integrated Intelligent Transportation System

- Define the process of planning, designing, operating, and maintaining a freeway management system.
- Provide an overview of the techniques and technologies available for accomplishing the functions of a freeway management system.
- Identify critical issues associated with planning, designing, operating, and maintaining a freeway management system.
- Provide guidance in developing a freeway management system that uses the National ITS Architecture and applicable standards.
- Identify points in the design development process where integration and interface with other systems should take place.

SCOPE OF THE HANDBOOK

This handbook is intended to be a "How To" manual for planning, designing, operating, and maintaining a freeway management system. This manual is directed at a mid-level administrator or engineer for a State or local agency that is responsible for planning, designing, operating, or maintaining all or portions of a freeway management system. As a result, it primarily focuses on the issues associated with each element of a freeway management system. For many of the elements and functions, there are excellent reference materials that provide detailed information about the technologies and techniques. For example, the *Communications Handbook for Traffic Control Devices* and the *Freeway Incident Management Handbook* provide many technical details on communications and incident management systems, respectively. In those cases where there are other manuals and reference materials to provide technical details, the details have not been reproduced in this manual. Instead, the reader has been provided with references to these materials as a source of more detailed information than that presented in this handbook.

STRUCTURE OF THE HANDBOOK

A modular approach has been used to prepare this manual. Each functional element of a freeway management system is covered in a separate module. Each module presents information specific to the planning, design, construction, operation, and maintenance of that particular functional element. This approach was used when preparing this handbook so that system designers and operators can turn to the modules of interest to them and find all the information pertinent to the planning, design, operation, and maintenance of those specific elements.

In addition, a decision process module has been provided. The decision process module describes the systems engineering approach that can be used to plan and design a freeway management system. The systems engineering approach can be used regardless of whether a system is being designed from scratch, modifications are being made to an existing system, or upgrades are being planned to an outdated system. The decision process module also serves as a model of each of the remaining modules.

The same structure has been applied to each of the modules. Each module contains an overview section that provides some background into the nature of the functional element, and the objectives and scope of the information. The section following the overview section describes a system engineering process for planning, designing, and implementing the functional element within a freeway management system. Another section describes the techniques and technologies commonly used in each functional element. Each module also has a section devoted to covering any special issues that could not be adequately covered in the previous sections. Wherever possible, examples of state-of-the-art facilities are provided in each module. The module concludes with a section listing the references and suggested readings for the module.

OVERVIEW OF FREEWAY MANUAL MODULES

A summary of the type of material to be covered in each of the previously mentioned modules is provided below.

Module 1. Freeway Management Concepts

This module provides an introduction to the handbook including objectives, scope, and structure. Also included is an overview of freeway management concepts as a primer or preface to the 10 modules addressing technical and management issues.

Module 2. Decision Process

The second module is devoted to discussing the process for determining functions and technologies to be included in a freeway management system. It provides the steps to be taken for conducting a system engineering analysis for planning, designing, and implementing a freeway management system. This module focuses on the issues associated with integrating each of the functional elements to form a comprehensive freeway management system.

Module 3. Surveillance

This module contains information related to planning, designing, and implementing the surveillance subsystem of a freeway management system. Using the structure for the decision process discussed in Module 2, this module provides a process for determining the appropriate elements to be included in a surveillance subsystem. It provides an overview of the various technologies and techniques that are available for performing the surveillance functions in a freeway management system.

Module 4. Lane Use Control

This module focuses on the process for planning, designing, operating, and maintaining systems for controlling the use of the freeway main lanes. This module provides information related to the design and operations of freeway main lane meters, techniques for using the shoulder, and providing reversible lane control on the freeway. It also provides insight into the special issues related to operating and maintaining these control systems.

Module 5. Ramp Control

This module presents information needed to plan, design, operate, and maintain freeway ramp control systems. It provides an overview of the theory and principles of ramp control, including ramp metering and ramp closures. It also presents information on the different types of ramp metering strategies. The module concludes with a section on the special issues associated with ramp control systems, including maintenance, enforcement, and public perceptions and acceptance of various ramp control strategies. It is intended to complement information in *Ramp Metering Status in North America (1995 Update).*

Module 6. HOV Treatments

This module presents information needed to include high-occupancy vehicle (HOV) priority treatments in a freeway management system. It provides a summary of the planning, design, and operations issues associated with including an HOV treatment in a freeway management system. It also provides an overview of the decision process for determining which type of priority treatment is appropriate for a specific system. It also discusses some of the special design, operating, and maintenance issues associated with HOV treatments.

Module 7: Information Dissemination

This module describes the process for establishing a cohesive information dissemination subsystem in a freeway management system. It identifies the existing and emerging technologies available to facilitate information dissemination to travelers. It also illustrates how the information dissemination subsystem integrates with the other subsystems of a freeway management system.

Module 8. Incident Management

Module 8 presents information related to the planning, design, operations, and maintenance of an incident management subsystem in a freeway management system. It is intended to illustrate how to develop or enhance the incident management capabilities of a freeway management system. It also provides insight into the key factors and issues to be considered in planning, designing, and implementing an incident management subsystem. It is intended to complement the material already presented in the *Freeway Incident Management Handbook.*

Module 9. Communications

This module provides insight into the issues associated with planning, designing, operating, and maintaining a communications subsystem in a freeway management system. It focuses on the decision process for determining the appropriate communication technologies for specific freeway management systems. It also provides a summary of existing and emerging communications technologies. It is intended to complement the material already presented in the *Communications Handbook for Traffic Control Systems.*

Module 10. Control Center

This module provides information related to planning, design, operations, and maintenance of the control center. It focuses on both the physical design and human factor elements associated with freeway management control centers. It also provides insight into how the functions of the freeway management system affect the design and operations of the control center. Special issues such as privatization of operator functions and multiagency control centers are also discussed in this module. It is intended to complement the material already presented in the *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition).

Module 11. Economic Analysis

This module presents information on some of the economic analyses that can be used in planning and evaluating alternative designs of freeway management systems. Included in this module is step-by-step instruction on how to conduct a life-cycle cost evaluation, a benefit-cost evaluation, and other pertinent economic analyses. This module also provides guidance to the reader on when it is appropriate to use the different types of economic analyses.

MODULE 1. FREEWAY MANAGEMENT CONCEPTS

TABLE OF CONTENTS

MODULE 1. FREEWAY MANAGEMENT CONCEPTS

Figure 1-1. I-35 Freeway in Austin, TX.

1.1 INTRODUCTION

Freeways were originally conceived and designed to provide continuous, free-flow, high-speed movement of traffic on limited-access facilities. In their original design, little thought was given to providing for the needs of traffic management and control systems to maintain a high level of mobility on these facilities. However, as urban areas continued to grow, the freeway system became more congested. Today, the previous approach of constructing more freeway lane-miles to relieve congestion is often politically and socially unacceptable and economically infeasible. It is incumbent on transportation agencies planning, constructing, operating, and maintaining freeway infrastructure to make the best possible use of available capacity.

Freeway management systems are a primary means that transportation agencies can use to manage traffic flow and make better use of the existing freeway system. Freeway management systems make use of control strategies, and operational activities such as incident management and information dissemination to 1) keep congestion from occurring in the first place, and 2) lessen the duration and extent of congestion when it does occur.

While the term *freeway management system* was probably not applied to the tasks, early freeway management systems consisted primarily of fixed signs on the roadway providing regulatory and directional information and police officers handling traffic during incidents. As freeway systems have matured and traffic demands have grown in urban areas over the past half century, freeway management systems have evolved and developed to provide many and varied services.

This handbook discusses the concepts and functional requirements for a freeway management system. It discusses some of the critical issues associated with planning, designing, operating, and maintaining each of the individual elements of a freeway management system. However, prior to comprehensive treatment of the various freeway management elements, it may be helpful to define management systems, the problems they address, and why they are important.

CONGESTION

Congestion on a freeway occurs when demand exceeds capacity. A section of freeway where traffic demand exceeds freeway capacity is called a bottleneck. Bottleneck (or congested) conditions occur either when demand has increased to a level greater than capacity or when capacity has decreased below a level that can accommodate the demand.(1)

Bottleneck conditions are commonplace on the freeway system in many urban areas. Generally, congestion can be classified as either recurring or nonrecurring. Recurring congestion is usually caused when the amount of traffic wanting to use the freeway exceeds the available traffic-carrying capabilities of the system. Generally, recurring congestion occurs at a predictable location during specific periods of the day. Nonrecurring congestion, on the other hand, is less predictable. It is generally caused by random or less predictable events, such as vehicle crashes and incidents, that temporarily reduce the capacity of the freeway, or by special situations (such as sporting events, construction and maintenance activities, inclement weather, etc.) that temporarily increase the demand on the freeway.

Understanding the type and primary causes of congestion in the freeway network is the first step in determining and evaluating options for addressing identified problems with a freeway management system. The strategies that might be implemented to address the recurring congestion problems are not necessarily the same as those that are effective in mitigating the impacts of nonrecurring congestion. From a driver's perspective, however, the impacts of congestion, regardless of whether it is recurring or nonrecurring, are the same:

- Reduced travel speeds.
- Erratic travel speeds characteristic of stop-and-go movement.
- Increased and inconsistent travel times.
- Increased potential for vehicle crashes.
- User dissatisfaction and frustration.

The inability to provide a reliable, albeit sometimes lower, level of service is perhaps a more severe problem than the inability to eliminate congestion altogether. If users know to expect a certain level of congestion during a travel period, they can plan their trip accordingly. If, on the other hand, drivers are unaware of the extent or nature of congestion, they cannot make accommodations to adjust their transportation mode, departure time, or route choices. From this standpoint, one objective of a freeway management system is to provide travelers a consistent level of operation on the freeway.

Measuring Congestion

A motorist usually thinks of congestion in terms of overcrowded freeways, freeway crashes, stop-and-go driving conditions, and the frustration and discomfort of restricted maneuverability. The transportation professional, on the other hand, often expresses congestion in terms of traffic variables such as flow rate, density (or occupancy), and average space speed, together with the fundamental relationships surrounding them. For example, figure 1-2 illustrates the fundamental relationship between flow rate and density. As traffic density increases from zero to some value, k_1, traffic flow rate increases, and the resulting operation is defined as uncongested. As density increases from k_1 to k_2, however, though flow rates tend to increase, traffic operations become unstable, and the probability of serious breakdown increases. Further increases in density above k_2 result in a decrease in flow rate until, theoretically, it reaches zero at jam density, k_j. The traffic flow regimes occurring at densities greater than k_2, are classified as congested.

The specific value of density used to define congestion depends on a number of factors including the geometrics of the freeway section, the composition of the traffic, and local driving habits. The 1994 *Highway Capacity Manual* defines the density of the freeway at congestion (i.e., Level of Service F) to be between 24.8 and 29.9 passenger cars per kilometer per lane (39.7 to 47.9 pc/mi/ln), depending on the original freeway flow speed of the freeway.(2) McDermott has reported that lane occupancies (a surrogate measure for density) in the range of 0 to 20 percent, 20 to 30 percent, and 30 to 100 percent indicate uncongested, unstable (impending congestion) and congested operations, respectively.(3) Figure 1-3 shows generalized freeway traffic operations curves that relate lane occupancy to flow rate and average space speed.(2) As lane occupancy exceeds 20 percent, travel speeds on the freeway decrease because of the following:

- There are fewer and shorter gaps between vehicles.
- Drivers have greater difficulty in changing lanes.
- There are generally more restrictive traffic flow conditions.

Causes of Congestion

Freeway congestion may be characterized as either recurring (generally caused by demand exceeding fixed capacity or fixed geometric restrictions) or nonrecurring (where fixed capacity is reduced due to non-normal events such as vehicle crashes, stalls, spilled loads, weather, or maintenance activities). FHWA estimates that nonrecurring congestion accounts for approximately 60 percent of all congestion.(4)

Factors and situations that may cause a freeway segment to become congested include the following:(5)

- Geometric design.
- Traffic operations (including capacity deficiency).
- Incidents.
- Maintenance and construction.
- Weather.

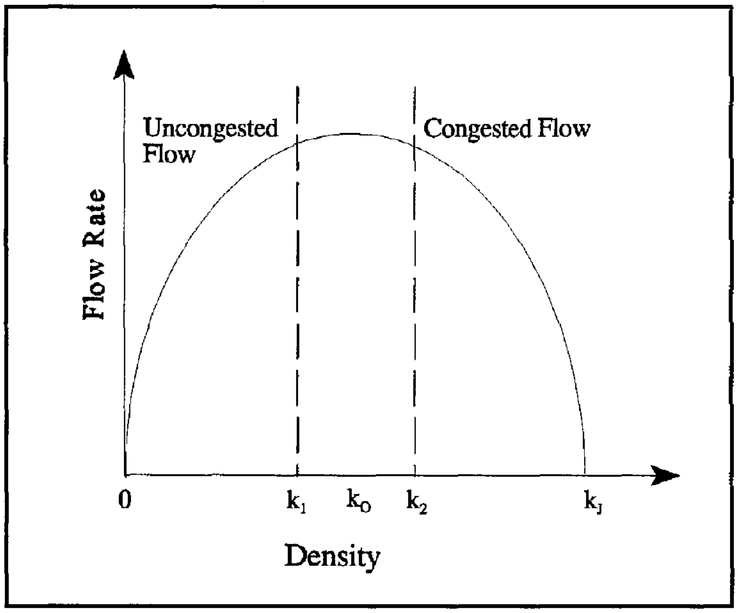


Figure 1-2. Congestion and the Fundamental Relationship Between Flow Rate and Density. [4]

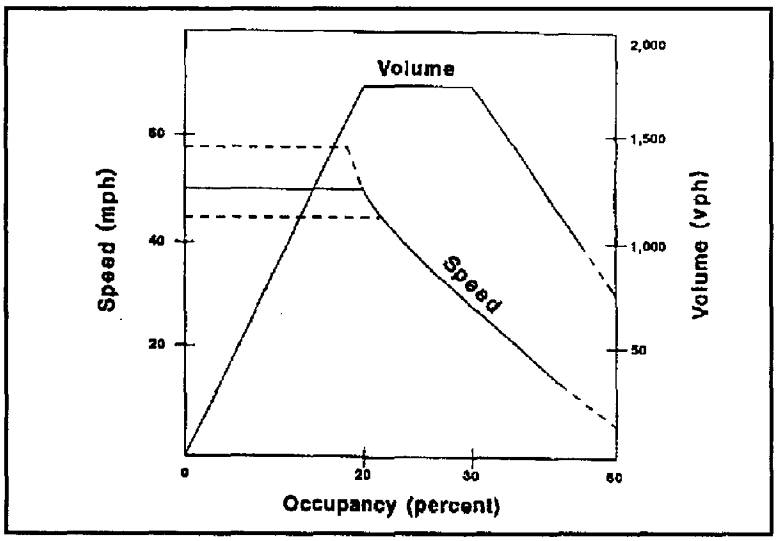


Figure 1-3. Generalized Traffic Flow Relationships. [3]

Geometric Design

The capacity of a freeway usually does not remain constant along its entire length. Certain physical features result in capacity restrictions. Upstream and downstream from the location of these features, capacity usually proves slightly higher, resulting in bottleneck conditions. Table 1-1 lists some of the features that restrict capacity of the freeway and are a source of congestion.

Traffic Operations

Traffic operations can also be a source of congestion—anything from too much demand on the freeway to the presence of heavy vehicles in the traffic stream. Some of the traffic operations factors that can cause congestion on a freeway include the following:

- True demands in excess of available capacity.
- Unrestrained ramp access where ramp traffic causes demand for the freeway to exceed the available capacity.
- Exit ramp queues where demand exceeds the ability of the merge area or downstream intersection to process it, causing queues to backup onto the freeway.
- Heavy weaving and merging movements between ramps and the freeway main lanes.

Incidents

Vehicle crashes and other traffic incidents are major sources of nonrecurring congestion. The factors that affect the amount of congestion resulting from an incident include the following:(5)

- The duration of the incident.
- The amount of capacity reduction caused by the incident.
- The amount of travel demand on the freeway at the incident location.

During an incident, the capacity of the freeway is reduced disproportionately to the physical reduction in width of the travel lanes. Table 1-2 shows the amount of capacity reduction imposed on freeways of different sizes by different incident types.

Maintenance and Construction

Maintenance and construction cause congestion with significant accompanying delays. Like incidents, construction and maintenance activities reduce the amount of capacity available to service demand. The impacts of construction and maintenance activities on traffic operations can be lessened by implementing the following measures:(4)

- Schedule activities for times when demand is anticipated to be low (i.e., at night or on weekends).
- Complete all activities in a given section and lane at one time.
- Provide adequate on-site traffic control and advance information to travelers.
- Report expected and current delays in activities.

Weather

The weather can also be a source of traffic congestion. Both rain and snow can significantly reduce the capacity of the freeway. For example, even trace amounts of rain can reduce the capacity of the

Table 1-1. Geometric Design Factors Causing Capacity Reduction. [4]

Design Factor	Result
Reduction in lanes	• May cause congestion where number of lanes is reduced. • Even though lane drop occurs at exit ramp, through volume may exceed remaining capacity. • Weaving out of dropped lanes may create turbulence, cause speed to decrease, and decrease capacity. (May cause problem where multiple freeways merge without maintaining the same number of lanes.)
Horizontal curvature	• Moderately sharp horizontal curve may reduce capacity. • In heavy flow, vehicle may cross into next lane, causing hesitation and speed decreases in adjacent lanes. Even momentary speed decreases during periods of unstable flow can result in congestion.
Vertical alignment	• Grades reduce capacity, particularly with trucks present. • Although design standards impose limitations on acceptable grades, vertical alignment may cause small, but imperceptible, speed changes that affect following traffic and can result in congestion. • Upgrades in tunnels limit capacity.
Other physical features: • Lane widths • Lateral clearance • Ramp design • Surface conditions	• Older freeways may have lanes narrower than 3.6 m (12 ft) standard, resulting in capacity reduction. • Lateral obstructions may reduce capacity if located closer than 1.8 m (6 ft) to a traveled lane. Examples include: - bridge abutments - retaining walls - illumination poles - sign supports • Lack of full shoulder-width bridges reported to result in a point reduction in capacity. • Weaving movements are restricted at access points and exits.

freeways in Houston, Texas by 14 to 19 percent. In Minneapolis, trace amounts of snow have been reported to reduce capacity by 8 percent and for each 0.02 cm/hr (0.01 in/hr) increase, capacity is reduced by an additional 0.6 percent.[4]

Table 1-2. Percentage of Freeway Section Capacity Available Under Incident Conditions. [4]

Number of Freeway Lanes in Each Direction	Shoulder Disablement	Shoulder Accident	Lanes Blocked		
			One	Two	Three
2	0.95	0.81	0.35	0	N/A
3	0.99	0.83	0.49	0.17	0
4	0.99	0.85	0.58	0.25	0.13
5	0.99	0.87	0.65	0.40	0.20
6	0.99	0.89	0.71	0.50	0.25
7	0.99	0.91	0.75	0.57	0.36
8	0.99	0.93	0.78	0.63	0.41

1.2 FREEWAY MANAGEMENT

WHAT IS FREEWAY MANAGEMENT?

The 1983 *Freeway Management Handbook* defined freeway management as the " . . . control, guidance and warning of traffic in order to improve the flow of people and goods on these limited access facilities."[6] Today, the definition of freeway management should be expanded to encompass all activities undertaken to operate a freeway facility in a manner consistent with predetermined goals and objectives of that facility including those related to the impacts on and the influence of surrounding communities and jurisdictions. Certainly, the efficient movement of goods and people continues to be one of the major goals of freeway management. However, legislative mandates and public pressure regarding environmental concerns, adjacent landowner and homeowner rights, and other issues can further influence the operation of the freeway system.

In many cases, freeway management requires striking a balance between competing goals and objectives. For example, a goal to minimize recurrent congestion may not necessarily be compatible with a goal to maximize the movement of people and goods on a facility, especially if the goal to maximize people movement is accomplished through the use of high-occupancy vehicle lanes. High-occupancy vehicle lanes must offer the user a significant travel time advantage over regular-use lanes to be attractive to travelers using the freeway. In terms of this example, it may be appropriate to allow some level of congestion in the regular-use lanes in order to achieve the best overall operation of the freeway system.

WHAT IS A FREEWAY MANAGEMENT SYSTEM?

In general terms, a system is defined as a set of components or elements that could be seen as working together for the overall objective of the whole.[7] These components or elements can be many different things, depending on the perspective of the person who defines the system. System components can be objects, concepts, processes, or even people. A system has a set of boundaries that define the interactions between system components and the environment. The environment consists of all those factors external to the system that influence the behavior of the system, but which cannot be controlled. There are interfaces between the components of the system which control how they interact with each other. Finally, the components themselves can be subsystems consisting of smaller elements or components.

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It is important to recognize that each freeway management system is a unique consolidation of components and interfaces that reflect the location-specific freeway, geographic, and political characteristics and needs of the region. However, most systems can be described in terms of which of the possible functions of freeway traffic management they perform. The following section presents a brief overview of these functions.

OBJECTIVES OF A FREEWAY MANAGEMENT SYSTEM

The goals and objectives of any one freeway management system are specific to the social and political desires of the community; however, there are goals and objectives for freeway management systems that are universal across all systems. These include the following:[8]

- To reduce the impacts and occurrence of recurring congestions on the freeway system.
- To minimize the duration and effects of nonrecurring congestion on the freeway system.
- To maximize the operational safety and efficiency of the traveling public while using the freeway system.
- To provide facility users with information necessary to aid them in making effective use of the freeway facilities and to reduce their mental and physical stress.
- To provide a means of aiding users who have encountered problems (crashes, breakdowns, confusion, etc.) while traveling on the freeway system.

HISTORY OF FREEWAY MANAGEMENT

Pioneering efforts in "freeway surveillance and control" as systems were generally known, took place in Detroit, Chicago, Houston, Los Angeles, Seattle, and Dallas. Highlights of some these early efforts are listed below:[9]

- **1960 Chicago** - Freeway service patrols.
- **1960 Detroit** - CCTV on freeways.
- **1962 Detroit** - Freeway lane control signs and variable speed signs.
- **1962 Chicago** - Surveillance by freeway loop detectors.
- **1963 Chicago** - Demand-capacity / occupancy metering.
- **1965 Houston** - Demand-capacity / gap-acceptance metering and surveillance by closed-circuit television and freeway loops.
- **1967 Los Angeles** - Fixed time metering and ramp closure.
- **1967 Seattle** - Reversible roadway control and closed circuit television surveillance.
- **1971 Dallas** - Corridor control integrating ramp metering, frontage road and arterial intersection control with preferential treatment for buses at ramps and intersections.
- **1972 Minneapolis** - Bus bypass ramps at metered ramps.
- **1990** - Intelligent Vehicle/Highway (IVHS) concept introduced including freeway management and related systems.
- **1992** - Intelligent Transportation Systems (ITS) succeeds IVHS, broadening scope of concept.
- **1993** - National ITS Architecture Initiative begun to address common interfaces and protocols for ITS systems.

As systems were upgraded and expanded, they began to be more properly termed "Freeway Management Systems." New and upgraded systems have incorporated many of the basic techniques developed on those earlier systems. The phenomenal developments in computer and communications technology have further enhanced capabilities for various freeway management tasks.

Functions of Freeway Management

Freeway management systems combine personnel, operational strategies and technologies together to control and manage traffic on the freeway more effectively. Figure 1-4 highlights the basic functions of freeway management. The functions that can be performed by a freeway management system include the following:

- Surveillance and incident detection.
- Lane use control.
- Ramp control.
- Priority treatment and control for high-occupancy vehicles.
- Information dissemination.
- Incident management.

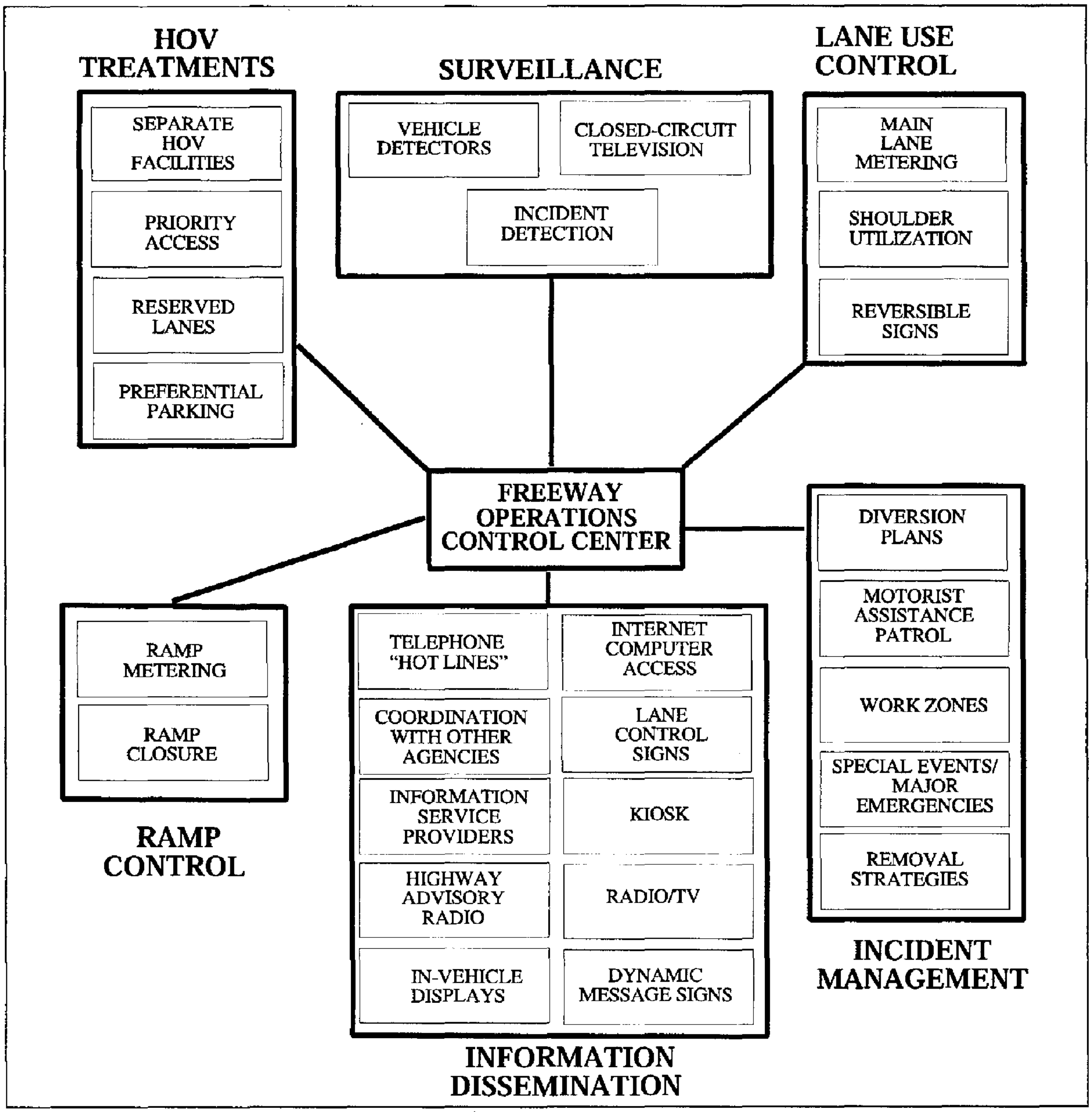

Figure 1-4. Functions and Elements of a Freeway Management System.

A brief review of each of these functions is provided below. A more detailed discussion of the pertinent issues affecting planning, design, operations, and maintenance is provided in subsequent modules.

Surveillance and Incident Detection

Traditionally, one of the primary functions of most freeway management systems is to provide traffic surveillance.[10] With surveillance, traffic conditions can be monitored and the location and causes of any operational problems that occur can be pinpointed. As traffic management systems have become increasingly multijurisdictional and multimodal, the surveillance function has expanded to include such things as transit and emergency fleet vehicle locations, weather and pavement conditions, and parking lot status.

Lane Use Control

The function of lane use control is to maximize the efficient use of existing pavement within the right-of-way. Mainline metering, temporary shoulder utilization, reversible lane operations, and large truck restrictions are all examples of lane use control.

Ramp Control

Managing the amount of traffic that can enter or exit the freeway is another function of freeway management systems. Both ramp metering and temporary ramp closures (during peak periods, for instance) are examples of the ramp control function. Controlling freeway access and egress reduces turbulence in freeway flow near the ramps and improves overall freeway operations.

High-Occupancy Vehicle (HOV) Priority Treatments

Another function of freeway management is to provide preferential treatment to buses, carpools, and vanpools on a freeway to generate a travel time advantage for the vehicle occupants and review the number of vehicles on the roadways. These treatments can include special lanes, priority access ramp controls for HOV vehicles, special surveillance of lanes to detect and remove incidents quickly, and occupant restriction enforcement.

Information Dissemination

From a traveler's perspective, information dissemination is one of the most important functions of freeway management. Research and experience have shown that travelers want and use real-time information about traffic conditions on the freeway and alternative routes; adverse weather and driving conditions; construction and maintenance activities; and special lane use and roadway control measures that are enacted. With current and accurate information, travelers are better able to make mode, departure time, and route choice decisions. A number of existing and emerging technologies are available to facilitate information transfer to travelers.

Freeway Management System

A freeway management system is generally the common interface for multiple transportation agencies in a given region. ITS infrastructure includes a "regional multimodal traveler information" element. This may be co-housed with the freeway management center. In that case, the freeway management center is the focal point for receiving, processing, and transferring various types of traffic and transportation data, including digital, video, and voice. Regional multiagency coordination will logically take place in the freeway management center.

Incident Management

Of all the major freeway management functions, incident management probably offers the greatest potential operational and safety benefit to freeway motorists.[5] Incident management requires the coordinated operation and preplanned use of human and technological resources to restore the freeway to full capacity quickly and efficiently after an incident occurs. Typically, incident management includes other freeway management functions such as the following:

- Control center operation.
- Surveillance.
- Information dissemination.

- Freeway service patrols.
- Ramp control.
- Decisions process control strategies.
- Lane use control signals.

Elements of a Freeway Management System

Each of the functions of a freeway management system requires one or more elements in order to successfully carry out that function. A number of these elements are pieces of hardware that must be in place, whereas others are procedures and strategies that are enacted. Generally, these elements can be categorized as existing or occurring either in the field, as part of the communication linkage, or within the control center.

Field Elements

A number of different technologies can be utilized in the field to monitor traffic conditions, control traffic access and lane utilization, manage incidents, and communicate with motorists. Most of the major field elements are illustrated in figure 1-4 (within each major freeway management function). Within certain elements, a variety of hardware technologies can be employed. For example, vehicle detection within the surveillance function can be accomplished through inductive loop detection, microwave or radar sensors, video imaging, automatic vehicle identification or location, or other technologies, depending on the type of data desired. Similar alternatives exist for information dissemination, lane use control, and incident management functions.

Communications Element

Communications can be thought of as the backbone of freeway management.[11] The communications element transfers information from the field elements back to the traffic control center. In some cases, instructions and other data are transferred out from the center to the field elements. Reliability and performance are critical issues related to communications system design.

The communications element consists of a number of hardware components and supporting software. Again, a number of hardware technologies are available upon which to base communications. The two basic categories that exist are buried or aerial cable (fiberoptic, coaxial, twisted pair) or airwave transmission (microwave, radio [including narrow band or spread spectrum], cellular telephone, and citizen-band radio).

Communications infrastructures (and continuing system operational and maintenance costs) are typically the most expensive part of a freeway management system. FMS functional design must include the communications system concurrently with field devices and central control elements to ensure compatibility and economies of system deployment.

Control Center Elements

The traffic control center is the hub or nerve center of a freeway management system. It is where information about the freeway system is collected, processed, and collated. It can also be the location where decisions about control strategies are made, coordinated with other agencies, and implemented. Information dissemination is also typically coordinated and implemented from the center.

The major elements of the control center are the display and control interfaces that link the center to the various field elements through the communications element. The other major elements of a center are the human operators who monitor conditions and make the adjustments in control and management strategies needed to maximize the efficiency of the freeway system. Ultimately, the degree to which a traffic control center meets the objectives of the freeway management system depends on how well the human operators are able to interface with the system devices.[12]

Toll Roads Versus Freeways

It is important to note that any of the elements of a freeway management system can also be applied to the toll roads. Toll roads exhibit many of the same design features and operating characteristics as freeways. For example, access to both types of facilities is controlled. Both try to achieve high operating speeds. Both need to communicate trouble locations to users of the facilities.

The primary operating difference between toll facilities and freeways is the presence of toll booths. Toll booths are necessary interruptions to the free flow of vehicles on the facility, and need to be considered in developing control strategies.

Relation to National ITS Architecture

It is beyond the scope of this handbook to describe the National ITS Architecture initiative. However, the reader is directed to the extensive documentation that has been developed under that FHWA sponsored project. Quoting from the *1996 ITS Architecture Executive Summary*:

> *The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It is not a system design nor is it a design concept.*

Agencies should seek to ensure that Freeway Management System design is compliant with the National ITS Architecture and applicable National Traffic Control/ITS Protocol.

Growing out of the National ITS Architecture development is the concept of Intelligent Transportation System infrastructure. The term "infrastructure" has been in common use for a number of years to describe the supporting roadways, bridges, water and sewer lines, and other public works structural items that allow movement of persons and goods. It is not the truck or car; it is the roadway and bridge. It is not the water; it is the pipes or conduits that carry the water. A logical extension of the infrastructure terminology is its application to flow and delivery of information in Intelligent Transportation Systems.

Many of the functions needed for ITS implementation are already being provided or supported by a broad variety of ITS infrastructure features, which can serve as the building blocks of a full ITS implementation. ITS infrastructure refers to those portions of ITS-related hardware, software, etc. that today, and increasingly in the future will manage and support the transportation-related activities. This is typically happening first in the metropolitan areas, but is expanding to include commercial vehicle and rural needs.[13]

An intregrated transportation management system contains two or more of the following nine components:

- Traffic Signal Control.

- Freeway Management.
- Transit Management.
- Incident Management.
- Electronic Fare Payment.
- Electronic Toll Collection.
- Railroad Grade Crossings.
- Emergency Services.
- Regional Multimodal Traveler Information.

Although freeway management and incident management are the components included in this handbook, the other components are often noted as they relate to those two components.

Freeway Management

Real-time information describing flow conditions is essential to managing the freeway system. Such information is repackaged for dissemination to the traveler, and is also used to make control decisions such as in-ramp metering or lane use control. Deployment objectives for the freeway management element of an ITS infrastructure are as follows:(13)

- Provide critical information to travelers through infrastructure-based dissemination methods such as variable message signs and highway advisory radio.
- Monitor traffic and other environmental conditions on the freeway system.
- Identify recurring and nonrecurring impediments so that short-term and long-term actions can be taken to alleviate congestion.
- Implement various control and management strategies (such as ramp metering and/or lane control, or traffic diversion).
- Use probe vehicles for additional sensors for collecting real-time traffic information.

Incident Management

Rapid detection, response, clearing the roadway, and restoring capacity are the essential elements of incident management. Reduction of secondary accidents and delays to the traveler are the result of an efficient incident management program. Deployment objectives for the freeway management element of an intelligent transportation management system are as follows:(13)

- Coordinate incident management across regional boundaries to ensure efficient and sufficient response.
- Use traffic management capabilities to improve response times.
- Use onboard moving map route guidance equipment to assist incident response vehicles (e.g., ambulances and tow trucks).
- Reduce traveler delay due to incidents.

Integration with Other ITS Infrastructure Components

As shown in Figure 1-5, freeway management is just one component of an integrated transportation management system. Freeway management, along with traffic signal control, form the hub of an

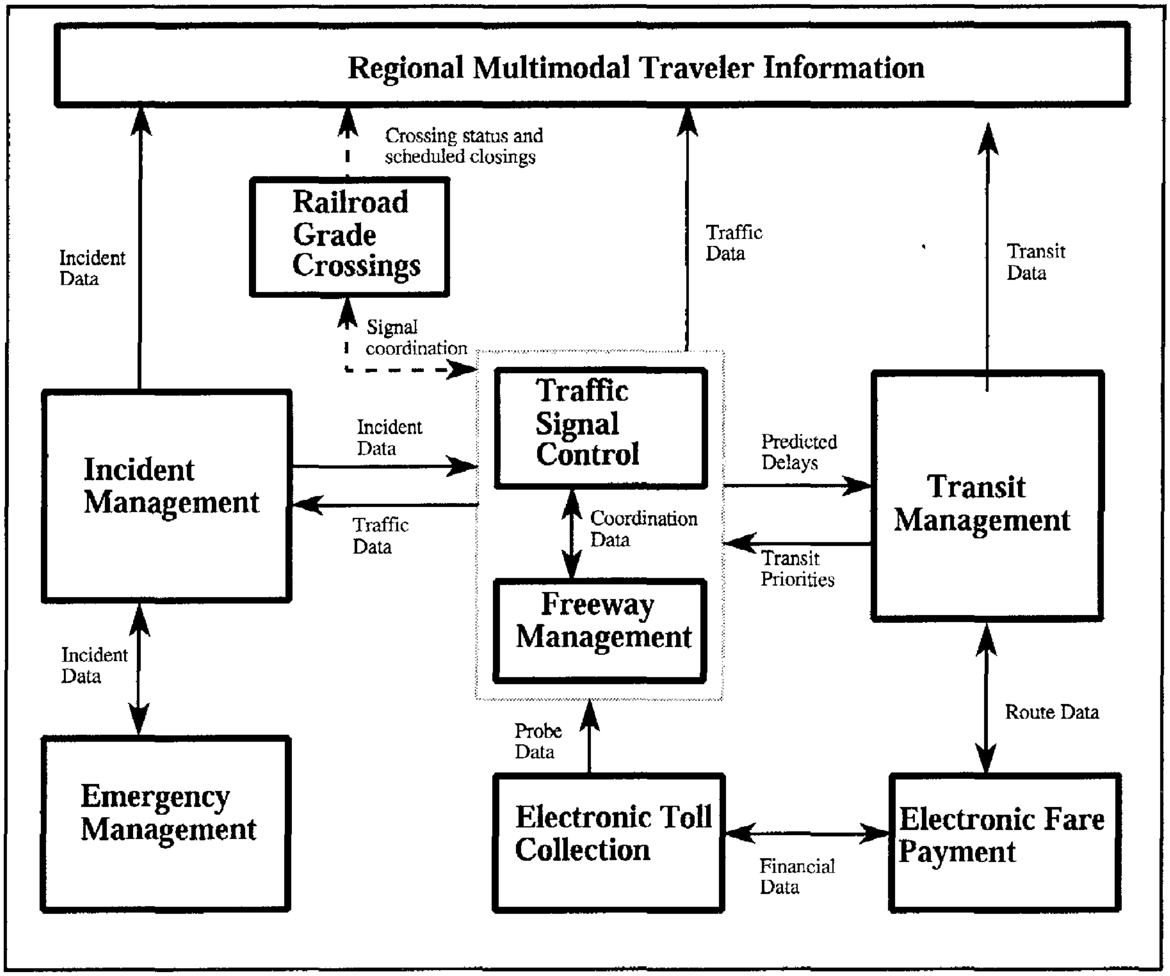

Figure 1-5. Freeway Management as Part of an Integrated Intelligent Transportation System. (14)

integrated transportation system. As shown inside the larger box, the traffic signal control and freeway management components exchange data with each other, allowing the traffic management strategies on the freeways, the freeway entrance ramps, and the surface street network to act as an integrated system. These data define the actions to be taken by the system when a particular signal timing plan is in effect on the road network, and when a particular sign plan is in effect on the highways. For example, ramp meter timings and traffic signal controls can be coordinated to ensure that queues do not back into intersections. When traffic is diverted off the freeway to bypass an incident, the traffic signals timings can be adjusted to handle the increased flow on the arterials. At the same time, dynamic message signs can be updated along the arterials to give directions on how to return to the freeway beyond the incident location.

In addition, both the freeway management and traffic signal control components can provide critical information to other components of the transportation system. Both the freeway management and traffic signal control components are responsible for the surveillance, monitoring, device control, and management of the road network. These components provide information on the status of the roadway system, including link travel times, traffic volumes, and speeds currently flowing on the road and highway network. These data can be passed to the other components in the overall transportation system, such as the incident management and transit management components, and information from these other systems can be channeled through the freeway management and traffic control components. Traffic data can also be output to a regional traveler information system for dissemination to the public for trip planning and other purposes. Because the freeway management and traffic signal control components are monitoring traffic conditions on the roadways, information about predicted delays and incidents can be passed to the transit management component, which in turn can use the information to establish transit priorities and operating strategies, which are implemented by the freeway management and traffic signal control components.

Although it may be possible for some transportation management subsystems to operate in an isolated or independent manner, their operation and functions will affect and be affected by the other transportation subsystems. This will be particularly evident in an urban environment. For optimal efficiency, the various transportation subsystems must operate in a cohesive, integrated manner. Multiple agencies must maintain open communication and cooperation to achieve the goal of a truly integrated transportation system.

For a description of the other infrastructure components and further information on the intelligent transportation infrastructure requirements for freeway management and incident management, the reader is referred to *Building the ITI: Putting the National Architecture into Action* and *Operation TimeSaver-Building the Intelligent Transportation Infrastructure.* [13, 14]

OBJECTIVE OF THE HANDBOOK

The objectives of this handbook are as follows:

- Define the process of planning, designing, operating, and maintaining a freeway management system.
- Provide an overview of the techniques and technologies available for accomplishing the functions of a freeway management system.
- Identify critical issues associated with planning, designing, operating, and maintaining a freeway management system.
- Provide guidance in developing a freeway management system that is compliant with the ITS National Architecture and applicable NTCIP and national standards.
- Identify points in the design development process where integration and interface with other systems should take place.

SCOPE OF THE HANDBOOK

This handbook is intended to be a "How To" manual for planning, designing, operating, and maintaining a freeway management system. This manual is directed at a mid-level administrator or engineer for a State or local agency that is responsible for planning, designing, operating, or maintaining all or portions of a freeway management system. As a result, it primarily focuses on the issues associated with each element of a freeway management system. For many of the elements and functions, there are excellent reference materials that provide detailed information about the technologies and techniques. For example, the *Communications Handbook for Traffic*

Control Devices and the *Freeway Incident Management Handbook* provide many technical details on communications and incident management systems, respectively.[5,11] In those cases where there are other manuals and reference materials to provide technical details, the details have not been reproduced in this manual. Instead, the reader has been provided with references to these materials as a source of more detailed information than that presented in this handbook is desired.

STRUCTURE OF THE HANDBOOK

A modular approach has been used to prepare this manual. Each functional element of a freeway management system is covered in a separate module. Each module presents information specific to the planning, design, construction, operation, and maintenance of that particular functional element. This approach was used when preparing this handbook so that system designers and operators can turn to the modules of interest and find all the information pertinent to the planning, design, operation, and maintenance of those specific elements.

In addition, a decision process module has been provided. The decision process module describes the systems engineering approach that can be used to plan and design a freeway management system. The systems engineering approach can be used regardless of whether a system is being designed from scratch, modifications are being made to an existing system, or upgrades are being planned to an outdated system. The decision process module also serves as a model of each of the remaining modules.

The same structure has been applied to each of the modules. Each module contains an overview section that provides some background into the nature of the functional elements, and the objectives and scope of the information presented in each module. Following the overview section, a section describes a system engineering process for planning, designing, and implementing the functional element within a freeway management system. Another section describes the techniques and technologies commonly used in each functional element. Each module also has a section devoted to covering any special issues that could not be adequately covered in the previous sections. Wherever possible, examples of state-of-the-art facilities are provided in each module. The module concludes with a section showing the references and suggested readings for the module.

A summary of the type of material to be covered in each of the proposed remaining modules is provided below.

Module 1. Freeway Management Concepts

This module provides an introduction to the handbook, including objectives, scope, and structure. Also included is an overview of freeway management concepts as a primer or preface to the 10 modules addressing technical issues and management issues.

Module 2. Decision Process

The second module is devoted to discussing the process for determining functions and technologies to be included in a freeway management system. It provides the steps to be taken for conducting a system engineering analysis for planning, designing, and implementing a freeway management system. This module focuses on the issues associated with integrating each of the functional elements to form a comprehensive freeway management system.

Module 3. Surveillance

This module contains information related to planning, designing, and implementing the surveillance subsystem of a freeway management system. Using the structure for the decision process discussed in Module 2, this module provides a process for determining the appropriate elements to be included in a surveillance subsystem. It provides an overview of the various technologies and techniques that are available for performing the surveillance functions in a freeway management system.

Module 4. Lane Use Control

This module focuses on the process for planning, designing, operating, and maintaining systems for controlling the use of the freeway main lanes. This module provides information related to the design and operations of freeway main lane meters, techniques for using the shoulder, and providing reversible lane control on the freeway. It also provides insight into the special issues related to operating and maintaining these control systems.

Module 5. Ramp Control

This module presents information needed to plan, design, operate, and maintain freeway ramp control systems. It provides an overview of the theory and principles of ramp control, including ramp metering and ramp closures. It also presents information on the different types of ramp metering strategies. The module concludes with a section on the special issues associated with ramp control systems, including maintenance, enforcement, and public perceptions and acceptance of various ramp control strategies.

Module 6. HOV Treatments

This module presents information needed to include high-occupancy vehicle (HOV) priority treatments in a freeway management system. It provides a summary of the planning, design, and operations issues associated with including an HOV treatment in a freeway management system. It also provides an overview of the decision process for determining which type of priority treatment is appropriate for a specific system. It also discusses some of the special design, operating, and maintenance issues associated with HOV treatments.

Module 7. Information Dissemination

This module describes the process for establishing a cohesive information dissemination subsystem in a freeway management system. It identifies the existing and emerging technologies available to facilitate information dissemination to travelers. It also illustrates how the information dissemination subsystem integrates with the other subsystems of a freeway management system.

Module 8. Incident Management

Module 8 presents information related to the planning, design, operations, and maintenance of an incident management subsystem in a freeway management system. It is intended to illustrate how to develop or enhance the incident management capabilities of a freeway management system. It also provides insight into the key factors and issues to be considered in planning, designing, and implementing an incident management subsystem. It is intended to complement the material already presented in the *Freeway Incident Management Handbook.*[5]

Module 9. Communications

This module provides insight into the issues associated with planning, designing, operating, and maintaining a communications subsystem in a freeway management system. It focuses on the decision process for determining the appropriate technologies and system architecture for specific freeway management systems. It also provides a summary of existing and emerging communications technologies. It is intended to complement the material already presented in the *Communications Handbook for Traffic Control Systems.*[11]

Module 10. Control Center

This module provides information related to planning, design, operations, and maintenance of the control center. It focuses on both the physical design and human factor elements associated with freeway management control centers. It also provides insight into how the functions of the freeway management system affect the design and operations of the control center. Special issues such as privatization of operator functions and multi-agency control centers are also discussed in this module.

Module 11. Economic Analysis

This module presents information on some of the economic analyses that can be used in planning and evaluating alternative designs of freeway management systems. Included in this module is step-by-step instruction on how to conduct a life-cycle cost evaluation, a benefit-cost evaluation, and other pertinent economic analyses.

This module also provides guidance to the reader on when it is appropriate to use the different types of economic analyses.

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MODULE 2. DECISION PROCESS

TABLE OF CONTENTS

MODULE 2. DECISION PROCESS

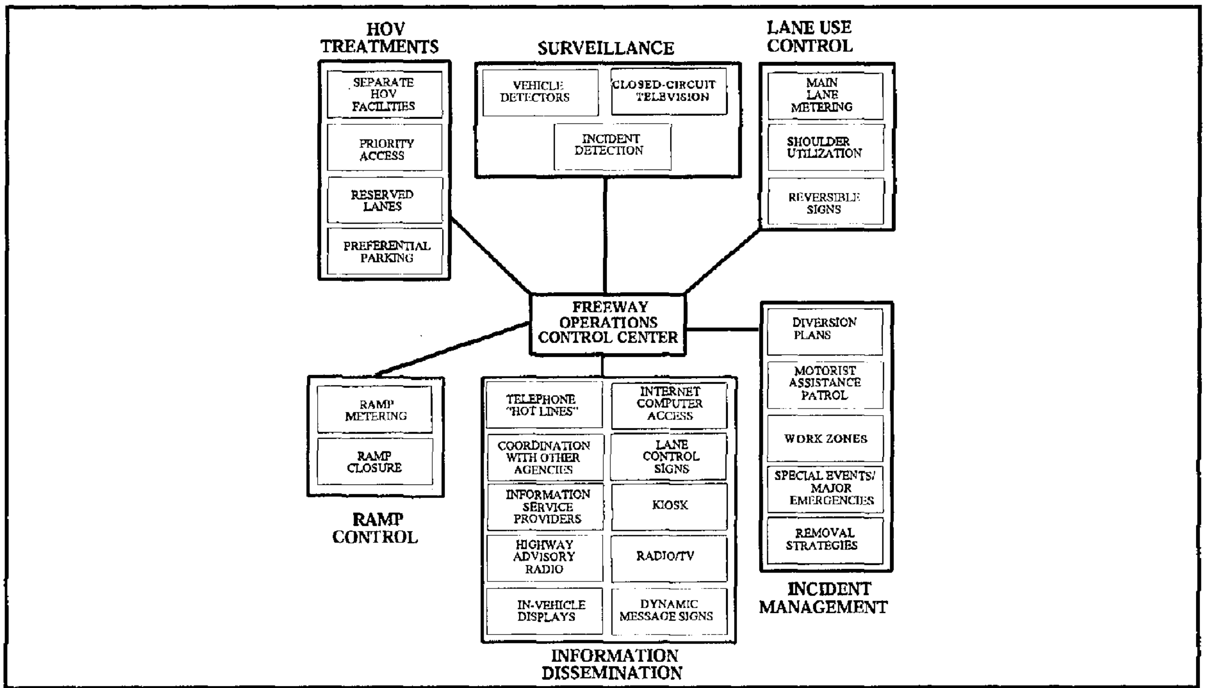


Figure 2-1. Elements of a Freeway Management System.

2.1 INTRODUCTION

Management of the freeway system has become increasingly popular as a tool for combating congestion problems in urban areas. A freeway management system is a collection of strategies, personnel, and technologies combined together to accomplish the following:

To promote the efficient and effective movement of people and goods, to improve the safety of the traveling public, and to improve the environment by reducing both the duration and extent of recurring and nonrecurring congestion on the freeway system.

A freeway management system includes one or more subsystems to accomplish the following tasks:

- Monitoring operations of the freeways and detecting sources of recurring and non-recurring congestion.
- Controlling use of existing lanes and shoulders to maximize the use of the existing pavement within the freeway right-of-way.
- Managing the amount of traffic that enters and exits the freeways via the ramps.
- Providing priority treatment of high-occupancy vehicles within the freeway.
- Disseminating both pre-trip and en route information to travelers so that they can make informed mode, route, and departure time decisions.
- Restoring the freeway to full capacity as quickly as possible after an incident.

Regardless of the size of the freeway system or the level of sophistication and extent of the existing freeway management system, a systems engineering approach to planning and designing a freeway management system should be followed. A systems engineering approach is an iterative process whereby operational problems are identified, system concepts and objectives are established, potential solutions are developed and evaluated, new solutions are identified, and system objectives are redefined. The approach is applied throughout the entire life cycle of the system (planning, design, operations, and maintenance), with the level of detail being progressively refined. The same systems engineering process can be used in each of the following applications:

- Planning and implementing a new system where no current freeway management system exists.
- Modifying an existing system to add new freeway management functions.
- Upgrading the technology in an existing freeway management system to current standards.

MODULE OBJECTIVES

The objectives of this module are as follows:

- Describe the systems engineering approach to planning and designing a freeway management system.
- Present techniques for quantifying operational problems and measuring performance of a freeway management system.
- Highlight some of the special issues that need to be considered in planning, designing, operating, and maintaining a freeway management system.

MODULE SCOPE

This module describes a systems engineering process for planning and designing a freeway management system. It highlights some of the major issues and decisions that planners and designers must address when developing a freeway management system. It also illustrates how decisions made during the planning and design phase affect the operations and maintenance of the system and how operational and maintenance issues can be addressed during the planning and design phases.

2.2 DESIGN PROCESS

A systems engineering approach examines how various tasks, components, and operational strategies can be combined to form a working and coherent unit to address specific goals, objectives, and user needs.[1] With the systems engineering approach, the components of the system are viewed as an entity rather than as an assembly of individual parts.

Figure 2-2 illustrates the steps involved in a typical systems engineering analysis. These same steps can be used to complete a systems engineering analysis, whatever the size of the system being designed and evaluated. The same process can be used to design an entire freeway management system, individual components of the system, or individual elements within each component: what varies is how much detail is used in the analysis and the data required to complete the analysis.

Also note that the process is iterative. After defining the problem, those internal and external organizations and agencies that must be brought on board if the system is to be effective can be identified. In cooperation with these organizations and agencies,

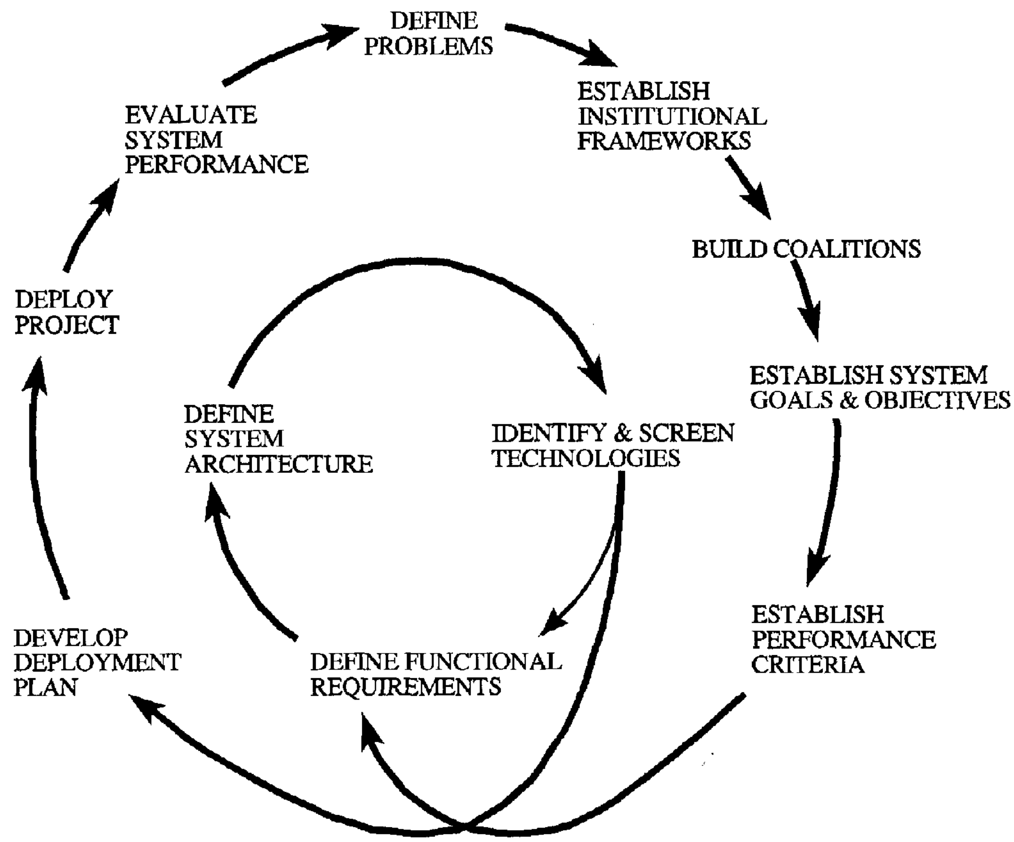


Figure 2-2. Steps Performed in a Typical Systems Engineering Analysis.

system goals and objectives can be identified and performance criteria established. Functional requirements can then be defined to meet the specified goals and objectives. Once the functional requirements have been identified, the system architecture can be defined, and technologies can be identified and screened. The process of defining functional requirements, defining system architecture, and identifying and screening technologies is reiterated at increased levels of detail until system plans and specifications can be prepared. Once the final design of the system is complete, the process of deploying the system can be planned. Using this plan, individual projects can be identified that will lead to the full deployment of the system. Once individual projects have been installed, the performance of the system can then be evaluated. This evaluation may lead to new operational problems being identified, whereby the systems analysis process can be used to identify new improvements to the system. Each step in a typical systems engineering analysis is discussed in the sections below.

A similar process was used to develop the National Intelligent Transportation System (ITS) Architecture. That process is shown in figure 2-3.(2) It is beyond the scope of this handbook to provide a detailed treatment of the National ITS Architecture development. The Architecture was being developed during the same time this handbook was prepared and, as of this date, has not been finalized. The reader is referred to numerous National ITS Architecture documents developed under a Department of Transportation contract with Loral Federal Systems and Rockwell International. In particular, the National ITS Architecture Implementation Strategy is of benefit because it summarizes many of the previous efforts and provides broad guidance in implementing not only freeway systems, but also other related systems.(2)

The National ITS Architecture approach began in 1993 with a concept of "user services" rather than specific hardware items or techniques to support the development of the architecture. The National Architecture work enhanced the user services concept by defining "market packages" that provide groupings of technologies and techniques to satisfy those user services. Reference is made to table 2.2-2 (page 2-29) in the Implementation Strategy document for a relationship of market packages to various services. Succeeding discussions in this module will refer the reader to the appropriate sections of the Implementation Strategy where appropriate.(2)

DEFINE PROBLEMS

The first step in the systems engineering approach is to adequately and properly define and quantify the problems to be addressed by the freeway management system. Properly defining the problems to be addressed by a freeway management system directly leads to the identification of the subsystems that can address those problems.

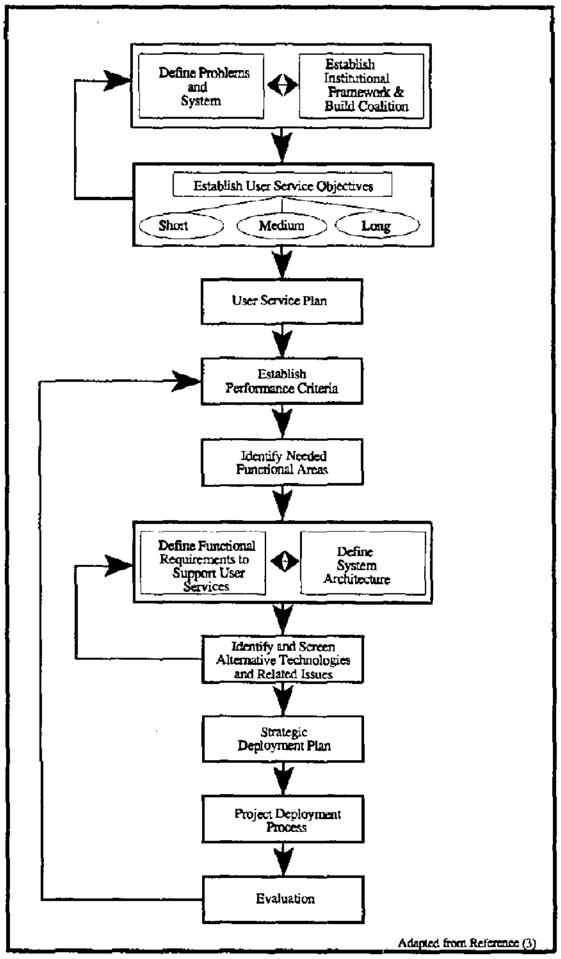


Figure 2-3. Systems Engineering Process Used to Develop National ITS Architecture. (2)

Several methods are available for quantifying the magnitude of the operational problems that can be potentially addressed by a freeway management system. Traditional analytical techniques that can be used to quantify operational problems in a freeway network include the following:

- Capacity and level of service analysis.
- Bottleneck analysis.

- Queuing analysis.
- Travel time and delay studies.
- Computer simulation modeling.
- Crash history analyses.
- Origin/destination studies.

The major tools available for conducting operational analyses of the freeways are discussed in Section 2.3 below.

The importance of coordinating with other transportation-related agencies to identify problems to be addressed should not be overlooked. For example, long-range transit plans can provide an indication of when high-occupancy vehicle facilities may be needed in the freeway system. Input from commercial industries can also be valuable in identifying specific areas of concerns or needs. Finally, and perhaps most importantly, input from local elected officials can also provide insight into the public's perception of problems with the roadway system.

Most of the techniques above help identify existing operational problems; however, in planning a freeway management system, it is important to consider the location and type of operational problems that might occur in the future. Potential sources of information that could be used to identify future operational problems include the following:

- Regional transportation and land use planning studies.
- Site impact analyses.
- Air quality assessments.

In addition to quantifying existing and future operational problems, another critical element in defining the problems that exist is to obtain an accurate and complete inventory of the entire existing transportation system. This inventory should include both physical and organizational components. Examples of physical components that should be identified in the inventory include the following:

- Roadway network.
- Existing surveillance and control systems.
- Existing information dissemination systems.

In addition to the existing physical elements in a system, how the system is envisioned to operate can also influence the design of the system. Examples of the operational components that might influence the design of a traffic management system and, thus, must be identified in an inventory include the following:

- Operating agencies.
- Funding sources.
- Political and agency jurisdictions.

ESTABLISH INSTITUTIONAL FRAMEWORKS AND BUILD COALITIONS

The most critical step in implementing a successful freeway management system is to build critical coalitions and institutional frameworks. Institutional frameworks and coalitions need to be established at the beginning of the planning and design process. These coalitions and institutional frameworks need to be established at three levels: between agencies (inter-agency), within agencies (intra-agency), and with other stakeholders (including the private sector) affected by traffic operations.

Traffic congestion is not restricted by jurisdictional boundaries. When one part of the transportation system (e.g., the freeway network) is not functioning properly, it affects the operations of other parts of the system (e.g., the surface streets, the high-occupancy vehicles lanes, etc.). Therefore, there is a strong need to develop good working relationships and build coalitions among agencies responsible for managing traffic in an area. Examples of the types of agencies with which strong coalitions would help in implementing a freeway management system include the following:

- Metropolitan planning organizations (MPOs).
- Federal, State, and local traffic and transportation engineering agencies.
- Federal, State, and local transit agencies.
- State and local law enforcement agencies.
- Emergency services (fire, ambulance).
- Turnpike / toll road authorities.
- Port authorities.
- State and local emergency management authorities.

In addition, private sector needs should be considered in developing a freeway management system, and should be included in the consensus building process. Examples of these private sectors entities that agencies may want to include in the consensus building process include the following:

- Private transportation information providers and services.
- Private transportation companies.
- Commercial delivery services.
- Interstate and intrastate commercial trucking companies.

Cooperation and coalitions within an agency are also essential in establishing an effective freeway management system. Often, this type of cooperation is the hardest to obtain. Some sections within an agency may view a traffic management system as usurping some of their responsibilities and power. It is essential that all elements within an agency (e.g., planning, administrative, construction, design, operations, and maintenance) are committed to constructing, operating, and maintaining the system.

Finally, there may be others in the community that may be important allies when implementing freeway management systems. Perhaps the most important of these is the general public. Without the support of the general public, it will be extremely difficult to implement a traffic management system. Extensive public relations and media campaigns may be required to show the public how a traffic management system will directly benefit them. Strong public support makes it easier to secure funding and political support. Without public support, it will be extremely difficult to generate elected officials' and agency interest and support for freeway management.

Other stakeholders that may be useful in implementing traffic management systems include the following:

- Major traffic generators.

- Utility companies.
- Elected officials.
- Media.
- Private transportation providers.

Establishing institutional frameworks and coalitions can be difficult at times. The first step in building effective coalitions is to identify "champions" in those agencies responsible for transportation in a community (e.g., State highway agencies, MPOs, transit authorities, etc.). These individuals are likely to be top administrative officials in these organizations. Since traffic management systems often compete with other "traditional" agency activities and expenditures (e.g., pot-hole patching, construction, etc.), the support of top management is essential if agency resources are to be allocated to the operation and maintenance of the system. If congestion is widely recognized as a major issue in a community, upper management support may already exist within many organizations and propagate through the agencies in a "top-down" fashion; however, if it is not, support must be generated from the bottom up.

In addition to identifying "champions" for the system, it is also important to identify those individuals who will be critical to the success of the systems (e.g., the public, elected officials, major employers, etc.). The support of one or more local elected officials can be highly effective in securing funding for the system. Often this support is automatic if traffic conditions have already deteriorated or if the potential for major traffic problems looms on the near horizon.

Another effective way of building strong coalitions between and within agencies is to take advantage of institutional frameworks that already exist. Many locales have institutional frameworks to address freeway management concerns. For example, many locations use Traffic Management Teams and Incident Management Teams to address problems on freeways. Often these teams are a coalition between State and local transportation agencies, and law enforcement personnel. These coalitions can be expanded to encompass additional functions of a traffic management system.

Finally, in building effective coalitions, it is important to identify, within organizations, key individuals who have the appropriate level of knowledge and experience. These individuals must have the level of authority that is appropriate to the type and level of responsibilities that will be performed by the agency. In addition, it is also important to identify individuals who are likely to be present throughout the entire planning and design process for a traffic management system. A common thread among past successful transportation management systems is that key personnel committed to the system have remained with the agencies throughout the planning, implementation, and ongoing operation of the system.

ESTABLISH SYSTEM GOALS AND OBJECTIVES

Once coalitions have been formed, agencies should work together to define the goals and objectives of the system. The system goals and objectives should describe what it is the system is supposed to accomplish. The goals and objectives should be directly related to the specific problems to be addressed by the system. Typical system goals include the following:

- Optimize the utilization of capacity on the freeway.
- Maintain an acceptable level of service of the freeway.

- Provide a balance between demand and capacity in a freeway corridor.
- Provide for the rapid detection, response to, and clearance of freeway incidents.
- Reduce the number of vehicle crashes on the system.
- Improve vehicle operating costs, fuel consumption, and air quality by reducing the amount of travel delay on the freeway system.

Generally, system goals are used to define the long-range vision of the system. System goals also tend to be broad in scope. System objectives, on the other hand, define the level of performance that is expected to be obtained in the future. As such, system objectives are measurable. Often, more than one system objective is required to fulfill a system goal. Likewise, more than one system goal may be required to address an identified problem in a system.

Figure 2-4 provides an example of a system goal and objectives developed to address the problems of incidents in a system. Note that while the defined problems and system goals are broad in nature, the objectives of the system are specific and measurable. Also note that more than one objective is required to fulfill the goal of the system.

It is also important to note that system objectives are defined in terms of what services and functions a system is to provide — not in terms of technology. Notice in the example that no mention is made of the type of technology that will be employed to achieve a 2-minute detection time. Focusing on what the system is to achieve, instead of on how it is to achieve it, gives the designers flexibility in the way that they can combine components to build a system to achieve a desired outcome.

The National ITS Architecture Implementation Strategy provides a good overview of the connection between problems, solutions, and the National Architecture.(2) The approach identifies traditional problems (e.g., traffic congestion) and a solution in terms of both a conventional approach (e.g., roadway construction) and an advanced systems approach (e.g., computer traffic control), and links them to ITS marketing packages. The reader is referred to that document for problems and solutions in the context of the National ITS Architecture.

ESTABLISH PERFORMANCE CRITERIA

After establishing the system goals, the next step in the systems engineering approach is to establish the criteria for judging the performance of the system or subsystem. The performance criteria are used to determine whether the objectives of the system are being achieved. The criteria include both qualitative and quantitative measures of performance for the system. They also form the basis for evaluating the design and operations of the system. The criteria used to measure the performance of the system should correspond directly to the objectives of the system. Examples of the type of criteria that are commonly used to evaluate the effectiveness of freeway management systems include the following:(3)

- Changes in congestion levels and travel patterns.
- Changes in system operation costs, both to the user and to the system operator.
- Changes in other measures that effect the overall community (e.g., reduction in crash frequencies, vehicle emissions, and increased transit usage).

Identified Problem
- Incidents are the primary source of congestion on freeway

System Goal
- Reduce the impacts of incidents

System Objectives
- Detect all major incidents within 2 minutes of occurrence
- Reduce the time to clear an incident from the freeway by 5 minutes

Figure 2-4. Example of System Goal and Objectives to Address an Identified Problem.

- Improved accessibility as evidenced by decreased delays, increased economic activity, and reduced travel time for commuters benefiting from HOV improvements.

- Changes in vehicular demands on congested facilities.

In selecting criteria for evaluating the system performance, the measures of effectiveness must reflect the goals and desires of the community, and must be important and understandable to local elected officials, administrators, citizens, and other affected groups.[3] Table 2-1 lists some of the criteria that should be used in developing and selecting measures to evaluate the performance of a freeway management system. Common measures used to evaluate the effectiveness of freeway management systems include the following:

- Reduction in total travel time.

- Reduction in individual and overall delays.

- Reduction in crash frequencies and rates.

- Reduction in the duration of periods of congestion.

- Reduction in the number of congested freeway segments or length of congestion on a freeway section.

- Improvements in throughput in a corridor.

- Reduction in vehicular demands in a corridor.

- Improvements in network speed.

- Improvements in the consistency of travel times on individual trips.

- Reduction in the number of single-occupant vehicles in the freeway system.

- Improvements in the response and clearance times of freeway incidents.

- Improvements in air quality.

The National ITS Architecture Implementation Strategy considers benefits in the context of market packages, where the benefits are likely to occur, and where

Table 2-1. Criteria for Developing Measures of Effectiveness (MOEs). [4]

• **Relevancy to Objectives** Each MOE should have a clear and specific relationship to transportation objectives to assure the ability to explain changes in the condition of the transportation system • **Simple and Understandable** Within the constraints of required precision and accuracy, each MOE should prove simple in application and interpretation • **Quantitative** Specify MOEs in numerical terms whenever possible • **Measurable** Each MOE should be suitable for application in pre-implementation simulation and evaluation (i.e., have well-defined mathematical properties and be easily modeled) and in post-implementation monitoring (i.e., require simple direct field measurement attainable within reasonable time, cost, and staffing budgets)	• **Broadly Applicable** Use MOEs applicable to many different types of strategies whenever possible • **Responsive** Specify each MOE to reflect impacts on various groups, taking into account, as appropriate, geographic area and time period of application and influence • **Sensitive** Each MOE should discriminate between relatively small changes in the nature or implementation of a control strategy • **Not Redundant** Each MOE should avoid measuring an impact sufficiently measured by other MOEs • **Appropriately Detailed** MOEs should be formulated at the proper level of detail for the analysis

the benefits may accrue.[2] The reader is referred to that document for a more detailed treatment of the approach as related to freeway systems, in particular tables 4.2.3, 4.2.4, and 4.2.5 (pp 4-17 and 4-18.)

DEFINE FUNCTIONAL REQUIREMENTS

The next step in the systems engineering approach in designing a system is to define all of the features or activities (commonly called functions) of the system that are necessary to achieve the identified objectives. The system functions need to be described, at least initially, independent of the technology or architecture to be employed in the system. In other words, this step focuses on describing *what* it is the system will be designed to do, not *how* the system will be doing it.

The functional requirements needed to achieve a system objective can often be outlined in hierarchial order. For example, the functional requirements of an incident management program might be described as shown in table 2-2. Note that each of the functional requirements defines an action or activity that is to be performed by the system and that is independent of technology.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

After defining *what* the system is supposed to accomplish, the next step in the systems approach is to define the functional relationships, data requirments, and information flows of the system. This provides a framework within which the system carries out the functions required to support the desired objectives. It describes the system elements and their relationship to one another.

The functional relationships, data requirements, and information flows of many freeway management systems in operation today have evolved as new functions were added to the system. However, there are real benefits to be achieved in planning how systems relate to one another in advance, even if the system will not be fully implemented immediately. Planning these relationships minimizes the number of redundant functions and efforts performed by the system. It also promotes the efficient use of equipment, staff, and resources. A well-planned system permits easy expansion and modernization of the system in the future. How the functions relate to one another also facilitates the sharing of information between jurisdictions, and leads to cost savings throughout the design, implementation, and operation of the system.

The design or achitecture of a system consists of three elements: the functional requirements, the logical design, and the physical design. As discussed above, the functional requirements define what the system is supposed to do. The logical design identifies what information flows between the functions. The physical design identifies where functions occur and who is responsible for performing each function. The physical design permits like functions to be grouped into subsystems.

It is extremely important when defining the design of the system that it remain as open as possible. An "open" design is a system that has been designed with standard data interfaces so that equipment from multiple vendors can be used throughout the system. In addition, an open design helps to keep the system from becoming obsolete, because new functions and technologies can be easily added as they became available. Furthermore, an open design will make systems being developed today compatible with the National ITS Architecture as it emerges.

IDENTIFY AND SCREEN TECHNOLOGIES

Once the system functional relatioships, data requirements, and information flows have been defined, the next step in the systems engineering process is to identify alternative technologies whose performance and reliability meet the defined functional requirements. Methods for estimating the benefits derived by implementing a particular technology or system component include the following:

- Capacity and level of service analyses.
- Bottleneck and queuing analyses.
- Computer simulation.
- Field measurements.

In addition, evaluation studies from other systems, promotional documents from vendors, and demonstrations from

Table 2-2. Example of Functional Requirements of an Incident Management System.

- ♦ Detect incidents
  - Identify location of incident
  - Identify impacts of incident
  - Identify characteristics of incident
- ♦ Formulate response actions
  - Identify necessary emergency vehicle response
  - Select incident information for dissemination to travelers
  - Identify traffic control strategies
- ♦ Initiate and monitor response
  - Provide response procedures to agencies
    - Implement emergency vehicle response
    - Provide incident information to travelers
    - Implement traffic control strategies
  - Monitor response
    - Arrival emergency vehicles
    - Implementation of traffic control
    - Clearance of incidents
    - Clearance of congestion

manufacturers are excellent sources of information on the state-of-the-art of specific technologies. Site visits to existing systems that use specific types of technologies can also be an excellent tool for evaluating various technologies.

The interaction between alternative technologies and other elements within the system should be considered when evaluating different technologies. How the systems work together and what functions they perform can greatly influence how different technologies perform in a system. The impacts of different technologies on the physical configuration of the system and on the performance of other technologies and components in the system should also be considered. The expandability and flexibility of the technologies should also be considered.

Cost is another factor that should be considered when identifying and screening different technologies. The designers should consider the life-cycle costs (see Module 11) of each alternative technology. When examining the life-cycle costs of each technology, the engineer should consider the following costs:

- The costs associated with procuring, installing, and constructing each alternative technology.
- The costs associated with operating and maintaining each alternative technology within the overall system.
- The costs associated with replacing each technology at the end of its life.
- The costs associated with expanding the system, given that each alternative technology has been implemented.

Operation and maintenance are also important factors that must be considered when evaluating different technologies for use in a management system. Often, each technology requires unique operating and maintenance activities. The resource requirements, in terms of the number and qualifications of the personnel, the equipment and facility needs, and the operating and maintenance costs, should be factored into the evaluation. In evaluating system alternatives, the following operations and maintenance requirements should be considered:[5]

- An assessment of the existing operation and maintenance capabilities in terms of personnel, skills, and equipment.
- A determination of the necessary skills and work load impact of each system alternative.
- A comparison of the existing conditions with what is required for the successful operation and maintenance of the various alternatives.
- An analysis of the operational and maintenance deficiencies that exist with each system alternative.
- An assessment of the feasibility of providing additional operational and maintenance capabilities to address the identified deficiencies.

The process of identifying and screening different technologies for inclusion in a system is often iterative. There are multiple ways that different technologies can be combined to achieve an objective. Because how different technologies interact with one another can affect system performance, each combination must be evaluated in an iterative fashion.

DEVELOP IMPLEMENTATION PLAN

After the technologies that will be used in the system have been selected, the next step in the process is to develop a plan for implementing the system. The implementation plan documents the results of the previous steps and identifies how the system will be implemented in the field. At a minimum, an implementation plan should include the following elements:

- A description of the transportation system problems and opportunities to be addressed by the system.
- The institutional arrangements (i.e., who, what, when, where, why, and how) needed to make the system work.
- The goals and objectives of the system (i.e., what the system will be expected to do).
- The functional requirements and architecture of the entire system.
- The technology options to be used in the system.

The implementation plan should also assess the phasing, procurement, and funding options available for implementing the system.

The purpose of an implementation plan is "to ensure that the system is designed, built, operated, and maintained so that it accomplishes its purpose in the most efficient manner possible, considering performance, cost, and schedule." An implementation plan is required when either a new traffic control system or an expansion of an existing system uses Federal funds. Because it completely describes how the system is going to be designed, operated, and maintained, it is highly recommended that an implementation plan be developed as well for those systems that do not use Federal funds. Figure 2-5 lists the elements of a typical implementation plan.[6]

The National ITS Architecture Implementation Strategy provides guidance for major traffic management design options in the context of its market packages.[2] The reader is referred to Section 4.5 of that document in particular tables 4.5.2 and 4.5.3 (pp. 4-59 to 4-63) for the National ITS Architecture approach to implementation.

DEPLOY PROJECTS

There are a number of approaches that are commonly used by agencies to deploy individual projects or systems. The more common types of procurement approaches include the following:[6]

- Sole-source.
- Engineer/contractor.
- Two-step approach.
- System management.
- Design-build.

With a sole-source project, a contract is awarded to a named supplier without any competition for the project. This type of procurement approach typically involves a standard off-the-shelf product that can be made only by one manufacturer. Such an approach should be used only if it can be justified to be more cost-effective than a competitive low-bid process.

With an engineer/contractor approach, a single contract is awarded to the lowest responsive bidder to a specific request by the highway agency. The contractor is then responsible for providing a complete and fully operational system. In designing and deploying the system, the contractor may elect to subcontract much of the work that is outside the area of expertise of the contractor. The highway agency should be careful to specify the appropriate level of qualifications for the prime contractor to avoid getting a contractor who is unable to complete the job.

A two-step procurement process helps to eliminate some of the problems associated with the standard engineer/contractor approach. With a two-step procurement approach, a formal technical prequalification process is added to the engineer/contractor approach. This helps ensure that the contract team has the appropriate skills and expertise for implementing the desired type of system.

A systems management approach is commonly used by many highway agencies to implement freeway management systems. With this approach, a system manager is hired to perform the system design, software development, and system integration activities. Separate contracts are then prepared and awarded for implementing the various subsystems as dictated by the design.

A design-build type of procurement approach is another common way that highway agencies deploy freeway management projects. In a design-build approach, a single entity is responsible for all of the work associated with deploying a system. This includes the system design, the contracts for and the construction of the system components, and the integration of the system elements. Upon completion of the project, the designer-builder turns over the system to the agency for operations and maintenance. This process is often used to fast-track projects, since it can significantly reduce the process time. Agency supervision is required, however, to ensure that a satisfactory quality of product is provided by the contractor.

The reader is referred to the *Traffic Control Systems Handbook* and Part 655-Traffic

- Needed Legislation
- System Design
  - System Designer
  - System Design Life
  - System Coverage
  - System Design and Operations/Maintenance Philosophies
  - System Architecture
  - Integration of Other Functions
  - System Components and Functions
  - Communication Subsystem Design Approach
  - Traffic Operations Center Design Features
  - Project Phasing/Scheduling
  - Design Review
- Procurement Methods
- Construction Management Procedures
  - Division of Responsibilities
  - Scheduling and Establishing Mileposts
  - Conflict Mitigation
  - Coordination with Other Projects
- System Start-up Plan
  - Software and System Acceptance Tests
  - Partial Acceptance
  - Documentation
  - Transition from Old to New Control
  - Operational Support and Warranty Period
  - Training
  - Coordination with Media
- Operations and Maintenance Plan
  - Evaluation
    - System evaluator
    - Method of evaluation
    - Cost of evaluation
  - Maintenance Plan
    - Maintenance policies for preventative maintenance, system malfunctions, etc.
    - Formal maintenance management programs
    - Initial inventory of spare parts and all necessary test equipment
    - Training in providing limited maintenance to software and equipment
- Institutional Arrangements
  - Contact Person/project Liaison Within Each Organization
  - Delineation of Organizational Responsibilities
  - Provisions for Periodic Project Updates
  - Utility Arrangements
  - Written Cooperative Agreements for Personnel-sharing, Cost-sharing, Metering, Traffic Diversion, Etc.
- Personnel and Budget Resources
  - Staffing Plan (including the number of persons and their functions per shift)
  - Contract Operations Staff Agreements (if used)
  - Provisions for Training New Staff
  - Sources of Budgetary Resources
  - Estimates of Annual Expenses by Category
  - Signatures of the Head of the Operating Agency, Head of State Highway Agency, and the FHWA Division Administrator (or their designates)

Figure 2-5. Elements of a Typical Implementation Plan.

Operations, Subchapter G-Engineering and Traffic Operations in the *Federal-Aid Policy Guide* (which has been regenerated in Appendix A at the end of this module) for more information on alternative procurement strategies.[3,6]

Staffing plays a critical role in the timing of the implementation of the system. Sufficient lead time must be allocated to allow system operators to establish new positions (if needed); develop position descriptions and salary classifications; recruit, hire, and train needed personnel. The agency's system supervisor should be employed (i.e., designated/hired) no later than the start of the implementation phase of the project. Other operations and maintenance personnel need to be employed during system construction so that they may receive training providing by the contractor/system manager, review system documentation, and participate in system testing. If these persons are to assist with construction inspection, they need to be hired even earlier.[5]

In addition, good preventative maintenance begins with and depends upon proper installation. Proper installation requires thorough inspection and testing of contractors' work. The system operators and maintainers should participate in the inspection process and during the acceptance testing. Such involvement is an excellent method of informal training and fosters the acceptance of the new system by these personnel. [5]

It is essential that all specified documentation and training be obtained during the installation phase of the system. Submitted materials (e.g., manuals, training course outlines, etc.) should be closely examined to ensure that they are complete and clear to the agency's personnel. Furthermore, the documentation must be kept up-to-date throughout the entire implementation phase to reflect any hardware or software modifications.[5]

EVALUATION

Evaluation is an ongoing process that occurs at all stages of system development and continues for the entire life of the system. Through the evaluation process, the system designers and operators are able to determine how well individual projects meet the previously established system objectives. The evaluation process also allows system managers to identify possible enhancements to the system. These enhancements can be to correct operational or design problems, expand the system either functionally or geographically, or incorporate additional systems into a regional architecture.

The most common method of evaluating the effectiveness of a freeway management system is *Before-and-After* studies. With Before-and-After studies, the performance of the freeway management system is measured before the system (or subsystem) being evaluated is implemented. The same performance measures are then taken again after the system has been implemented. The effectiveness of the system is then determined by comparing the performance of the freeway before the system (or subsystem) was implemented to the performance of the freeway after the system (or subsystem) was implemented.

Potential limitations of the *Before-and-After* approach for evaluating system performance include the following:[7]

- The effects of individual improvements are difficult to distinguish when more than one improvement is made at a time.
- Usually there is a long time lag between the "before" condition and the "after"

condition, which causes this approach to be susceptible to errors caused by time-related factors (such as changes in travel patterns, population growths, economic fluctuations, etc.).

- Usually, it takes some time for the drivers to adjust their travel behavior after the system has been implemented; therefore, depending upon when the "after" data are collected, true system performance may not be measured.

- Some performance measures (like the number of crashes, or demand) can fluctuate considerably over time. There is a tendency for these performance measures to return to more typical values after an extraordinary value has been observed. This tendency is called *regression to the mean.* It is possible that either the "before" condition or the "after" condition could fall at one of these extreme values, thereby, hiding the true performance of the system.

Before-and-After studies with a Control Condition is one way of mitigating the negative aspects of Before-and-After studies.(7) The concept of this evaluation methodology is illustrated in figure 2-6.

With this approach, the before-and-after system performance measures are compared to the same performance measures taken from a segment of freeway with similar characteristics as the first freeway, but not affected by the operation of the system. While this approach reduces history, maturation, and regression to the mean problems, it may be difficult to find a segment of freeway not impacted by the performance of the freeway management system.

In evaluating the effectiveness of the components of a freeway management system with field measured data, it is important to remember the following considerations:(3)

- The impacts of many alternative strategies are frequently small both in absolute and in percentage terms.

- The impacts of specific strategies may be confined to isolated or small geographic areas.

- It may not be possible to accurately estimate the specific impacts using commonly available data and estimation procedures.

In some limited situations, it may be appropriate to use simulation models to estimate the effectiveness of different elements of a freeway management system. Oftentimes, systemwide benefits of different freeway management elements are difficult to measure directly. In these cases, simulation could be used as a tool to estimate the impacts of isolated control elements on the entire system. Furthermore, the results of a simulation study should only be considered as estimates of the performance of the system, since the performance measures are often directly influenced by the assumptions inherent in the simulation model. Whenever simulation is used as an evaluation tool, limited field data should be collected to support the results of the simulation model. As a general rule, simulation should never be used when the same performance indicators can be measured directly in the field.

Another way to illustrate the benefits of a freeway management system is to use anecdotal information collected from travelers who have benefited from the system. For example, many locations keep records on the number of positive letters

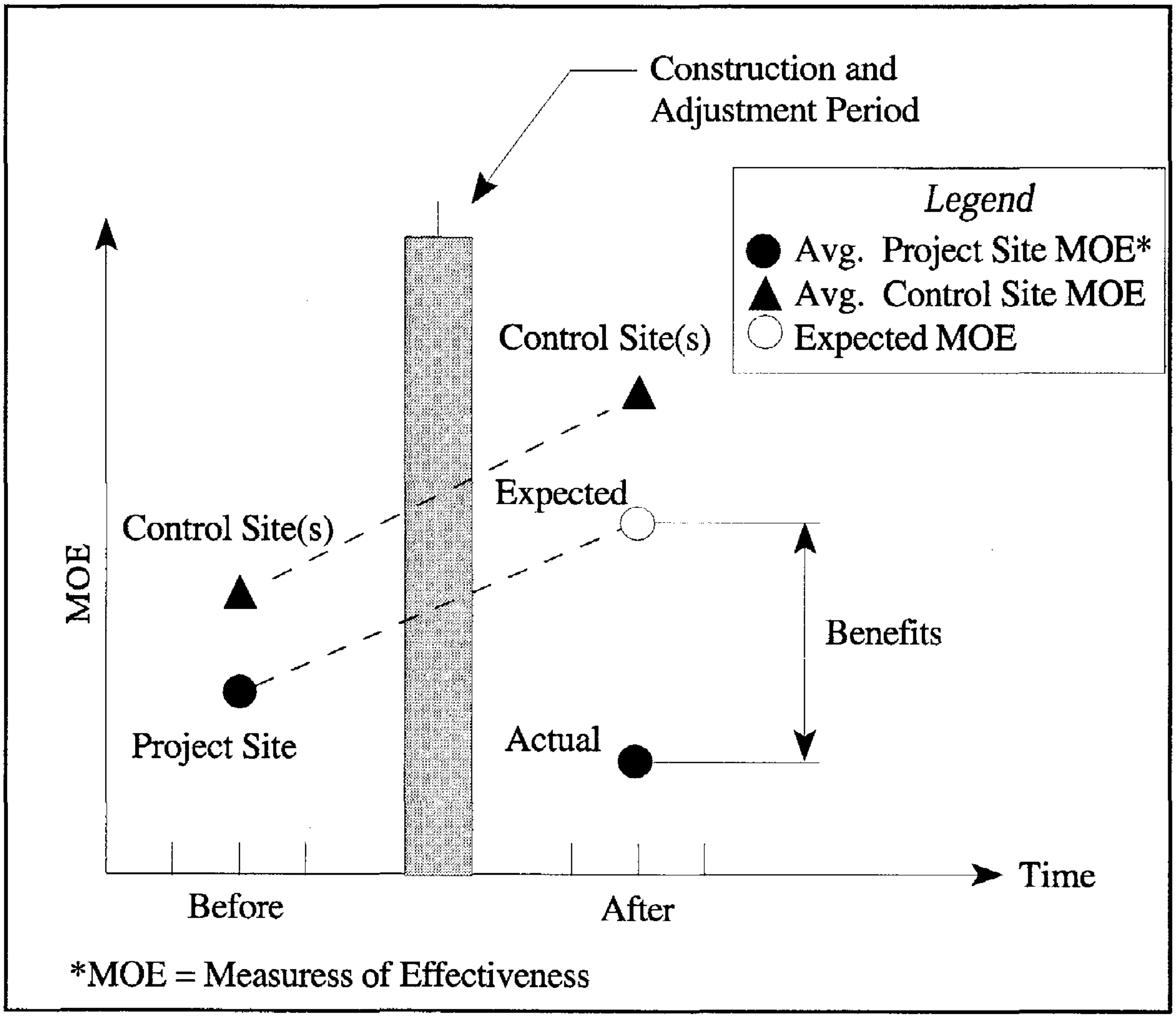


Figure 2-6. Conceptual Illustration of Before-and-After Evaluation with Control Conditions. [7]

they receive concerning their freeway service patrols.

Also, one of the most critical parts of the evaluation process is to document the lessons learned during the development and operations of the system. These lessons provide critical information to others who may be considering implementing a similar type of system. The lessons learned should not focus solely on the problems that were encountered during the development or operations of the system, but also describe the positive elements of a particular system architecture or technology.

2.3 TECHNIQUES AND TECHNOLOGIES

This section describes some of the measures of performance, techniques, and technologies used to identify and quantify operational problems on freeways.

PERFORMANCE MEASURES

Congestion occurs when the amount of traffic desiring to use a facility (demand) exceeds the traffic-carrying capabilities of the facility (capacity). There are two types of congestion: recurring and nonrecurring. Recurring congestion occurs when normal, everyday demand exceeds the physical capacity of the freeway. Nonrecurring congestion is caused either by a temporary reduction in capacity (e.g., a crash or stalled vehicle blocking a lane) or by a temporary excess of demand (caused by a special event or other similar activity).

In planning and designing a freeway management system, it is important to quantify the magnitude of the congestion problem and the amount of improvement that can be made by implementing elements of a freeway management system. The following section provides some of the more common measures of performance used to quantify congestion levels both from a systemwide perspective and at isolated locations such as bottlenecks and incident sites.

Systemwide

There are a number of measures that have traditionally been used to quantify the performance of the freeway system, both with and without a freeway management system in place. These measures include the following:[8]

- Total Travel Time.
- Total Travel.
- Vehicle Delay.
- Total Minute-Miles of Congestion.

Each of the traditional measures of system performance is discussed below. Most of these measures can be computed using data routinely collected by freeway surveillance systems.

Total Travel Time

Total Travel Time is one measure used to quantify operational deficiency and measure the performance of the freeway system. Expressed in units of vehicle-hours, it is the product of the total number of vehicles using the roadway during a given time multiplied by the average travel time of the vehicles. The equation that can be used to compute the Total Travel Time is as follows:

$$TTT_j = N_j \, \overline{tt}_j = \frac{N_j X_J}{\bar{V}_j}$$

where,

TTT_j = Total Travel Time over freeway section j, in vehicle-hours.

N_j = Number of vehicles traveling over freeway section j, during time period T.

$\overline{tt}_j$ = Average travel time of vehicles over freeway section j, in hours.

X_j = Length of roadway section j, in kilometers.

$\bar{V}_j$ = Average speed of vehicle over freeway section, in kilometers per hour.

The Total Travel Time, TTT, in vehicle-hours, for all sections of a freeway can be computed using the following equation:

$$TTT = \sum_{j=1}^{K} TTT_j$$

where,

TTT = Total Travel Time for all sections of the freeway, in vehicle-kilometers.

TTT_j = Total Travel Time for section j, in vehicle-kilometers.

K = Total number of freeway sections.

Total Travel

Total travel is another measure commonly used to quantify operational problems and measure the performance of the freeway system. Total travel is the product of the total number of vehicles using the freeway during a given time interval multiplied by the average trip length of the vehicles. It can be determined using the following equation:

$$TT_j = X_j N_j$$

where,

TT_j = Total Travel over freeway section j, in vehicle-kilometers.

X_j = Length of freeway section j during time period T, in kilometers.

N_j = Number of vehicles traveling over section during time period T.

Total Travel (TT) for all sections of freeway can be computed using the following equation:

$$TT = \sum_{i=1}^{K} TT_j$$

where,

TT = Total Travel for all sections of the freeway, in vehicle-kilometers.

TT_j = Total travel for section j, in vehicle-kilometers.

K = Total number of freeway sections.

Vehicle Delay

Vehicle delay is another common measure used to quantify the level of performance of the freeway system. For freeways, vehicle delay is defined as the increase in travel time on a route over the free-flow travel time. Vehicle delay can be computed by subtracting the total free-flow travel time from the total travel time. Total free-flow travel time is the product of the total number of vehicles using the roadway during a given time interval multiplied by the average free-flow travel time.

Total Minute-Miles of Congestion

Originally developed to measure the effectiveness of the Chicago Area Freeway Surveillance Project, the total minute-miles of congestion method was used to indicate the extent of freeway congestion in both time and space.[9] (Minute-Miles was the measure of performance at the time of the study. Minute-kilometer is also appropriate.) To compute the total minute-miles of congestion, each mainline detector is assigned a section of freeway that covers half the distance between the adjacent mainline detectors on either side. The minute-miles of congestion at each detector is equal to the product of the minutes of congestion at the detector, multiplied by the distance, in miles, assigned to the detector. The sum of the minute-miles of congestion of all detectors then would represent the total minute-miles of congestion.

Isolated Locations

Congestion caused by incidents and bottlenecks tends to be located at isolated locations. Engineers evaluating these locations are primarily concerned with the following issues:

- What is the cause of the congestion?
- How quickly can the congestion clear?
- What are the effects of the congestion on drivers through the congested area?
- How large is the effected area?

The types of measures that are commonly used to quantify the impacts of congestion at isolated locations include the following:

- Time until normal flow.
- Total vehicles delayed.
- Average delay per vehicle.
- Maximum time of queue.
- Maximum queue length.
- Fuel consumption.
- Air pollution.

Most of these measures can be computed by conducting a bottleneck/queuing analysis, which is discussed below.

METHODS TO QUANTIFY OPERATIONAL PROBLEMS ON FREEWAYS

The types of analytical methods used to quantify the freeway operational problems include the following:

- Capacity and Level of Service Analysis.
- Bottleneck and Queuing Analysis.
- Computer Simulation.
- Field Measurements.

How these methods are used to quantify operational problems on freeways is discussed in more detail below.

Freeway Capacity Analysis and LOS

One of the most basic types of analysis required for a section of freeway is a determination of the amount of traffic-carrying capacity that the section can provide. Capacity is defined as the maximum number of vehicles that can reasonably be expected to use the facility in a given time period under prevailing roadway, traffic, and control conditions.[10] Related to this definition is the concept of the operational quality or level of service (LOS) provided to users of a facility.

Definition of Freeway Subareas for Capacity Analysis

Freeways are composed of three types of component subsections. These are defined as follows:

- *Basic Freeway Segments* -- These are freeway sections that are unaffected by either merging or diverging traffic movements at nearby ramps or by weaving movements.

- *Weaving Segments* -- These are freeway sections where two or more vehicle flows must cross each other's path. Weaving areas exist where merge areas are closely followed by diverge areas, and where a freeway on-ramp is followed closely by an off-ramp and an auxiliary lane is used to connect the two.

- *Ramp Junctions* -- These are freeway sections where on- and off-ramps join the freeway.

Figure 2-7 illustrates the various types of freeway components. Capacity analyses treat each one of these components with a separate computational procedure. After the components have been evaluated in isolation, the results are laid out together to assess how the freeway operates as a system. A system analysis perspective is particularly important in the evaluation of closely-spaced ramp effects upon the capacity and operating characteristics of the freeway.

Basic Freeway Segments

Definition of Ideal Freeway Capacity. According to the 1994 edition of the Highway Capacity Manual, the capacity of basic freeway segments under ideal roadway, traffic, and environmental conditions is assumed to be 2,200 passenger cars per hour per lane (pcphpl) on four-lane freeway sections and 2,300 pcphpl on six-or-more lane freeway sections.[10] These capacity values represent the maximum number of vehicles that can reasonably be expected to use the facility (an average over all lanes) in a given time period under prevailing roadway, traffic, and control conditions. Flow rates in excess of these values can sometimes occur in individual lanes, particularly in inside or median lanes where there is no influence of upstream or downstream ramps.

Conditions that are "ideal" from a freeway capacity perspective include the following:

- 3.6 m (12 ft) minimum lane widths.

- 1.8 m (6 ft) minimum lateral clearance between the edge of the travel lane and the nearest roadside or median obstacle influencing traffic behavior.

- All passenger cars in the vehicle stream (no trucks, buses, or recreational vehicles).

- Motorists who are regular and familiar users of the freeway.

Factors Affecting Capacity. Obviously, conditions more restrictive than those listed above reduce the traffic-carrying capacity of the freeway. For example, lane widths narrower than 3.6 m (12 ft) cause drivers to travel closer to one another laterally, and so they adjust by increasing the distance between themselves and the vehicle in front of them. Roadside obstructions closer than 1.8 m (6 ft) to the roadway cause drivers to shy away from the edge of the roadway, and they again respond by increasing the gap between their vehicles and the vehicles they are following. Trucks, buses, and recreational vehicles are larger than passenger cars and have more sluggish operating characteristics, which create larger gaps between them and passenger vehicles. Finally, the characteristics of the driving population have been shown in several studies to affect the capacity of a freeway segment. Nonfamiliar users of a facility are generally more cautious and therefore leave more room between themselves and vehicles they are following.

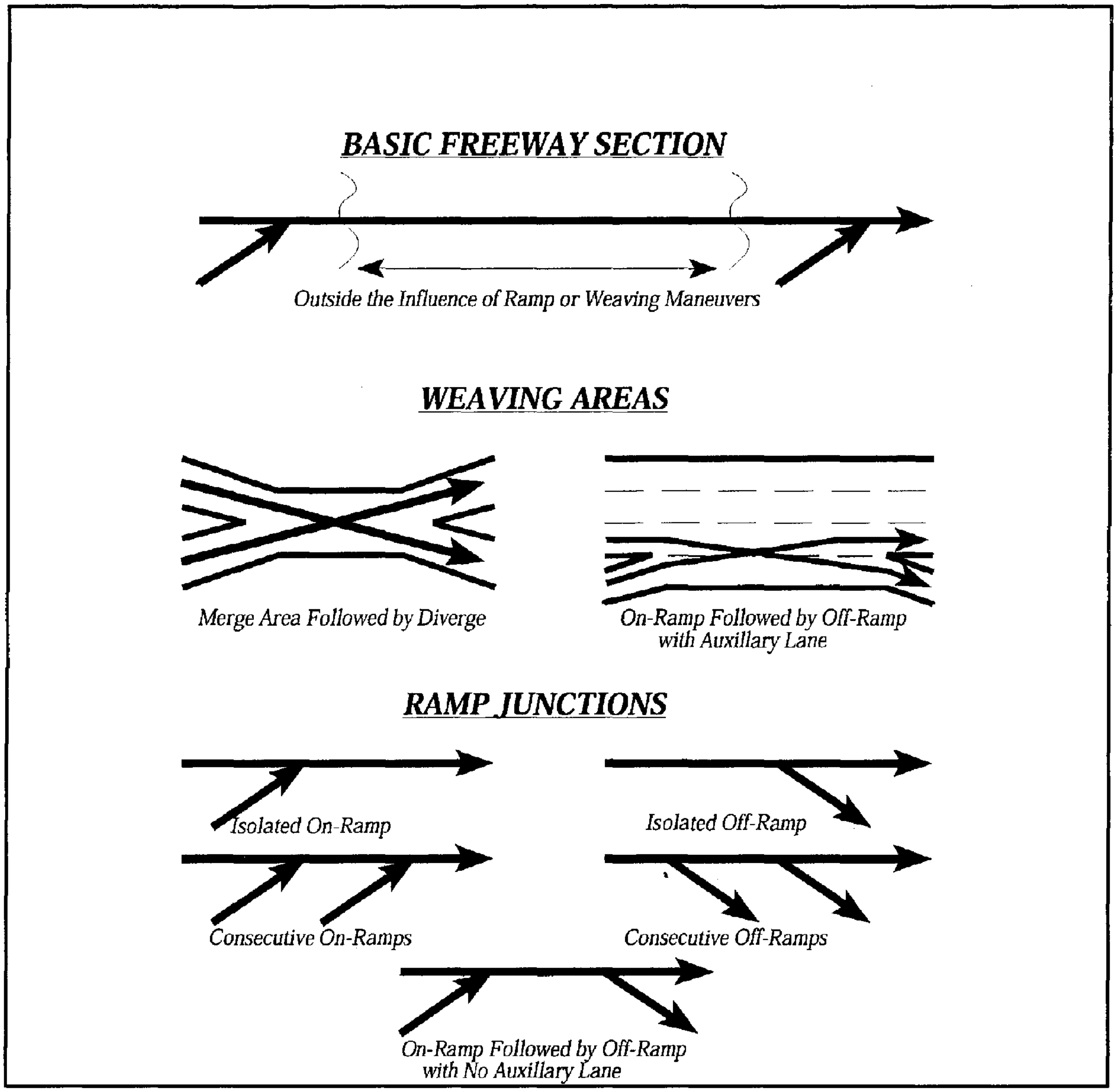


Figure 2-7. Illustration of Freeway Components for Capacity Analysis. [11]

Traffic operations and the capacity of basic freeway segments are also affected by horizontal and vertical alignment. Specifically, sharper horizontal curves and longer, steeper grades reduce the traffic-carrying capacity of the freeway segment.

Level of Service. As indicated previously, the concept of LOS was introduced into operational analysis as a means of quantifying the quality of operation attainable under a given roadway and traffic configuration. Although the traffic-carrying capacity of a basic freeway segment is defined in terms of vehicular flow, density (number of vehicles per lane per kilometer (mile)) is the parameter used to define LOS for basic freeway segments. LOS is defined by the letters A through E, with LOS F used to define breakdown, stop-and-go conditions. Table 2-3 gives a qualitative description of each level of service, and the density value that has been associated with each level.

Weaving Areas

Definition of Weaving Area Capacity. Weaving is defined as the crossing of two or more traffic streams traveling in the same general direction along a significant length of freeway. Weaving areas represent a region of intense lane-changing behavior and increased traffic flow turbulence as drivers attempt to access lanes to reach their desired exit points from the weaving area. Many different roadway and traffic factors can influence operations within these areas. Because of this complexity, the capacity of weaving areas as estimated by procedures in the *Highway Capacity Manual* is not defined in terms of maximum flow rates or vehicle densities, but in terms of estimated operating speeds.[10] Specifically, calculations are made to estimate the speeds expected of weaving and of nonweaving vehicles. These are then compared to tabular values to determine the LOS being provided by that weaving section.

Types of Weaving Areas. Because lane-changing is the critical operational feature of weaving areas, weaving sections are categorized according to the minimum number of lane changes that must be made by weaving vehicles.

Weaving areas are referred to as Type A, Type B, or Type C sections. Figure 2-8 illustrates each type of weaving area.

Type A weaving areas require that each weaving vehicle make one lane change in order to execute the desired movement. These areas may be ramp-weave areas created by adjacent entrance and exit ramps connected by an auxiliary lane, or major weaving areas characterized by three or more entry and exit roadways having multiple lanes.

Type B weaving areas may also be referred to as major weaving sections if they involve multilane entry and/or exit lanes. However, these areas differ from Type A areas in that one weaving movement can be accomplished without changing lanes, whereas the other weaving maneuver requires no more than one lane change.

Type C weaving areas are similar to Type B areas in that one weaving movement can be made without changing lanes. The major difference between these two types of areas is that Type C areas require the other weaving maneuver to make two or more lane changes. This can be an effective design if the second weaving flow is fairly small. However, it can have very adverse effects on operations if the second flow is large, the number of lane changes being made is large, and the length of the weaving area is fairly short.

Operational Characteristics of Weaving Areas. Traffic operations within weaving areas are affected by the following geometric features:

- Weaving length.
- Weaving area configuration.
- Number of lanes (weaving width).

Shorter weaving lengths create greater traffic flow turbulence as drivers are forced to make necessary lane changes over a limited distance. The configuration of a weaving area influences the number of lane changes that must be made and also the proportion of vehicles that must make a weaving maneuver. The number of lanes available within the weaving area defines the amount of space available to weaving vehicles to make the various types of lane changes.

Table 2-3. Level of Service (LOS) Descriptions. [11]

Level of Service	Status	Density Threshold, pc/km/ln (pc/mi/ln)	Description
A	Free Flow	6.25 (10)	Individual motorists are unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is high.
B	Stable Flow	10 (16)	Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream. The presence of others in the traffic stream begins to affect individual behavior.
C	Stable Flow	15 (24)	The behavior of individual motorists is significantly affected by interactions with others in the traffic stream. Selection of speed is affected by other vehicles and maneuvering within the traffic stream requires vigilance by the motorist.
D	High-Density Stable Flow	20 (32)	Speed and freedom to maneuver are severely restricted, and the driver experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems.
E	Unstable Capacity Flow	23-30 (36.7-47.9)[a]	Operations are at or near capacity. Speeds are lower, but relatively uniform among vehicles. Freedom to maneuver is extremely limited. Operations are unstable.
F	Forced or Breakdown Flow	>23-30 > (36.7-47.9)[a]	Amount of traffic approaching a point exceeds the amount which can traverse the point. Queues form and operations are characterized by unstable stop-and-go waves.

[a] Capacity occurs at different densities depending on the design speed of the freeway

If the weaving length, configuration, and width in combination with the traffic demand pattern permit the weaving and nonweaving vehicles to spread out evenly across the available lanes in the weaving section, the operation of the weaving area is more effective and is classified as **unconstrained**. Conversely, if the configuration and traffic demand limit the ability of weaving vehicles to occupy their proportion of available lanes to maintain balanced operations, the operation is less effective and is classified as **constrained**. Imbalanced or constrained operations within weaving sections will result in weaving vehicles traveling at a lower average speed than nonweaving vehicles. Not only will the LOS being provided by the weaving section be lower because of this condition, but also the general safety of the section will be lower because of a mixing of lower and higher speed traffic flows.

Capacity and Level of Service for Weaving Areas. In weaving sections, operations are estimated to be at capacity when estimated weaving and nonweaving speeds are between 48 and 56 km/h (30 and 35 mph). Table 2-4 summarizes the weaving and nonweaving speed thresholds that have been defined for the other levels of service. Those average speeds are based on regression equations.

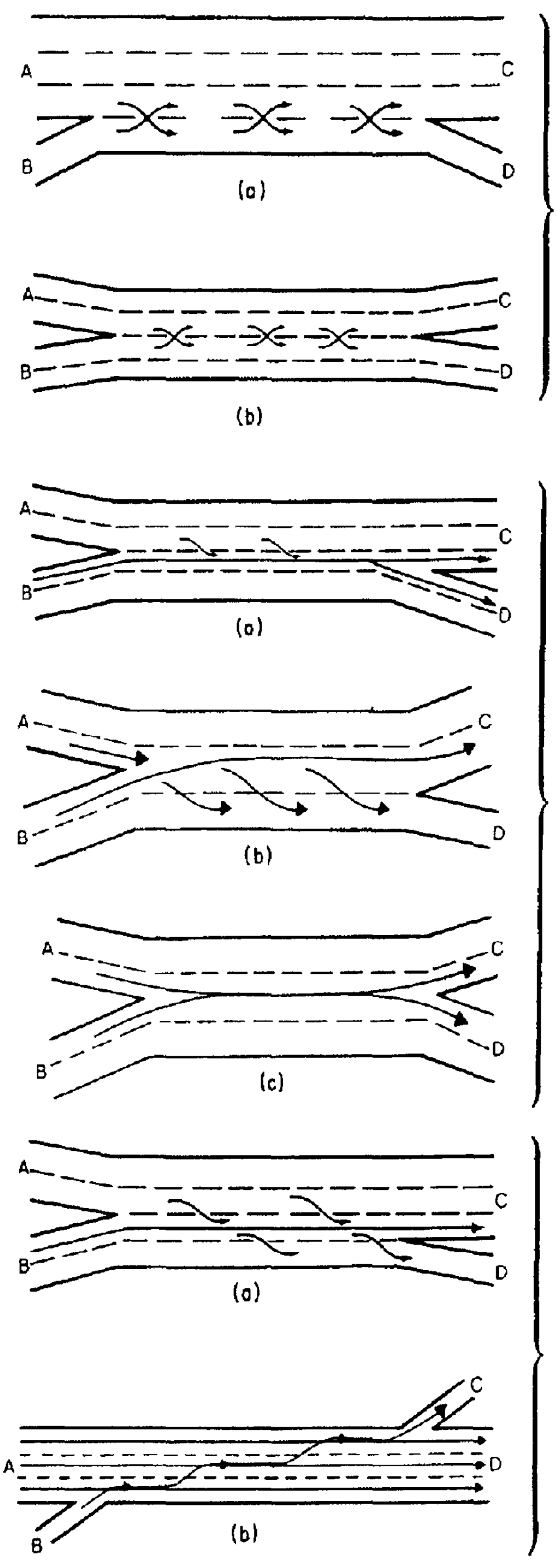
The regression constants vary according to the weaving configuration of the section and whether or not the weaving section operation is unconstrained or constrained. Both the weaving and nonweaving speeds must satisfy the criteria specified in table 2-4 for a given LOS. For example, the average weaving speed must exceed 80 km/h (50 mph) and the average nonweaving speed must exceed 90 km/h (54 mph) in order for the weaving section to be considered as operating at LOS B.

It is important to note that the above LOS criteria have been established in conjunction with the regression equations, and only provide a mathematical procedure for assessing the general operations at weaving areas. Considerable variation may exist between the estimates obtained via the mathematical procedures and the actual operations observed at a given weaving area. Research continues to improve the estimates of weaving area operations. The formulas and thresholds presented in this chapter should be supplemented with sound engineering judgement and actual field data as necessary until a better understanding and mathematical formulation are available.

Ramp Junctions

Definition of Ramp Junction Capacity. The points at which vehicles enter a freeway mainlane from an on-ramp or the point at which mainlane traffic diverges to an off-ramp are termed freeway-ramp junctions. A freeway-ramp junction is an area of competing traffic demand for space. Analyses of freeway-ramp junctions focus on the merging and diverging behaviors required in the outer two freeway lanes and the acceleration or deceleration lane in the vicinity of on- and off-ramps, respectively, as depicted in figure 2-9. Elements such as the length and type (e.g., taper, parallel) of acceleration and deceleration lanes, free-flow speed of the ramp in the immediate vicinity of the junction, and sight distances all influence traffic operations within these regions.

For freeway-ramp junctions, two capacity values are important. The first refers to the requirement that the capacity of the freeway lanes (plus the off-ramp lane in the case of diverging freeway-ramp junctions) where vehicles *exit* the region of ramp influence must not exceed the capacity of those lanes as defined for basic freeway segments. This value is 2,200 pcphpl for four-lane facilities or 2,300 pcphpl for freeway facilities with six or more lanes. The second capacity value of interest is the freeway traffic flow *entering* the ramp influence area. This cannot exceed 4,400 pcph on four-lane



Type A weaving areas: (a) ramp-weave/one-sided weave, and (b) major weave with crown line.

Type B weaving areas: (a) major weave with lane balance at exit gore, (b) major weave with merging at entrance gore, and (c) major weave with merging at entrance gore and lane balance at exit gore.

Type C weaving areas: (a) major weave without lane balance or merging, and (b) two-sided weave.

Figure 2-8. Categories of Weaving Areas. [13]

Table 2-4. Level-of-Service Criteria for Weaving Sections. [11]

Level Of Service	Minimum Average Weaving Speed, S_w km/h (mph)	Minimum Average Nonweaving Speed, S_{nw} km/h (mph)
A	90 (55)	100 (60)
B	80 (50)	90 (54)
C	70 (45)	77 (48)
D	60 (40)	67 (42)
E	50/60 (35/30)	50/60 (35/30)
F	<60/50 (<35/30)	<60/30(<35/30)

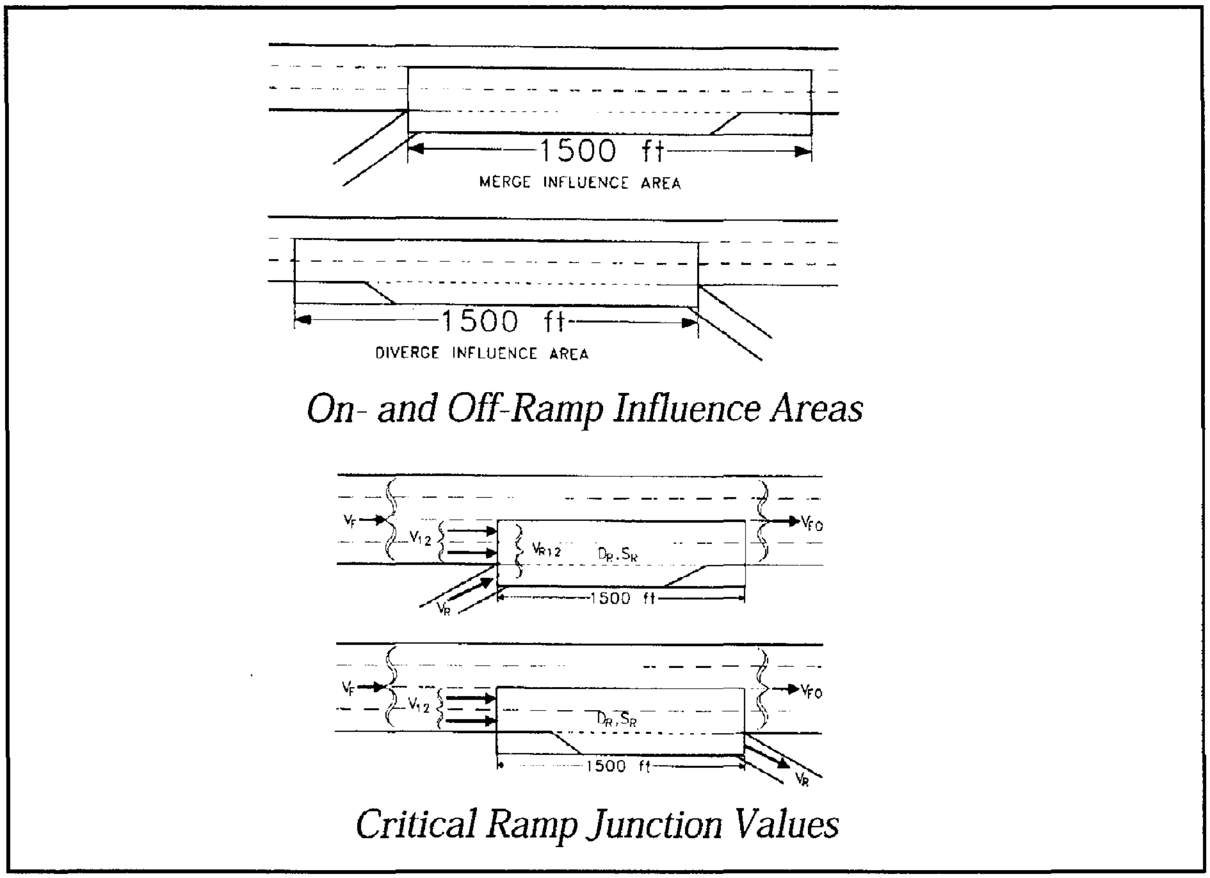


Figure 2-9. Influence Areas and Critical Flow Values for Freeway-Ramp Junctions. [11]

facilities or 4,600 pcph on six- or more lane facilities.

Operational Characteristics of Ramp Influence Areas. In the merge area at an on-ramp, individual merging vehicles from the ramp attempting to enter the outer freeway lane (lane 1) create turbulence in the traffic stream in the vicinity of the ramp. Approaching freeway vehicles therefore tend to move towards the left to avoid this turbulence. As ramp volumes increase, more and more freeway vehicles will move to the left as long as there is available capacity to do so. However, the interaction between freeway and ramp vehicles in the influence area is quite dynamic. Although the intensity of the ramp demand flows most generally affects what percentage of approaching freeway vehicles move to the left, any congestion that develops on the freeway itself affects the ability of ramp vehicles to enter the freeway and can cause diversion of some of the ramp traffic to other routes or ramps in the vicinity, or excessive ramp queuing.

In the diverge area of an off-ramp, the basic maneuver being performed is the separation of a single traffic stream into the through and exiting movements. Since exiting vehicles must occupy lane 1 in order to utilize the off-ramp, they begin moving towards that lane in the influence area. This in turn also causes through freeway vehicles to begin moving towards the left in order to avoid the turbulence of the diverge area.

These operational characteristics serve as the basis of current freeway-ramp junction analytical procedures included in the 1994 *Highway Capacity Manual.*[10] Regression equations are presented in that manual to estimate the percentage of freeway traffic that remains in the two lanes closest to the ramp in the influence area. The choice of the appropriate regression equation depends on the following factors:

- The number of freeway lanes in the influence area.
- The presence of nearby on- or off-ramps.

Level of Service of Freeway-Ramp Junctions. Although the capacity analysis procedures for freeway-ramp junctions focus on the flow rates entering and exiting the influence area, traffic flow is not the primary measure used to evaluate the LOS that exists within a ramp influence area. Rather, as is done for basic freeway segments, vehicle density is the primary measure used to define levels of service. Table 2-5 provides the density thresholds corresponding to each level of service in ramp influence areas. Regression equations presented in the Highway Capacity Manual are used to estimate volumes, densities, and speeds in the ramp influence area.

As shown in table 2-5, the density threshold values for each LOS are somewhat higher than for basic freeway segments. This is because drivers naturally expect some increased turbulence and closer proximity of other vehicles in a merge or diverge area, and because drivers are typically traveling at a slightly slower speed in any given lane in the influence area than they would on a similar section of open freeway.

Freeway Systems

The freeway is a complex facility made up of many component segments, each having a potential impact on operations in upstream and downstream segments. Capacity and LOS analyses discussed to this point have addressed each of the major types of freeway components. After the component analysis has been completed, the final step in such an analysis is to put the various components

Table 2-5. Level of Service (LOS) Descriptions for Freeway-Ramp Junction Influence Areas. [11]

Level of Service	Status	Density Threshold, pc/km/ln (pc/mi/ln)	Description
A	Unrestricted Operations	6.25 (10)	Merging and diverging maneuvers occur without disrupting freeway flow. No noticeable turbulence exists. Freeway speeds are nearly as high as in basic freeway sections.
B	Stable Operations	12.5 (20)	Merging and diverging maneuvers become noticeable to motorists, but only minimal levels of turbulence exist. Merging vehicles must adjust their speeds in order to move into available gaps in the freeway traffic stream.
C	Stable Operations	17.5 (28)	Average speeds in the ramp influence area begin to decline. Driving conditions are still relatively comfortable at this level.
D	High-Density Stable Operations	21.9 (35)	Turbulence levels become intrusive. All vehicles in influence area slow to accommodate those making merging and diverging maneuvers. Freeway operations tend to remain stable.
E	Capacity Operations	> 21.9 (> 35)	Operations are at or near capacity. Speeds are lower. Freedom to maneuver is extremely limited and intrusive to all drivers. Operations are unstable.
F	Breakdown Operations	[a]	Traffic attempting to use influence area exceeds the amount which can traverse the area.

[a] Density criteria is not valid or relevant under breakdown conditions

together to get an overall systemwide picture of anticipated freeway operations.

Generally speaking, capacity and LOS analyses can be oriented towards design (determining necessary number of lanes, locations of ramps, weaving area lengths, etc.) or operations. In this section, the basic steps for an operational analysis of a freeway system are outlined.

As the first step, the analysis of individual freeway components occurs as per the techniques described earlier.

1. Basic freeway segments are evaluated using the procedures discussed in chapter 3 of the *Highway Capacity Manual.*[10]

2. Ramp junctions are evaluated using the procedures in chapter 4 of the *Manual*, considering each ramp as follows:[10]

- As an isolated ramp.

- In conjunction with the adjacent downstream ramp.

- In conjunction with the adjacent upstream ramp.

   Ramps that are clearly operating as part of a weaving section would not be evaluated with these procedures.

3. Weaving sections are evaluated using the procedures documented in chapter 5 of the *Manual.*[10]

When a given component falls under more than one of these categories, the analysis category that results in the lowest LOS is used as the controlling factor defining operations within that component.

Once the analysis results of the various freeway components have been computed, a graphical procedure can then be used to obtain an overall perspective of the operating conditions of the freeway system as a whole. The general freeway alignment is plotted along with an indication of the level of service that has been predicted for each particular freeway component or segment. Figure 2-10 illustrates this pictorial layout of level of service for a hypothetical freeway section.

As the illustration shows, the weaving area in section 4 of this hypothetical situation is a candidate bottleneck situation that will likely be the segment that controls the operation of the overall system. Whereas the weaving section is anticipated to operate near level of service E, the upstream segments **could** operate at levels of service B or C as long as the weaving section does not break down and create queues and congestion that propagates upstream into these segments. However, if. flows are slightly higher than anticipated, it is likely that the weaving segment would break down very quickly and lead to operational problems within those upstream segments as well.

Highway Capacity Software (HCS)

Capacity and LOS analyses for each type of freeway segment can be performed manually using the procedures, nomographs, tables, and worksheets that are provided in the *Highway Capacity Manual.* However, these computations can be quite repetitive and time-consuming for the analysis of many design or operational alternatives. Fortunately, these procedures have been automated, and can be performed quite easily on a personal computer using the *Highway Capacity Software (HCS)*, developed under FHWA sponsorship and maintained by the McTRANS Center at the University of Florida.

The HCS is a macroscopic, primarily empirical, deterministic simulation program used to quickly and easily evaluate traffic flow conditions at specific freeway features. The program contains separate modules for analyzing basic freeway segments, freeway-ramp junctions, weaving areas, and freeway systems. Modules for analyzing signalized and unsignalized intersections are also included (these may be needed when

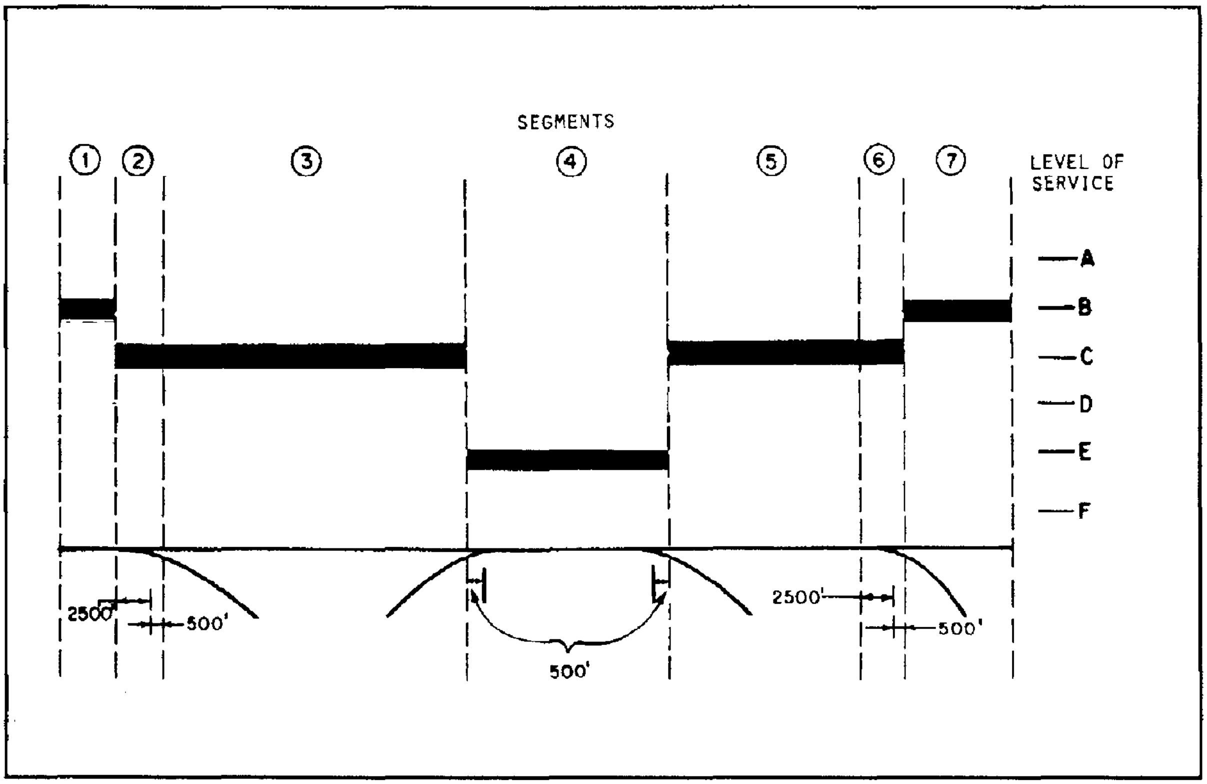


Figure 2-10. Graphic Representation of Level of Service for Freeway Systems. [11]

evaluating ramp-arterial street terminals at the ends of exit ramps).

The HCS (and the HCM procedures in general) are most appropriate for quick analyses of individual freeway components or for specific locations. If a more accurate and detailed evaluation of freeway operations as a system is required or desired, it is necessary to revert to the more sophisticated traffic simulation and optimization models in order to fully examine traffic operating conditions. These simulation and optimization models are addressed below.

BOTTLENECK/QUEUING ANALYSES

The state of the freeway (as determined by its flow-speed-density relationship) changes over space and time. When these changes of state occur, a boundary is established that denotes the time-space domain of one flow state as distinguishable from another. These boundaries are referred to as shock waves. As shown in figure 2-11, when a change in state occurs on a high-volume freeway, the queue and its resulting congestion begin to back upstream from the scene of the bottleneck. The boundary that denotes this change in state is a shock wave.

As shown in figure 2-12, there are four common types of shock waves. A *frontal stationary* shock wave always forms at a bottleneck location and occurs when demand exceeds capacity. It can be caused by either recurrent or nonrecurrent congestion situations. The term *frontal* implies that the shock wave is at the front (or downstream edge) of the congested region. It is called *stationary* because the shock wave is fixed by the location and does not change its location over time.

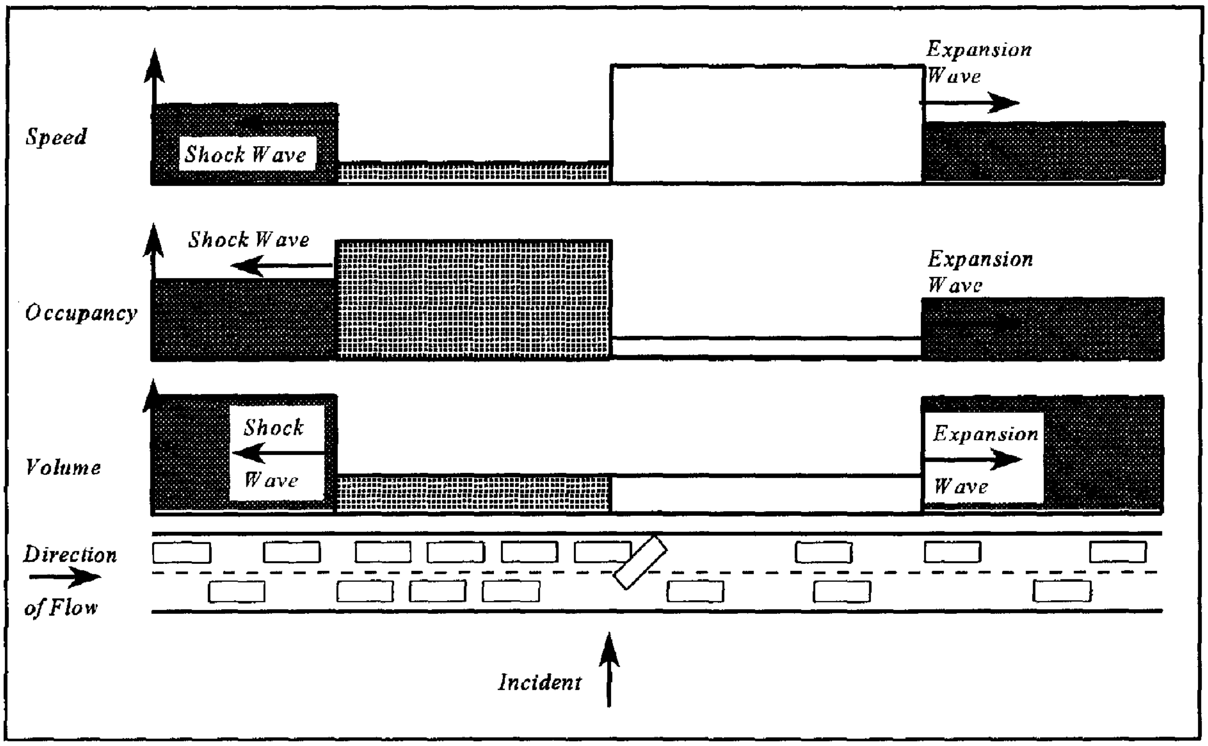


Figure 2-11. Fundamentals of Shock Wave Analysis. (15)

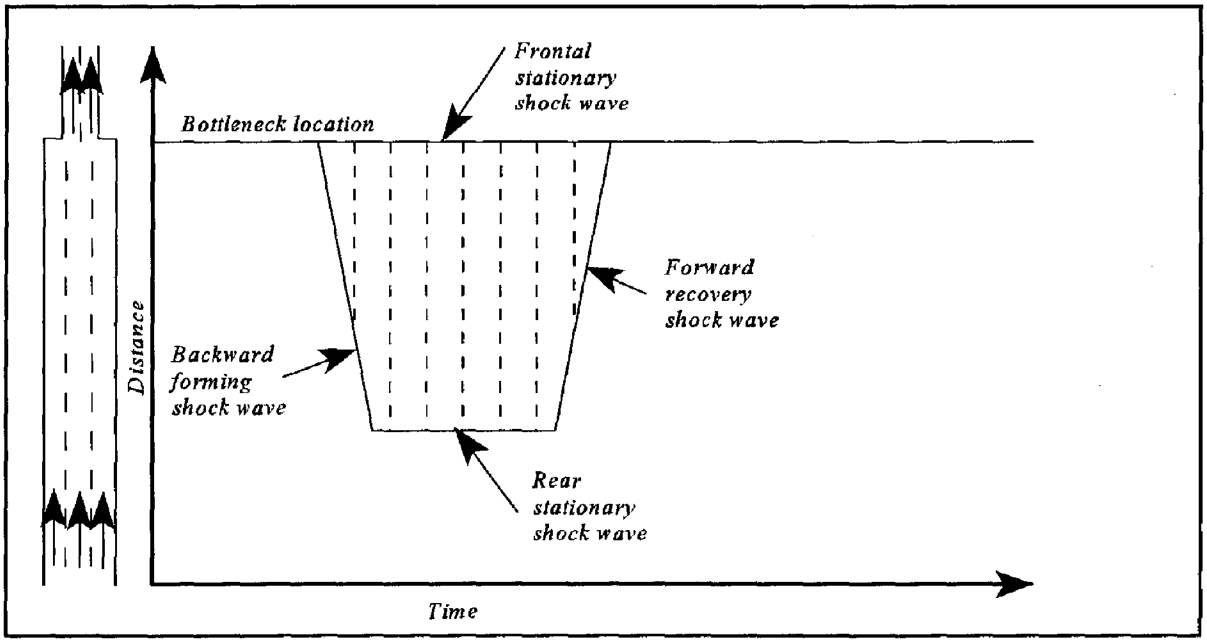


Figure 2-12. Shock Wave Phenomena at a Freeway Bottleneck During a Peak Period. (14)

A *backward forming* shock wave is also always present when congestion occurs. It is formed by the area where excess demands are being stored (i.e., the queue). It is termed *backward* because, over time, the shock wave moves backwards or upstream in the opposite direction of traffic. The term *forming* implies that, over time, the congestion gradually extends farther upstream. The slope of the wave represents how fast the shock wave is traveling upstream (e.g., a flatter slope implies that the shock wave is moving slowly upstream, while a steeper slope implies that the shock wave is moving rapidly upstream). A backward forming shock wave is the most commonly occurring type.

A *forward recovery* wave is the next most commonly encountered type of shock wave. It occurs when there has been congestion but demand decrease is below the bottleneck capacity. It forms as the length of congestion reduces. It is a *forward* wave because it moves downstream in the same direction as the flow of traffic. The term *recovery* implies that free-flow conditions are gradually occurring as the wave moves forward.

A *rear stationary* shock wave occurs when the arriving traffic demand is equal to flow in the congested region for some period (i.e., the queue is neither growing or dissipating). It is a *rear* wave because it occurs at the rear (or upstream edge) of the congested region with higher densities downstream and lower densities upstream. It is *stationary* because the shock wave does not change its location over time.

Another type of shock wave encountered on freeways is the *backward recovery* shock wave. This wave commonly occurs after the source of congestion (e.g., an incident) has been removed from the freeway. After the capacity has been restored, the discharge rate through the congested area exceeds the flow rate in the congested region. This causes the shock wave to move upstream (or *backwards*) in the opposite direction from traffic. It is a *recovery* wave because over time, free-flow conditions are extending further and futher upstream from the previous bottleneck location.

A final type of shock wave that may be encountered is the *forward forming* shock wave. This type of shock wave moves in the same direction of traffic. It is a *forming* wave because, over time, congestion is gradually extending further and further downstream. This type of wave is not commonly observed with freeway operations.

Queues form when demand on a freeway facility exceeds the capacity for an interval of time. To conduct a queuing analysis the following inputs are required: [14]

- The mean (or average) arrival flow rate (vph).
- The distribution of arriving vehicles.
- The mean (or average) service flow rate (vph).
- The distribution of vehicles being serviced.
- The queue discipline.

"First In First Out (FIFO)" is the commonly used queuing discipline used in transportation engineering. With FIFO, vehicles are serviced in the order in which they arrive. Another queuing discipline that can be used is "first in last out (FILO)." This type of queuing discipline would be used to model how queues might dissipate from behind a slow-moving vehicle on a multilane freeway.

Queuing analyses can be conducted at two levels of detail. With the first, queues are analyzed at a macroscopic level where arrival patterns and service patterns are considered to be continuous. The other level of detail is microscopic, and is conducted where arrival and service patterns are considered to be discrete.

One situation where queuing analysis is commonly used in freeways is in analyzing the impacts of temporary blockages (caused by incidents or work zone activities) on traffic flow. Figure 2-13 provides an illustration of this situation. Figure 2-13a provides all the input requirements needed to analyze this situation. The arrival rate (λ) is specified in vehicles per hour and is constant for the analysis period. The normal service rate (without the blockage) is indicated in the diagram as μ, and since it exceeds the arrival rate, no queuing would normally exist. However, an incident occurs that reduces the service rate to μ_R, which is below the arrival rate, and this lower service rate is maintained for t_R hours. As is the case in most freeway situations, a FIFO queue discipline is assumed.

In figure 2-13b, a cumulative vehicles versus time diagram is constructed. The arrivals are shown as a straight line passing through the origin with a slope up and to the right equivalent to the arrival rate (λ). For the first period, the service line follows the arrival line, until the blockage occurs. At that point, the service rate becomes equivalent to μ_R and maintains a flatter slope until the blockage is removed. When the service rate increases to μ, the service line asumes a steeper slope. This continues until the arrival line and service line intercept, at which time the service line once again overlays the arrival line. A triangle is formed with the cumulative arrival link forming the top side of the triangle and the cumulative service line forming the other two sides of the triangle. The triangle represents the congestion that is caused by the bottleneck. Table 2-6 summarizes the equations used to analyze this queuing situation.

FREEWAY SIMULATION/ OPTIMIZATION MODELS

Capacity and LOS analysis is a very useful tool for gauging the expected operating conditions at certain freeway locations, and for determining the magnitude-of-scale changes that would result in those operations if a major freeway improvement were made. However, the characteristics of the freeway system and/or the traffic demands on the freeway create conditions that cannot be easily or accurately evaluated with the capacity analysis techniques. The changes to the freeway may be too subtle in nature to be addressed by the capacity and LOS analysis. In addition, the capacity analysis procedures only indicate where traffic operations are expected to break down or the LOS being provided by a particular roadway and traffic configuration. Information on total and individual vehicle delays, stops, fuel consumption, vehicle emissions, and other measures are not provided by capacity analysis techniques. Consequently, it is often necessary to turn to more complicated but powerful traffic simulation or optimization analyses.

The following sections provide an overview of the major traffic simulation and optimization computer models available for freeway operations analysis. The models are discussed according to the analysis approach used to represent traffic flow in each. First, the macroscopic models are described. Then, models that provide a microscopic analysis of freeway operations are reviewed.

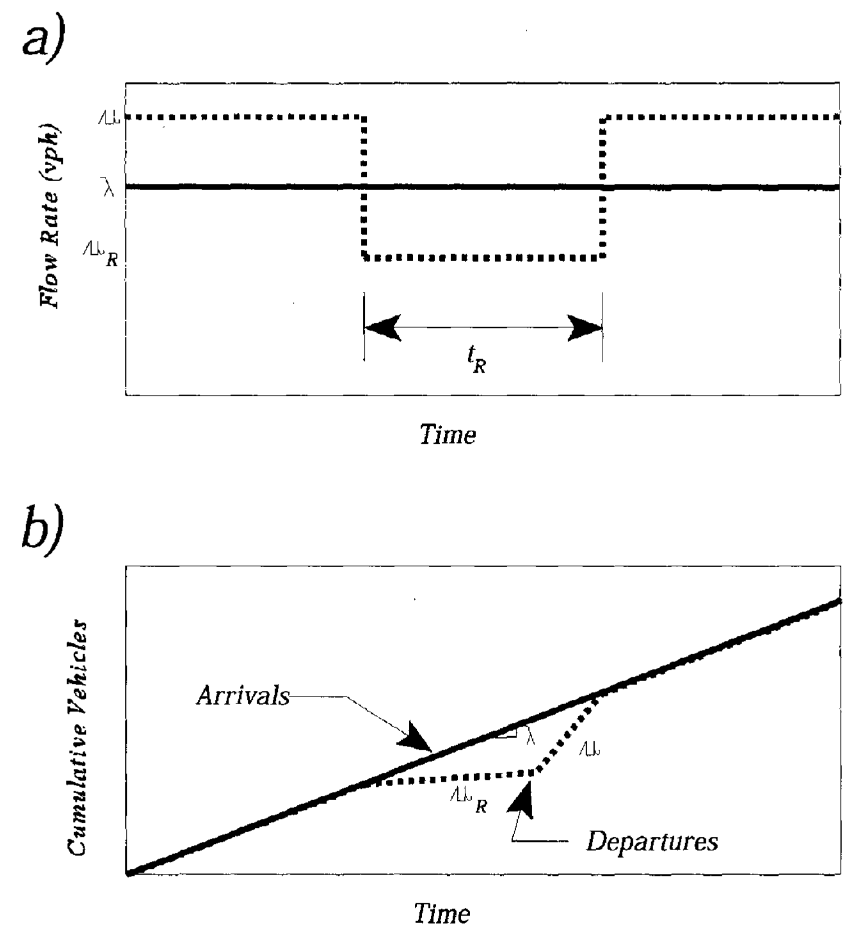


Figure 2-13. Use of Queuing Analysis to Analyze Temporary Blockage. [14]

Macroscopic Freeway Simulation/Optimization Models

One of the principal advantages of most freeway simulation/optimization models is their incorporation of the time element into the analysis. Typically, this is accomplished by dividing the duration of analysis into incremental units, or "slices," of time over which traffic demands and freeway characteristics are approximately constant. The time slices are then analyzed sequentially to allow the traffic impacts of previous slices to be considered in the evaluation of the current time slice. In a similar manner, the spatial relationships between various components on the freeway are specified by defining homogenous segments of freeway in the program and linking those segments together to form the freeway section of interest. These segments have uniform characteristics in terms of traffic demand, number of lanes, basic geometry, etc.

A number of simulation and optimization models have been developed over the years to assist in the analysis of macroscopic traffic flow behavior on freeways. Characteristics of the three such programs that are most widely used are discussed below:

Table 2-6. Queuing Performance Equations for Freeway Lane Blockage. [14]

Performance Measure	Equation
Time duration in queue, t_Q (hr)	$\frac{t_R(\mu - \mu_R)}{\mu - \lambda}$
Number of vehicles queued, N_Q (vehicles)	λt_Q
Maximum queue length, Q_M (vehicles)	$t_R(\lambda - \mu_R)$
Average queue length while queue present, $\bar{Q}_A$ (vehicles)	$\frac{t_R(\lambda - \mu_R)}{2}$
Maximum individual delay, d_M (minutes)	$\frac{60t_R(\lambda - \mu_R)}{\lambda}$
Average individual delay while queue present, d_A (minutes)	$\frac{30t_R(\lambda - \mu_R)}{\lambda}$
Total delay TD (vehicle-hours)	$\frac{t_R t_Q(\lambda - \mu_R)}{2}$

λ = the mean arrival flow rate (vph)
μ_R = Capacity flow rate during incident (vph)
μ = Capacity flow rate (vph)
t_R = duration of incident (hrs)

- FREQ.
- CORFLO.
- QUEWZ-92.

FREQ

FREQ is a macroscopic, analytic, deterministic, simulation and optimization program designed to evaluate freeway operations in a single direction of travel.

The program has been tested and validated extensively, and is widely used to evaluate the impacts of temporary freeway lane blockages, various freeway lane and ramp configurations, and high-occupancy vehicle treatments (dedicated lanes, priority treatments at entrance ramps).(15,16) FREQ can also develop optimized timing plans for ramp metering, based on one of several optimization objectives (e.g., maximize vehicle throughput, vehicle-kilometers of travel, passenger throughput, or passenger-kilometers of travel). However, the program is not capable of evaluating freeway-to-freeway interchange operations.

Input data requirements for FREQ include the following characteristics for each freeway segment within the study section:

- Segment length.
- Number of travel lanes.
- Grade.
- Capacity.
- Design speed.
- Ramp configuration.
- Ramp capacity.

Traffic demand data required by FREQ are as follows:

- Mainline volume entering the upstream end of the first freeway segment in section.
- Mainline volume exiting the downstream end of the last freeway segment in section.
- All entrance and exit volumes within the section being analyzed.

The major types of output of the FREQ analysis are listed below:

- Freeway travel time (vehicle- and passenger-hours).
- Ramp and freeway delays (vehicle- and passenger-hours).
- Total travel time (vehicle- and passenger-hours).
- Total travel distance (vehicle- and passenger-kilometers (miles)).
- Speed and density contour maps.
- Average speeds.
- Fuel consumption.
- Vehicle emissions by pollutant type.
- Optimized ramp metering rates.

CORFLO

CORFLO is an FHWA-sponsored package of macroscopic, analytical, deterministic simulation models that allows the analyst to evaluate traffic operations on a freeway, a freeway corridor, or an entire roadway network. CORFLO consists of a freeway simulation model, FREFLO, an arterial street analysis tool, NETFLO, and a user-equilibrium traffic assignment program, TRAFFIC. These programs have a common coding format that allows a unified, interactive analysis of combined freeway-arterial street operations.

The freeway component, FREFLO, is capable of evaluating freeway-to-freeway interchanges, or even an entire freeway network. The program is capable of simulating ramp metering impacts on operations, but is not capable of optimizing the metering rates. Temporary lane blockages and HOV treatments can also be evaluated using the FREFLO program.[15,17]

Data input requirements for FREFLO are similar to those for FREQ. These requirements are listed below:

- Segment length.
- Number of travel lanes for regular use and HOV operations.
- Capacity.
- Free-flow speed.
- Ramp configuration.
- Volumes entering at the upstream segment and at on-ramps.
- Traffic volume exiting percentages at off-ramps.
- Percentage of volumes which are trucks or carpools.

The measures-of-effectiveness attainable from FREFLO are as follows:

- Travel distance measures (vehicle and person trips, vehicle- and person-kilometers [miles] traveled).
- Travel time measures (vehicle- and person-minutes).
- Average speed measures (vehicle- and person-kilometers per hour [miles per hour]).
- Space mean speeds by vehicle type and lane type.
- Lane density by vehicle type and lane type.

QUEWZ-92

QUEWZ-92 (Queue and User Cost Evaluation of Work Zones) is a simple macroscopic, analytical, deterministic simulation program designed to evaluate the traffic impacts and additional road user costs of freeway work zone lane closures. The program can also determine acceptable times of the day when lane closures can be allowed without causing freeway queues to become too extensive.[15,18]

QUEWZ-92 relies on simplistic assumptions about the freeway segment being analyzed, treating the approach as a basic freeway segment. The data requirements of the program are listed below:

- Configuration of the work zone (how many lanes are open, how many lanes are normally available, how long is the work zone section).
- The schedule of the lane closure activities.
- Hourly freeway traffic volumes approaching the lane closure.

The output obtained from QUEWZ-92 consists of hourly and cumulative estimates of the measures listed below:

- Average speed through the work zone.
- Average queue length if one exists.
- Traffic volumes diverted because of excessive queuing.
- Additional road user costs.

Microscopic Freeway Simulation Models

In cases where macroscopic models do not provide the measures needed to properly analyze a freeway situation, or the assumptions about traffic behavior inherent in the macroscopic models do not represent the condition being evaluated, it may be necessary to utilize a microscopic freeway simulation model for the analysis. Generally speaking, such models are extremely data intensive and time-consuming to set up, debug, and use in an analysis. However, they are very powerful tools for assessing the impacts of more subtle changes in freeway geometrics and for evaluating complicated freeway sections such as at weaving areas with unusual geometrics.

There are two main microscopic freeway simulation models available at the present time. These include FRESIM, an FHWA-sponsored model that is designed to fit within the TRAF system of computer models that FHWA has developed, and INTEGRATION, a proprietary model developed in Canada that links the freeway and arterial street systems together in a single modeling structure. A third model, INTRAS, was also developed under FHWA sponsorship and has been used in past microscopic analyses of freeway operations. However, the more recent FRESIM model is intended to replace INTRAS. Consequently, that model is not discussed in detail.

FRESIM

FRESIM is a microscopic, analytical, stochastic freeway simulation model. FRESIM is capable of simulating freeway mainlanes, ramps, freeway-to-freeway connectors, variations in grade, horizontal curvature and superelevation, lane additions and drops, temporary lane blockages, acceleration or deceleration lanes, and auxiliary lanes. The model can also simulate freeway surveillance via loop detectors, one of three incident detection algorithms based on the loop detector data, and ramp metering operations.[19] However, the model is not capable of optimizing these metering rates. Furthermore, the user has the ability to control very detailed driver characteristics such as the parameters of the lane-changing algorithm or the aggressiveness of the driving population (which affects the acceleration and deceleration rates and gap lengths that will be acceptable to drivers).

FRESIM requires extensive input data in order to fully analyze a given freeway section. Fortunately, default values are provided for many of the input requirements. However, the analyst should understand what these default values represent and be able to adjust them to local conditions if warranted. The following is a list of the data that can be entered into FRESIM on a segment-by-segment basis:

- Segment length and type (mainlane or ramp).
- Number of through and auxiliary lanes.
- Length of auxiliary lanes.
- Grades and superelevation.
- Pavement condition (dry, wet, asphalt, concrete).
- Free-flow speed.
- Average queue discharge headway.
- Lanes that are restricted to trucks.
- Turning/exiting percentages.
- Loop detector locations and characteristics.
- Incident characteristics (effect of lane blockage on capacity, effect of rubbernecking on capacity, duration of incidents).

- Location of lane additions or drops.

- Ramp metering settings and operating type (fixed, demand/capacity, speed control, gap acceptance).

- Traffic volumes entering and exiting the section.

- Car-following sensitivity factors.

- Pavement friction coefficients.

- Lane-changing characteristics (rates of compliance to warning signs, acceptable gap sizes, speed of lane change, acceptable acceleration rates).

- Operating characteristics by vehicle type.

Categories of output statistics computed by FRESIM for each segment and for the entire section include the following:

- Vehicles discharged from each segment.

- Vehicles making turning/exiting maneuvers.

- Average delay (actual travel time minus free-flow travel time) per vehicle.

- Average time spent moving.

- Average speed.

- Number of lane changes.

- Total travel distance (vehicle-kilometers [vehicle-miles]).

- Volume.

- Density.

- Speed.

- Vehicle emissions.

INTEGRATION

INTEGRATION is also a microscopic, analytical, stochastic traffic simulation model. The major difference between INTEGRATION and FRESIM is that the former includes dynamic routing capabilities that can change the intended trip path of vehicles as they progress through the network, depending on current estimates of travel time on the available paths. The program developers see this model as a way of evaluating the effect of advanced technologies (particularly advanced traffic management systems and advanced traveler information systems) upon traffic operations in urban areas. The program has been tested on networks in both the United States and Canada, with favorable results.(20,21)

Because the program models both freeway and arterial street segments within the analysis area, data requirements are fairly large. However, specific geometric details such as grades, superelevation, and pavement conditions are not modeled explicitly. Specific data items needed are listed below:

- Segment length.

- Number of "effective" through lanes.

- Saturation flow rate per lane.

- Free-flow speed.

- Traffic signal characteristics for ramp meters and signalized intersections.

- Loop detector locations and characteristics.

- Incident characteristics (effect of lane blockage on capacity, effect of rubbernecking on capacity, duration of incidents).

- Zonal traffic origin-destination tables for each time period (work is underway to build these synthetically from freeway and ramp volumes).

The output of the INTEGRATION model includes the following categories of statistics:

- Trip times for each origin-destination pair (total and per vehicle).
- Total trips entering the network.
- Speeds on each segment.
- Volume-to-capacity ratio for each segment.
- Trip times on each segment (total and per vehicle).
- Number of stops.
- Queue sizes.
- Fuel consumption.
- Vehicle emissions.

Strengths and Weaknesses of the Available Models

Table 2-7 summarizes the strengths and weaknesses of each of the freeway simulation/optimization models discussed in this chapter. Generally speaking, the microscopic models offer more detailed analyses, but at the cost of more extensive data requirements. The inability to model freeway-to-freeway connectors is the major limitation of FREQ, whereas the FREFLO portion of the CORFLO computer package does not collect environmental statistics on the freeway segments that are evaluated.

QUEWZ-92 is a special-use tool appropriate only for the evaluation of alternative work zone lane closure alternatives. FRESIM does not offer the ability to model HOV lanes, nor can the influence of reduced lane widths be modeled. Finally, despite the microscopic analysis approach utilized by INTEGRATION, the model is not designed to offer detailed operational analyses of freeway geometrics. Rather, the model focuses attention on how operational control and driver information influence freeway and arterial street traffic conditions.

FIELD MEASUREMENTS

One way to quantify the magnitude of operational problems on freeways is through field studies. The following two types of field studies can be used to provide useful insight in identifying problem locations on a freeway and to identify methods for improving operations on the freeway.

Travel Time and Delay Studies

Travel time and delay studies can be used quantitatively for the following purposes, which can help identify and equate operational problems and solutions in a freeway management system:[(22)]

- Determining the efficiency of a route with respect to its ability to carry traffic, and relative to other routes, through the use of sufficiency ratings or congestion indices.
- Providing input to capacity analysis of roadway segments.
- Identifying problem locations as indicated by delay.

Table 2-7. Strengths and Weaknesses of Freeway Traffic Simulation/Optimization Models. [12]

	Macroscopic Models			Microscopic Models	
	FREQ	CORFLO	QUEWZ-92	FRESIM	INTEGRATION
Strengths	Widespread validation Easy to use Can optimize ramp metering rates	Can explicitly model freeway-arterial street interface Can simulate freeway-to-freeway connectors	Simple to use Tailored to work zone lane closure analysis Computes road user costs directly	Detailed analysis of geometrics are possible Can configure parameters to local driver and vehicle characteristics Can simulate freeway-to-freeway connectors	Explicitly models freeway-arterial street interface Can dynamically route vehicles to simulate real-time motorist information Can simulate freeway-to-freeway connectors
Weaknesses	Analysis limited to one direction of a single freeway Does not model freeway-to-freeway connectors	FREFLO does not provide fuel consumption or vehicle emission statistics	Does not evaluate restricted lane widths only Applications limited to work zone analyses	Does not model HOV lanes Does not evaluate impact of reduced lane widths Extensive geometric data requirements (curvature, superelevation rates, grade)	Detailed vehicle interactions and lane-changing behavior not explicitly modeled Extensive data requirements (i.e., zonal origin-destination data)

Source: Adapted from Reference 11.

- Providing input to transportation planning models, trip assignment models, and route diversion models.
- Providing input to economic analyses of alternatives.
- Generating travel time contour maps.
- Providing input to studies that evaluate trends in efficiency and level of service over time.

There are several techniques available that can be used to conduct travel time and delay studies, including the following:

- Test-car runs.
- License-plate observations.
- Toll-road electronic payment/automatic vehicle identification cards.
- Observation of vehicles from vantage points.

The reader is referred to ITE's *Manual of Traffic Engineering Studies* for specific details on how to perform travel time and delay studies.(22)

Origin/Destination Volume Studies

In a number of situations, simply knowing the number of vehicles at various locations is not sufficient to assess travel demands and patterns on the freeway system. Knowing where vehicles are coming from and where they are going is essential in many freeway applications. For example, simply counting the number of vehicles entering and exiting a certain ramp on the freeway does not provide the type of information that allows alternative routes and diversion strategies to be adequately planned and analyzed. For these applications, it is important to know how many vehicles entering the freeway at a specific ramp exit at another ramp downstream. This type of information can be collected using origin/destination studies. Situations where origin/ destination information would be useful include the following:

- Freeway interchanges.
- Weaving areas.
- Traffic at major activity centers.
- Regional planning studies.

There are a number of techniques that can be used to collect origin/destination information from travelers, including the following:

- Light-on studies.
- License-plate studies.
- Post-card studies.
- Interview studies.

The reader is referred to ITE's *Manual of Traffic Engineering Studies* for specific details on how to use these techniques to collect origin/destination information.(23)

2.4 LESSONS LEARNED

SYSTEM MAINTENANCE

System maintenance should be considered at all levels of the planning, design, and implementation process of the freeway management system. Without proper maintenance, the effectiveness of the system is significantly reduced. Equipment failures can lead to vehicle crashes that not only affect the overall level of congestion on the freeway system, but also expose the agency to liability concerns if the malfunction is not corrected in a timely manner. Inadequate maintenance also affects the ability of the control system to perform at an optimal level. Furthermore, inadequate maintenance can also reduce the service life of system components, leading to higher overall life-cycle costs in the system.

To be effective, a maintenance program must have the following elements:[5]

- Adequate staff of well-trained personnel.
- Up-to-date documentation on all system components.
- Adequate budget for spare parts and expendables.
- A long-term commitment on the part of the agency to utilize the system to its full potential including keeping the system "up-to-date" on a continual basis.

Ways in which maintenance can be supported during the design of the system include the following:[5]

- Specify modular components so that components can be swapped in the field and repairs handled in the shop, where they will not interfere with field operations.
- Specify environmentally-hardened components that meet recognized standards.
- Use standardized equipment makes and models to reduce the number of spare parts and different maintenance techniques.
- Specify self-diagnostic capabilities.
- Specify transient protection (e.g., power surges and lightning) and equipment grounding.
- Locate components to minimize vulnerability to damage (e.g., knockdowns of field equipment).
- Provide for safe and convenient access to the hardware for maintenance personnel (e.g., will traffic lanes need to be closed when variable message signs are being repaired or relamped, etc.).

Types of Maintenance Requirements

The maintenance of hardware elements in a system traditionally falls under the maintenance heading. In fact, there are three major types of maintenance activities that are performed in a freeway management system:[3]

- Functional.
- Hardware.
- Software.

Functional

Traffic conditions, travel patterns, land-use patterns, and the political environment in many communities are continuously changing. Therefore, the control strategies and functions performed by a freeway management system need to be continuously reviewed, revised, and updated to keep pace with the change in operating environments. The types of activities included in this maintenance category include the following:

- Relocating or repositioning system detectors and surveillance equipment.
- Reconfiguring subsystems.

- Expanding the system to cover a greater geographic area.
- Expanding the system to provide additional functionality.
- Changing detection and/or control technologies to keep pace with technological changes.
- Updating or improving control strategies.
- Updating, revising, and improving incident response plans.

Hardware

Hardware maintenance can be divided into three categories, each of which must be planned for in designing the system and accounted for in the preparation of annual operating budgets:[3]

- Remedial.
- Preventative.
- Modification.

Remedial maintenance refers to the type of maintenance activities performed to correct or replace malfunctioning or failed equipment. Because this type of maintenance activity includes maintenance performed on an emergency basis, it usually commands the highest priority.

Preventative maintenance refers to those activities that are performed to keep equipment failures from occurring. Examples of the types of activities performed in this category include the following:

- Relamping and cleaning of variable message signs, ramp meters, etc.
- Inspection of poles, foundations, and wiring.
- Re-tuning of detectors.

Good preventative maintenance begins with and depends upon proper installation, and proper installation requires thorough inspection and testing throughout the design and installation process.[5] System operators and maintainers should participate in the inspection process and acceptance testing. Such involvement is an excellent source of informal training and fosters a sense of ownership of the new system, essential ingredients to developing an effective maintenance program.

System modification or reconstruction is often included as a maintenance item because, in many cases, maintenance personnel are used to implement the changes. Generally, system modification or reconstruction becomes necessary when the following situations occur:

- A manufacturing or design flaw is identified.
- Changes are needed to improve the performance characteristics of the equipment.

Good maintenance practices require that hardware functions and specifications be well documented. Table 2-8 lists some of the items that should be included in the documentation of the hardware to support hardware maintenance activities.

Software

The maintenance of software is often overlooked in freeway management systems. Most computer software undergoes (or should undergo) complete and extensive testing and debugging before it is accepted by the operating agency; however, because of the multitude of different possible computational combinations and operational circumstances, it is impossible to discover every flaw or bug during the testing and acceptance period. Additionally, as operators gain experience with the system, they often discover additional procedures or features that could improve operations. Agencies need to have a mechanism for making corrections and modifications to software after the initial warranty period has expired.

Operating agencies must be committed to providing adequate funding and staffing resources to effectively maintain software. Traditionally, two mechanisms exist for maintaining system software:

- In-house.
- Maintenance contract.

If an agency elects to maintain the software system in-house, it must provide a sufficient number of qualified staff to perform these functions. If software maintenance is to be performed in-house, most agencies devote one or more full-time positions solely to developing and maintaining system software. Many agencies use engineering staff that also happen to have the requisite software skills to maintain their system software.[22] Because highly qualified programmers and software engineers are in great demand, agencies may find it difficult to attract and retain qualified programmers. In these situations, an agency can contract its software maintenance. Under this type of agreement, the contractor can correct any latent bugs and make minor enhancements based on the experience of the operations personnel.[5] Oftentimes, software maintenance can be accomplished over a phone link and modem.

One way software maintenance can be facilitated at the design and implementation phase of the system is through the adoption of coding standards.[24] Coding standards should be adopted prior to beginning work on the system. The purpose of the coding standards is to ensure that programmers use the same style and format when developing their software. The coding standards are to be used by every programmer working on the system. Coding standards are important because many routines written by one programmer may be used by other programmers in developing their routines. Furthermore, since all the programmers use the same style, the overall package has a consistent "look and feel" about it. Coding standards also lead to better documentation and enforce good programming practices. All of these aspects of coding standards can save considerable time in the initial programming of the system, plus making it easier for unfamiliar programmers to make modifications and enhancements after the original programmers are no longer working on the system.

Another way software maintenance can be fostered in the initial design and implementation phase is through good documentation.[24] Documentation is one of the most valuable and yet variable deliverables associated with any software development effort. It can be very difficult to obtain the necessary level of detail when project funds run short and the programmers are disinterested in the documentation effort. Documentation standards should be established as a guide for both in-house and contract programmers. Table 2-9 lists some of the elements that should be submitted as part of the software documentation.

Table 2-8. Items to be Included in Hardware Documentation. [5]

- General description — General description of the component.
- Theory of operation — Detailed description of the operation of the component.
- Normal operating procedure — Description of the procedure for the routine operations of the component, including normal operating characteristics, voltage levels, and waveforms measured at test points.
- Parts list — Listing and identification of various parts of the component.
- Schematic drawings — Complete and accurate electronic schematics that specify component interconnections, component values, voltage levels, and component locations.
- Drawings of cabinet layouts, wiring diagrams, and lightning protection. Wiring and cabling lists describing interconnection of all plugs, chassis, and other components. In addition, they must identify wire type, size, and color code. They should also identify connector type, pin numbers or terminal strip numbers, and test points.
- Mechanical details — Equipment layouts, physical dimensions, access points, and test point locations.
- Power supply cabling — A description of the power supply, the power distribution system, and the characteristics of the power supply. The power source and all protective devices in the power system must also be described.
- Environmental controls — Power, heating, cooling, and humidifying.
- Descriptions of all preventative maintenance activities for all system components (e.g., computer, communications units, controllers, etc.). This information must include both the procedures and the frequency with which these activities are to be performed.
- Description of emergency maintenance trouble-shooting and diagnostic procedures. This documentation begins with a list of symptoms and proceeds through a series of analyses until the most common cause of the symptom is identified.
- A recommended set of spares and test equipment to be purchased by the local agency or supplied under the contract.
- Instructions on the use of computer diagnostic software furnished by the computer manufacturers for evaluation of the computer and peripheral equipment operation.

MARKETING SYSTEMS

The importance of marketing freeway management systems should not be overlooked. Public acceptance and cooperation are essential to achieving the goals and objectives of a freeway management system. Without public acceptance and support, an agency will find it difficult, if not impossible, to maintain a secure and stable political support and funding base for operating and maintaining a freeway management system. Marketing the system — highlighting what it does and how it will directly benefit the traveling public — is crucial to building public support and acceptance.

Target Audiences

Transportation agencies should develop a plan for marketing their freeway management system. The market plan should address how the system will be marketed to the following four target audiences:[26]

- The operating agency itself.
- Other agencies that are affected by the system.
- Important public and elected officials.
- The general public and users of the system.

Operating Agency

A freeway management system will not be successful or effective without strong support from those individuals who will be funding, operating, and maintaining the system. Decision-makers within the agency need to be aware of the costs and benefits of the system and where the freeway management system fits into the overall future of the organization as a whole.[25] Often, these decision-makers can be converted to being champions for the system. Marketing strategies need to be employed internally within an organization so that champions can be identified, and pride and ownership in the system can be developed.

Affected Agencies

The marketing plan should also include those agencies that are not directly responsible for but directly affected by a freeway management system. Examples of affected agencies that should be addressed in a marketing campaign include the following:

- Law enforcement agencies.
- Emergency service providers.
- Local and regional transportation agencies.
- Transit providers.

These agencies are concerned primarily with how the system will affect their operations. Law enforcement agencies will want to know whether the system will require additional enforcement emphasis, reduce their enforcement burden, or have no effect on their service. Emergency service providers will want to know whether the system will enhance or hinder their response time and access to facilities. Local transportation agencies and transit providers will want to know whether the system will increase or decrease the demands on their systems.[25] A marketing strategy should be developed that addresses these concerns.

Table 2-9. Elements of Software Documentation. [5]

• Source listings of the programs. These listings must be well-annotated to describe input/output, variables, purpose of subroutines, other lower level subroutines called.
• Flowcharts or HIPO's indicating the processing steps taken by every functional grouping of instructions. The flowcharts should be keyed to the software listings using instruction addresses and subroutine names. Each flowchart must be preceded by a functional description of the subroutine's purpose, storage requirements, and execution time.
• Descriptive discussion of each routine and subroutine in the application program and the database update program.
• Lists that define every variable used in the software. These definitions must include variable name, its purpose, structure, and a list of the routines in which it is used.
• Maps showing the layouts of data and programs within the computers and storage facilities.
• A summary of system timing, including average execution times of all routines and average execution times of each priority level.
• All computer inputs and outputs, including addresses, command structures, data transfer rates, source/destination equipment, and printer and CRT formats.
• Backup and disk-resident copies of the source programs, along with hard-copy listings.

Elected Officials

Elected officials are primarily interested in cost-effective systems that support the goals of their jurisdiction or district. They are interested in secondary effects of technologically advanced systems, such as the effects on the environment, privacy, and land use. They are also interested in the views of constituents, and whether the systems will be perceived as having a positive or negative impact on their constituency. To enable the system to be effectively marketed to elected officials, the information about the system should be concise and easy to understand.[25]

General Public

The ultimate success of any advanced transportation system depends on the perceptions of the users of the system. If the general public does not see benefits that outweigh any perceived costs or disadvantages, the system will not be successful, even if there are positive benefits being achieved by the system. It is critical that public agencies remember that the ultimate customers of the system are the people who will be traveling on the freeway. The marketing campaign should illustrate how these travelers will directly benefit from the system.[25]

Marketing Strategies

There are numerous methods available for marketing freeway management systems. Determining which is the most appropriate and effective method depends on the target. Strategies commonly employed to market freeway management systems included the following:

- Logos.
- Brochures.
- Slide shows/videos.
- Meetings with agency boards, citizen advisory committees, and operating staffs.
- Meetings with community groups, professional organizations, high schools, college groups, employers, etc.
- Workshops and meetings with City Council members, public works departments, and transportation advisory committees.
- Press releases and media events.
- Displays and billboards.
- Newsletters and fact sheets.
- Internet home pages.
- Tours and site visits.

Table 2-10 lists some of the key items to be remembered and included in developing a marketing plan for freeway management systems.

Table 2-10. Guidelines for Developing a Marketing Plan for Freeway Management Systems. [27]

- While it is critical and necessary to involve members of operating and affected agencies early in the marketing of the system, be careful about involving the public too early. Very early involvement of the public can lead to high and unrealistic expectations.
- Identify the target audiences in the beginning stages of the program. Have a clear understanding of what it is the audience is supposed to get from the media campaign and how they are likely to respond to having knowledge of the system.
- A good marketing plan supports the strategic plan for project implementation. The marketing plan should support the goals and expectations of the project and clearly convey them to the target audiences.
- Do not overexaggerate the impact the system will have on the transportation system. Encouraging high expectations may lead to disappointment and the immediate loss of public trust. Moderate goals are most appropriate when implementing new technologies. Do not let the public believe that the system will solve all their transportation problems.
- Keep communications as open and honest as possible throughout the program implementation. If something goes wrong, let the public know what happened in terms they can understand. Chances are the public will appreciate the explanation and understand the circumstances, and will be more likely to give you the benefit of the doubt if other problems arise.
- If you do not have the qualified staff to develop a marketing plan, hire an outside firm that is familiar with transportation projects to assist you. Human behavior is an unpredictable phenomenon. It may be beneficial to consult with individuals who are experienced with dealing with the public in formulating your marketing plan.
- When promoting the system, whether verbally, visually, or in written form, use terms that are understandable and tangible to the general public. Highlight the positive aspects of the system. For example, indicate that the ramp metering system is intended to maintain speed above 40 mph on the freeway. Take car to mak the wording direct so that it cannot be misinterpreted easily.
- Have something to show. A tangible product is easier to relate to than a drawing or report. The public will be able to see how it works and the benefits that can be derived. They want to see it, not just hear about it.
- Throughout the implementation of the system, survey user needs to determine whether the needs of the public are being met. If not, adjust the program accordingly. Monitoring of user acceptance and attitudes should continue after the system has been implemented to ensure that it is working as planned.

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APPENDIX A: SUBCHAPTER G - ENGINEERING AND TRAFFIC OPERATIONS

PART 655 - TRAFFIC OPERATIONS

Subpart D - Traffic Surveillance and Control

Subpart E - [Reserved]

Authority: 23 U.S.C. 101(a), 104, 105, 109(d), 114(a), 135, 217, 307, 315, and 402(a); 23 CFR 1.32 and 1204.4; and 48 CFR 1.48(b).

Source: 49 FR 8436, Mar. 7, 1984, unless otherwise noted.

Sec. 655.401 Purpose.

The purpose of this regulation is to provide policies and procedures relating to Federal-aid requirements of traffic surveillance and control system projects.

Sec. 655.403 Traffic surveillance and control systems.

(a) A traffic surveillance and control system is an array of human, institutional, hardware and software components designed to monitor and control traffic, and to manage transportation on streets and highways and thereby improve transportation performance, safety, and fuel efficiency.

(b) Systems may have various degrees of sophistication. Examples include, but are not limited to, the following systems: traffic signal control, freeway surveillance and control, and highway advisory radio, reversible lane control, tunnel and bridge control, adverse weather advisory, remote control of movable bridges, and priority lane control.

(c) Systems start-up is the process necessary to assure the surveillance and control project operates effectively. The start-up process is accomplished in a limited time period immediately after the system is functioning and consists of activities to achieve optimal performance. These activities include evaluation of the hardware, software and system performance on traffic; completion and updating of basic data needed to operate the system; and any modifications or corrections needed to improve system performance.

Sec. 655.405 Policy.

Implementation and efficient utilization of traffic surveillance and control systems are essential to optimize transportation systems efficiency, fuel conservation, safety, and environmental quality.

Sec. 655.407 Eligibility.

Traffic surveillance and control system projects are an integral part of Federal-aid highway construction and all phases of these projects are eligible for funding with appropriate Federal-aid highway funds. The degree of sophistication of any system must be in scale with needs and with the availability of personnel and budget resources to operate and maintain the system.

Sec.655.409 Traffic engineering analysis.

Traffic surveillance and control system projects shall be based on a traffic engineering analysis. The analysis should be on a scale commensurate with the project scope. The basic elements of the analysis are:

(a) Preliminary analysis. The Preliminary Traffic Engineering Analysis should determine: The area to be controlled; transportation characteristics; objectives of the system; existing systems resources (including communications); existing personnel and budget resources for the maintenance and operations of the system.

(b) Alternative systems analysis. Alternative systems should be analyzed as applicable. For the alternatives considered, the analysis should encompass incremental initial costs; required maintenance and operating budget and personnel resources; and expected benefits. Improved use of existing resources, as applicable, should be considered also.

(c) Procurement and system start-up analysis. Procurement and system start-up methods should be considered in the analysis. Federal-aid laws, regulations, policies, and procedures provide considerable flexibility to accommodate the special needs of systems procurement.

(d) Special features analysis. Unique or special features including special components and functions (such as emergency vehicle priority control, redundant hardware, closed circuit television, etc.) should be specifically evaluated in relation to the objectives of the system and incremental initial costs, operating costs, and resource requirements.

(e) Analysis of laws and ordinances. Existing traffic laws, ordinances, and regulations relevant to the effective operation of the proposed system shall be reviewed to ensure compatibility.

(f) Operations plan. The final element in the traffic engineering analysis shall be an operations plan. It shall include needed legislation, systems design, procurement methods, construction management procedures including acceptance testing, system start-up plan, operation and maintenance plan. It shall include necessary institutional arrangements and the dedication of needed personnel and budget resources required for the proposed system.

(Approved by the Office of Management and Budget under control number 2125-0512)

Sec. 655.411 Project administration.

(a) Prior to authorization of Federal-aid highway funds for construction, there should be a commitment to the operations plan (see Sec.655.409 (f)).

(b) The plans, specifications, and estimates submittal shall include a total system acceptance plan.

(c) Project approval actions are delegated to the Division Administrator. Approval actions for traffic surveillance and control system projects costing over $1,000,000 are subject to review by the Regional Administrator prior to approval of plans, specifications, and estimates.

(d) System start-up is an integral part of a surveillance and control project.

(1) Costs for system start-up, over and above those attributable to routine maintenance and operation, are eligible for Federal-aid funding.

(2) Final project acceptance should not occur until after completion of the start-up phase.

1. ELIGIBILITY OF POLICE ENFORCEMENT AND SURVEILLANCE ACTIVITIES IN TRAFFIC MANAGEMENT DURING MAJOR HIGHWAY RECONSTRUCTION (23 CFR 655.403)

a. In December 1986, the Washington Headquarters office provided guidance on traffic management actions that may be eligible for Federal-aid (FA) funding during major highway reconstruction. See NS 23 CFR 655A, paragraph 1, for activities discussed involving police surveillance and enforcement necessary to mitigate congestion and/or improve the safety of motorists and workers within the highway corridor. General guidance for these particular activities are contained in 23 CFR 655A, Traffic Operations Improvement Programs (TOPICS), and 23 CFR 655D, Traffic Surveillance and Control.

b. Police surveillance and enforcement activities are often essential to safety and efficient traffic operations during major highway reconstruction. To avoid any possible misunderstanding, this supplement is intended to further define FHWA's policy regarding the eligibility of FA funding. The following criteria are provided.

(1) Police enforcement and surveillance activities that normally would be expected in and around highway problem areas requiring management of traffic are not eligible for Federal-aid funding.

(2) On projects where normal police enforcement and surveillance practices within construction zones may not be adequate, the traffic management plan should address the appropriate extra police activities required.

(3) The primary purpose of extra police enforcement and surveillance activities must be to control traffic in order to maintain safe travel and efficient operations throughout the highway corridor.

(4) The State and FHWA division office must agree that extra police activities would be an effective and appropriate means to maintain safe and efficient travel and adequately protect workers. The traffic management plan should set forth the justification and details of the proposed activities. The costs of extra police enforcement and surveillance activities documented in the approved traffic management plan are eligible for Federal-aid reimbursement.

(5) Extra police activities should not be limited to passive monitoring and could also include appropriate positive guidance of traffic and enforcement of regulations.

2. IMPLEMENTATION PLAN GUIDANCE (23 CFR 655.409)

a. An Operations Plan is the final element of a traffic engineering analysis according to 23 Code of Federal Regulations (CFR) 655.409(f). Since an operations plan covers such a wide range of activities both prior to and after construction such as system design, procurement, personnel, operations and maintenance, the name **"Operations Plan"** is being changed to **"Implementation Plan"** to more accurately reflect its contents. The name change is being made in the CFR and will be used throughout the remainder of this guidance. The following is issued to provide State and other agencies, which are utilizing Federal funds, guidance traffic control systems, ensure adequate planning by the sponsoring agency, and commit the sponsoring agency to use Federal funds efficiently.

b. Implementation plans are **required** both for new traffic control systems, as well as expansions of existing systems, which use Federal funds and are encouraged for those systems which do not use Federal funds. Traffic control systems are defined as systems which contain elements to monitor, guide, control, and/or process forms of traffic along the surface streets and/or freeways. Implementation plans can be for individual projects (i.e. stand-alone), or as a part of a larger system. For expansion projects, if an implementation plan had not previously been prepared, one **must be prepared** and include the expansion as well. The plan should be completed prior to authorization of construction. This will ensure that the system is designed, built, operated, and maintained so that it accomplishes its purpose in the most efficient manner possible, considering performance, cost, and schedule. Too often in the past, plans were developed after the system was operational and did not include the design approach and other information which should have previously been addressed and documented.

c. An implementation plan need not be a legal document; however, if it is to be effective, it must carry the weight of a memorandum of agreement (understanding) and should be signed by the head of the operating agency, State highway official, and Federal Highway Division Administrator, or their designates.

d. Before the guidance is explained, a few words need to be mentioned in regards to conformity and the planning process. Transportation Improvement Programs (TIPs) and Statewide Improvement Plans (STIPs) are area wide programs, while implementation plans are project specific. Hence, projects for which implementation plans are being developed have already been approved in the related TIPs and STIPs and the related conformity and management systems issues have been addressed. In non-attainment areas, the traffic control system being proposed for implementation must be consistent with what was proposed in a conforming transportation plan. If the traffic control system deviates from that design concept and scope, it may trigger a new conformity determination.

e. The following sections correspond to the implementation plan **requirements** listed in 23 CFR 655.409 (f) and provide discussion for each. The level of detail of the implementation plan will depend on the type and size of the system. Since some of the items required in an implementation plan will have been covered in other contract documents and other elements of the traffic engineering analysis (23 CFR 655.409), these items may be summarized and referenced in the plan.

(1) Legislation. This section includes the legal considerations, if any, for the project. **Existing** laws, regulations, and policies affecting the project need to be reviewed and assessed. In addition, State or local legislative changes such as authority for metering and HOV facilities, enforcement authority, and roadway clearance policies should be addressed if applicable to the project. Also, the operating procedures for the system may need to be defined to be sure that there are no potential legal problems.

(2) System design. A system contains elements which may monitor, guide, control, and/or process forms of traffic along the surface streets and/or freeways. System design consists of taking the recommendations from the planning phase, converting those needs into hardware/software requirements, and formulating the equipment needs into contract documents. The system design may be based on off-the-shelf, customized, or experimental technologies. Actual systems vary greatly in practice. For example, a system may contain several like devices such as

an expansion of a traffic signal system, or it may consist of a traffic management center and its associated hardware/software. For the purpose of this guidance, system operation and maintenance must be the responsibility of a public agency. The conduct of the system operation and maintenance may be carried out either by (1) the public agency (2) contract, or (3) franchise operation. An implementation plan should include the following elements for the system design portion:

(a) System Designer: Depending upon the complexity of the system and in-house expertise, consultant services are usually needed to design a system. The designer needs to be identified in order to resolve any conflicts.

(b) System Design Life: The functional operating life of the system should be identified. The design life and the costs can be used to perform an economic analysis to identify the return on their investment. The system design life will be helpful for a Life-Cycle Cost Analysis (LCCA).

(c) System Coverage: This should address the area that the system covers. The coverage related to the future expansibility of the system should also be addressed. Ideally, the expansibility should be commensurate with the system's design life.

(d) System Design and Operations/Maintenance Philosophies: System operations philosophies have a significant impact on the system design. For example, system operations centers that are staffed only during rush hours do not require kitchen and/or shower facilities. However, operations centers that are staffed during the majority of the day, especially during special events and inclement weather, do require extra amenities. Ideally, system operations and maintenance functions, as well as facilities, should be close to each other to facilitate coordination.

(e) System Architecture: A discussion of the overall system architecture (i.e. central, distributed, or hybrid) should be addressed.

(f) Integration with Other Functions: Ideally, consideration should be given to integrating a traffic control system with other systems to provide for data base exchange and other strategies so that the entire metropolitan area is covered and coordinated.

(g) System Components and Functions: Hardware components needed to perform system functions such as, surveillance, control, and coordination should be identified.

(h) Communication Subsystem Design Approach: Typically, the communication portion of the system, because of the necessary redundancy, represents a large portion of the system budget. Great care should be given to the subsystem design approach. An economic analysis of the design approach, should be a key consideration.

(i) Traffic Operations Center Design Features: The design of a control center is largely dependent upon the agency's operating philosophies (time of operation, special event operation, tour accessibility; media facilities etc.) The size of the system will also affect the design (As an example, agencies utilizing large numbers of closed circuit television (CCTV) will need more space for wall monitors.)

(j) Project Phasing/Scheduling: A formalized tracking system should be used to manage the project. Many common methods utilize critical path analysis. Depending upon the approach used, these management tools don't necessarily have to be developed during the design phase but should be in place prior to any construction scheduling.

(k) Design Review: The system design is reviewed and the problems and concerns are addressed and documented. (The system design should be checked for consistency with the statewide and metropolitan plans, if applicable.)

(3) Procurement methods. An important element of the implementation plan is the method used for procuring and implementing the system (23 CFR 172). Regardless of the method used, the implementation plan should include the following procurement related items: (1)Method, (2) Schedule, and (3)Funding. A brief description of common procurement methods follows:

(a) Sole-Source - a single manufacturer's specifications are openly used, or they serve as the basis for contract negotiations between the owner and the supplier. The contract is then awarded without competition. Sole-source contracts can be used in Federal-aid projects, but only if there has been a finding that it is more cost-effective than a competitive low-bid process. This method is most common for system expansions.

(b) Engineer/Contractor (turn-key) - an engineer prepares a single set of contract documents (i.e., plans, specifications, and estimates (PS&E) for the proposed system), the contract documents go through the procurement channels, and the contract is awarded to the lowest responsive bidder. The winning contractor is responsible for providing a complete and fully operational system, including furnishing and installing all hardware/software, system integration efforts, and training and documentation. This method is the traditional low-bid process. However, there may be some significant potential problems with this method as it relates to traffic control systems: No single contractor may process the necessary experience and qualifications to perform all of the work; administering multiple layers of subcontractors and suppliers is difficult; and the prime contractor may not have sufficient knowledge of some of the elements of a traffic control system to select appropriate or qualified subcontractors.

(c) Two-Step Engineer/Contractor - in the first step, the plans and functional specifications, along with a Request for Proposals (RFP), are submitted to contractors. The submitted proposals are evaluated and the qualified proposals go to the second step. In the second step, a formal request for bid is issued. From this point on, the standard bid/award process of the engineer/contractor approach is used.

(d) Systems Manager - instead of a single turn-key contract in which all of the work is outlined, several contracts for the various subsystems are prepared. The agency's normal procurement process is utilized to obtain the equipment, but the systems manager administers the contracts and is responsible for integrating the various subsystems into an operating system.

(e) Design/Build- this concept involves awarding a single contract to provide for both the design and construction of a project. For certain circumstances, design/build has the potential for improving the contracting process by allowing contractors the maximum flexibility in the selection of innovative designs, materials, and construction techniques. Under current statutes and regulations, the design/build concept is a viable option for Federal-aid highway projects, as long as the following **requirements** are met:

1 The contracts are awarded following competitive bidding procedures;

2 If a warranty requirement is included, the period of coverage should only be sufficient in length (i.e., 1 - 5 years) to allow defects in materials and workmanship to become evident. Ordinary wear and tear, damage caused by others, and routing service maintenance should remain the responsibility of the State; and

3 Federal-aid projects which provide for evaluation of either the design/build or warranty concepts must be approved, under Special Experimental Project No. 14 (SEP 14), by FHWA Headquarters Office of Engineering (HNG-22), prior to project approval.

(4) Construction management procedures. Procedures which will be used for the particular system should be specified in the implementation plan. Construction management procedures provide the necessary framework for coordinating construction and installation activities to ensure the system is built in accordance with the contract documents. Implementation plan construction management procedures that can be addressed include, but are not limited to:

(a) Division of Responsibilities (identifying who is involved and their associated responsibilities).

(b) Scheduling and establishing mileposts (developing a construction schedule to keep track of system installation). This will also ensure a mechanism for monitoring progress, cost, and quality assurance.

(c) Conflict Mitigation (developing a procedure or mechanism for resolving contract disputes).

(d) Coordination with other projects (defining project's relationship with other projects).

(5) System start-up plan. Integration is the "glue" that binds components together to form the system. Components are physically tied based on interfaces defined by the system architecture and tests are performed to verify and validate whether or not system requirements are met. Verification of a component or subsystem determines if the components or subsystems are interfaced as per design and are working properly. Validation consists of ensuring (through acceptance tests) that all interfaced components or subsystems meet system requirements. Software coding and database development are also important elements of this phase. The start-up process is typically performed in a limited time period immediately after system integration. A start-up plan is necessary to document the validation process (software and system evaluation). An implementation plan should include, but is not limited to, the following:

(a) Software acceptance tests (responsibilities of those involved, test procedures, equipment involved, test criteria, verification of specific software features, methods to correct errors, etc.);

(b) System acceptance tests (responsibilities of those involved, test procedures, equipment involved, test criteria, verification that system performs required functions, methods to correct errors, final acceptance, etc.);

(c) Partial acceptance (provisions for accepting a partially completed system);

(d) Documentation (detailed documentation pertaining to hardware and software should be discussed as well as references to operating manuals for the system);

(e) Transition from old to new control (procedures for transitioning from a previously functioning system to a system with new features and functions);

(f) Operational support and warranty period (provisions for initial or continuing operational support and a system warranty period). Federal regulations on guaranty and warranty clauses are defined in 23 CFR 635.413;

(g) Training (provided to system operators and maintenance technicians prior to system acceptance);

(h) Coordination with the media is very important and should be included in the system start-up plan. Public support is critical to the success and ongoing operations of the system.

(6) Operations and maintenance plan. Traffic control systems require active management to be effective, including periodic reassessment of the control strategies used. In order to have a system that is operated and maintained properly, there must be a staff and budget commitment by the operating agency. The resources required to effectively operate and maintain a traffic control system may represent a significant continuing investment, particularly if the agency responsible for the system is relatively small or is implementing a traffic control system for the first time. The process of defining system operations and maintenance activities during the preparation of the implementation plan can expose these issues and allow time for their resolution prior to system implementation. The operations and maintenance plan may include a section for evaluation and applicable maintenance policies:

(a) Evaluation. Federal-aid highway funds may be used for evaluation activities (23 CFR 655.403 (c) (Systems Start-Up); (23 U.S.C.307 (c) (1) (e) (State Planning and Research); 23 U.S.C. 133 (b)(6) (Surface Transportation Program); and 23 U.S.C. 103 (i) (8) (National Highway System). A comprehensive evaluation of a traffic control system determines if the system meets the goals and objectives established for it. A formal evaluation is recommended at appropriate stages. The evaluation should be completed as soon after the implementation of the system as possible, after traffic patterns have stabilized. Regular system re-evaluating should subsequently be planned every few years and should be executed by the operations and maintenance personnel. Key evaluation issues to be described in the implementation plan include:

1 The system evaluator (Preferably, this should be an independent third party, **not** the system installer.) The system evaluator should be selected prior to the implementation of the system in order to properly perform the evaluation.

2 The method of evaluation (This should also include time period for evaluation.)

3 The cost of evaluation.

(b) Maintenance Plans. Development of maintenance plans cannot be performed by designers alone. Maintenance persons must be consulted. In addition, a system may require a higher and more responsive degree of maintenance than an agency may be accustomed to. Some agencies may choose to use contract maintenance as opposed to in-house staff. Whatever method of maintenance is selected, the following implementation plan issues will help the operating agency to determine the necessary maintenance resources (budget and staff) :

1 Maintenance policies for preventative maintenance, system malfunctions (response times), etc. There should be a documentation of the policies, possibly as an attachment.

2 Formal maintenance management programs (software and hardware agreements with the developers). There should be a documentation of the programs, possibly as an attachment.

3 Initial inventory of spare parts and all necessary test equipment.

4 Training in providing limited maintenance to software and equipment.

(7) Institutional arrangements. Nearly all projects involve numerous organizations and multiple levels of government, all of which approach the project from various perspectives. However, the institutional aspects of a system are likely to be even more complex because of the additional governmental entities and organizations (e.g., FHWA, regional organizations, State and local governments, traffic engineering departments, MPOs, fire, police, transit, private sector groups, media utility companies, etc.) which are typically involved. The complex mix of governmental and private sector interests has the potential for difficulties: overlapping responsibilities, lack of understanding, and conflicting priorities and policies. To avoid these problems, it is important that close coordination be established during the early stages of planning. This will permit the various agencies to develop a better understanding of the system alternatives and the recommended system's features and functions; to identify overlapping responsibilities and determine which agency will take the lead in various areas; and to work harmoniously so that each agency can better fulfill its role. Developing a good, early working relationship with each involved organization and then maintaining this cooperation throughout the system process will help ensure that the system effectively meets the needs and expectations of each agency. An implementation plan should include, but is not limited to, the following institutional arrangement issues:

(a) A contact person/object liaison within each organization should be identified.

(b) Delineation of organizational responsibilities and the lead organization for the various elements of the system.

(c) Provisions for periodic project updates to be given to upper management to keep them informed.

(d) Utility arrangements.

(e) Written cooperative agreements for: personnel-sharing, cost-sharing, metering, traffic diversion, etc.

(f) Consideration should be given to the formation of an "Advisory Committee" which will meet to discuss and resolve system issues and to acquaint participants with the overall project goals, schedule, and work plan. All agencies involved in the project should be represented on this committee and should be involved throughout the entire project.

(8) Personnel and budget resources. Staffing for operations and maintenance of systems is a function of system complexity, hours of operation, and activities supported by the system. Ideally, staffing responsibility for

operating and maintaining the system should be integrated into the operating agency's existing organizational structure. It is understood that institutional agreements may need to be developed for personnel/cost-sharing purposes. The following personnel and budget items, as a minimum, should be addressed:

(a) Staffing plan (listing of the job functions supported by the system and the number of persons who fulfill those functions).

(b) If shifts are to be used, the number of persons and their functions per shift.

(c) Contract operations staff agreement (if used).

(d) Provisions for training new staff on the system.

(e) Sources of budgetary resources, including Federal, and their committed contributions.

(f) Estimates of annual expenses by category (operations, maintenance)

(g) The last page should have a section for the signatures of the head of the operating agency, head of the State highway agency, and FHWA Division Administrator or their designates. This concurrence ensures that the necessary agencies are committed to the implementation plan.

MODULE 3. SURVEILLANCE

TABLE OF CONTENTS

MODULE 3. SURVEILLANCE

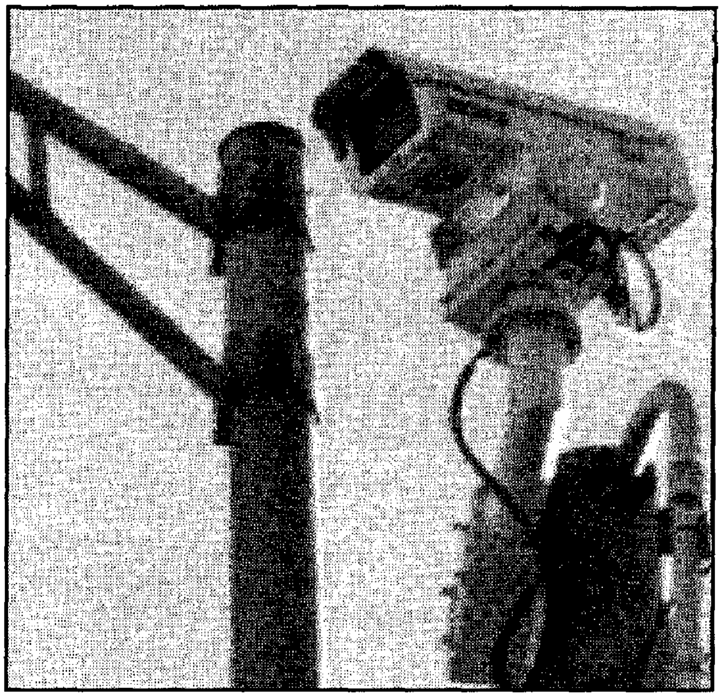

Figure 3-1. Closed-Circuit Television Camera.

3.1 INTRODUCTION

In a traffic management system, the surveillance component is the process in which data is collected in the field. This data is used to supply information about conditions in the field to other system components. Surveillance provides the information needed to perform the following functions:

- Measure traffic and environmental conditions.
- Make control decisions.
- Monitor system performance.

Surveillance is intended to provide support for other elements in the system (e.g., incident detection, information dissemination, ramp metering, etc.), not to drive the decisions about what system elements should be included. In other words, the goals and objectives of a surveillance system should be defined first, and then the system should be designed to meet these goals and objectives. A common mistake to be avoided is to first install a surveillance system, then ask the question "What can this system do for me?". It is essential to determine what system elements are to be supported before selecting and designing a surveillance system.

MODULE OBJECTIVES

The objectives of this module are as follows:

- Provide insight into the issues associated with planning, designing, installing, operating, and maintaining a surveillance system.
- Provide a summary and description of available and emerging surveillance technologies.

MODULE SCOPE

The intent of this module is to help engineers/planners in the decision process involved in implementing an appropriate surveillance system. Included in this module are a description of the decision process, a summary of the components of a surveillance system, a discussion of available and emerging surveillance technologies, and examples of existing traffic management centers that are using various surveillance technologies. In addition, special issues such as privacy concerns and spacing requirements for sensors are addressed.

3.2 DESIGN PROCESS

This section describes the process for planning, designing, and installing a surveillance system. Issues associated with operations and maintenance are also addressed. The focus of this section is on the decision process involved in implementing a surveillance system using a systems engineering approach. Instead of focusing on technological solutions to perceived problems, the system engineering approach described in this section involves identifying user needs and system requirements first, and then designing a system to meet these needs and requirements.

PROBLEM IDENTIFICATION

The first step in the decision process is to identify the problems to be addressed by the system. Issues that should be addressed in the problem identification stage include the following:

- Identifying and locating operational deficiencies.
- Determining functions to be performed by surveillance system.
- Inventorying existing surveillance capabilities.

Table 3-1 describes the objectives for conducting each of the above tasks.

Identify and Locate Operational Problems

This process involves identifying those freeways that would greatly benefit from the use of surveillance and traffic management. Areas benefiting the most would be those with significant amounts of congestion. There are two types of congestion:

- **Recurring.** Typically predictable and occurs at locations where demand exceeds capacity or at geometric bottlenecks (e.g., lane drops, high-volume entrance ramps, etc.).
- **Nonrecurring.** Caused by a random event (e.g., incident, maintenance activity, special event, etc.) and has the effect of reducing the capacity on a specific section of freeway.

Whether the congestion is recurring or non-recurring, the effects on traffic operations include:[(1)]

- Increased delay.
- Slower and inconsistent travel speeds.
- Increased accident potential.
- Other undesirable characteristics.

Table 3-1. Tasks Involved in Problem Identification.

Task	Objective
Identify Operational Problems	• Identify freeway sections to receive surveillance system
Determine Functions of Surveillance System	• Evaluate freeway system to determine surveillance needs • Determine type of data needed • Determine importance of data • Develop criteria for selecting detection technology
Inventory Existing Surveillance Capabilities	• Determine if existing system needs to be replaced/expanded based on cost and needs • Estimate how long the existing system will be able to meet the needs • Identify advantages and disadvantages of existing system to aid in the process of selecting new equipment

Other freeways that might be considered for surveillance include the following:

- Freeways in areas in which significant increases in traffic demand are expected.
- Freeways in areas with significant amounts of maintenance or construction activities.
- Freeways in areas with high frequencies of traffic incidents.

These areas can expect an increase in congestion, and surveillance in combination with traffic management may be used as an alternative to the very expensive solution of building additional lanes.

Determine Functions of Surveillance System

A surveillance system can serve several purposes, including the following:

- Detect incidents that have an impact on traffic operations.
- Monitor incidence clearance.
- Monitor traffic operations and support the implementation of control strategies (e.g., lane control, ramp metering, etc.).
- Monitor environmental and pavement conditions (e.g., flood, ice, winds, fog, etc.).

Table 3-2 lists several scenarios in which surveillance is used and typical methods that meet the surveillance needs.

The type of surveillance system needed depends not only on the purpose(s) that it will serve, but also the type and importance of data to be collected. The following sections discuss the types of data typically collected through surveillance systems and factors that should be considered when determining the importance of the data.

Table 3-2. Methods for Meeting Typical Surveillance Needs.

Need	Method of Surveillance
Detect incidents and monitor incident removal	Mainline detectors, vehicle probes, mobile reports, closed-circuit TV
Meter ramps	Mainline detectors, ramp detectors
Disseminate travel information to motorists	Mainline detectors, vehicle probes, mobile reports, closed-circuit TV
Monitor traffic during special event	Closed-circuit TV
Inform motorists and/or maintenance personnel of icy conditions on freeways	Environmental sensors, weather stations, probe reports

Type of Data

Traffic Measures. The measurements that have traditionally been used to monitor traffic operations on freeways include the following:

- Volume.
- Speed.
- Occupancy.

Volume is used to measure the quantity of traffic and is defined as the number of vehicles traveling a given section of freeway over a period of time. The capacity of a freeway represents the maximum volume of traffic that can pass a given roadway section under prevailing roadway and traffic conditions. [2] As volume increases and approaches capacity, congestion will occur. Volume is typically used to track historical trends and to predict the future occurrence of congestion on given freeway sections.

Speed is an important measurement in determining the quality of traffic operations. Speed is frequently used to describe traffic operations because it is easy to measure in the field, and it is easy to explain and understand. Speed measurements are typically taken for individual vehicles and averaged to characterize the traffic stream as a whole. Measured speeds can be compared to optimum values to estimate the level of operations for a freeway or to detect incidents. For example, an alarm for an incident detection system might be set to go off if average speeds fall below a target value. Taking speed measurements at different points along a freeway can help in determining where congestion might exist.[1]

Occupancy is defined as the percent of time a given section of roadway is occupied and can be used as a surrogate for density. Occupancy is measured using presence detectors, and is much easier to obtain than density. When occupancy is being measured, a single lane is usually considered, with occupancy ranging from 0 percent (no vehicles passing over a section of roadway) to 100 percent (vehicles stopped over a section of roadway).

Although volume, speed, and occupancy have been the traditional types of data collected by a surveillance system, today's traffic management centers also rely on other types of data for traffic management purposes. Examples of other data include the following:

- Vehicle travel times.
- Bus location.
- Emergency vehicle location.
- Queue length.
- Pavement condition.

Until recently, most of the data listed above was difficult to measure in the field; however, due to improvements in detector technologies, these measurements can now be obtained.

Real-Time and Historical Data. Both real-time and historical data may be used for traffic management purposes. Real-time data is needed for the following purposes in a freeway management system:

- Monitoring current traffic operating and environmental conditions.
- Detecting incidents.
- Implementing control strategies.

Historical data refers to past traffic conditions on a given section of freeway. Historical data can be used for several purposes, including the following:

- To establish a record of past traffic conditions on a certain freeway section.
- To compare real-time data to historical data to determine irregular traffic patterns; results of this comparison can be used to detect traffic congestion and incidents.
- To perform before/after analyses to determine the effects of implementing certain traffic management techniques.
- To create simulation models for analyzing potential improvements.
- To create planning models for establishing priorities for deployment.

Importance of Data

In the decision process involved in selecting an appropriate surveillance system, the importance of the data to be collected must be identified to establish the data requirements. The following factors should be considered when determining the data requirements:

- Speed.
- Accuracy.
- Cost.

The speed of a surveillance system relates to the frequency in which information about field conditions is relayed to the traffic management center. Speed plays an important role for some applications. For example, in order to minimize the effects of an incident on freeway operations, it is important to minimize the detection time. In addition, the speed of data collection is important when the data is used to implement a control strategy to reduce or prevent the formation of congestion.

Other factors must be considered when determining the speed of a surveillance system. The speed of the data collection determines the amount of data to be transmitted to the traffic control center. Therefore, operator overload should be taken into consideration. In addition, the amount and speed of data collection affects the type of communication system required. As the amount of data to be transmitted increases, the communication requirements increase.

Data accuracy requirements are also dependent upon the elements that the surveillance system is to support. For example, the accuracy of the data is important for incident detection systems to avoid false alarms. Accuracy, however, may not be as crucial when collecting traffic data for traveler information systems. Typically, the faster and more accurate a surveillance system is, the more it is going to cost; therefore, it is important to balance speed, accuracy, and cost when choosing a system.(3)

Inventory Existing Surveillance Capabilities

The existing surveillance resources should be identified and evaluated to determine if they are suitable for continued use. The evaluation should include items such as the following:(4)

- Detectors.
- Controllers.
- Communication media.

It is important to determine if these components can meet existing needs and if they can accommodate changes in system requirements. The existing surveillance system should be evaluated to determine if the required speed and accuracy of data collection are attainable. Other factors that should be considered are the reliability and required maintenance of the existing system. It may be more cost effective in the long run to replace a system that requires extensive maintenance with a more reliable, low maintenance system.

The capabilities of the existing communications system should be evaluated, because the various detection technologies available have different communications requirements. For example, transmitting full-motion video requires a wide communication bandwidth (such as that provided by fiber optic cable); however, transmitting only data requires considerably less bandwidth than can be met by most communication media.

Existing infrastructure on which non-intrusive detectors and CCTV cameras may be mounted should be identified at this stage. In addition, existing conduit for the communication system should also be noted.

IDENTIFICATION OF PARTNERS

Another important step in implementing a successful surveillance system is to identify partners to be involved. Partners should be considered in the following three areas:

- Intra-agency (within agency).
- Interagency (between agencies).
- Additional resources.

Intra-agency

During the planning and design stages, all interested groups and individuals that will be involved in the surveillance system should be identified and included in the decision making process. The project team should include representatives from the following areas:(4)

- Management.
- Planning.
- Design.

- Operations.

- Maintenance.

Including representatives from each of these areas will help ensure the success of the system. For example, it is important to include persons from management on the team to help gain support for the surveillance system. Since freeway management systems often compete for funding with other agency expenditures, the support from top management is essential if agency resources are to be allocated to the operation and maintenance of the system. By including representatives from operations and maintenance, the following issues may be addressed:

- Support staff required for surveillance system.

- Number and qualifications of existing support staff.

- Training required to operate and maintain specific surveillance systems.

Using this team approach, specific concerns and requirements from each area can be addressed from the beginning. The team should then prioritize the requirements to determine which are most important and which are desirable but not needed.

Interagency (Information Exchange)

During the operation of a traffic management system, it is important for public agencies to exchange certain information on a continual basis. Information to be exchanged includes scheduled maintenance activities and special events. This coordination between agencies will ensure that proper measures are taken to minimize the effects of the event on overall traffic operations. Data exchange should take place between the following public transportation agencies:

- State.

- City.

- County.

- Transit.

- MPO.

Sharing information about the occurrence of incidents between agencies permits joint incident management by two or more agencies.[4] This allows more than one agency to be involved in responding to and clearing incidents. Data exchange may take place between public transportation agencies and the following enforcement and emergency agencies and companies:

- Police.

- Fire.

- Medical.

- Wrecker operators.

Real-time traffic information may be relayed to the motorists through traveler information systems such as dynamic message signs, highway advisory radio, or in-vehicle information systems. In addition, motorists may be informed about traffic conditions by providing real-time traffic data to the following sources:

- Media.

- Cable television companies.

- Public kiosks.

- Other traffic advisory services.

Another private sector entity that benefits from real-time traffic data is commercial vehicle operators. For example, dispatchers can use information about current traffic conditions to re-route commercial vehicles in an effort to minimize delay for the commercial drivers. This not only benefits operators of the commercial vehicles, but it also benefits other vehicles in areas of heavy congestion by directing the commercial vehicles away from the congested areas.

Additional Resources

During the process of selecting the appropriate equipment to be used in the surveillance system, it is important to identify and evaluate all of the alternatives. Because of the constant change in available systems, the following groups should be considered as resources during the planning and design of a surveillance system:[4]

- Manufacturers.
- Suppliers.
- Users.
- Researchers.
- Consultants.
- Other interested groups or individuals.

Manufacturers continually develop and improve system capabilities and therefore can provide information on the state-of-the-art in surveillance technology. Information on the equipment specifications, functional and design features, and costs may be obtained from the manufacturers and suppliers. Users of available systems develop unique approaches for some systems and can provide evaluations for certain technologies. Researchers and consultants test the available technologies to determine strengths and weaknesses. In addition, researchers produce technological advances in surveillance systems.[4]

ESTABLISH GOALS AND OBJECTIVES

To establish the goals and objectives of a system, it is important to identify what the system is to accomplish. Goals are used to define the long-range desires for the system. Objectives define the level of performance that is to be expected in the future. At this stage, it is important to note that system objectives are defined in terms of what services and functions the system is to provide — not in terms of technology. The focus should be on *what* the system is to achieve instead of on *how* it is to achieve it.

As discussed earlier, the surveillance system provides support for other elements of a traffic management system (such as incident management, information dissemination, ramp control, etc.). Therefore, the goals and objectives of the surveillance system must relate to the goals and objectives of the elements that it is supporting. For example, a goal of an incident management system is to reduce the impact of incidents on traffic operations. The objectives of the system might be to detect an incident in less than two minutes and reduce the incident clearance time by five minutes. The surveillance system can be evaluated by determining the system's ability to meet these established objectives.

Since the goals and objectives of a surveillance system relate to those of the element that the surveillance system is supporting, the reader is referred to the specific modules within this report that address each element. Additional goals and objectives of a surveillance system might include those that relate to monitoring the performance of a certain system. For example, a goal might be to ensure that the proper message is being displayed on a dynamic message sign. Objectives would be to determine if the sign was operational and to identify the message being displayed. Other goals and objectives of a surveillance system might relate to the effects of implementing certain control strategies.

ESTABLISH PERFORMANCE CRITERIA

There is currently a wide range of traffic detectors from which to choose, and with advancements in technology, the number of alternatives is becoming even greater. It is important, therefore, to establish performance criteria to aid in the selection of an optimum system. Establishing performance criteria allows alternative systems to be compared against these criteria in a later task.

The established performance criteria should be related to the ability of the system to meet the pre-established goals and objectives. Criteria that may be used to measure the performance of a surveillance system include the following:

- Reliability of system.
- Accuracy of data.
- Timeliness of data.

Each of the above criteria is important in measuring the performance of a system. For example, a system is not effective if it provides accurate data but produces it 30 minutes after it is needed.

The above criteria should be used to establish parameters by which to evaluate the system. The desired performance of the system together with a selected range of tolerance should be used to develop quantifiable measures. The measures identified will be based on the elements of the traffic management system that the surveillance component will support. In addition, the established performance measures will be based on local concerns and policies. Table 3-3 provides some examples of performance measures that may be used to evaluate a surveillance system.

DEFINE FUNCTIONAL REQUIREMENTS

The next step in the decision process involves defining all of the functions of a system that are necessary to achieve the established objectives. At this stage, the focus should still be on *what* the system will be designed to do, not *how* the system will do it. Therefore, the functions should be defined independent of the available technology.

Again, the surveillance system provides support to other elements in a traffic management system. Therefore, the functional requirements of a surveillance system are dependent upon the element that it will support. For a surveillance system, the functional requirements typically relate to the type, frequency, and quantity of data required. The data typically used for freeway surveillance have included measures such as volume, speed, and occupancy; however, surveillance should not be limited to these measures only. Additional measures might include travel time, queue length, headway, origin/destination, vehicle classification, etc. These measures have been difficult to obtain in the past but can now be measured because of improvements in technology.

In the past, various surveillance concepts have been investigated in an attempt to meet different functional requirements, and have failed. Some of these concepts failed

Table 3-3. Examples of Performance Measures for a Surveillance System.

Category	Examples
Reliability	• Percent of time that system produces desirable results in various environmental conditions. • Amount of maintenance required.
Accuracy	• Percentage of false alarms generated from an automatic incident detection system. • Difference between a value measured by the detectors in the field (e.g., speed, volume, etc.) and the actual value.
Timeliness	• Average time between when an incident occurs and when it is detected. • Average time between when hazardous weather conditions occur (e.g., ice, fog, flooding, etc.) and when they are detected.

because they were not appropriate; however, others have failed because of a lack of ability to provide the needed data. Therefore, designers/planners should look at the various alternatives for meeting the functional requirements of a traffic management system and not just at the traditional approach. Even though some concepts have failed in the past, they may become viable alternatives due to improvements in technology.

Since the functional requirements of a surveillance system relate to those of the element that the surveillance system is supporting (e.g., ramp metering, incident in the above section on establishing goals and objectives, additional requirements of a surveillance system might include those that are involved in monitoring the performance of a certain system. Table 3-4 shows examples of functional requirements as they relate to the goals and objectives of a surveillance system.

In defining the functional requirements of a system, it is important to determine the needs of all partners involved. The project team should prioritize needs in order to identify those that must be met and identify those needs that may be desirable but not required. For example, a system to detect the location of incidents might be required, but a system to monitor incident clearance might only be desirable.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

After functional requirements of a surveillance system are defined, the relationships between functions, the data required by each function, and the information produced by each function must be defined. The National ITS Architecture Implementation Strategy defines the various ITS elements in terms of market packages.[5] This concept recognizes that various ITS components must work together to achieve system goals. They are " tailored to fit-separately or in combination-real world transportation problems."[5] The market packages related to surveillance are:

Table 3-4. Examples of Functional Requirements Related to Monitoring System Performance.

Goal	Objective	Functional Requirement
Ensure that proper message is being displayed on variable message sign.	Determine if sign is operational and identify message being displayed.	View operation of variable message sign.
Maximize benefits of a certain control strategy (i.e., ramp metering, lane control, etc.).	Determine the effects of the control strategy on traffic operations.	Monitor traffic operations where control strategy has been implemented.

- **Network Surveillance Marketing Package**. This market package includes the roadside sensors with appropriate control and communication infrastructure to interface with other market packages such as traffic management and traveler information.

- **Probe Surveillance Marketing Package**. This market package is an alternative to traditional network surveillance elements and does not require the extensive distributed roadside infrastructure but does require wireless communication between probe vehicles and other market packages such as freeway control and surface street control.

- **Emissions and Environmental Hazards Marketing Package**. This market package provides emissions and hazards information to the Traffic Information Dissemination market package.

Development of the surveillance system should recognize the national architecture standards and be tailored to fit local issues and requirements.

IDENTIFY AND SCREEN TECHNOLOGIES

After the functional requirements and architecture of the system have been defined, the next step is to identify alternative technologies that can meet the defined requirements. The following steps are involved in identifying and choosing the appropriate technologies for the surveillance system:

- Identify alternative technologies.

- Evaluate alternative technologies.

- Select the appropriate system.

Identify Alternative Technologies

There are a number of alternative technologies available for collecting traffic data. The characteristics, applications, and requirements for various existing traffic detection technologies are discussed in a later section of this module. This review can be used as a starting point for identifying alternative technologies; however, due to continuous technological advancements and system improvements, available systems and their capabilities are constantly changing. Therefore, the current state-of-the-art in surveillance technologies should be identified in this stage. To identify available technologies, it is important to continually interface with the following groups and individuals during the identification process:[4]

- Manufacturers.
- Suppliers.
- Users.
- Consultants.
- Researchers.
- Other interested individuals.

By keeping in contact with these groups and individuals, the analyst can accomplish the following:

- Keep up with current trends in technology.
- Identify the advantages and disadvantages of available systems.
- Obtain information on system specifications and costs.

Evaluate Alternative Technologies

The first step in evaluating alternative technologies is to identify the selection criteria (see previous section, *Establish Performance Criteria*). The next step involves the following measures:

- Initial screening of all available technologies.
- Detailed evaluation of the remaining alternatives.

During the initial screening process, the following factors should be considered for each type of surveillance technology included in the analysis:

- Location of sensors (i.e., embedded or non-intrusive).
- Installation, operation, and maintenance requirements.
- Reliability.
- Expected life.
- Life-cycle costs.
- Type of communications medium available.
- Requirements for future expansion.

After the initial screening, the detailed evaluation typically includes the following steps:[4]

- Estimating costs and benefits of each alternative.
- Performing comparative analyses.
- Selecting the system offering the greatest potential.

The advantages and disadvantages of the system must be quantified or weighted and evaluated. There are many techniques available to perform an analysis of the costs and benefits for each alternative. **Module 11** contains descriptions of procedures for performing a benefit-cost analysis.

Select Appropriate Technology

Surveillance technologies that are viable alternatives should have benefits that outweigh the costs. The argument can be made that the best system will have the greatest benefit-cost ratio; however, this is not always the case. For example, a simple, low-cost system with fewer benefits may have the same benefit-cost ratio as a more sophisticated, affordable system with more benefits. Therefore, the analysis should include allowable expenditures for the system and the net benefits of each alternative.[4]

PLAN DEVELOPMENT

After the technologies that will be used in the system have been selected, the next step is to develop a plan for implementation. The Implementation Plan documents the results of the previous steps and identifies how the system will be implemented in the field. The Implementation Plan should also assess the phasing, procurement, staffing, and funding options available for implementing the system. **Module 2** contains a description of elements that should be included in the Implementation Plan.

One of the tasks at this stage is to develop the design plans and specifications. This task involves transforming the needs and goals of the surveillance system into design documents and specifications suitable for competitive bids. The plans include drawings that show the physical layout of the system, and the specifications define the quality and type of workmanship and materials. [4]

Design Plans

The design plans provide information for the contractor and equipment supplier to prepare a project bid and for the construction manager to aid in controlling the construction. Table 3-5 shows typical information that should be provided on the design plans. [4]

Specifications

Specifications contain detailed information on the minimum acceptable standards for the surveillance system's equipment along with procedures on how the equipment should be installed. Detailed specifications are important to ensure that the proper equipment is obtained. Sources for equipment and materials specifications include the following:[4]

- Federal Highway Administration.
- Institute of Transportation Engineers.
- Other State transportation departments.

These specifications may be used as they exist or modified to fit particular needs. Guidelines for specifications for the various components of a surveillance system are provided in table 3-6.[4]

IDENTIFY FUNDING SOURCES

As described in **Module 2**, funding sources should be identified during the development of the Implementation Plan. Funding for surveillance systems may come from both the Federal and State levels. On the Federal level, funding is available through the Intermodal Surface Transportation Efficiency Act (ISTEA) and continuing with the proposed National Economic Crossroads Transportation Efficiency Act (NEXTEA). Under the ISTEA act, capital and operating expenses for traffic management programs are eligible for Federal aid. By including projects in the Transportation Improvement Program (a spending plan required by the Federal government), agencies can receive federal funds. Under Title 23 of the United States Code (as amended by the ISTEA of 1991) the following funding sources can be used to purchase and operate freeway management surveillance systems:

Table 3-5. Typical Information in Design Plan. [4]

Item	Description
Title Sheet	Shows name, location, and scope of project.
Summary of Quantities	Shows material and equipment quantities.
General Notes	Frequently call special attention to critical requirements to ensure they are not overlooked; must avoid conflicts with specifications.
Site Schematics	Scale drawings of each site showing the roadway geometry, location of poles, conduit locations, and any other pertinent site information.
Construction Design Drawings	Shows locations of detectors to be installed and minimum requirements for construction dimensions.
Traffic Control Plan	Indicates handling of traffic during construction.
Details of Barricades and Signing	Illustrates the construction phase of the project.
Diagram of Underground Utilities	Shows details of location.
Standard Plans	Possessed by each agency, generally provide numerous standard drawings of frequently encountered details already approved for use in situations applicable to the project.

Table 3-6. Guidelines for Specifications. [4]

Specification	Guidelines
Detectors	Include physical properties, electrical properties, environmental conditions under which the equipment must operate, controls, and methods of operation.
Computer Software	Provide functional specifications for control software, compilers, assemblers, utilities, and diagnostic programs.
Video Terminals	Specify sample operator screens and controls, screen size, refresh rate, and colors.
CCTV Monitoring	Specify monitors, cameras, and interface protocols.

- Surface Transportation Program (STP).
- National Highway System (NHS).
- Congestion Mitigation and Air Quality Program (CMAQ).

STP funds are available on eligible projects with no time limit. NHS and CMAQ funds have definite time limits, and cannot be used for maintenance.[6]

Although some Federal funds are available for operating costs, Title 23 funds are generally used for system deployment and start-up assistance. Typically, funding for both operations and maintenance costs are provided on the State and local levels through maintenance budgets. Funding operations and maintenance costs for surveillance systems through the maintenance budgets often causes problems because of competition from other traditional maintenance activities. Therefore, it is crucial to identify the funding needs and funding sources for operation and maintenance activities early in the decision process.

Public/private partnership is an approach that many agencies are using to increase the source of funding for traffic management purposes. For example, many cellular telephone companies offer free or reduced rates to agencies for incident detection purposes. This approach allows other partners to get involved in a fair and equitable manner.

IMPLEMENTATION

The implementation process includes the activities involved in installing the components of the surveillance system to meet the established goal and objectives. **Module 2** gives a description of issues to be addressed during the implementation process. Additional issues that should be considered when implementing a surveillance system include the following:

- Phasing of installation.
- Training.

During the installation of a surveillance system, some disruptions to traffic are to be expected. To minimize delay to traffic, construction should take place during off-peak hours. In addition, the maximum number of lanes that can be simultaneously closed should be specified.[4] When possible, phasing of installation for the surveillance system should be coordinated with other freeway construction to minimize the overall delay to traffic.

Another area that must be addressed during the implementation of a system is the development of training programs for operators and maintenance personnel. Training should provide the technical skill necessary to effectively operate and maintain the system. The amount of training required depends upon the qualifications and knowledge of existing personnel and the requirements of the new system. For example, maintenance personnel that are familiar with an inductive loop detection system will require extensive training to maintain a video image processing system. Additional information concerning training requirements is contained in reference 9.

EVALUATION

After a surveillance system has been installed, the system should be evaluated for its effectiveness in meeting the objectives. The objectives of a surveillance system may include any of the following:

- Monitoring traffic operations.

- Detecting incidents.
- Supporting implementation of control strategies.
- Monitoring environmental conditions.

Monitoring Traffic Operations

The goals of monitoring traffic operations include:

- Providing measures of traffic operations (e.g., speed, flow, density, etc.).
- Identifying locations of congestion.
- Indicating the severity of congestion.

Records should be kept to track system operations and note any problems. An overall evaluation of the equipment should include monitoring the following:

- System reliability.
- Ability to provide required data.
- Timeliness of data.
- Accuracy of data.
- Ability to perform under various environmental conditions.
- Operational and maintenance requirements and costs.
- Any other problems with system.

Detecting Incidents

Automatic incident detection systems apply data collected from the field equipment to computer algorithms. The algorithms are designed to detect incidents by identifying discontinuities in traffic operations (e.g., speed, occupancy, etc.) measured upstream and downstream from an incident.

After an incident detection system has been implemented, it must be monitored and evaluated to calibrate the incident detection algorithm. The system is monitored by detecting incidents through alternative means such as the following:

- CCTV.
- Mobile reports (cellular call-ins, call boxes, service patrols, etc.).
- Emergency channels.

The algorithm is calibrated by adjusting the threshold values. The measure of effectiveness typically used for calibration is the false alarm rate. Threshold values are adjusted until an acceptable false alarm rate is achieved. The acceptance level is dependent upon available means of verifying the incident. For example, if an incident can be verified using CCTV, then a higher acceptance level might be tolerated. The threshold values may need to be recalibrated for major operational or geometric changes.[7]

Implementing Control Strategies

There are two types of control systems that may be used for freeways:

- Lane use control (see **Module 4**)
- Ramp control (see **Module 5**).

The objectives of these systems are to meter the demand or prohibit a certain movement in order to keep freeway volume below capacity to ensure continuous movement on the freeway. Detectors provide traffic data to these control systems to aid in the decision making process about the extent to which control should be implemented. The detectors used in a control system should be evaluated based on the following criteria:

- Reliability of detectors.
- Ability to provide needed data.
- Timeliness of data.
- Accuracy of data.

Monitoring Environmental Conditions

Typical environmental conditions on freeways that are monitored include the following:

- Ice.
- Wind.
- Fog.
- Rain.
- Dust.

The goals of monitoring these conditions include the following:

- Warn drivers of dangerous driving conditions.
- Reduce number of incidents.
- Reduce secondary incidents.
- Help maintenance personnel monitor pavement conditions.
- Improve response time.
- Reduce costs associated with monitoring and treating ice on pavements.

Additional conditions that require monitoring in tunnel sections include noxious gases, such as carbon monoxide.

The evaluation of environmental detection systems should include the following determinations:

- Ability to meet established goals.
- System reliability.
- Ability to provide required data.
- Timeliness of data.
- Accuracy of data.
- Operational and maintenance requirements and costs.
- Any other problems associated with system.

3.3 TECHNIQUES AND TECHNOLOGIES

SYSTEM COMPONENTS

The complexity and size of a surveillance system will vary with the size of the freeway system being monitored and with the specific functions that it will perform. For example, when the area being surveyed is relatively small, a section of the traffic engineering offices may be sufficient to house the control center. As the system expands and the responsibilities of the control center increase, a larger center with more sophisticated equipment may be required. Figure 3-2 shows a simple example of the control center components included in a surveillance system.

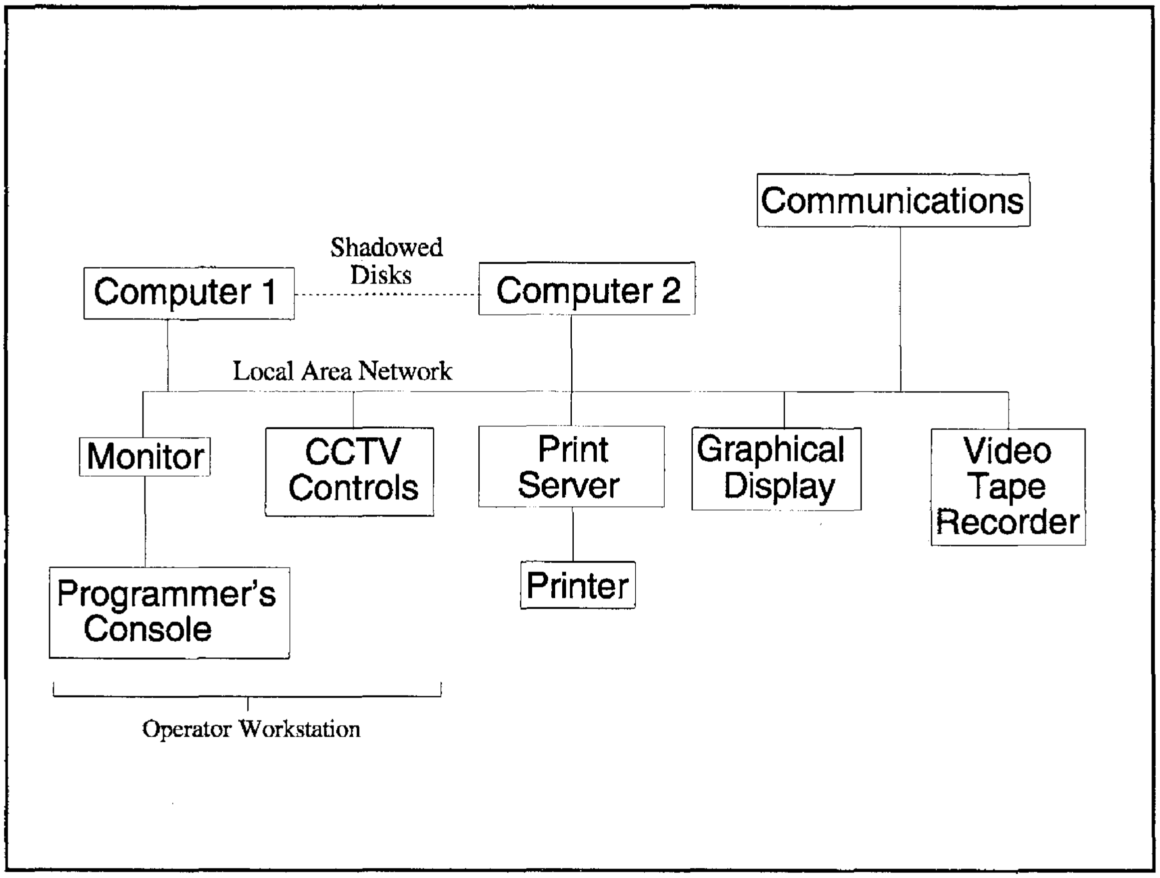

Figure 3-2. Control Center Components Typically Included in a Surveillance System.

The components of a surveillance system include the following:

- Detection methods.
- Hardware.
- Software.
- Communications.

Table 3-7 provides a list of typical system components.

Detection Methods

There are many technologies available for collecting traffic and environmental data for surveillance purposes. These technologies can be divided into the following groups:

- Embedded detectors.
- Non-intrusive detectors.
- Vehicle probes.
- Mobile reports.
- Closed-circuit television cameras.
- Environmental sensors.

Available detection methods are listed in table 3-7. Descriptions of each of these technologies is provided in a later section, entitled *Surveillance Technologies.*

Table 3-7. Typical Components for a Surveillance System.

Component	Alternatives
Detection Methods	Inductive Loop Magnetometer Microwave Radar Infrared Ultrasonic Acoustic Video Image Processing Automatic Vehicle Identification Automatic Vehicle Location Cellular Telephone Probes Cellular Call-Ins Freeway Service Patrol Reports Call Boxes/Emergency Telephones Closed-Circuit Television Environmental Detectors
Hardware	Computers Disk Drives Printers Monitors Controllers Displays Video Tape Recorders
Software	Incident Detection Algorithm Real-Time Expert System Interface Software
Communications	Internal - Local Area Network External - Fiber Optic - Coaxial - Twisted Pair - Microwave - Radio - Cellular Telephone - Citizen Band Radio

Hardware

Computers play significant roles in the operations of a surveillance system. The functions performed by the computers in the control center include the following:[7]

- Reception of data transmission from the field devices.
- Transmission of data from the control room to the field equipment.
- Reception of operator commands from keyboards or control panels.
- Control of graphical displays.
- Data processing to perform such functions as detecting incidents, deriving traffic flow characteristics, and identifying equipment failures.
- Storing data to create a historical database.

Computer 1 in figure 3-2 is an online computer that receives and transmits information to and from the field devices. Computer 2 serves as a backup and performs offline functions such as program development and database updating. The computers are typically microprocessor versions of minicomputers. The disk shadowing feature transfers data from the online computer to backup a system.[4]

The operator workstation typically consists of a personal computer unit. Functions that take place at the workstation include monitoring traffic operations, incident detection, decision making, and implementation of control strategies.

Closed-circuit television (CCTV) can be used for monitoring traffic conditions or detecting and confirming incidents. Controls for operating the CCTV system are also located at the workstation. The operator may have software installed on the personal computer to control the cameras or may have a separate control panel. Camera controls usually include camera selection, pan, tilt, zoom, and focus.

The printers interface with the local area network communication system through the use of print servers. Printers may be used to provide any of the following:[4]

- Hard copy reports of mode status and equipment failure logs.
- Traffic data summaries.
- Database status summaries.
- Special reports requested by the operator.
- Logs of system operations.

The functions of graphical displays are to provide observations of system operations and camera field of views for CCTV. Graphics may be provided on monitors at the workstations or on a large screen graphics display. The large screen displays have generally replaced the wall map displays used in older centers. The display may consist of a projection video display, a large video screen, or an array of smaller video screens. This new system has proven to be much easier to modify when new systems come online than the wall map system.[4]

Another important component of a surveillance system is the video tape recorder. Traffic operations can be recorded for analyzing and comparing conditions over a given period of time or for demonstration purposes. Depending on the size of the system and the recording requirements, one or more recorders can be provided to interface with any camera in the system.[7] Some traffic management centers choose not to record and archive incidents because of the potential drain on their staff (video tapes requested by claims adjusters, lawyers, private citizens, etc.) and the possiblity of having to appear in court.

Software

Software is an important component of a surveillance system. Without software, the data collected by the surveillance system has little value.

Three general types of software used with surveillance systems include the following:

- Software such as incident detection algorithms, etc. that apply the data supplied by the surveillance system
- Software that supports the operations support software such as real-time knowledge-based systems.
- Software for interfacing and communicating with the field devices.

Incident Detection Algorithms

One of the primary objectives of a surveillance system is to detect non-recurring congestion, such as that caused by an incident. Incidents cause significant amounts of delay for freeway vehicles; however, because they are random, they are impossible to predict and difficult to detect. Incident detection algorithms attempt to automatically detect incidents based on field data received from detection equipment. **Module 7** provides further discussion on incident detection algorithms.

Real-Time Expert Systems

Real-time expert systems are currently being developed for application in traffic operation centers. These expert systems provide decision support for operations personnel so they can more efficiently carry out their functions.[8] The knowledge-based support is based on the knowledge of experts in the field of traffic management. Functions of an expert system include:[8, 9]

- Detecting, verifying, and estimating the severity of incidents.
- Providing advice in areas such as dispatch of traffic and incident management teams.
- Developing and coordinating messages on variable message signs and other methods of information dissemination.
- Controlling traffic with lane control and ramp control systems.

The University of California at Irvine is in the process of developing a prototype real-time knowledge-based expert system called FRED (Freeway Real-Time Expert System Demonstration). The expert system uses advanced processing capabilities to integrate diverse types of traffic surveillance data for freeway monitoring and control purposes. After detecting an incident, the system uses additional information from several sources to formulate appropriate responses. The information includes the following:[10]

- Traffic data from detectors (e.g., speed, volume, occupancy, etc.).
- Information on traffic conditions from CCTV.
- Field reports from police officers and other official personnel.

- Cellular and emergency telephone calls from motorists.

Figure 3-3 illustrates the overall system layout of FRED.[10] In terms of incident detection and verification, this system is consistent with many traffic operation centers around the country. The system uses two methods to detect incidents:

- An incident detection algorithm on a central computer receives 30-second occupancy counts from freeway loop detectors and notifies FRED if an incident is detected.

- Outside reports from various agencies and motorists are received by a communications center that filters the reports and sends the high priority ones to FRED.

The knowledge-based support in FRED comes from the real-time expert system shell, G2. This system has the ability to determine what data is required at any particular stage, and to send for it. Given the incoming data, decisions are made on the basis of a predetermined set of rules. Once an incident has been detected and verified, the system recommends actions to be taken, such as using ramp metering or closing a ramp.[10]

Communications

Communications between the major components in the control center are accomplished through a local area network (LAN). The benefits of a LAN architecture include the following:[4]

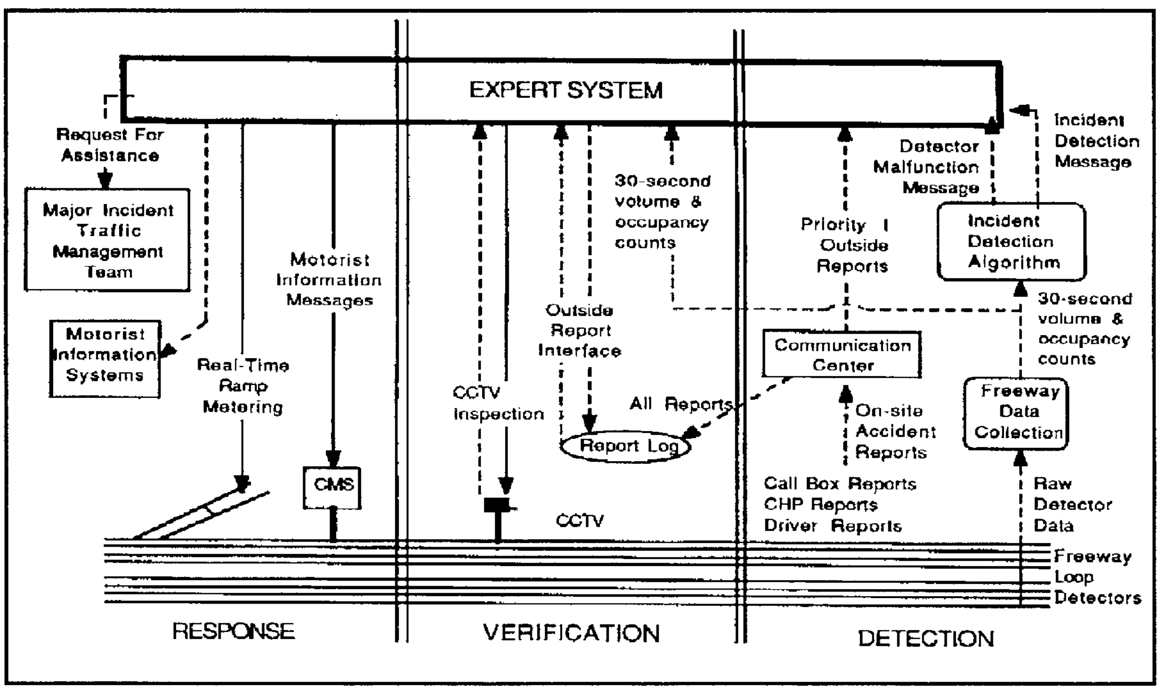

Figure 3-3. External System Overview for Real-Time Expert System. [10]

- Facilitate the addition of components to the network.

- Serve more devices in the operations center.

- Interface with additional field devices and controllers.

- Communicate with additional outside agencies and traffic data users.

Communications between the control center and the field devices occur through an external communication system. There are two basic categories of communication media:

- Physical cable (fiber optic, coaxial, twisted pair).

- Airwave transmissions (microwave, radio, and cellular telephone).

The type of communication medium required depends on the type of detection equipment being used. For example, transmission of video data requires a wide bandwidth that exceeds the capacity of many communication media. Transmission of voice and traffic data, however, requires a much narrower bandwidth which can be met by standard communication media. Table 3-8 lists some available communication media and their capabilities.(3) **Module 9** provides a detailed discussion of communication systems.

SURVEILLANCE TECHNOLOGIES

There are many technologies available for collecting traffic data. Although inductive loop detectors are currently used more than any other method, other technologies are beginning to replace loop detectors in many applications. This section provides descriptions of currently available detectors.

The discussion is organized under the following headings:

- Embedded Detectors.

- Non-intrusive Detectors.

- Vehicle Probes.

- Mobile Reports.

- Closed-circuit Television Cameras.

- Environmental Sensors.

Table 3-9 provides a summary of the detectors discussed in this section. The majority of detectors used for traffic data collection purposes are of either the embedded or non-intrusive type. Within these two groups, there are many alternative detectors, and each has advantages and disadvantages.

Table 3-10 provides summaries of the characteristics for embedded and non-intrusive detectors that are either currently available or in the developmental stage. The following discussions will address each of these detectors in more detail. The following areas are addressed for each traffic detector discussed:

- Characteristics.

- Applications.

- Installation requirements.

EMBEDDED DETECTORS

An embedded detector system consists of sensors in or below the surface of the roadway. These detectors are currently the most widely used form of vehicle detection. The main detectors being used include the following:

Table 3-8. Communication Media. (3)

Medium	Type	Data Type	Bandwidth	Distance Capabilities
Fiber Optic	Physical	Video, digital, voice	High	Long
Coaxial	Physical	Video, digital, voice	Moderate	Short
Twisted Pair	Physical	Digital, voice	Low	Long
Microwave	Airwave	Video, digital, voice	High	Line-of-Sight
Radio	Airwave	Digital, voice	Low	Long
Spread Spectrum	Airwave	Digital, voice	Low	Line-of-Sight
Cellular Telephone	Airwave	Digital, voice	Low	Moderate
Citizen Band Radio	Airwave	Digital, voice	Low	Moderate

- Inductive loop detector.
- Magnetometers.

Inductive Loop Detector

Characteristics

The inductive loop detector (ILD) is by far the most common form of detector used for traffic management purposes. Figure 3-4 illustrates the used of loop detectors for freeway surveillance purposes. The principal components of an inductive loop detector include the following:(11)

- One or more turns of insulated wire buried in a narrow, shallow saw-cut in the roadway.
- Lead-in cable that connects the loop to the detector via a roadside pull-out box.
- Detector unit (or detector amplifier) that interprets changes in the electrical properties of the loop when a vehicle passes over it.

The loop system becomes active when the detector unit sends an electrical current through the cable, creating a magnetic field in the loop. When a vehicle passes over the loop, the ferrous material in the vehicle causes a decrease in the inductance of the circuit. This increases the frequency of oscillation that is sensed by the detector unit.

Applications

Loop detectors can measure many traffic parameters including the following:

- Vehicle count.
- Speed.
- Occupancy.
- Presence.
- Vehicle classification.

Loop detectors can operate in either a pulse or presence mode. In the pulse mode, a short signal (typically 0.125 s) is sent from

Table 3-9. Summary of Detectors.

Detector Type	Detector	Data Collection	Information Type
Embedded	Inductive Loop	Site Specific	Data
	Magnetometer	Site Specific	Data
Non-Intrusive	Radar	Site Specific	Data
	Infrared	Site Specific	Data
	Ultrasonic	Site Specific	Data
	Acoustic	Site Specific	Data
	Video Imaging	Site Specific	Video, Data
Vehicle Probes	Automatic Vehicle Identification	Site Specific	Data
	Automatic Vehicle Location	Variable Location	Data
	Cellular Telephone Probes	Variable Location	Data
Mobile Reports	Cellular Reporting	Variable Location	Voice
	Service Patrols	Variable Location	Voice
	Call Boxes	Site Specific	Coded Message
Closed-Circuit Television (CCTV)	Fixed Location Cameras	Variable Location	Video
	Portable Cameras	Variable Location	Video
Environmental Sensors	Freeways	Site Specific	Data
	Tunnels	Site Specific	Data

the loop to the detector unit and can be used to provide volume counts. In the presence mode, the signal that is sent to the detector unit lasts as long as the vehicle is in the detection area. Presence detectors are used to provide volume counts and occupancy measurements. Presence detection is used for most detector applications, and is the preferred mode for most system management purposes.

Table 3-10. Summary of Traffic Detectors.

Detector Type	Detector	Description	Advantages	Disadvantages
Embedded	Inductive Loop	Coil of cable embedded in the pavement surface that creates a magnetic field. Vehicle is detected when this magnetic field is disturbed.	• Flexible design. • Wide range of applications. • Provides basic traffic parameters (e.g., volume, speed, presence, occupancy).	• Installation requires pavement cuts. • Installation and maintenance requires lane closure. • Detectors subject to stresses of traffic.
	Magnetometer	Small cylinders containing sensor coils that operate in a manner similar to inductive loops. Developed as alternative to loop detectors for special situations.	• Can be used in situations where loops are not feasible (e.g., bridge decks). • Less susceptible than loops to stresses of traffic.	• Installation requires pavement cuts. • Installation and maintenance require lane closure. • Small detection zone. • Typically used onlyto provide count and occupancy.
Non-Intrusive	Microwave Radar	Transmits electromagnetic energy toward vehicles on roadway. Traffic parameters are calculated by measuring the return signal frequency from vehicles.	• Generally insensitive to weather conditions. • Provides day and night operation.	• Requires FCC license for operation and maintenance. • May lock on to the strongest signal (e.g., large truck).
	Infrared	Active infrared detectors transmit electromagnetic energy. Passive infrared detectors do not transmit energy but measure the amount of energy that is emitted by objects in the field of view.	• Active detector emits narrow beam allowing for accurate determination of vehicle position. • Provides day and night operation. • Provides most basic traffic parameters. • Passive detectors can be used for strategic loop replacement.	• Operation affected by precipitation (e.g., rain, fog, etc.). • Difficulty in maintaining alignment on vibrating structures.

Table 3-10. Summary of Traffic Detectors (cont.).

Detector Type	Detector	Description	Advantages	Disadvantages
Non-Intrusive (Continued)	Ultrasonic	Transmits sound waves at frequencies between 20 and 200 kHz. Detects vehicle by measuring return waves.	• Provides most basic traffic parameters.	• Environmental conditions (e.g., temperature, humidity, air turbulence, etc.) can affect performance. • Snow covered vehicles are difficult to detect. • High level of special maintenance capability is required.
	Acoustic	Uses microphones along with signal processing technology to listen for sounds associated with vehicles.	• Completely passive. • Generally insensitive to weather conditions. • Provides day and night operation.	• Relatively new technology for traffic surveillance.
	Video Image Processing	Video image processors receive information from video cameras and use algorithms to analyze the video image input.	• Location or addition of detector zones can easily be done. • Provides basic traffic parameters. • Provides wide-area detection.	• Inclement weather, shadows, and poor lighting can affect performance. • May require significant processing power and a wide communication bandwidth.

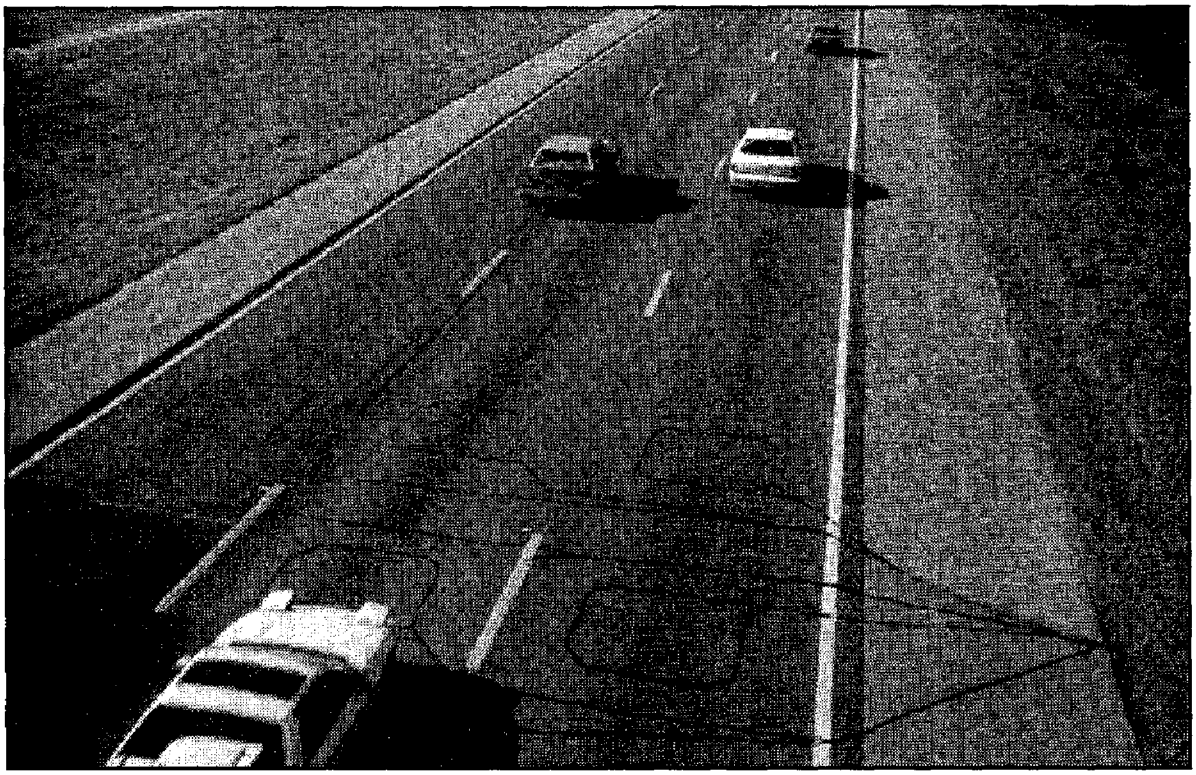

Figure 3-4. Inductive Loop Detectors Used for Freeway Surveillance. [12]

Loops can be used to detect vehicle speeds by placing two loops in pulse mode a short distance apart (see figure 3-5).[4] The distance between the loops divided by the time required for a vehicle to travel between the loops provides the speed of the vehicle.

Installation Requirements

The ILD provides for a wide range of vehicle detection because of the flexibility of its design. Loop configurations are generally grouped into two areas: short loops and long loops. For vehicle detection, the short loop configuration is recommended. The most common loop size for traffic management purposes is 1.8 m by 1.8 m (6 ft by 6 ft). The maximum length of a short loop should be 3.1 m (10 ft).[3] Detailed information concerning the design, installation, and maintenance of ILDs is contained in the *Traffic Detector Handbook*.[11]

The most important process in implementing a loop detection system is the one related to the installation procedures. Installation procedures will have a significant effect on the long term operational effectiveness of the detector system. Improper installation techniques may result in detector failures and require extensive maintenance. Installing the wire loops in the pavement requires the following steps:

- Cutting a slot in the pavement.
- Cleaning and drying the slot.
- Laying in the detector wire.
- Sealing the saw cut.

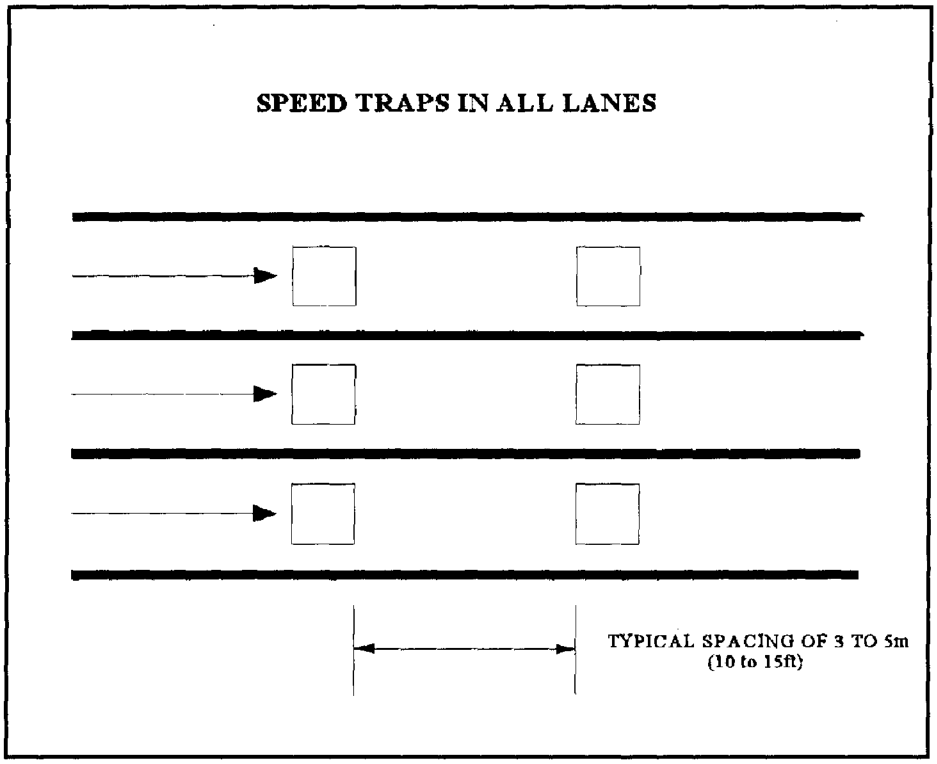

Figure 3-5. Typical Loop Installation for Measuring Speed. [4]

- Connecting the wire loop to the lead-in cable.
- Connecting the lead-in cable to the detector unit.

The main concern with the use of ILDs is reliability. Because the detectors are embedded within the pavement, they are subject to the stress of traffic traveling on them and to pavement deterioration. In northern States, other problems are associated with freeze-thaw conditions.[13]

The primary causes of loop failure include the following:

- Pavement problems (cracking and moving).
- Deterioration of wire insulation.
- Poor sealants or inadequate sealant application.
- Inadequate splices or electrical connections.
- Damage caused by construction activities.
- Improper detector unit tuning.
- Detector unit failure.
- Lightning/electrical surges.

Most of these problems can be traced back to improper installation techniques.

Magnetometer

Characteristics

Magnetometers contain small probes that range in size from 5 cm (2 in) to 11 cm (4.25 in) in diameter. The magnetometer was developed as an alternative for loop detectors in special situations, such as bridge structures. Figure 3-6 illustrates a typical installation for magnetometers. Similar to loop detectors, the components of a magnetometer detection system include the following:[11]

- One or more small probes (sensors) embedded in the pavement.
- Probe cable.
- Lead-in cable that connects the probe to the detector via a roadside pull-out box.
- Detector unit.

Magnetometers measure the density of vertical flux lines of the earth's magnetic field. When a vehicle passes over the probe, the ferrous material in the vehicle increases the density of the flux lines. Magnetometers sense this increase and interpret it as the presence of a vehicle.

Applications

Magnetometers can operate in either presence of pulse modes and are most effective in determining occupancy and volume. This type of system is usually used when the only information required is that a vehicle has arrived at a specific point.[11] Speed can also be measured by placing two sets of probes a known distance apart.

Installation Requirements

Similar to the installation of inductive loops, installing magnetometers requires cutting the pavement; however, because magnetometers are more compact in size, not as much cutting is required. Detailed information concerning the design, installation, and maintenance of magnetometers is contained in the *Traffic Detector Handbook*.[11]

For a magnetometer to detect a vehicle, some part of the vehicle must pass over the probe. Therefore, optimum lateral placement of probes in the pavement is dependent upon the following factors:

- Width of narrowest vehicle to be detected.
- Width of lane.
- Required detection quality.

Since most vehicles are wider than 1.5 m (5 ft), a single probe might not be adequate for lane widths greater than 3 m (10 ft). For lane widths of 3.7 m (12 ft), two probes per lane should be adequate for detecting all four-wheeled vehicles.

Installing the magnetometers requires placing the detectors in the pavement. The installation procedures include the following steps:

- Drill holes in pavement for probes.
- Saw slots in pavement for detector wires.
- Clean and dry saw cuts.

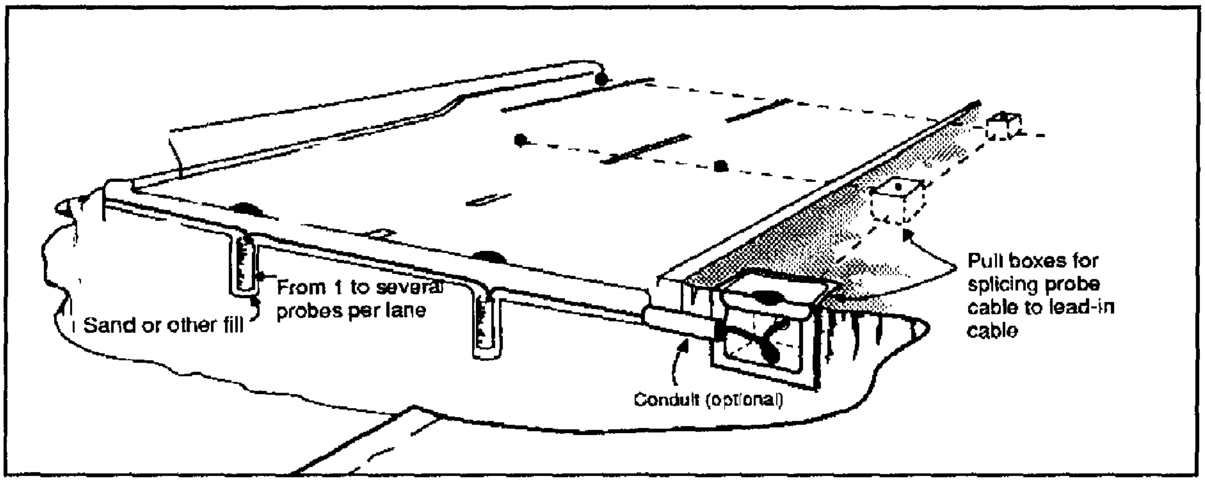

Figure 3-6. Typical Layout for Magnetometer Installation.[4]

- Place each probe in the proper hole.
- Secure probe with housing, sand, or sealant.
- Connect detector wire to lead-in cable.
- Connect lead-in cable to the detector unit.
- Test system.
- Seal drilled holes.

Because the probes are buried several centimeters below the surface of the pavement, magnetometers are less susceptible than ILDs to deteriorating pavement conditions. Therefore, magnetometers are primarily used in northern States that suffer pavement deterioration due to freeze-thaw cycles. In addition, the magnetometer can usually be used on bridge decks where cutting the pavement for loop installation is not an option.

When using magnetometers on bridge structures, the probes should be placed at the maximum distance from steel supports (see figure 3-7). The presence of steel over or under the probes has little effect on performance; however, vertical structural steel members may influence the magnetic field surrounding the probe, and affect performance.

The causes of magnetometer failures are usually either improper installation or maintenance procedures. The major factors that affect the operation of a magnetometer detector system include the following:

- Proper burial depth of probe.
- Stability of the probe in the pavement.
- Moisture penetration into the probe cable.
- Saw slot maintenance.

NON-INTRUSIVE DETECTORS

In response to an increasing demand for alternatives to loop detectors, a broad range of non-intrusive detectors have become

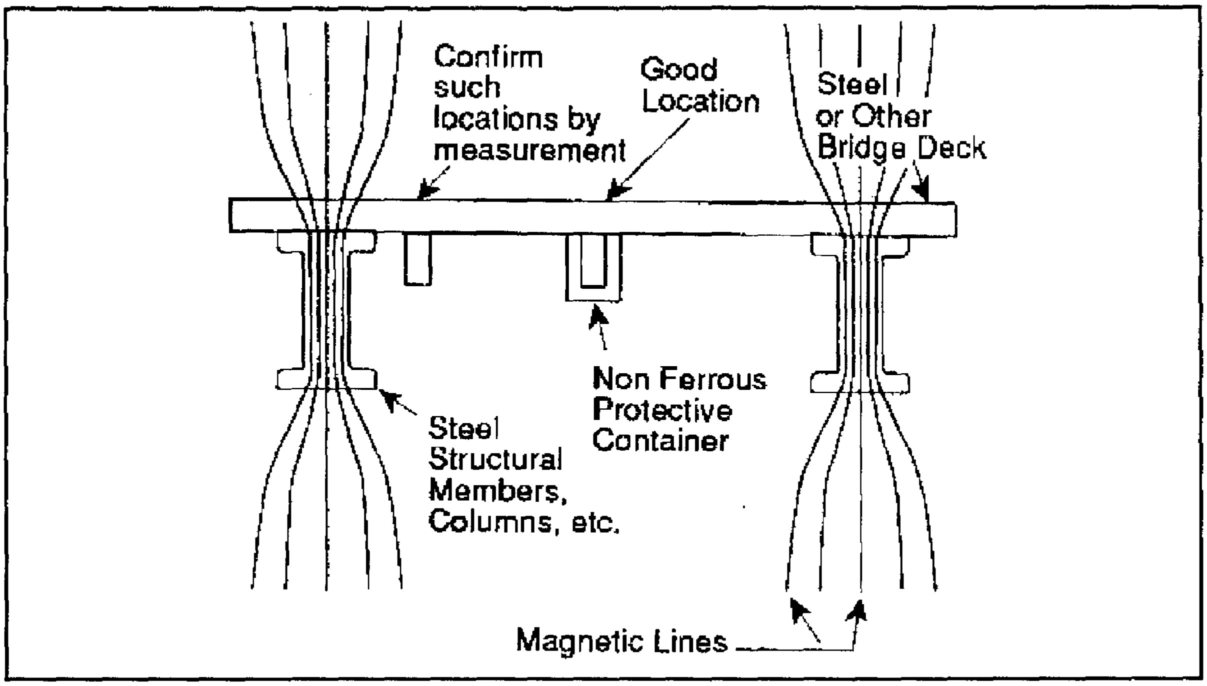

Figure 3-7. Typical Bridge Deck Installation for Magnetometer. [4]

available. [14] Non-intrusive detectors are mounted on a structure above the surface of the pavement. Figure 3-8 shows an example of a non-intrusive detector. Advantages that non-intrusive detectors have over embedded detectors include the following:[15,16]

- Modifications to pavement are not required for installation.
- Detectors can be moved or replaced more easily.
- Lane closure may not be required during installation and maintenance.
- Detectors are not subject to stresses of traffic.
- Detectors can be used during and after any reconstruction or maintenance activities.

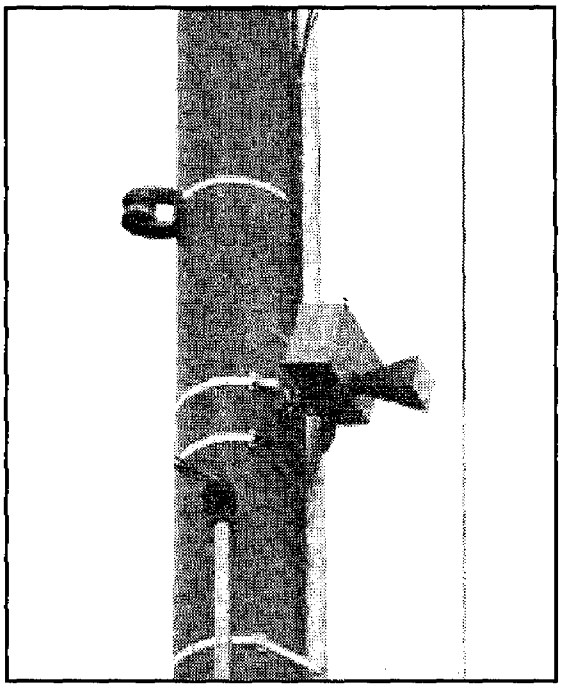

Figure 3-8. Example of Non-Intrusive Detector. [17]

A disadvantage of non-intrusive detectors is that they may produce unreliable results during adverse weather conditions.

Over the past few years, however, improvements in technology have improved the performance and reliability of certain non-intrusive detectors, and costs have become more and more competitive with loops. There are currently many non-intrusive technologies that provide viable alternatives to loop detectors. These alternatives include the following:

- Microwave radar.
- Infrared.
- Ultrasonic.
- Acoustic.
- Video image processing.

Microwave Radar

Characteristics

Microwave radar detectors have been used in both law enforcement and traffic management for some time to monitor vehicle speed. For traffic management, radar sensors are mounted either above or beside the road and direct a beam of microwave energy onto a detection area. Most radar detectors transmit electromagnetic energy at the speed of light at the K-band (24 gHz) or the X-band (10 gHz).[18]

The form of the electromagnetic wave transmitted by the detector determines the type of data that can be obtained by the unit. Three types of radar frequency include the following:[18]

- Continuous wave.
- Frequency modulated continuous wave (FMCW).
- Pulsing waveform.

Continuous Wave. With constant wave radars, electromagnetic energy is transmitted at a constant frequency. This type of radar is the most common form of radar detection. As shown in figure 3-9(a), vehicle speeds are calculated by measuring the Doppler shift that occurs in the return signal frequency. The shift in the return signal is proportional to the speed of the vehicle. Because only moving vehicles cause a frequency shift in the return signal, these detectors cannot detect stationary vehicles, and thus cannot be used as presence detectors.

Frequency Modulated Continuous Wave (FMCW). FMCW radar detectors can be used to measure the presence of vehicles as well as the speed. Figure 3-9(b) illustrates a typical waveform of these types of detectors. Presence detection occurs in the portion of the waveform where the frequency changes with time. The portion of the waveform that is constant is used to measure the speed of vehicles in the same manner as the continuous wave detectors.

Pulsing Waveform. Pulsing waveform is a variation of the FMCW signal. As illustrated in figure 3-9(c), it is generated by using differences in frequency change rates, time duration of each waveform segment, and numbers and sequencing of the waveforms. Detectors that use this type of waveform can measure differences between the range to the road and the vehicle, making it possible to provide not only vehicle counts and presence detection, but also occupancy. Speeds can also be determined by measuring the elapsed travel time between two detectors.

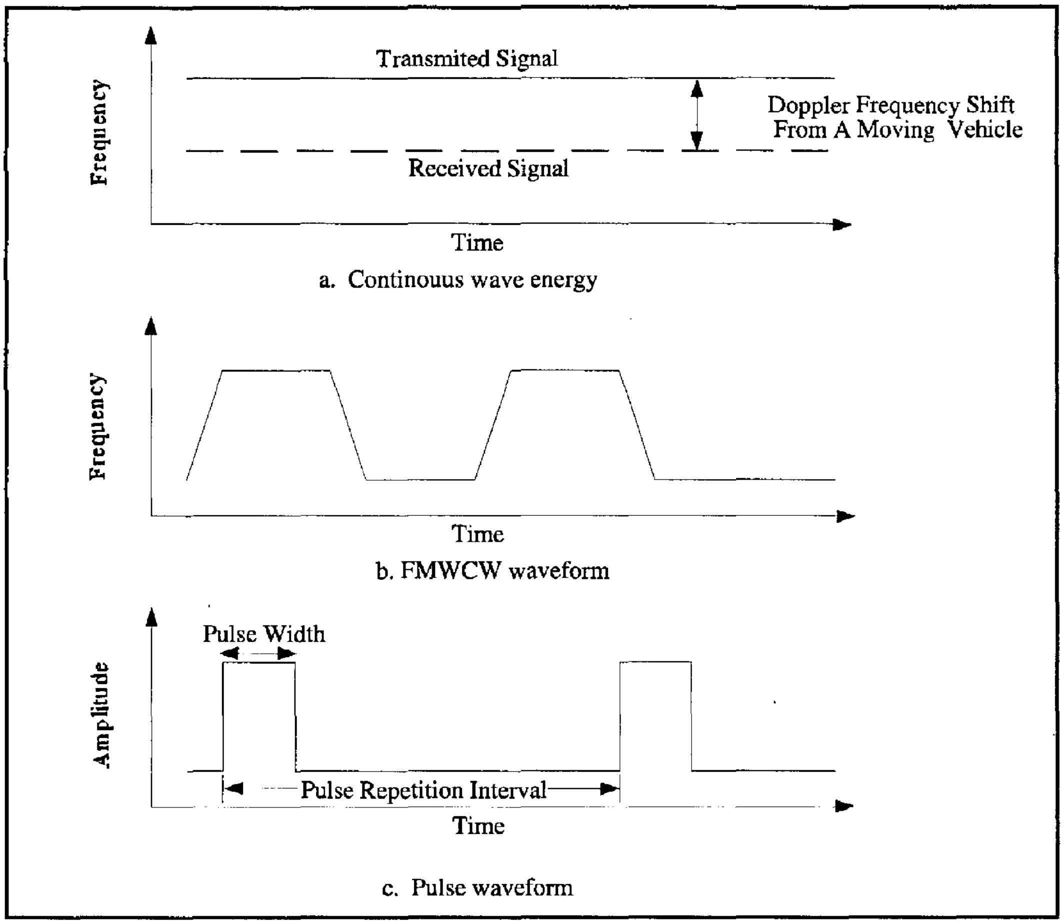

Figure 3-9. Waveforms Used with Microwave Detectors. [18]

Depending on the width of the radar beam, radar detectors may be used to monitor from one to several lanes. Three types of radar detectors exist:[13]

- Wide beam.
- Narrow beam.
- Long-range.

Wide Beam. Wide beam detectors monitor all lanes of traffic in one direction of the freeway (see figure 3-10(a)). They provide information on the overall traffic speeds; however, every vehicle is not detected.

Narrow Beam. Narrow beam detectors monitor only a single lane of traffic in one direction (see figure 3-10(b)). They are typically installed where freeway lanes have varied uses (e.g., through lanes and exit lanes, or through lanes and HOV lanes).

Long-Range. Long-range detectors project the radar beam over greater distances, up to 245 m (800 ft). This type of detector may be installed alongside a freeway with traffic traveling in one direction to measure speeds of freeway traffic traveling in the opposite direction (see figure 3-10(c)).

One advantage of radar detectors is that they can discriminate between approaching and receding traffic. [15] This capability would be

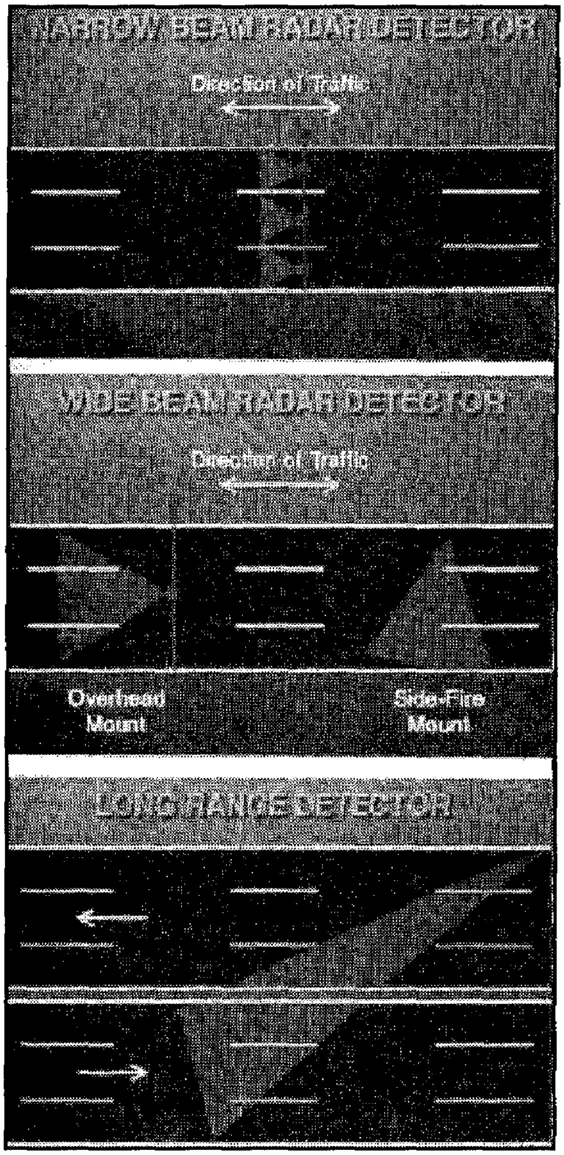

Figure 3-10. Alternative Radar Beam Widths. [13]

useful for monitoring operations on reversible or contraflow lanes.

Applications

The most common applications of microwave radar detectors are to measure vehicle speeds, and in some applications to provide volume counts. As mentioned above, advanced units that are available can be used as presence detectors. In addition, some radar units can measure vehicle profiles to perform classification counts.[18]

An area in which the use of microwave radar detectors is increasing is incident detection. Incident detection algorithms used with radar detectors typically detect incidents by using speed data. This differs from the majority of incident detection algorithms, which detect incidents based on occupancy data. A recent study suggests microwave radar incident detection systems are highly accurate and reliable.[13]

One of the biggest advantages of microwave radar detectors is their ability to perform adequately in all weather conditions. Because the detectors are mounted above the pavement surface, they are not subject to the effects of ice, sand, and salt during the winter months, as are many embedded detectors. Microwave radar detectors can be useful under the following conditions:[13,19,20]

- Rain.
- Fog.
- Snow.
- High winds.
- Day and night.

Installation Requirements

One advantage of using non-intrusive detectors is ease of installation. This is especially true if the detectors can be mounted on existing structures, such as the following:

- Bridges.
- Luminaire poles.

- Sign structures.

Radar detectors can be mounted in either the side-fire position (see figure 3-11) or the overhead position (see figure 3-12). Setup of the detector is simple and involves simply aiming the unit at the traffic flow. Unlike other detection systems, most current radar units do not require setup, configuration, or calibration to provide accurate data.[13]

Maintenance costs of radar detectors have also proven to be relatively low. One study conducted in a northern State showed only a 2 percent failure rate for radar detectors over 2 years. This compares with a 34 percent failure rate of loop detectors over a 5-year period.[13] Costs are also kept lower, because maintenance of the detectors typically does not require lane closure on the freeway.

Infrared

Characteristics

There are two types of infrared detectors:

- Active.
- Passive.

Active. Active infrared detectors (see figure 3-13) operate by directing a narrow beam of energy toward a background, such as the surface of a roadway, at a certain pulse rate. A portion of the beam is directed back to the sensor, and vehicles are detected by changes in the characteristics of the infrared beam. The infrared beam can be transmitted from one side of the road to the other, or from an overhead or roadside position to a device in the pavement surface. Disadvantages of active infrared sensors include the following:[3]

- Difficulties of maintaining alignment on vibrating structures.
- Inconsistent beam patterns caused by changes in infrared energy levels due to passing clouds, shadows, fog, and precipitation.
- Lenses used in some devices may be sensitive to moisture, dust, or other contaminants.
- Inconsistent reliability under high volume conditions.

An advantage of active infrared detectors is the very narrow beam width that they emit. This allows for accurate determination of the spatial position of a vehicle on a road. In addition, the profile of a vehicle can be measured to within a few centimeters for some systems.[22]

Passive. Passive infrared detectors (see figure 3-14) do not transmit energy themselves, but measure the amount of energy that is emitted by objects in the field of view. The amount of energy that is emitted by an object depends on its surface temperature, size, and structure, but not on its color or the surrounding lighting conditions. For years, these detectors have been used as motion detectors; however, detectors are currently available for detecting presence as well.[14] As with active infrared detectors, the ability of passive sensors to detect vehicles can be affected by environmental effects, such as fog and precipitation, that can scatter and emit energy of their own. [18]

Applications

Active. Currently available active infrared detectors can provide speed, count, density, and vehicle classification. Accuracy is based

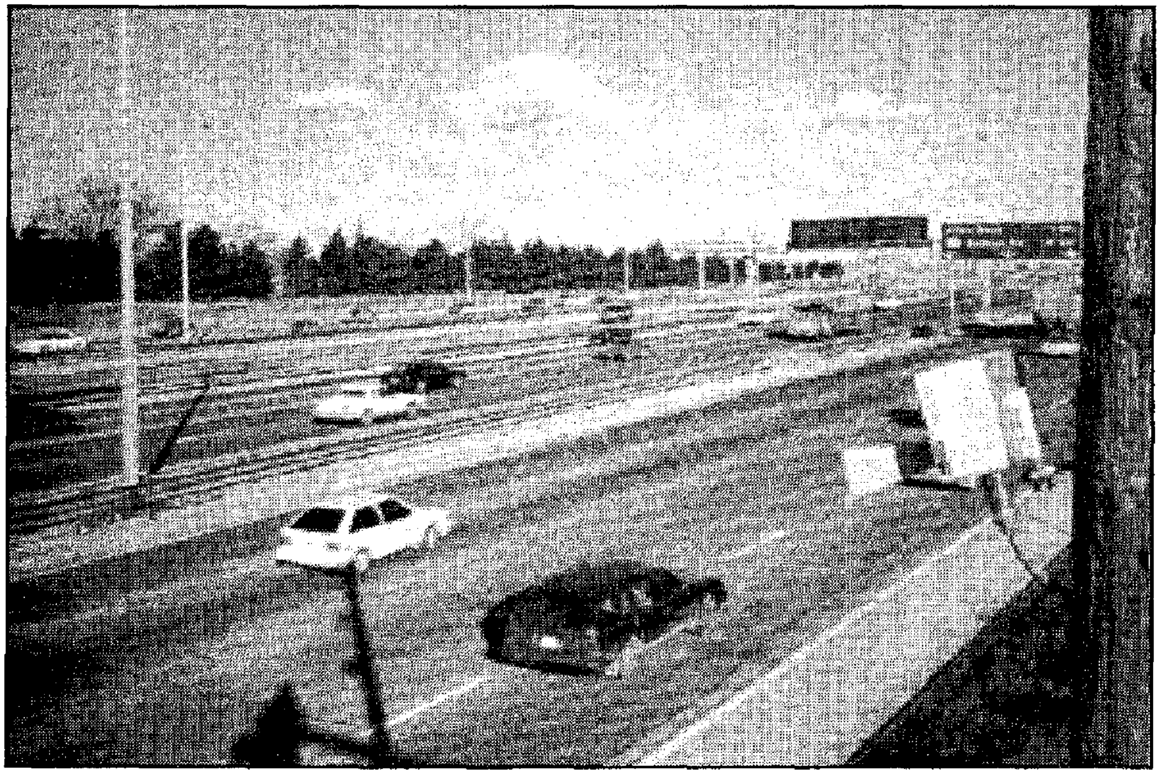

Figure 3-11. Detector in Side-Fire Position. [21]

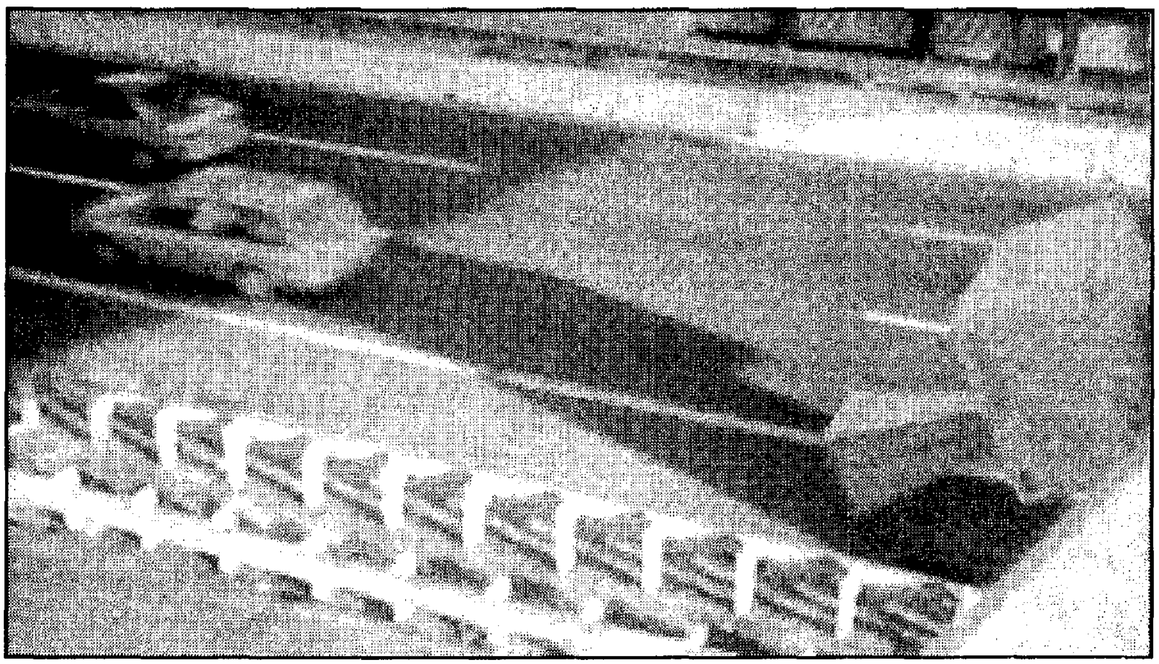

Figure 3-12. Detector in Overhead Position. [19]

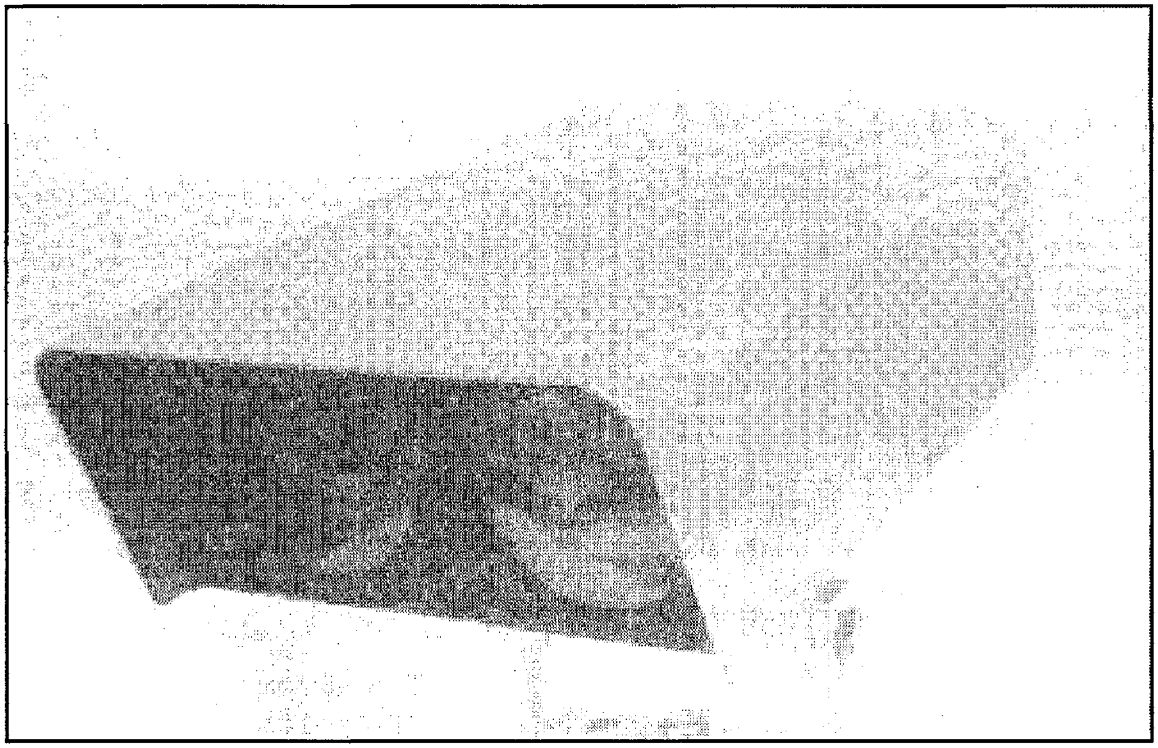

Figure 3-13. Active Infrared Detector. [11]

on the pulse rate, scan rate, and speed of vehicle. Faster pulse rates and scan rates improve the accuracy of the system up to a certain point.[22]

The presence of a moving or stationary vehicle is determined by measuring the round-trip propagation time of an infrared pulse. This time will be shorter when a vehicle is present. Speeds are measured by using two fixed beams, one slightly ahead of the other. By comparing the times at which the front of a vehicle passed through each beam, the speeds can be determined.[22]

One system that is coming onto the market can determine vehicle classification by measuring the profile of a vehicle. A two-dimensional profile of a vehicle passing through the infrared beam is obtained by measuring the distance from the detector to the vehicle (see figure 3-15). If the beam is scanned across the roadway at a fast enough pulse rate, a very accurate profile of a vehicle can be obtained. The vehicle may then be classified by using an algorithm to compare the vehicle's profile against defined profiles for various vehicle classifications. [22]

Passive. Passive infrared detectors can provide volume counts as well as presence detection. Using a multichannel presence detector, passive infrared detectors can be made to mimic the pattern of an inductive presence loop, and can replace malfunctioning loop detectors.[14]

Installation Requirements

For speed measurement and presence detection, infrared detectors may be installed in either the side-fire or overhead position.

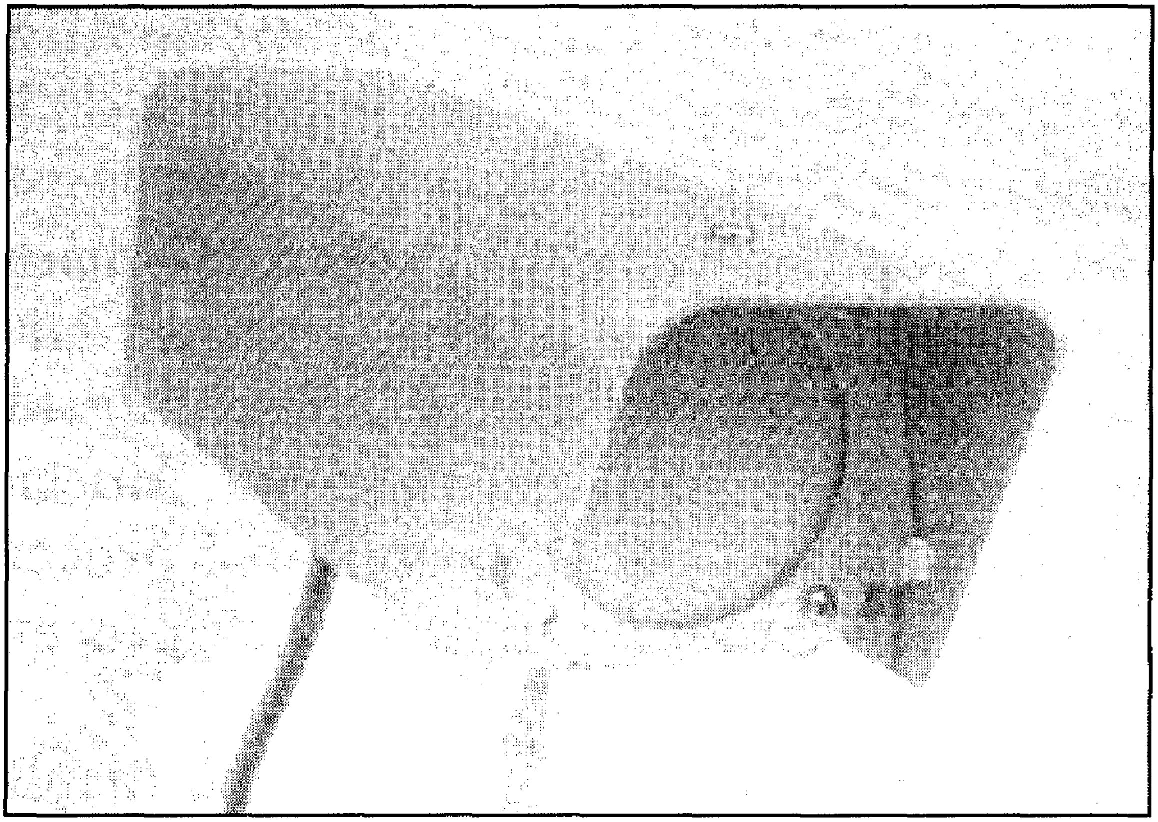

Figure 3-14. Passive Infrared Detector. [11]

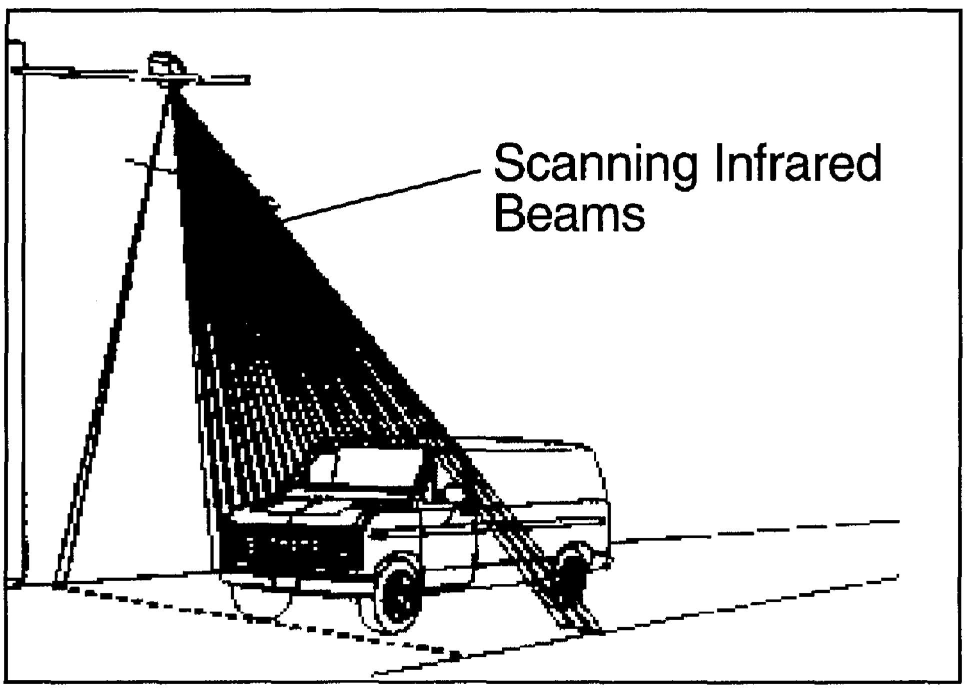

Figure 3-15. Active Infrared Detector Measuring Vehicle Classification. [23]

In order to obtain vehicle classification, the detector must be mounted in the overhead position. Active infrared detectors are suitable for single lane detection, but can be used only at short ranges. Passive infrared detectors offer lane discrimination at long range, but have relatively slow response time. [14]

Some currently available active infrared systems have incorporated microcontrollers that offer continuous built-in testing. For these systems, all adjustments to the system are automatically performed, and no initial calibration is required during installation. In addition, maintenance or design changes may be performed by uploading the system's program code, thereby, eliminating the need to remove the detector from the mount.[22]

Ultrasonic

Characteristics

Ultrasonic detectors use electronic sound wave signals and a receiving unit to detect vehicles traveling in a traffic stream. These detectors operate on the same principle as microwave radar detectors in that both transmit a beam into an area and receive the reflected beam to detect a vehicle. [11] Similar to radar detectors, ultrasonic detectors operate using the following waveforms:[22]

- Continuous.
- Pulse.

For a continuous waveform, a continuous signal is emitted, and vehicle presence is measured using the Doppler principle. This form can be used to detect volume, occupancy, and speed. For pulse waveform, the detector operates by pulse allowing the measurement of classification, as well as volume and presence.

The development of ultrasonic devices for vehicle detection began in the mid-1950s. Michigan, Illinois, New York, and California were among the early users of ultrasonic detectors in the 1960s. The use of these detectors was abandoned for the most part because of the problems experienced. Recently, however, there have been efforts to improve ultrasonic vehicle detectors. Results from these efforts continue to show promise.[11]

Disadvantages of current ultrasonic vehicle detection systems include the following:[3]

- Environmental conditions (such as temperature, humidity, and air turbulence) can affect operations because the detectors use sound waves that propagate through the air.
- Surface of a vehicle may affect the performance of the detector. For example, porous or textured surfaces (e.g. snow on a vehicle) produce weaker reflected sound waves.
- Speed is not measured directly.
- Systems require a high level of special maintenance capability.

Applications

Ultrasonic detectors can be used for both presence and pulse applications. Using signal processing techniques, the reflected waves may be converted into volume, speed, and occupancy measures. In addition, some detectors can be used for presence detection and vehicle classification. Vehicles are classified by comparing the sonic signature created by a vehicle with a set of pre-programmed signatures of vehicles of various classes.[22]

Installation Requirements

Ultrasonic detectors can be mounted in either the side-fire or overhead position. Detectors can provide either single lane or multi-lane coverage. An example of an ultrasonic detector installation is shown in figure 3-16.

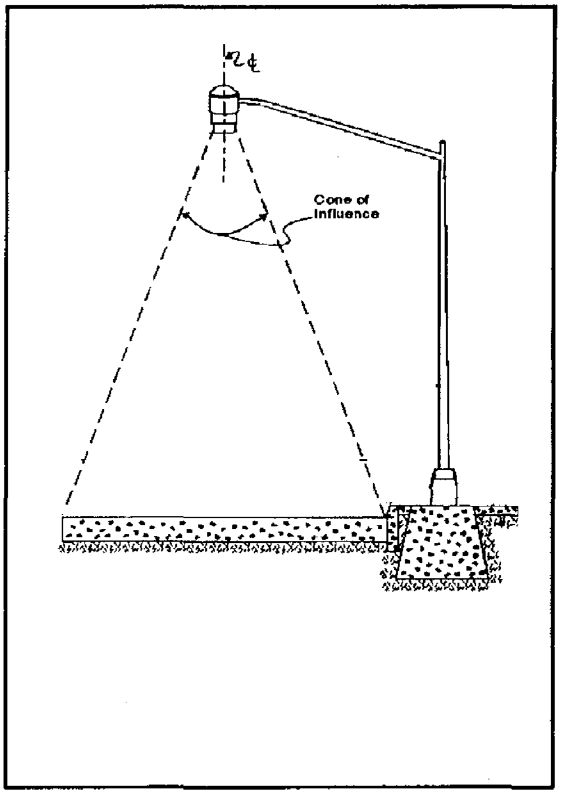

Figure 3-16. Example of Ultrasonic Detector Installation. [11]

Acoustic

Characteristics

Acoustic detectors are completely passive devices. Vehicles are detected by using microphones along with signal processing technology to listen for sounds associated with vehicles. The acoustic technology used by these detectors was originally developed for military defense purposes, such as tracking enemy submarines. The use of this acoustic technology for vehicle detection purposes has emerged within the last few years. The advantages of acoustic detectors are that they work well in all lighting conditions and in wide temperature and humidity extremes. [22]

Applications

Acoustic detectors can be used to measure volume, occupancy, and presence. Vehicle classification can also be determined by comparing the sonic signature of a vehicle to pre-programmed sonic signatures of vehicles for various classes. [22]

Speed can be measured by using an array of microphones as shown in figure 3-17. The configuration shown in this figure consists of two microphones, one mounted above the other. The concept behind this configuration is that the time delay of sound arrival will be different for the upper and lower microphones. This difference in time delay will vary as a vehicle approaches the sensors. For example, when the vehicle is a certain distance from the sensors, the sound arrives at both microphones almost simultaneously. When the vehicle passes under the sensors, the sound reaches the lower microphone first. By plotting time delay versus time, the relationship can be used to estimate speed (see figure 3-18).[24]

Installation Requirements

Acoustic detectors can be mounted either on the side of the roadway or in an overhead position. The detectors can monitor one or many lanes. Multilane detectors cannot distinguish between lanes, and may experience interference among vehicles in different lanes. Single lane detection is accomplished using directional microphones; however, this increases the complexity and cost of the system. [24]

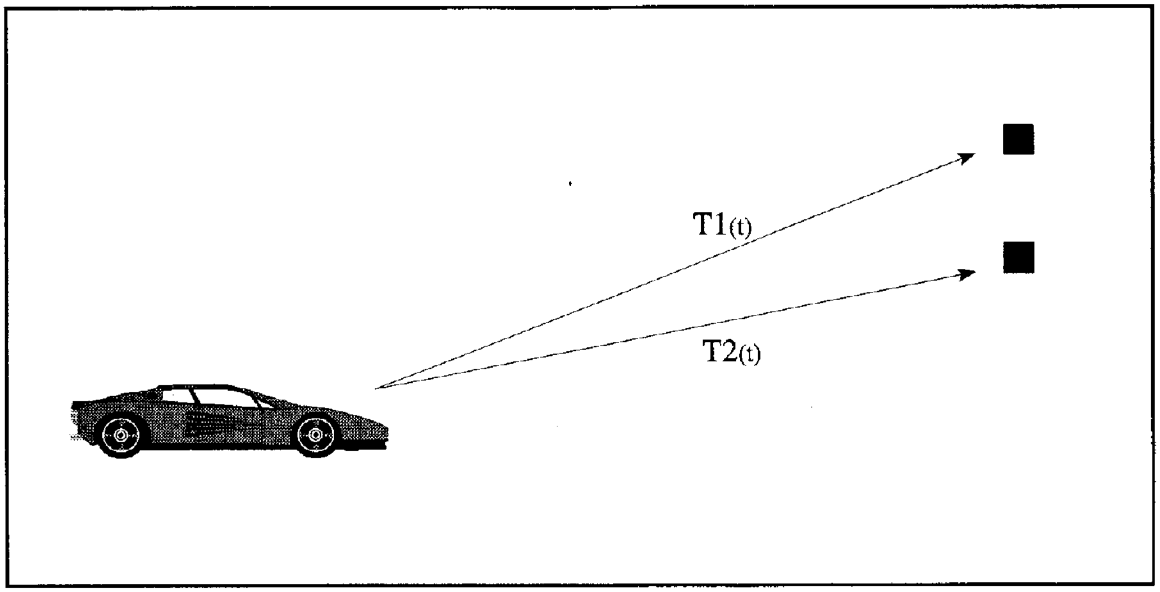

Figure 3-17. Acoustic Detector.

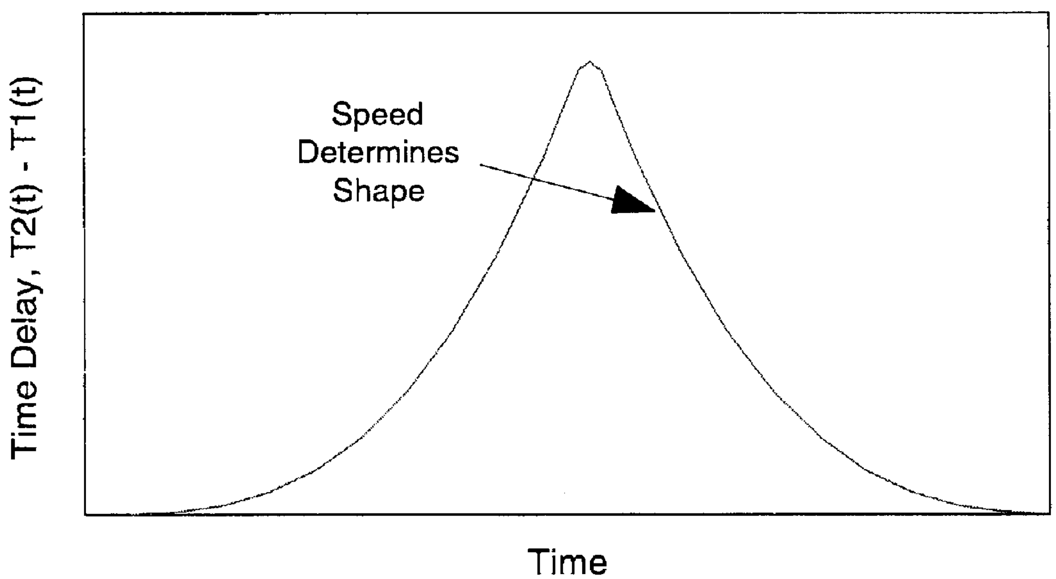

Figure 3-18. Time Delay Versus Time Curve.

Video Image Processing

Characteristics

An emerging technology that appears to be very promising for meeting future data collection and surveillance needs is known as video image processing (VIP). VIP systems detect vehicles by monitoring specific points in the video image of a traffic scene to determine changes between successive frames.[25] The components of a VIP system are shown in figure 3-19. Most systems consist of the following major elements:

- One or more video cameras.
- Microprocessor-based system for processing the video image.
- Software for interpreting the processed images as vehicle detections.

The microprocessor-based system receives video inputs from the cameras. After receiving video input, the processor analyzes the variation of gray levels in a series of pixels from the video image. The processor must filter out gray level variations resulting from weather conditions, shadows, and day- or night-time-related aspects. The resulting image consists of a blank background containing only identified objects such as vehicles, motorcycles, and/or bicycles. By analyzing successive video frames, the system is able to calculate vehicle-related information.[20]

Classes of VIP Systems. VIP systems have evolved through the following three classes:

- Tripline.
- Closed Loop Tracking.
- Data Association Tracking.

Tripline. These first generation systems are the least demanding in terms of computer power and speed. Most of the VIP systems that are commercially available at this time are of this class. Tripline systems operate by allowing the user to define a limited number of detection zones in the field of view of the video camera. When a vehicle enters one of these detection zones, it is identified in a manner analogous to that of inductive loops. In fact, tripline systems are the functional equivalent of inductive loops and are intended to replace inductive loops in areas where a large number of loops are employed. Limitations of tripline systems include the following:

- Difficulty in detection due to the presence of shadows or light changing conditions.
- Problems of occlusion (vehicle hidden by another vehicle or object).

Closed Loop Tracking. These systems are second generation VIP systems. They are an extension of the tripline approach in that detection is performed using the same type of detection zones. Closed loop tracking systems represent the first attempt to perform vehicle tracking. These systems have the same problems as tripline systems with shadows and occlusion. They provide more traffic flow information than tripline systems, but the complexity of both hardware and software subsystems is significantly greater than for tripline systems.

Data Association Tracking. These systems, commonly used in satellite surveillance systems, are third generation VIP systems. A basic requirement for these systems is the capability to identify and track a distinguishable object as it passes through the field of view of the camera. In this mode, the computer identifies vehicles by

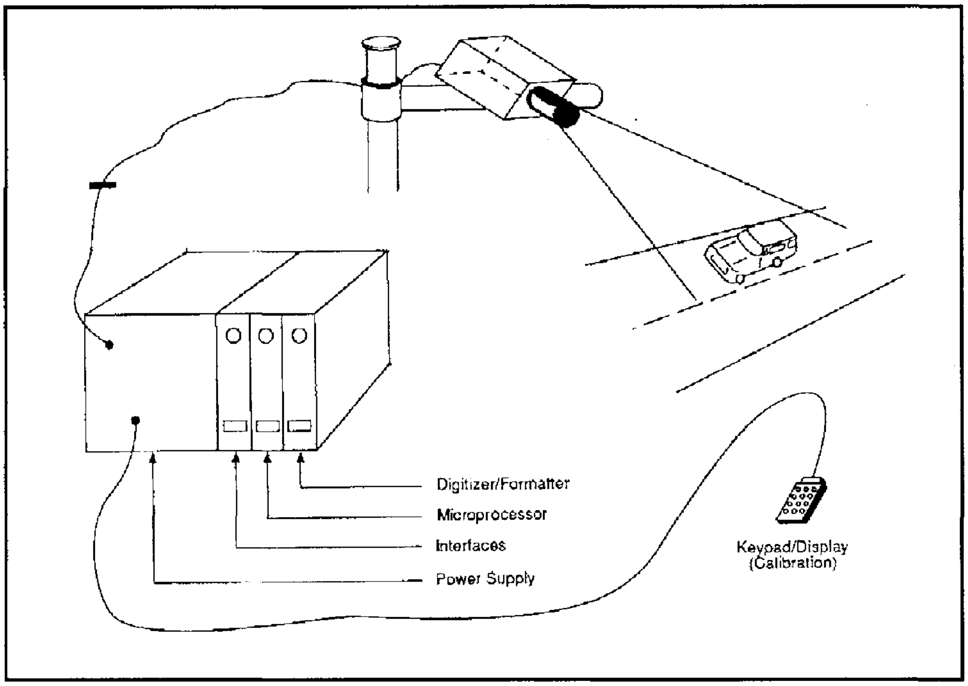

Figure 3-19. Components of Video Image Processing System. [11]

searching for connected areas of pixels that indicate motion when compared with the background information. A series of such vehicle detection is then associated to produce tracking data for each vehicle.

Data association tracking systems require less processing power than closed loop tracking systems, because they do not have to operate at the frame rate of the camera. They also offer better performance with regard to shadows and occlusion. Shadows are addressed using image analysis. Observed differences in the geometry of the image reduce the effects of occlusion. A greater reliance on software sophistication may reduce the hardware costs for these systems. An additional advantage of these systems is that a series of video cameras can be used to cover a wide area, and a vehicle can be "handed off" and tracked from one sensor to another as it passes from one field of view to another.

VIP Detector Performance. Factors influencing detector performance include the following:[20]

- Type of image being processed (i.e., upstream or downstream image).
- Mounting height of the video camera (affects occlusion of vehicles).
- Number of lanes being processed.
- Stability of video camera with respect to wind and vibration.
- Inclement weather, shadows, and poor lighting.

In most instances, the factors that affect VIP detection capability the most are shadows and reduced visibility due to inclement weather and poor lighting on detection capability. As discussed above, a VIP system detects vehicles by analyzing changes in pixels. Therefore, it may be difficult to differentiate between vehicles and changing light conditions in all situations.[16]

During the implementation of a VIP system at signalized intersections in Oakland County, Michigan, the effects of shadows and lighting were minimized by improving the detection algorithms.[16] This improvement made it possible to distinguish the direction a vehicle enters a detector, thereby, eliminating false detections due to "wrong-way" entries. Typical causes of wrong-way entries include the following:

- Shadows from vehicles in adjacent lanes.
- Light reflections (day or night) from other objects.
- Vehicles that enter the detection zone from the wrong direction.

An evaluation of the system during various environmental conditions revealed both improvements in the detection accuracy and reductions in false detections.[16] Table 3-11 presents the results from that evaluation.

Advantages of VIP Systems. The purpose of the Oakland County project was to implement an Advanced Traffic Management System (ATMS), which included installing AutoScope VIP systems at 90 signalized intersections. After 1.5 years of operation, several benefits of VIP over inductive loop detectors were noted:[16]

- Life cycle cost of video detection is lower than when using conventional loops for a typical situation.
- Visual inspection of detection performance allows for detector size and placement optimization.
- Installation requires less set up time and fewer pieces of equipment.
- Installation and maintenance can be done year-round, and require minimal traffic disruption.
- Relocation or addition of detector regions can be done with software, resulting in no disruption to traffic.

Table 3-11. Results from Oakland County Evaluation of VIP System.

Environmental Conditions	Detection Accuracy (%)	False Detection Rate (%)
High Winds, Shadows	98.1	3.0
Overcast Skies, Snow, Wind	99.6	4.2
Overcast Skies, Wet Road, Wind	96.1	2.0
Day/Night Transition	97.1	7.4
Night	98.1	6.1
Partial Cloudiness, Light Wind	96.2	4.1

- Detection is unaffected by resurfacing or construction projects.

Additional advantages of a VIP system include the following:[16]

- Camera pointing is easily done and verified by a portable video monitor or hand-held viewer.

- Camera location is very flexible, allowing mounting on existing structures.

- Installation of VIP system requires minimal training.

- Detector layout can be done either in the field or in the office.

CCTV Applications. Closed-circuit television (CCTV) cameras can be equipped with VIP capability to give operators the added capability to immediately verify incident warning messages. If an incident has occurred, operators may switch the VIP from the video imagery mode to a standard CCTV mode and monitor nearby incidents via pan/tilt/zoom controls. Once the camera viewing field has been modified, the VIP's preset detection zones are lost and must be reset prior to switching back to the video imagery monitoring mode. In the past, resetting the detection zones has been a cumbersome task; however, several VIP manufacturers have stated that this problem is being solved.[26]

Applications

Currently available VIP systems can detect traffic at a number of locations within the camera's field of view. The detector locations are specified with interactive video graphics and can be easily changed at any time. Using a video monitor, detection lines are placed in the field of view by means of a mouse or keyboard (see figure 3-20). Different detector sizes and locations can be selected. Vehicles are detected when they cross a detection line.[11]

The processing system of a tripline VIP system provides outputs comparable to those provided by loop detectors. These outputs include presence and passage as well as speed. From these measurements, other traffic parameters can be extracted, including volume and occupancy. Similar to loop detectors, speed trap detectors can extract vehicle speed and vehicle classifications as defined by length.[4] An advantage of VIP systems is that a single camera can replace many loops, offering true wide-area detection.[11]

For the more sophisticated systems in which vehicles are tracked, vehicle location and travel time through the detection zone may be obtained, as well as a higher level of accuracy in vehicle speed and vehicle length. Detector lines and speed traps are not needed with these systems. Instead, vehicles are tracked frame-by-frame through the entire field of view. The time and distance traveled between successive video frames is known, thereby providing an accurate measurement of speed.[28]

VIP systems are also very effective in incident detection. For tripline systems, incident detection algorithms similar to those used for loop detectors may be used. A video tracking system can provide traffic information to automatic incident detection systems, and can often implement these algorithms directly with the same hardware platform. Since all vehicles are tracked with this system, parameters pertaining to each vehicle are known.[28]

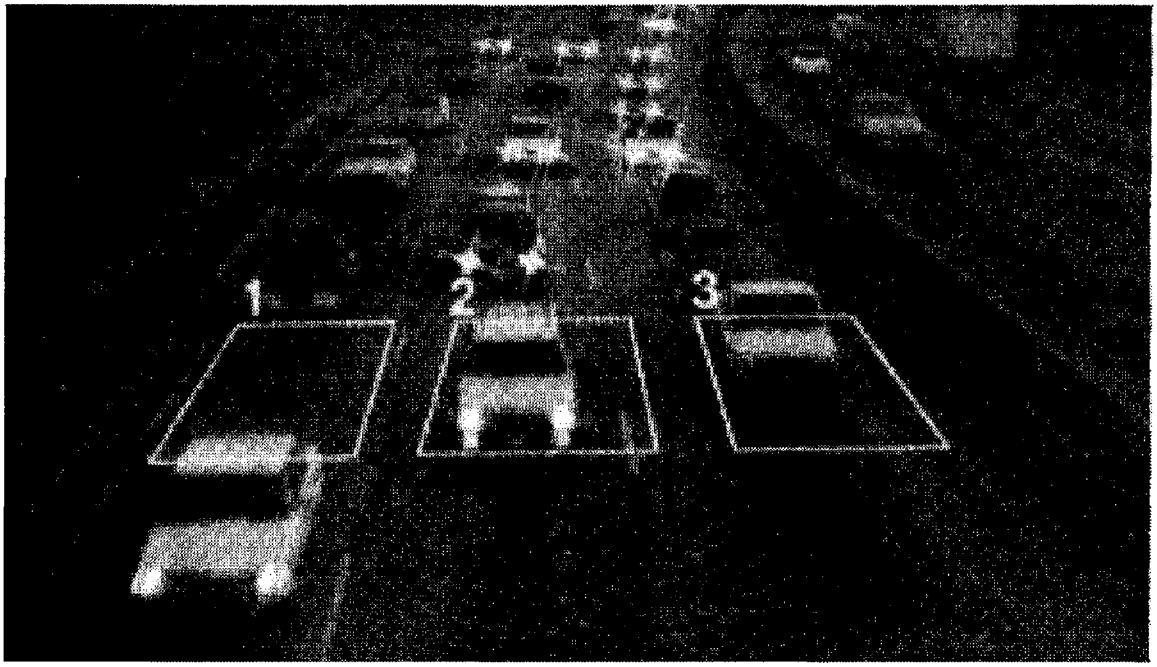

Figure 3-20. Identification of Detection Lines in Field of View.

Installation Requirements

The video detection system includes the following elements:

- Roadside cameras.
- Video processor.
- Appropriate software.

The cameras are mounted above the roadway, typically on existing poles, bridges, or other structures. Occlusion caused by other vehicles or objects can be minimized by selecting proper camera location and defining optimal detector sizing.(28)

Some existing VIP systems offer complete fail-safe operation. For example, each camera is monitored for video signal quality and picture usability. If a camera fails, the affected detection zones will be switched to a user-defined mode, such as "always on." The nature of the problem is also reported to operators in the traffic control center.(28)

COMPARISON OF EMBEDDED AND NON-INTRUSIVE DETECTORS

A summary of the advantages and disadvantages of each of the systems discussed was given toward the beginning of this section (see table 3-10). Table 3-12 lists the functional capabilities of the various systems, as well as estimated installation and detector costs. These estimates will vary by manufacturer and quantity purchased.

VEHICLE PROBES

With the recent advances in computer, communications, and vehicle locating technologies, the vehicle itself can become an important surveillance tool for monitoring traffic conditions in the roadway network. Vehicles, acting as moving sensors (or probes), can provide information about traffic conditions on each link traversed. This information can be transmitted to a central computer system where it can then be merged with information from other sources to provide an accurate representation of actual travel conditions in the transportation

Table 3-12. Characteristics of Traffic Detectors.

Detector	Applications					Lane Coverage per Sensor	Communication Bandwidth	Life	Reliability	Technology	Cost	
	Count	Presence	Speed	Occupancy	Classification						Install	Detector (each)
Inductive Loop	X	X	X	X	X	Size of loop	Low	Moderate	Moderate	Current	Moderate ($1,000)	Low ($500-$800)
Magnetometer	X	X	(1)	X		Single lane	Low	Long	High	Current	Moderate ($1,000)	Low - Moderate ($500 - $1500)
Microwave Radar	X	(2)	X	(2)	(2)	Multiple	Moderate	Long	High	Current	Low ($500)	Low - Moderate ($700 - $3,000)
Infrared	X	X	X	X	(2)	Single (active); Multiple (passive)	Low - Moderate	Long	High	Developing	Low ($500)	Moderate - High ($1,000-$8,000)
Ultrasonic	X	X	X	X	(2)	Single	Low	Moderate	High	Developing	Low ($500)	Low - Moderate ($600 - $1,500)
Acoustic	X	X	X	X	(2)	Multiple	Low - Moderate	N/A	N/A	Developing	Low ($500)	Moderate ($1,500)
Video Image Processing	X	X	X	X	X	Multiple	Moderate - High	Moderate	Moderate	Developing	Low ($500)	Very High ($10,000 - $25,000)

(1) Speed can be calculated by spacing sensors a known distance apart.

system. Advantages of vehicle probes are that the following measurements can typically be obtained:

- Link speeds.
- Link travel times.
- Origin and destination of vehicle traveling through system.

Types of Vehicle Probes

Emerging technologies that utilize vehicles as probes include the following:

- Automatic Vehicle Identification (AVI).
- Automatic Vehicle Locating (AVL).
- Cellular Telephone Probes.

Automatic Vehicle Identification (AVI)

AVI systems permit individual vehicles to be uniquely identified as they pass through a detection area. Although there are several different types of AVI systems, they all operate using the same general principles. A roadside communication unit broadcasts an interrogation signal from its antenna. When an AVI-equipped vehicle comes within range of the antenna, a transponder (or tag) in the vehicle returns that vehicle's identification number to the roadside unit. The information is then transmitted to a central computer where it is processed. In most systems, the transponder and reader/antenna technology are independent of the computer system used to manage and process the vehicle identification information.(3)

Currently, the most common application of AVI technology is for automatically collecting tolls on tollways. In this application, toll charges are electronically deducted from the driver's account when he or she passes through a toll plaza. Because tolls are collected automatically, the vehicle can pass through the toll plaza without stopping.

AVI technology may also be used as a means of automatically collecting travel time information along freeways. In Houston, Texas, AVI systems have been installed to monitor traffic operations on the main lanes and the high-occupancy vehicle (HOV) lanes on three major freeways. Vehicles equipped with transponders are used as probes to collect current travel time information. This information is used to alert freeway operators to potential incidents and congestion on both the main lanes and the HOV facilities. (29)

The original AVI technology, which has been in use for several years, uses a radio frequency signal from the roadside to activate a transponder located in the vehicle. Transponders can be classified according to the type of source required to power the transponder and the degree to which the transponder can be programmed.

Classes of transponders, based on type of power source, include the following:(30)

- Active.
- Passive.
- Semi-Active.

Active. With active transponders, power to the transponder is supplied from either an internal battery or a connection to the vehicle's power supply. The transponder is activated by an interrogation signal from the roadside communication unit. It responds to the signal by broadcasting its own signal (which contains the identification number for the vehicle) from an internal transmitter. This type of transponder generally has a greater operating range and is more reliable than other types of transponders. The life expectancy of an active transponder is between 7 and 10 years.

Passive. With passive systems, the transponder does not require any internal or external power supply. Instead, the interrogation signal from the antenna is modulated and reflected to the reader. Because the return signal is weaker, passive systems typically produce less lane-to-lane interference than active systems. The weak return signal, however, causes passive transponder systems to have shorter operating distances. Due to the simplicity of their circuitry, passive transponders have a life expectancy of approximately 40 years.

Semi-Active. Semi-active transponders use an operating approach similar to that of passive transponders in that they are activated only after an interrogation signal is received from the reader. Unlike passive transponders, however, semi-active transponders use an internal power to boost the return signal to the reader. This increases the reading distance of the transponder. Like active transponders, a semi-active transponder has a life expectancy of approximately 7 to 10 years.

Classes of transponders, based on the degree to which they can be programmed, include the following:[(25)]

- Type I.
- Type II.
- Type III.

Type I. Type I transponders are read-only tags that contain fixed data, such as a vehicle identification number. They can initially be programmed either at the manufacturing facility or by the agency issuing the transponder; however, they cannot by reprogrammed without returning the transponder to the manufacturer.

Type II. These transponders have read/write capability. In these transponders, some of the memory contains permanent information (such as vehicle identification number) and cannot be reprogrammed. However, additional memory can be provided and may be reprogrammed or written remotely from the reader. This type of transponder is typically used in toll systems to record time, date, location, and account balance for vehicles.

Type III. These transponders are also known as "smart cards." They have extended memory and are capable of full two-way communication. With this system, vehicles can be warned of incidents, congestion, or adverse weather conditions, enabling drivers to take alternative routes. This type of system requires sophisticated technology for both the roadside and vehicle-based equipment.[(4)]

Automatic Vehicle Location (AVL)

AVL systems enable the approximate location of a vehicle to be determined and tracked as it traverses the transportation network. These systems have many uses for many different customers, including the following:[(31)]

- Emergency Services - aid in dispatching emergency vehicles.
- Transit Agencies - track vehicles and provide passengers with arrival time estimations through information displays.
- Delivery Companies - plan the most efficient dispatch of fleet vehicles.

- Private Citizens - allow instant dispatch of tow truck in the event of a vehicle breakdown or to recover a stolen vehicle.

This technology can also be used to determine the severity of congestion or the occurrence of an incident, by obtaining probe reports from vehicles traveling in the network. Software in a control center can automatically monitor travel speeds and transit times of vehicles equipped with AVL technology.

There are numerous techniques and technologies than can be used for locating the vehicle, including the following:[31]

- Dead-Reckoning and Map-Matching.
- Signpost.
- Ground-Based Radio Navigation.
- Loran-C.
- Global Positioning Systems (GPS).
- Differential GPS.

Dead-Reckoning and Map-Matching. Dead-reckoning systems monitor the vehicle's internal compass and odometer and calculate its position by measuring its distance and direction from a known central starting point. Dead-reckoning systems frequently get off track and can be corrected using a technique called map-matching. Map-matching systems store a map of the vehicle's coverage area in a database and assume that when a vehicle changes direction, it must have turned from one road on to another. When a vehicle does make a turn, map-matching systems alter the vehicle's record location to the nearest possible point at which the turn could have taken place. Because of the low degree of positional accuracy of dead-reckoning and map-matching, most AVL systems use more advanced technology options.

Signpost. When vehicles, such as transit buses, regularly travel a fixed route, many fleet operators have found that signpost-based positioning systems offer an alternative to more advanced AVL technologies. Antennas are placed at locations throughout the vehicle's route and record the time when the vehicle passes nearby. A signpost-based AVL system can also be a valuable extension of systems intended for other purposes. Reader antennas that communicate with vehicle tags for electronic toll collection can also track the location of vehicles from one toll booth to another. The Harris County Toll Authority in Houston and the Illinois Toll Authority in Chicago are currently using such systems.

Ground-Based Radio-Navigation. In "terrestrial" or "ground-based" radio-navigation, the AVL vendor sets up several receiving antennas in a metropolitan area. Each appropriately equipped vehicle broadcasts a radio frequency (RF) signal to all nearby receiving antennas. By measuring the time it takes for the signal to travel to the antenna, the distance from the vehicle to the antennas can be determined. If the vehicle's signal was received by three or more antennas, the vehicle's position can be uniquely determined. A disadvantage of radio-navigation is that RF signals have difficulty transmitting through large obstructions, such as mountains, tunnels, parking garages, and metropolitan canyons formed by the large buildings that line many downtown city streets.

Ground-based radio-navigation systems are among the most inexpensive AVL systems for the user. However, since constructing the necessary infrastructure requires significant financial investment on the part of the AVL vendor, these systems are usually available only in dense metropolitan areas with large market potential.

LORAN-C. LORAN-C is similar to ground-based radio navigation, except that it uses a communication system set up by the U.S. Government. Uncertainty about the government's future plans for this system have lead to a decrease in the number of commercial AVL systems using LORAN-C. In addition, LORAN-C communication signals often experience errors due to atmospheric conditions.

Global Positioning System. Global positioning systems (GPS) use a network of 24 satellites that are continuously orbiting the Earth to locate any object anywhere on the planet. The satellites are available free-of-charge to anyone with a device capable of receiving the satellite signals. The U.S. Department of Defense (DOD) launched the satellites in order to track objects of interest on the ground. The position of the objects is determined measuring how long a radio signal takes to reach the object from multiple satellites. GPS is by far the most accurate global navigation system ever devised, with accuracies in the range of 5 to 30 meters. Similar to radio-navigation, GPS signals have difficulty transmitting through large objects. The signals also have trouble transmitting through opaque objects, such as leaves on trees.

Differential GPS. Differential GPS is a technique used to improve the accuracy of standard GPS. With differential GPS, a receiver placed at a known location calculates the combined error in the satellite range data. By knowing the error, correction factors can be applied to all other receivers in the same locale, virtually eliminating all errors in measurements.

Cellular Telephones

Using radio frequency receivers and triangulation techniques, it is possible to determine a vehicle's location by measuring signals resulting from cellular phone usage within the vehicle. In conjunction with map-matching algorithms, vehicles (cellular probes) can be tracked as they traverse area freeways. The ability to track vehicles via cellular telephones allows vehicle speeds, as well as travel times for various freeway segments to be measured. With so many cellular telephones currently in operation, this system has a potential to provide an inexpensive source of traffic surveillance.[31]

A test project was conducted in the Washington, DC, area to test the feasibility of using cellular probes to obtain real-time travel information.[32] The surveillance system was based on passive geolocations (only vehicles that have initiated a call will be used for the period during which the call is active). This method typically provides a sufficient probe population, since cellular phone usage is directly correlated with traffic congestion.

The cellular surveillance system consists of two basic components:

- Geolocation control system (GCS).
- Traffic information center (TIC).

At the GCS, a direction finding system (consisting of a series of towers) is used to provide latitudes and longitudes of cellular probes. This information is sent to the TIC, where information on traffic conditions is derived from a series of probes. Traffic information is then disseminated to the users (e.g., operators at control center).

When an initiated call is detected by the GCS, the following information is collected and sent to the TIC:

- Time.
- Probe ID number (randomized to ensure privacy).
- Latitude and longitude.
- Information as to whether a key number (such as 911) was called.
- Information on whether the probe was within the boundary of interest.
- Confidence factor associated with the accuracy of the latitude and longitude.

If the message is within bounds, the TIC uses the position to determine which traffic link the probe is traveling on. If a key number is used, the TIC requests additional information from vehicles within a certain distance of the call. Once it has been verified that the requested probes are on the traffic link in question, speeds are calculated. The TIC keeps historical information on speed profiles for various traffic links by time-of-day. Incoming speeds are compared with these historical files. If the difference between current speed and historical speed exceeds a set threshold value, a potential incident flag is set. Data from additional probes is then requested by the GCS. If the threshold value is exceeded a certain number of times, an incident is posted.

MOBILE REPORTS

Potential freeway surveillance techniques that should not be overlooked are those classified as mobile reports. Examples of mobile report methods include the following:

- Cellular telephones.
- Freeway service patrols.
- Call boxes.

Mobile reports are most often used for incident detection. A survey of existing freeway management systems around the United States revealed that a significant portion of incidents are detected either through service patrols or cellular calls.(33) Frequently, mobile reports help detect incidents faster than many methods of automatic incident detection.(34)

Cellular Telephones

This method of quick detection is becoming more of a resource as the number of cellular telephones on the roadways continues to increase. Some traffic management systems have established free cellular call numbers for reporting incidents or requesting aid. These toll free numbers connect the caller directly to the traffic management center or to other agencies responsible for responding to incidents. Numbers that are easy to remember (such as 999 or CALLMAP) should be used to help these systems be effective. It is estimated that half of all incidents are reported via cellular telephones. Other advantages of this system include the following:(3)

- Low start-up costs.
- Two-way communication between caller and response agency.

The effectiveness of this method of incident detection depends on the number of cellular telephones on the roadway and the willingness of drivers to report incidents. To increase effectiveness, a campaign to inform drivers about the cellular call-in system and the benefits of reporting an incident is recommended.[3]

Freeway Service Patrols

Another effective method for monitoring traffic conditions and detecting incidents is freeway service patrols. A freeway service patrol consists of a team of trained drivers who cover a particular area of freeway, monitoring traffic operations. Many different vehicles are used for freeway service patrols around the United States, including light trucks, mini-vans, and tow trucks. An example of a patrol vehicle and equipment used by the Illinois State Department of Transportation is illustrated in figure 3-21. The most noticeable benefits of service patrols are those involving incident management.[35] Typical objectives of a service patrol include the following:[36]

- Helping stranded motorists.
- Locating incidents, clearing them, and contacting the appropriate agency.
- Providing assistance at major incidents.
- Providing traffic reports to particular agencies.

Freeway service patrols have the benefit of not only being able to detect an incident, but also to assist travelers and remove vehicles upon detecting them. By performing the entire incident management process on their own, service patrols greatly reduce the time to remove an incident which, in turn, minimizes negative effects on traffic operations. The operations of service patrols are covered more extensively in **Module 8**.

Call Boxes/Emergency Telephones

Call boxes or emergency telephones may also be used to detect incidents or to locate motorists in need of help. These devices are located on the side of the freeway (see figure 3-22) and are typically spaced from 0.40 km to 0.80 km (0.25 to 0.50 mi) apart.[3] Motorists can stop and use these devices to report a problem.

Using emergency telephones, motorists can contact a dispatcher to report conditions and request help. With call boxes, motorists simply press certain buttons to request various services (such as police, fire, or ambulance). Because there are no voice transmissions with call boxes, they are relatively inexpensive to install as compared to telephones. However, emergency telephones result in fewer false alarms and greater likelihood that the appropriate services will be provided.[3]

CLOSED-CIRCUIT TELEVISION (CCTV)

Closed circuit television (CCTV) systems have been used for many years to provide visual surveillance of the freeway system.[1] Control centers typically use CCTV systems for the following purposes:

- Detection and verification of incidents.
- Monitoring traffic conditions.
- Monitoring incident clearance.

The discussion in this section will address two types of CCTV systems:

- Fixed location.
- Portable.

Figure 3-21. Illinois DOT's Advanced Technology Quick-Tow Incident Response Vehicle with Equipment.

Fixed Location

For fixed location CCTV systems, video cameras are permanently mounted either on existing structures along the freeway or on specially installed camera poles (see figure 3-23). This type of system consists of various components, including the following:[39]

- Video camera unit.
- Mounting structure (existing or installed).
- Controller cabinet housing the control equipment.
- Communication system connecting camera to control center.
- Video monitors and camera controls located in control center.

CCTV systems allow control room personnel to visually monitor sections of roadway and to react directly to the actual conditions on the roadway. Since operators can lose interest if required to constantly view CCTV monitors, and may fail to notice incidents immediately after they occur, current systems are being designed to automatically position cameras at suspected incident locations (as signaled by incident detection algorithms) and to alert the operator.[26]

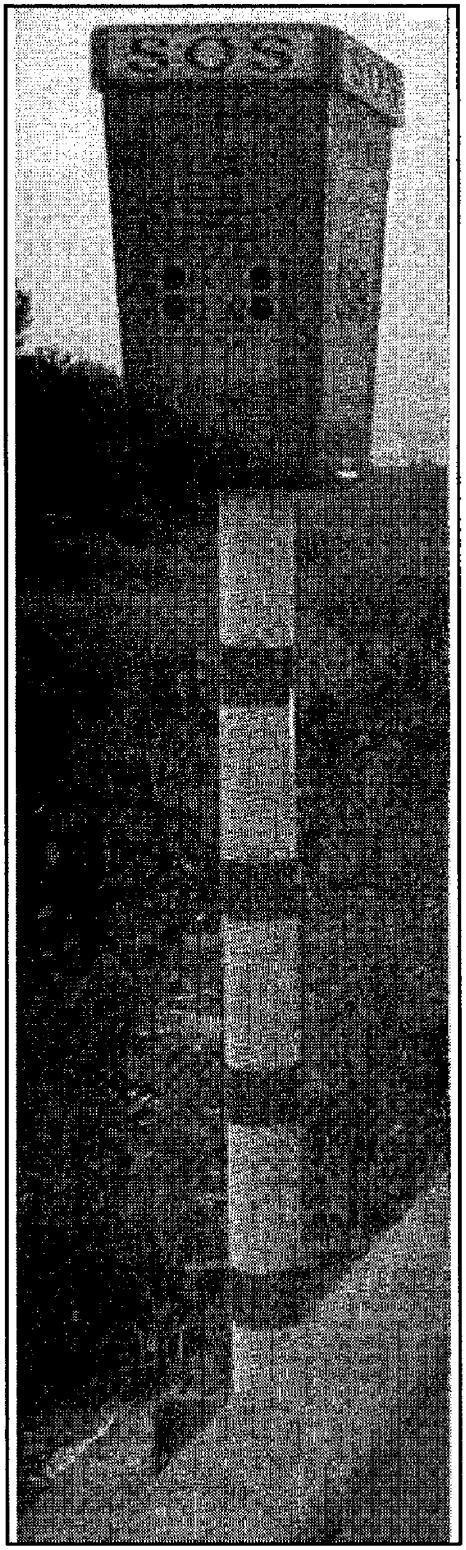

Figure 3-22. Call Box. [38]

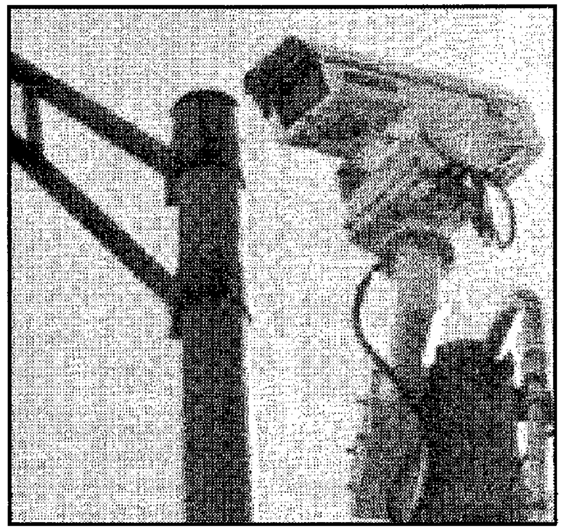

Figure 3-23. Fixed-Location Closed-Circuit Television Camera. [16]

Video images from cameras may be transmitted to a control center using one of the following video transmission types:

- Full motion video.
- Compressed video.

Full Motion Video

Using full motion video, real-time video is transmitted to the control center. Real-time video is typically transmitted at a rate of 30 frames per second. This transmission type results in no information loss; however, it requires a wide communication bandwidth, such as that provided by coaxial cable or fiber optic cable. [3]

Compressed Video

When it is not feasible to install the communication medium required for full motion video, compressed video offers an attractive alternative. An advantage of compressed video transmission is that video data can be transmitted over conventional telephone lines and cellular channels. [3]

With compressed video techniques, transmission rates of 8 to 10 frames per second are possible. Because some information is lost between pictures frames, the resulting image appears slightly "jerky". The image, however, is adequate for monitoring freeway operations.(27)

A compressed video system typically includes the following:

- Compression and decompression computer (standard industrial PC) for each camera/monitor link.
- Appropriate software.
- Communications medium (typically a leased ISDN [Integrated Service Digital Network] line).

Standard cameras, monitors, and control hardware can be used, and therefore, can be reused if the communications medium is upgraded to allow for full motion video transmission.(26)

Portable

Portable CCTV systems can serve several purposes including the following:(39)

- Short term traffic monitoring in areas with non-recurring congestion (e.g., work zone, critical incident, etc.).
- Traffic monitoring at special traffic generators (e.g., stadiums, parades, etc.).
- Determination of optimum camera location for fixed location CCTV systems.

Portable CCTV systems are typically mounted in a light truck or van or on a trailer (see figure 3-24). Components of a portable system include the following:(40)

- Camera mounted on a pan-and-tilt unit.
- Telescopic boom.
- Television monitor.
- Video recorder.
- Camera control unit for controlling pan, tilt, and zoom functions.
- Generator for powering equipment.
- Air compressor for operating telescopic boom.

Video transmission can be accomplished using the same techniques available for fixed location CCTV systems. A system used in Dallas, Texas, consists of portable surveillance trailers with the ability to transmit video images over temporary telephone lines.(26) A system in Los Angeles, California uses a video van that is capable of transmitting full motion video back to the control center via wireless communication.(39)

SUMMARY OF TRAFFIC SURVEILLANCE APPLICATIONS

Table 3-13 summarizes the traffic surveillance technologies discussed and particular applications for which they are best suited. The recommendations shown in this table are not meant to imply that other detection methods cannot be used; rather, the table shows which technologies currently work best for specific applications. However, it should be taken into consideration that as technological improvements are made, the applications of certain technologies will be expanded.

Figure 3-24. Portable Closed-Circuit Television System. [17]

The factors used to assign the technologies to certain applications were detector performance and reliability. Cost was not taken into consideration. As technology continues to improve, detectors that are currently not cost feasible will become more competitive.

ENVIRONMENTAL DETECTORS

Environmental detectors on freeways are used to detect adverse weather conditions such as ice. These systems alert motorists to dangerous conditions and in some situations inform maintenance personnel so that evasive actions may be taken. An early warning system for detecting icy conditions on certain freeway sections can reduce the following:[4]

- Response times.
- Staffing levels.
- Anti-icing material.

Other areas where environmental detectors are used are in tunnels. In these areas, special sensors are needed to monitor the level of noxious fumes, such as carbon monoxide. The sensors are typically used to control the ventilation systems in tunnels.

Freeways

There are a number of commercially available systems for monitoring environmental conditions on freeways. These systems can be used to warn drivers

Table 3-13. Traffic Surveillance Applications.

Monitoring Application	Inductive Loop	Magneto-meter	Microwave Radar	Infrared		Ultrasonic	Acoustic	Video Image Processing	CCTV		Vehicle Probes	Mobile Reports
				Active	Passive				Fixed	Portable		
Incident Detection	X		X					X			X	X
Incident Removal									X	X		
Traffic Conditions	X	X	X	X	X	X	X	X	X		X	X
Special Event	X		X	X	X	X	X	X	X	X		
Implement Control Strategies	X	X	X	X	X	X	X	X	X		X	
Maintenance Activity	X	X	X	X	X	X	X	X	X	X	X	X
Vehicle Classification	X			X				X				
Ramp Metering	X							X				

of potentially dangerous driving conditions. In addition, the information can be used by operators in traffic management centers to do the following:[40]

- Control dynamic message signs.
- Decide whether to close roads.
- Integrate weather information into incident detection algorithms.

There are several environmental sensors available today. Categories of environmental sensors include the following:[40]

- Road condition sensors - measure surface temperature, wetness or dryness, presence of snow, and surface moisture conductivity.
- Visibility sensors - detect presence of fog, smog, heavy rain, snow, or sandstorms.
- Thermal mapping - detects presence of ice.

Figure 3-25 shows a roadside environmental monitoring system that is capable of measuring visibility and precipitation.

Figure 3-25. Roadside Environmental Monitoring System. [41]

Several manufacturers also produce complete weather stations. An example of such a system is the SCAN (Surface Condition Analyzer) developed in the United States. SCAN is able to monitor pavement and environmental conditions and provide the following information:[42]

- Pavement temperature.
- Presence of water, ice, snow, or chemicals on pavement.
- Precipitation.
- Air temperature, humidity, and dew point.
- Wind speed and direction.

The system consists of sensors the size of hockey pucks that are embedded in the pavement. Capacitors within the sensors measure electrical charges from water, snow, ice, or chemicals. Thermostats are used to measure surface temperatures. SCAN systems are currently used in 48 States and in 8 countries.[41]

Tunnels

Monitoring systems in tunnels are used to limit the build-up of noxious fumes from vehicle exhausts. Output from the monitors is used to perform the following functions:

- Control tunnel ventilation.
- Warn drivers of poor visibility.
- Set safe speed limits within the tunnel.

Most systems monitor the level of noxious gases and visibility by using infrared absorption techniques. A gas monitoring system typically consists of the following:

- Infrared transmitter and receiver.
- Electronic signal processing unit.

Outputs from the monitors are sent to the system controlling tunnel ventilation. Tunnel ventilation becomes more cost effective when operated in conjunction with a monitoring system. Cost savings arise from reduced frequency of operation and maintenance of the ventilation system.[43] There are currently many systems available for monitoring air quality within a tunnel; however, it is important that a monitoring system be reliable, accurate, and able to operate with minimal maintenance.[44]

3.4 LESSONS LEARNED

OPERATIONS AND MAINTENANCE

Effective operations and maintenance of a traffic management system are required to ensure that the system meets certain objectives, such as the following:

- Continuously accomplishes the goals and objectives for which it was designed.
- Responds to changing technologies and transportation system demands.

The ability of agencies to effectively operate and maintain a freeway management system is vital to the success of the system.[6] This section discusses issues associated with the operations and maintenance of surveillance systems.

Operations

Operations includes those tasks involved in the day-to-day function of a system. The primary responsibility of personnel in charge of operating a surveillance system is to monitor freeway conditions. Freeway monitoring may serve several purposes, including the following:

- Monitoring traffic operations.
- Detecting incidents.
- Monitoring incidence clearance.
- Monitoring environmental conditions.
- Supporting the implementation of control strategies.

Operators may monitor freeway conditions by using any of the following devices:

- Displays or printouts showing conditions either graphically or in a tabular format.
- Closed-circuit television systems.
- Mobile reports.

Additional tasks with which an operator may be involved include the following:[4, 6]

- Controlling and managing equipment and ensuring continuity of operation.

- Monitoring system performance criteria.
- Updating system databases.
- Notifying maintenance personnel of system malfunctions.
- Communicating with transportation and emergency response agencies.
- Documenting daily operational functions and events such as incident occurrences, equipment failures and repairs, and changes in software and hardware components.

Maintenance

Proper design and installation techniques are important to ensure the success of a system. Maintenance, however, is also a critical task that must be considered if the system is going to operate as intended. Maintenance activities can be grouped into three categories:(4)

- Remedial.
- Preventive.
- Modification.

Remedial maintenance is necessitated by malfunctions and equipment failures, and usually demands emergency repair to restore operations. Preventive maintenance includes work done at scheduled intervals to minimize equipment failure. Modification involves replacing equipment and usually results from equipment design flaws or required upgrades to improve system performance. All three maintenance categories should be considered in determining budget requirements.

For a maintenance program to be successful, the following factors should be considered:(4)

- Address maintenance needs (e.g., maintenance requirements, maintenance costs, personnel requirements) during the planning process.
- Ensure that required budget and staffing needs can be met.
- Perform cost tradeoff analyses during the design phase to identify techniques for reducing maintenance requirements.
- Consider that complex surveillance technologies require higher personnel skill levels to maintain.
- Ensure that maintenance personnel receive adequate training.
- Keep accurate records of maintenance activities to aid in predicting future maintenance needs and in analyzing costs.

Operations and Maintenance Costs

The success of a system begins with the type and quality of the equipment being utilized. Budgetary and funding problems that traffic agencies typically face may result in the selection of equipment mainly on the basis of initial start-up cost, rather than on lifetime cost. Consequently, less expensive equipment is purchased during the installation process. However, this is not always the most cost-effective solution. (11) Therefore, operations and maintenance costs should be considered together with start-up costs during the equipment selection process.

A Texas Department of Transportation (TxDOT) research project established guidelines for estimating operations and maintenance costs.(6) The cost estimates were based on the following sources:

- TxDOT metropolitan districts with substantial ITS deployment.
- ITE report, *Operation and Maintenance of Electronic Traffic Control Systems.*
- FHWA report, *Cost Estimates and Assumptions for Core Infrastructure.*
- Texas municipalities and transit agencies.
- Technical journals.
- Equipment suppliers.

Table 3-14 shows the operations and maintenance cost estimates for a surveillance system. This table lists the estimated unit operations cost, estimated unit maintenance cost, combined operations and maintenance cost, and the assumptions related to factors included in each of the costs. Using quantities measured in terms of the base units shown in the table, total operations and maintenance costs can be determined. Note that the estimated maintenance costs include maintenance personnel costs, while the estimated operations costs do not included personnel costs.

Most of the operations and maintenance costs in table 3-14 are given as ranges in order to allow for adjustments for the following factors:

- Age and quality of equipment.
- Personnel skill levels.
- System designs.

In many situations, outside financing sources are more readily available for the development and construction of new systems than for operating and maintaining the systems once they are built. Operating and maintenance costs are typically funded through State and local maintenance budgets. These funds are often insufficient because of competition with other maintenance functions. Therefore, it is important that continued funding for operations and maintenance be addressed in the planning stage.

PRIVACY CONCERNS

Most surveillance technologies have little impact on privacy, because there is no need for vehicle identification. Privacy, however, is a critical concern when using technologies that identify vehicles, such as AVI, AVL, and cellular telephone tracking. Privacy is also a concern with the use of closed-circuit television.

A survey of drivers in the United States showed that in 1978, 67 percent of people were concerned about privacy. Results from 1994 showed that the percentage had climbed to 84 percent, revealing that privacy is a major concern for drivers.[45]

Although some people may not mind if their vehicles alone are identified, many fear that surveillance from different sources (e.g., credit card purchases, phone calls, travel habits, etc.) could be combined to build a detailed personal profile of their lifestyles. The ability to compile information about an individual's travel patterns, toll payments, and other activities creates the potential for a database that has not previously existed. Due to advances in computer technology, this kind of information is highly transportable, and opportunities exist for inappropriate access to and use of this personal information.[46]

It must be taken into account that privacy is one of the goals against which any system's effectiveness may be measured. For example, one of the first AVI tolling systems

Table 3-14. Estimated Operating and Maintenance Costs for Surveillance Systems.[6]

Description	Base Unit	Estimated Annual Operations Cost/Unit	Estimated Annual Maintenance Cost/Unit	Estimated Annual Combined O&M Costs/Unit	Cost Assumptions
CCTV	each	$0	$500 - $1300	$500 - $1300	Costs include routine maintenance for CCTV cameras, as well as the camera controls, housing, and/or support pole.
CCTV Cameras w/ Video Image Processing Capability	each	$0	$700 - $1800	$700 - $1800	Costs include routine maintenance for CCTV cameras, as well as camera controls, housing, and/or support pole, and VIP calibrations.
Imbedded Detectors:					
Inductive Loop	per station	$0	$200 - $300	$200 - $300	Costs include contract maintenance/replacement of loops. Costs assume four lanes per station, with two loops per lane. Costs also assume loop failure rates of 4% to 6% per year.
Non-Intrusive Detectors:					
Radar, Ultrasonic, Acoustic, Infrared	per station	$0	$200 - $300	$200 - $300	Costs include routine maintenance of detectors. Costs assume four lanes per station, with one detector per lane.
Video Image Processing	per station	$0	$500	$500	Costs include routine maintenance and calibration of detectors. Costs assume one video detector per station.

Table 3-14. Estimated Operating and Maintenance Costs for Surveillance Systems (cont.).[6]

Description	Base Unit	Estimated Annual Operations Cost/Unit	Estimated Annual Maintenance Cost/Unit	Estimated Annual Combined O&M Costs/Unit	Cost Assumptions
AVI:					
Transponders	each	$0	$10 - $15	$10 - $15	Costs include routine maintenance and replacement of transponders.
Readers	per station	$0	$500	$500	Costs include routine maintenance.
AVL:					
Leased Transceivers/ Antennae	per vehicle	$750 - $1200	$0	$750 - $1200	Operations costs include the lease cost of the transceivers and antennae, and the associated communications cellular air time charges; maintenance is provided by the transceiver/antennae provider.
Owned Transceivers/ Antennae	per vehicle	$250 - $500	$100 - $200	$350 - $700	Operations costs include communications cellular air time charges; maintenance costs include routine maintenance and replacement of transceivers and antennae.

to be implemented was in Hong Kong in 1983. Each month, drivers using the electronic tolling system were sent statements that contained itemized accounts of where they had driven and when. The drivers didn't like the idea of a government agency tracking their daily highway travel; therefore, the system was removed two years after it was introduced, despite the fact that the technology worked.(46) For reasons like these, it is very important to design any surveillance with privacy in mind.

Fortunately, it is relatively easy to design most surveillance systems with privacy in mind.(45) For example, AVI systems can be designed to assign vehicles a random identification number for monitoring purposes, in which case the identification of the driver is never made. This same process can be used with AVL and cellular-based traffic surveillance systems.(32)

In general, consumers may be willing to give up a certain degree of privacy if they feel that the benefits will outweigh the risks (as in the case of credit card use). It is therefore important that the public be informed about the benefits of using certain surveillance technologies. The key to overcoming privacy concerns is to inform the public about what information is being collected and how the data will be used.(47)

SPACING AND PLACEMENT ISSUES

Selecting the location of detectors is an important step in the implementation of a surveillance system. Spacing and placement affect both the cost and performance of the system. The detectors should be placed close enough together to provide adequate surveillance of the system, but as the spacing decreases, the cost of the system increases. In addition, it is desirable to place the detectors in a location that will result in minimum delay to traffic during installation and maintenance procedures. The following discussion presents recommendations for the spacing and placement of mainline traffic detectors and CCTV cameras.

Mainline Traffic Detectors

Spacing

For monitoring traffic conditions and incident detection, detectors should be placed along the freeway and on ramps to detect changes in traffic conditions. Guidelines for detector spacings are as follows:(3,4)

- Typical mainline detector spacings range between 0.40 and 0.80 km (0.25 and 0.5 mi).
- Spacings over 0.8 km (0.5 mi) are inadequate for incident detection purposes.
- Spacings below 0.4 km (0.25 mi) generally produce little or no increase in effectiveness.
- Tunnels or covered roadway sections are exceptions, and may require spacings of less than 0.4 km (0.25 mi).
- Minimally, at least one traffic detector station should be provided between interchanges or freeway ramps, with maximum spacings of 1.6 to 2.4 km (1.0 to 1.5 mi).
- Detectors are also typically placed before and after freeway bottlenecks (e.g., entrance ramps, lane closures, etc.) and metered entrance ramps.

Placement

As discussed earlier, most existing traffic detectors can be classified as either embedded or non-intrusive. An embedded detector system consists of sensors in or below the surface of the roadway. Non-intrusive detectors are mounted on a structure above the surface of the pavement.

The following issues associated with installing and maintaining embedded detectors:

- Installation typically requires drilling into or cutting the pavement.
- Embedded detectors usually have higher installation costs than non-intrusive detectors.
- Installation may require lane closure, which results in delay to vehicles.
- When feasible, embedded detectors should be installed during the construction or rehabilitation of a freeway to avoid delays to traffic.
- Because modifications to the pavement structure are required for the installation, deterioration of the road surface is escalated; therefore, there are further ongoing maintenance costs associated with replacing damaged detectors or repairing degraded road surfaces.

Non-Intrusive Detectors

Issues associated with installing and maintaining non-intrusive detectors include the following:

- Can typically be installed and maintained without disrupting traffic.
- Installation costs are significantly reduced when an existing mounting structure can be used.
- Ongoing maintenance costs may be minimal.

CCTV Cameras

The primary objective of a CCTV system is to provide visual monitoring of freeway conditions and to verify incidents. The California Department of Transportation, District 7, has developed guidelines for CCTV camera site selection.[39,48,49] The following is a summary of these recommendations.

Site Selection Criteria

Most cameras with a standard 10-to-1 zoom have a viewing range of 0.8 km (0.5 mi) in all directions. Full freeway coverage would therefore require a maximum camera spacing of 1.6 km (1 mi). Full coverage of all freeways, however, is frequently cost prohibitive. Therefore, proper camera site selection becomes a critical factor. Factors that should be considered in the selection of a camera site include:

- Surveillance of congested freeway sections to provide maximum visibility and coverage of weaving and merging areas near ramps and interchanges.
- Ability to provide a clear view of areas with high accident frequencies (based on accident data).
- Ability to provide suitable access for maintenance personnel based on the geometric layout of the area.
- Minimal obstruction to view caused by landscaping, billboards, freeway signs, or topography.
- Ability to verify messages of variable message signs.

- Ability to effectively address power, communication, and underground utility considerations.

- Ability to provide suitable access to the proposed communication system.

Candidate sites for CCTV systems may be prioritized on the basis of accident frequency (high, medium, and low). Threshold values to classify accident frequencies should be based on local conditions. Areas with high accident frequencies will require video surveillance to expedite incident detection and clearance. Areas with medium and low accident frequencies may also require video surveillance. Site selections for these locations will be based on local criteria, such as the importance of a particular freeway section. In addition, video surveillance may be used to monitor ramps and freeway sections near heavy traffic generators (e.g., stadiums) during special events.

Preliminary Site Selection

Preliminary site selection should be based on the criteria discussed above. These sites should be noted on a scaled base map, along with the following characteristics of the freeway:

- Accident frequencies plotted over 0.4 km (0.25 mi) intervals.

- Strategic roadway infrastructure.

- Locations of variable message signs.

- Locations of underground high-risk utility lines.

Cameras should be located in the vicinity of high-accident frequency areas and near variable message signs and other strategic areas. Areas with high-risk utility lines should be avoided if possible. For cameras with standard 10-to-1 zoom and a viewing range of 0.8 km (0.5 mi), video surveillance can be provided for a 1.6 km (1 mi) freeway section (assuming no blockage due to horizontal or vertical curves).

The next step in the preliminary site selection process is to perform a field check. The objectives of the field check are to verify the following:

- Veiling range at "ground eye level."

- Geometric layout.

- Maintenance access.

- Power and utility concerns.

While in the field, each preliminary site selected should be marked so that the site is easily identifiable for the final site selection process.

Final Site Selection

The purpose of the final task is to perform a video survey to verify camera viewing ranges and select correct mounting heights. For high-speed freeway sections, a mobile CCTV camera system is recommended.

Following are considerations for selecting mounting heights:

- Mounting heights on poles generally vary from 6.0 to 13.7 m (20 to 45 ft).

- Heights below 6.0 m (20 ft) may be susceptible to vandalism.

- Pole heights above 13.7 m (45 ft) may result in maintenance problems and safety hazards.

- Lower heights (between 6.0 and 9.1 m [20 and 30 ft]) are preferred when it is necessary to look beneath overpasses.

- Cameras at heights below 10.7 m (35 ft) can be accessed by a small bucket truck.

- Cameras at heights between 10.7 and 13.7 m (35 and 45 ft) would require a larger hoist truck.

When possible, cameras should be mounted directly on existing structures. This will result in a significant reduction in the initial installation costs.

3.5 EXAMPLES

MIAMI AUTOMATIC VEHICLE LOCATION (AVL) (32)

The City of Miami, Florida, needed an accurate, inexpensive method of collecting average travel speed data in order to calculate roadway level of service as required by the 1985 Florida Growth Management Act. In 1988, the City of Miami staff determined that automatic vehicle location (AVL) technology could be used to measure speeds on specific corridors. (AVL is a means of continuously monitoring the location of vehicles in a road network. Vehicles are equipped with a transponder device that transmits a radio-frequency (RF) signal to a central location at regular intervals.) In 1993, the City of Miami contracted with the Center for Urban Transportation Research (CUTR) to set up a field operational test of AVL to measure vehicle operating speeds on 17 transportation corridors in the city. CUTR recruited AirTouch Teletrac to serve as the vendor for the AVL system. AirTouch Teletrac agreed to provide 25 transponders, one workstation, one copy of its FleetDirector™ software, and training on how to use the software to the City of Miami for 112 days at a nominal cost.

The City of Miami was responsible for recruiting 25 volunteer drivers willing to have their vehicles equipped with transponders. Many of the drivers recruited commuted from the periphery of the city to downtown, and this provided coverage for 5 of the 17 corridors in the peak direction during the peak period. Installation of the transponders for each vehicle took about one hour. A single AVL unit consisted of a control unit (about the size of a video tape cassette) and a "pancake" antenna.

AirTouch Teletrac provided training on the use of the software to CUTR researchers and the City of Miami Planning staff and then provided a workstation, which was a Compaq 386 computer with an internal high-speed modem. The city provided a dedicated phone line for communication between the workstation and AirTouch Teletrac's operations center in Fort Lauderdale. (AirTouch Teletrac maintains a network of 27 receiving antennas throughout Dade, Broward, and Palm Beach counties in South Florida. RF signals from the receiving antennas are transmitted to AirTouch Teletrac's operations center in Fort Lauderdale.)

The software was configured to poll each of the 25 vehicles' positions every 30 seconds when the vehicle ignition was on and every 5 minutes when the vehicle ignition was off. Each time a vehicle's position was recorded, the following information was obtained: vehicle number, speed, time, date, and location. Data were recorded for the following time periods:

- Weekday mornings, 5 a.m. to 10 a.m.

- Weekday afternoons, 3 p.m. to 8 p.m.

- Saturdays, 10 a.m. to 2 p.m.

Data were gathered for 112 days, and data for over 4400 vehicle trips were obtained. CUTR staff wrote two software programs to analyze vehicle-location data and report average speed. In order to determine the accuracy of the calculations for average trip speeds, CUTR researchers also set up a process to compare observed values with calculated values for the average speed over a vehicle trip. Method 1 yielded a ± 8.3 percent accuracy, and Method 2 yielded a ± 7.1 percent accuracy. Since Method 2 was more accurate, it was used in compiling the output.

CUTR has demonstrated that the AirTouch Teletrac automatic vehicle location system can be used to measure average vehicle operating speeds on Miami's 17 transportation corridors in the peak direction during the peak period, given sufficient electronic storage capacity, appropriate data analysis software, and volunteer drivers. This system could be used anywhere in the six metropolitan areas where AirTouch Teletrac is available. However, in order to conduct this experiment outside of those six areas, an AVL vendor would have to be enlisted.

TRANSCOM ELECTRONIC TOLL AND TRAFFIC MANAGEMENT (ETTM)[50,51]

ETTM, or electronic toll and traffic management, has seen rapid growth. Currently, more than 20 agencies in 8 countries have installed a system and are collecting tolls automatically. Another 23 agencies in 7 countries are in the process of testing, studying, or implementing automatic toll collection. ETTM systems have the potential to be used for other ITS applications that could include congestion pricing, advanced payment systems, traveler information, and traffic management. ETTM requires the installation of readers with the capability of identifying tagged vehicles at periodic intervals along the roadway.

TRANSCOM is an umbrella organization serving the New York/New Jersey metropolitan area in coordinating and disseminating transportation information. In 1991, TRANSCOM retained a team led by PB Farradyne, Inc., to establish the feasibility of using ETTM equipment for traffic surveillance and incident detection applications. The project was called TRANSMIT (TRANSCOM's System for Managing Incidents and Traffic) and was divided into two phases. The first phase concentrated on evaluating the use of ETTM technology for traffic surveillance and on developing a preliminary design of a traffic surveillance system for an ETTM incident detection system. The second phase included the final design and construction of the initial stage of the system as an 28.8-km (18-mi) operational field test along sections of the New York State Thruway and the Garden State Parkway. The primary objective of the TRANSMIT project was to process available traffic flow data for early detection of incidents and abnormal traffic congestion.

An analysis was conducted to determine the reader antenna spacing and toll tag penetration necessary to detect an incident within five minutes with a false alarm rate of two percent or less. The analysis used the following roadway classes: arterial, two-lane highway, and three- to four-lane highway. The results indicated that the arterial roadway class would result in the longest detection time. The analysis concluded that the five-minute detection time could be achieved if the following percentages of equipped vehicles were provided:

- Two-lane highways: 0.9 percent.

- Three- and four-lane highways: 2.1 percent.
- Arterials: 7.6 percent.

An 28.8-km (18-mi) corridor along the New York State Thruway in Westchester and Rockland Counties and the Garden State Parkway in Bergen County were defined for an operational field test. Twenty-two ETTM sites were constructed, and existing overhead sign structures and overpasses were used for the placement of reader antennas. New structures were built where existing structures were not available.

The incident detection algorithm developed by PB Farradyne, Inc., determines the probability of an incident when tagged vehicles detected at an upstream reader are not detected at the downstream reader within the expected arrival time. The later a vehicle is, the higher the probability of an incident.

At the time this project was designed, the technology for Electronic Toll Collection (ETC) in the Greater New York/New Jersey Metropolitan Area was undetermined, so it was decided that the ETTM antennas and reader cabinet equipment would be leased, not purchased. Therefore, if the traffic surveillance concept is found to be successful and is expanded throughout the region, the equipment can be made compatible with the regional ETC equipment from which the tag population originates. The construction cost estimate for the operational field test was $1,195,600, which included equipment leasing costs for a 24-month period.

HOUSTON AUTOMATIC VEHICLE IDENTIFICATION (AVI) [52]

The Texas Department of Transportation awarded the first of three contracts to instrument the metropolitan freeway system in Houston with an automatic vehicle identification (AVI) system to monitor traffic conditions. The AVI system was designed to provide travel time information on about 120 miles of freeways and 100 miles of reversible high-occupancy vehicle (HOV) lanes.

The initial planning began in 1991. The North Houston Corridor, with three parallel radial freeways, was selected as the study site. This corridor had several favorable characteristics: one toll facility with available capacity; one freeway with heavy congestion because of inadequate capacity and reconstruction activities; and one freeway with moderate congestion and an HOV lane. The corridor also served the Houston Intercontinental Airport, the central business district, and other major activity centers. A demonstration project was designed using cellular telephones for the collection of traffic condition information. This project recruited 200 volunteers who commuted to and from work using one of the three freeway routes. The demonstration project was conducted for about 18 months, during which time a more permanent and automated system for traffic monitoring was being developed using AVI technology. The demonstration project was a success in that valid, useful real-time travel time information was collected and made available to the public in a variety of ways.

CONNECTICUT MICROWAVE RADAR [13]

The Connecticut Department of Transportation (ConnDOT) chose radar detection for the recent design of their freeway surveillance system. Connecticut has two separate systems operating within the State. The first system is a federal demonstration project covering approximately 19 km (12 mi) of Interstates

I-84 and I-91 in the Hartford area, and it is the first surveillance system in the country to utilize radar as an incident detection technology. Because of the early success in Hartford, radar detection is also being used in the design of the I-95 Freeway Management System. The I-95 system is installed along the southern coast of Connecticut, covering 90 km (56 mi) from the New York State border east to Branford. Both systems rely on speed data being sent back from the radar detectors to monitor traffic flow condition and to detect incidents.

Three different types of radar detectors are being used on the projects: wide beam detectors, narrow beam detectors, and long range detectors. The Radar detectors for the Hartford Area ATMS (44 individual detectors) have been installed for 2 years. During this time, only one detector has failed, and the others have survived harsh winters with record snowfalls and significantly below-average cold temperatures. In addition to their reliable operation, the radar detectors have proven to be easily installed and setup.

The detectors have been installed for only a few years, but the data looks promising. Testing has been performed for the various detectors and installation configurations to determine the detector accuracy. The difference between vehicle and detected speed ranges from 4 km/h (2.5 mi/h) for the narrow beam detector, to 5.6 ki/h (3.5 mi/h) for the wide beam detector in a side-fire configuration, and up to 10 mi/h for the long range detector. The errors associated with the long range detector can be attributed to the operating principle and placement of the detector. The detector operation is based on the Doppler principle: it is most accurate when it is aimed directly at the traffic flow.

Testing and day-to-day operations have shown that the radar detectors are highly accurate during varying traffic and weather conditions. The degree of reliability and accuracy demonstrated by the detectors has allowed ConnDOT engineers to be confident in the data displayed. With the use of the video cameras that are also part of the system, ConnDOT engineers have been able to detect and verify incidents that would otherwise have been unknown to them, and to initiate a timely response. Lessons learned from the Connecticut system have been applied in the development of systems in Maryland, New Jersey, Massachusetts, and Georgia.

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MODULE 4. LANE USE CONTROL

TABLE OF CONTENTS

MODULE 4. LANE USE CONTROL

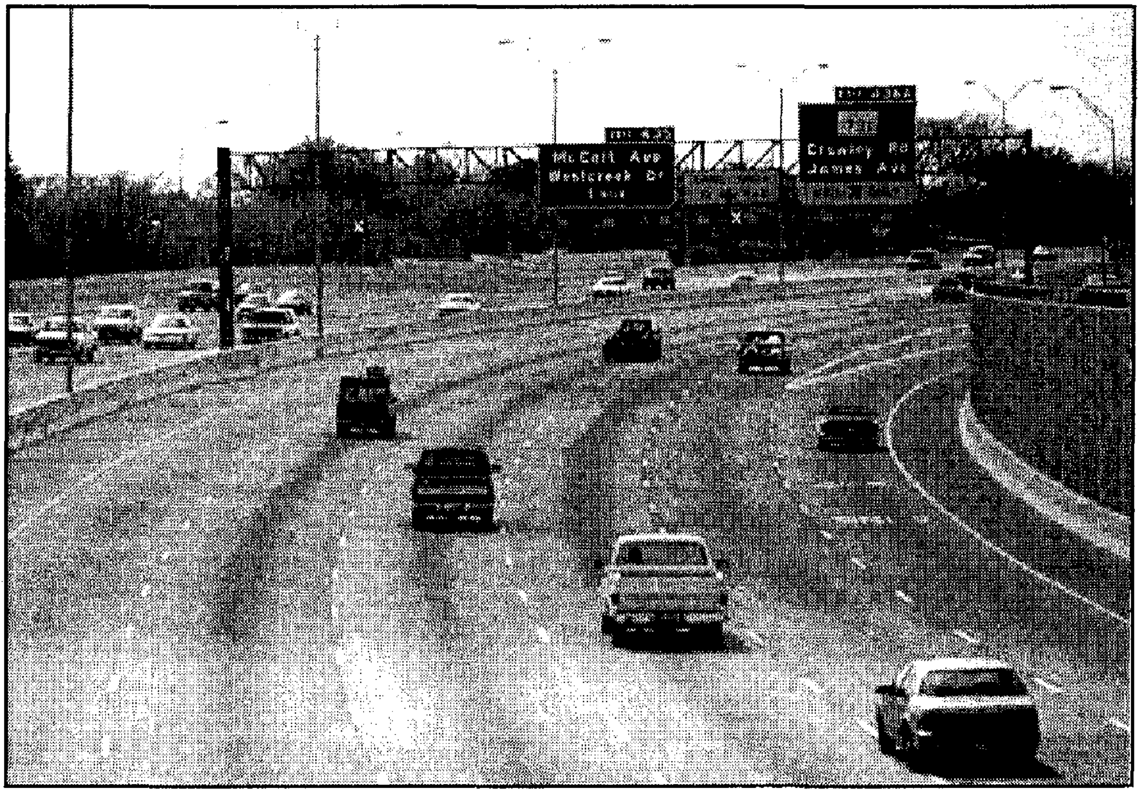

Figure 4-1. Proper Lane Use Control Can Facilitate Safe and Efficient Operations.

4.1 INTRODUCTION

BACKGROUND

Another approach to improving the safety and efficiency of freeway operations is the control of traffic on the freeway mainline. This involves the regulation, warning, and guidance of traffic on the freeway mainline so that some or all of the following objectives are addressed:[1]

- To achieve a more uniform and more stable traffic flow as the freeway demand approaches capacity, thereby improving the utilization of the facility and preventing the onset of congestion.
- To reduce the probability of rear-end collisions caused when motorists unexpectedly encounter congested conditions.
- To distribute total delay in a more equitable manner, saving some freeway capacity for downstream segments.
- To increase the efficiency of operation under restricted-capacity conditions caused by incidents or maintenance operations.
- To divert some freeway traffic to alternative routes or to alternative departure times in order to make better use of corridor capacity.

TREATMENTS

Traditionally, freeway lane use control is accomplished through one or more of the following methods:

- Static signing.

- Dynamic message signs.
- Temporary traffic control devices.
- Law enforcement/legal restrictions.
- Economic incentives/disincentives.

These methods are often combined to form an effective subsystem from both a safety and operations perspective. For example, both appropriate static signing and temporary traffic control devices are required in order to temporarily close a freeway travel lane for maintenance or construction activity.[2] In some instances, dynamic message signs may be provided upstream to encourage diversion from the freeway or to further warn of the downstream lane closure. As another example, the restriction of large trucks to certain travel lanes may be accomplished by static signing to notify truck drivers of the restriction, and by police enforcement of those restrictions.

MODULE OBJECTIVES

The objectives of this module are as follows:

- To provide a summary and description of different lane use control philosophies and treatments.
- To provide insight into the issues associated with lane use control subsystems for freeway traffic management.

MODULE SCOPE

This module begins by applying the decision process described in **Module 2** to the lane use control subsystem analysis. The techniques used to control lane use on freeways are then described. Special issues associated with lane use control are addressed following description of the techniques. The module concludes with examples of lane use control subsystems, describing the dynamic information system component of TransGuide in San Antonio, and the use of congestion pricing on the SR 91 Express Lanes in Orange County, California.

4.2 DESIGN PROCESS

PROBLEM IDENTIFICATION

The development of a lane use control subsystem begins by developing a full understanding of the problems or situations that need to be addressed through this subsystem. At the most basic level, the problems treated via lane use control are similar to those specified for other freeway management subsystems. These include excessive peak period vehicle demands that result in congestion, safety problems, excessive vehicle emissions that degrade the air quality of a region, etc. Most generally, the types of problems that need to be treated through lane use control are as follows:

- One or more vehicle lanes must be closed to all traffic for some period of time (due to scheduled work activity or an incident).
- One or more types of vehicles need to be separated from each other in one or more vehicle lanes.
- Speeds and flow rates in a given lane are judged to be too high for safe and efficient operations.

These problems lead directly into the three basic categories or situations that are most commonly treated through some form of lane use control:

- Restricting the use of freeway lanes and shoulders by all vehicles.
- Restricting the use of freeway lanes or shoulders by specific vehicle types.
- Metering how vehicles utilize a freeway lane or shoulder.

The restriction of freeway lane usage by all vehicle types includes such specific actions as temporary lane closures for roadway maintenance and construction activities or incidents when crashes or vehicle stalls block individual travel lanes, and peak-period congestion relief actions where vehicles are allowed to utilize a shoulder as a temporary travel lane during the peak period. Lane use restrictions based on vehicle type covers such topics as high-occupancy vehicle lanes and large truck restrictions. Finally, strategies to meter a freeway lane or a shoulder include freeway-to-freeway connector metering or the reduction of speed limits through dynamic advisory speed signs or speed enforcement.

For freeway lane use control, it is imperative that decision makers have a true understanding of the problem(s) being addressed through lane use control, and also a sense of the degree of urgency or severity of those problems. Not all strategies available for use are equally effective or costly in managing freeway lane usage. For example, both dynamic advisory speed signs and speed enforcement strategies can be viewed as methods of reducing freeway speeds in one or more lanes. However, the effectiveness and costs would be expected to be significantly greater for enforcement than for advisory signing.[3]

IDENTIFICATION OF PARTNERS AND CONSENSUS BUILDING

For all aspects of freeway management, information sharing is essential in today's environment. This is particularly true for lane use control strategies. The political implications of these control strategies can be very important, particularly with respect to lane restrictions which require legislation and enforcement to enact. Also, support by enforcement agencies of the decisions made regarding lane use control is essential if those decisions are to achieve their intended purpose.

Potential Partners

The partners involved in lane use control will vary depending on the particular problems being addressed. The partners that are most commonly associated with these types of activities include the following:

- State and local DOTs.
- State and local law enforcement agencies.
- Elected officials.
- Transit agencies.
- Trucking companies.
- Private contractors.

Concern over the interaction between automobiles and trucks on freeway facilities is often a controversial part of freeway management activities. Fortunately, trucking companies have demonstrated a willingness to work with public transportation and enforcement agencies to develop compromises about when and where trucks will travel during peak periods, major freeway construction activities, or special events.[4] Consequently, they can be an integral partner in decisions regarding lane use control as well.

Consensus Building

After identifying the partners affected by lane use control actions, a consensus about the problems and need for solutions must be developed. Early on, it is critical to establish support for the general concepts about lane use control from elected officials and the general public. This is particularly important when not all motorists are affected equally by the actions that may be implemented (via tolls, lane restrictions for certain vehicles, etc.). Support is also needed from upper management at each of the agencies listed above.

ESTABLISH GOALS AND OBJECTIVES FOR LANE USE CONTROL

Proper decision making about the selection, design, and implementation of lane use control strategies requires goals and specific objectives about what is to be accomplished by using these strategies. General goals and objectives that feed directly into this step may have been established early on in the development of a comprehensive freeway management system . If not, it is imperative that the exact objectives to be accomplished via lane use control be specified. As discussed in **Module 2**, goals are broad statements of intended outcomes, whereas objectives specify exactly what is to be accomplished. Examples of objectives which lane use control may be able to address include the following:

- Increasing the available throughput over a given section of freeway.
- Providing at least a travel time incentive to high-occupancy vehicles.
- Extending pavement life (by restricting trucks from particular lanes).
- Reducing truck-automobile accidents over a given freeway segment.
- Reducing peak-period traffic demand on the freeway.

ESTABLISH PERFORMANCE CRITERIA

Performance criteria must be established for each of the objectives identified in the previous step of the process. These criteria are used to determine whether each of the objectives is met or exceeded. For the most part, performance criteria to be used will be fairly obvious if the objective(s) to be accomplished are specified correctly. For example, an objective to reduce high-occupancy vehicle travel time would utilize a travel-time measure as its performance criterion. However, additional performance criteria may be specified as checks of the primary performance criteria, or to measure other constraints that may exist on freeway lane operations. As another example, performance criteria concerning single-occupant vehicle violation rates might also be used to evaluate the need for a barrier-separated HOV lane (see **Module 6**) versus a concurrent flow HOV lane with no barrier separation. The following list presents some typical performance criteria for lane use control subsystems.

- Level of service on a facility (see **Module 2**).
- Compliance (lane violation) rates.
- Change in mode split, average occupancy rates.
- Accident reductions.

- Results of public and/or special interest opinion polls.

DEFINE FUNCTIONAL REQUIREMENTS

The functional requirements of a lane use control component in a freeway management system define specific actions or activities that are to be performed in order to achieve one or more of the objectives for that component. In theory, the functions should be defined independent of the technology used to implement them. However, some lane use control objectives may be so narrowly defined and governed by standards or policies (temporary freeway lane closures for maintenance, for instance) that this step in and of itself defines the technology to be used.[5] For other objectives, though, the technology required may not be so obvious, and so a definition of functional requirements would be warranted. Figure 4-2 presents an example of possible functional requirements of a lane control subsystem to increase peak period freeway capacity.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The functional relationships, data requirements, and information flows show how the lane use control functions will be integrated with each other and with the other freeway management system components (such as surveillance or motorist information dissemination). When defining the functional relationships, data requirements, and information flows as they impact dynamic message signs and surveillance, the National Transportation Communications Interface Protocol (NTCIP) and the National ITS Architecture should be followed.[6] This approach provides the following advantages:

- Automatically determine when freeway lane volumes reach 90 percent of estimated capacity.
- Check to ensure that no stalled vehicles are located on the shoulder in the affected section of freeway.
- Notify motorists at the beginning of the affected section that freeway shoulder can be used as a travel lane.
- Notify motorists at the end of the affected section that they should return to the normal freeway travel lanes.
- Terminate motorist notification of allowability of freeway shoulder usage at the end of the peak period.

Figure 4-2. Example of Possible Functional Requirements of a Lane Use Control Objective.

- It allows components from different vendors to be used interchangeably, increasing competition and reducing costs.

- It eases future upgrades or expansions of the components. The necessary interfaces to other components of the freeway management system (i.e., surveillance) have already been established.

For other lane use control functions, informal functional relationships, data requirements, and information flows may be acceptable, but should be prepared nonetheless. For example, the functional relationships, data requirments, and information flows for managing a temporary total freeway closure over the weekend might include how real-time data concerning traffic conditions, project status, and/or the effects of weather are transferred between the transportation agencies (such as the traffic, maintenance, and public information divisions), enforcement agencies, the media, and the private contractor.

IDENTIFY AND SCREEN TECHNOLOGY

After the functional relationships have been specified for the functions to be accomplished through freeway lane use control, decision makers must then assess available technologies and strategies to determine which are most appropriate to meet the desired objectives of this subsystem. Depending on the types of functions being accomplished, the assessment should include considerations of both the spatial and temporal characteristics of the freeway system and motoring public. For example, spatial considerations address technology/strategy adequacy from the aspect of roadway design and construction, and may require the decision maker to answer questions such as the following:

- Is the pavement on the shoulder adequate to support vehicle travel?

- How will restricting large trucks to a specific lane or lanes affect vehicle merging or diverging maneuvers at entrance and exit ramp locations?

Temporal considerations are also important for assessing technologies for real-time lane use management. For example, before considering truck lane restrictions on a freeway facility, a decision maker may want to consider whether truck-automobile conflicts and crashes are a problem at all times of the day or only during certain periods. Likewise, decisions regarding when and how many lanes will be closed to accomplish a given work activity are a major part of the work zone planning process.[7] For instance, it may be possible to close more travel lanes at night to do the work, but this requires channelizing devices and other traffic control devices that provide higher levels of retroreflectivity (increasing planning and traffic control costs).[7]

Another factor to consider when identifying and assessing alternatives for lane use control are the political sensitivities and ramifications to those alternatives. Those alternatives which would adversely impact some motorists in order to provide an advantage to other motorists have typically been met with resistance. For instance, those HOV projects which have taken a regular-use travel lane and converted it into an HOV lane (i.e., take-a-lane alternatives) have generally been less successful than those which have constructed a new HOV lane while maintaining the same number of regular-use lanes as before (i.e., add-a-lane alternatives).[4] Alternatives that involve direct cash outlays, such as toll facilities or congestion pricing schemes, have also been met with resistance.[8] These alternatives require more public outreach and political interaction between the partners to ensure that they will be successful if implemented.

PLAN DEVELOPMENT

After the various lane use control alternatives available have been screened and the one(s) most appropriate for use selected, decision makers then prepare detailed plans regarding implementation of the selected alternatives. The actual format and content of the plan varies dramatically by the type of alternative being implemented. The plan for a temporary lane closure for maintenance work may be as simple as a standard traffic control plan (TCP) that has been adopted by the agency for that particular roadway/road work condition. Conversely, the plan to implement a congestion pricing scheme based on real-time traffic conditions and utilizing ITS technologies may need to follow detailed implementation plan requirements as specified by FHWA (see **Module 2**).[9]

Enforcement should be a key element of all lane use control plans that are developed. Plans should address both the management and coordination requirements between the various partners, relative to enforcement. Operational issues such as staff requirements and citation locations also need to be addressed during plan development.

FUNDING SOURCE IDENTIFICATION

Many of the lane use control strategies employed during freeway management activities are supported as part of an operating agency's normal activities, or are addressed during development of other components of the freeway management system (i.e., information dissemination subsystems). Consequently, the primary concern for these strategies is the extent to which introducing the new strategy affects the existing budget for operations and maintenance, and whether this impact can be accommodated through a reallocation of agency funds.

Those strategies which are larger in scope and/or applied across jurisdictional boundaries often require more innovative and complex funding mechanisms. Funding of lane use strategies involving HOV lanes, information dissemination, and/or incident management subsystems are addressed in **Modules 6**, **7**, and **8**, respectively.

Two of the major lane use control options, implementation of tolls and/or congestion pricing strategies, result in revenues that are used to offset the cost of constructing and operating these strategies. Traditionally, toll facilities were converted to "free" roadways once the bonds used to construct the roadway had been paid. Recent changes in legislation, however, now allow agencies to continue toll operations after bond payment, and to use the revenues to fund other traffic management activities.

IMPLEMENTATION

Experiences from past freeway management projects indicate that it is best to implement strategies and techniques incrementally where possible in order to develop operational experience with the strategies, and to demonstrate the advantages of the techniques to elected officials and to the public.[4] This may be true for some of the more "innovative" or controversial lane use control strategies as well. For these situations, consideration should be given to initiating small, demonstration-type projects at a location or over a section of freeway where the benefits are expected to be the greatest. In this way, the partners can illustrate the benefits of the strategy and generate the support necessary to proceed with more extensive implementation if desired.

EVALUATION

The final step in the decision process for lane use control is to establish the mechanism for evaluation of the strategies once they have been implemented. It is important to monitor the impacts and benefits of new strategies and techniques as they are implemented to determine if they meet the intended objectives and functions for which they were designed. Also, it is important that these data be collected so that they can be collated and disseminated in an ongoing manner to elected officials and the general public. In this way, continued funding for these strategies can be obtained more readily, and expansion of activities to further improve facility operations will be more readily accepted.

4.3 TECHNIQUES AND TECHNOLOGIES

Lane use control can be implemented through the following means:

- Static signing.
- Dynamic information systems.
- Channelizing devices.
- Use of narrow lanes and shoulders.
- Mainline metering.
- Toll facilities/congestion pricing.
- Automated highway systems.

A brief description of how each of these technologies applies to the lane use control concept is provided below.

STATIC SIGNING

Signs are used to provide guidance and warnings as needed to ensure the safe and informed operation of individual elements of the traffic stream. Signs can provide lane use control by restricting certain vehicles from using or not using a particular lane. Examples include the following:

- Restricting trucks to the right most lane(s) or to specific times of day that they can use a facility.
- Establishing lane(s) for high-occupancy vehicle use only.

Discussions of these examples follow.

Static signing is also used for warning purposes in advance of construction and maintenance work zones to inform motorists that one or more travel lanes are closed downstream. These generally supplement the channelizing devices placed at the point of closure to require drivers to vacate the lane at that point (channelizing devices are discussed later in this module).

Truck Restrictions

Several States restrict the lanes in which trucks may operate. The objective in restricting trucks to the right lane or lanes is typically to improve highway operations and reduce accidents. Also, to provide for uniform pavement wear, trucks are sometimes restricted from the right lanes. Lane restrictions through construction zones are used to move the trucks away from workers and from narrower lanes. Table 4-1 is a summary of experience regarding lane restrictions in various states and in research studies.[5] Several States adopted lane restrictions because trucks were often observed traveling abreast across several lanes, denying passing opportunities for other vehicles.

A survey of State practice in 1986 by the FHWA identified the most common reasons given for using truck lane restrictions:

- To improve operations (fourteen States).
- To reduce accidents (eight States).
- For pavement structural considerations (seven States).
- Because of restrictions in construction zones (five States).

A total of 26 States used lane restrictions, according to survey information. The survey of FHWA field offices also indicated that, in most cases, restrictions have been applied without detailed evaluation plans, including before-and-after studies. Where accident analyses were undertaken, little change in accident experience was noted under any of the restrictions.[10]

Truck restrictions can be implemented in a number of other ways as well. Table 4-2 summarizes the constraints and impacts of different types of restrictions.

HOV Restrictions

Another form of lane use control is when a lane is restricted for use by high-occupancy vehicles only. Several types of static signs have been used to communicate the restriction. (For discussion on high occupancy vehicle lanes, see **Module 6**).

INFORMATION DISSEMINATION SYSTEMS

Information dissemination systems can be employed to advise motorists of freeway conditions so that appropriate actions can be taken to enhance the efficiency and safety of freeway operations. **Module 7** provides a discussion of information dissemination principles and technologies. For lane use control applications, both lane control signals (LCS) and full-matrix dynamic message signs (DMSs) can be used to convey lane use and lane status information to drivers. LCSs are a fixed-grid DMS (refer to **Module 7**) that use both color and symbols to convey information. The Manual on Uniform Traffic Control Devices (MUTCD) defines LCSs as special overhead signals having symbols that are used to indicate whether the use of a specific lane or lanes of a street or highway is permitted or prohibited, or to indicate the impending prohibition of use.[2] In the United States, LCSs have most commonly been used for reversible-lane control. However, they are also appropriate for use on freeways in the following situations:[2]

- On a freeway, where it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from an entrance or exit ramp or other freeway.
- On a freeway, near its terminus, to indicate a lane that ends.
- On a freeway or long bridge, to indicate a lane that may be temporarily blocked by an accident, a breakdown, or some other incident.

In addition, at least one operating agency (Virginia) uses LCS to indicate to motorists that a shoulder can be used as a travel lane

Table 4-1. Lane Restrictions Experiences.[5]

Location/Study	Conditions	Results/Comments
Florida I-95, Broward County	Conducted a 6 month, 7 am to 7 pm study in 1988	Public feels safer with lane restrictions for trucks. Overall accidents up 6.3 percent (7 am to 7 pm period); truck accidents down 3.3 percent.
Georgia	Beginning Sept. 1986, trucks were restricted to the right lane(s) except to pass or to make a left-hand exit.	On I-285, trucks were at fault in 72 percent of lane-changing violations. Before the restriction, trucks were observed occupying all lanes thus prohibiting passing.
New Jersey	Turnpike Authority (NJTA) imposed lane restrictions in the 1960s. Restrictions do not allow trucks in the left lane of turnpike roadways that have three or more lanes by direction.	Sources at the NJTA stated that the compliance rate for truck lane restrictions is very high.
Illinois	Began in 1964.	Public feels safer, and better operations.
Maryland Capital Beltway	Believed to have been implemented as a reaction to a major truck accident.	Public feels safer. Effects on safety not well known.
Virginia Capital Beltway	Four studies, one for 24 months, others for 12 months.	Public and political perception: safer highways. Engineering study recommended removal. Accident rate increased 13.8 percent during 2-yr study. Second study also showed increase.
Michigan	Statewide restrictions require trucks to use the right two lanes on roadways that have three or more lanes.	Establishment was thought to be politically motivated No studies available to evaluate the countermeasure.
Garber Study	Simulation based on data from nine sites.	Decreased headways in right lane Slight increase in right lane accidents.
Hanscom Study	Two 3-lane suburban sites, all <100,000 AADT.	Beneficial traffic operations and reduced congestion.

Table 4-2. Summary of Impacts from Truck Restrictions. [11]

Action	Constraints/Limitations	Impacts
Lane Restrictions	• Lane drops at freeway-freeway interchanges limit application. • Could be difficult to enforce. • Could accelerate pavement deteriorations. • Could reduce visibility of overhead signing (if trucks restricted to outside lanes).	• For freeway segments with lane drops, would concentrate lane changes in short section of freeway. • Would increase merging conflicts.
Time-of-Day Restrictions	• Truck traffic peaks do not coincide with typical commuter peaks. • Could be difficult to enforce. • Could be challenged on legal basis.	• Negligible impact on operating speeds. • Could divert trucks to other less congested time periods, or other, lower quality roadways. • Could negatively impact trucks that must travel during restricted periods.
Speed Restrictions	• Differential speed limits for trucks and non-trucks could be difficult to enforce. • Could require extensive enforcement program. • May require use of innovative detection, apprehension, and citation strategies.	• Reduction in speed (differentials) could have positive safety impacts.
Route Restrictions	• Efficient routing plan could not exclude freeways.	• Negligible impacts on safety and operations. • Could have positive impacts if applied to transportation of hazardous materials.
Driver Training/ Certification	• Requires strict application and enforcement of regulations.	• Short-term impacts minimal. • Long term impacts could be significant.
Increased Enforcement of Existing Regulations	• Would require additional enforcement personnel. • Could require incorporation of enforcement requirements in design/re-design of freeways.	• Increased enforcement could lead to increased compliance with traffic laws. However, there is no conclusive proof that increased compliance reduces accidents.

during peak travel periods.[12] Figure 4-3 shows a typical freeway LCS.

The MUTCD gives information on the design, location and operation of lane-use control signals. The meanings of freeway lane-use control signals are as follows:[2]

- A steady DOWNWARD GREEN ARROW means that a driver is permitted to drive in the lane over which the arrow signal is located.
- A steady YELLOW X means that a driver should prepare to vacate, in a safe manner, the lane over which the signal is located because a lane control change is being made, and to avoid occupying that lane when a steady RED X is displayed.
- A steady RED X means that a driver shall not drive in the lane over which the signal is located, and that this indication shall modify accordingly the meaning of all other traffic controls present.

In contrast to LCSs that display a rather small number of colors and symbols, full-matrix DMSs are capable of providing a large number of descriptive messages to indicate that one or more travel lanes are closed downstream, that a freeway shoulder can be used as a temporary travel lane, that an HOV lane is open to mixed-use traffic (as might occur during a major incident), or that trucks normally restricted to a right lane can use other travel lanes as well (as also might occur during a major incident).

Figure 4-3. Typical Freeway Lane Control Signal.

LCSs are smaller than full-matrix DMSs, and so are considerably cheaper to purchase and maintain. This means that LCSs can be installed more frequently along a freeway than can larger and more expensive DMSs. Also, since LCSs use symbols and colors rather than words to convey information, they can be more readily understood by non-English speaking motorists. However, the amount and type of information that can be displayed via LCSs is much more limited than via a typical DMS.[13]

Regardless of the technology used, information dissemination systems alone cannot force vehicles to vacate a lane or utilize a shoulder as a travel lane. They do provide guidance about lane status, and are intended to promote safer operations by warning motorists upstream of an actual lane blockage.

USE OF NARROW LANES AND SHOULDERS

Research has confirmed that shoulders and narrow lanes can be used effectively to increase capacity in congested metropolitan corridors. Based on a recent NCHRP study, it is recommended that these strategies be reserved for use as techniques to improve traffic flow in congested corridors.[14] Widening a corridor over an extended length through the use of these strategies is not recommended. Rather, applications of these strategies should be viewed as a temporary technique for congestion relief. It is recommended that this technique should typically be limited to sections of 1.61 km (1 mi) or less.

Reduction in the travel-lane width to 3.4 m (11 ft) should be the first modification considered. Next, reduction of the left shoulder should be considered before reducing the right shoulder. Research and observations by enforcement personnel indicate that the right shoulder is the preferred refuge area. Also, emergency response is easier to provide if the right shoulder is maintained. If the right shoulder is used and the left shoulder maintained, emergency equipment entering a congested area must work its way across the queue to the left shoulder as opposed to proceeding on the right shoulder. In some cases, the right shoulder or both shoulders have been used. Table 4-3 summarizes the primary advantages and disadvantages of each approach.

Where there is a high percentage of truck traffic (i.e., 5 to 10 percent) during the peak period, use of shoulders and narrow lanes is not recommended. Also, for projects involving possible application of shoulders and narrow lanes, a step-by-step approach (site specific) must be used to ensure an adequate evaluation.

MAINLINE METERING

Mainline metering controls the mainline traffic entering a freeway control section. While the technique can create congestion on the mainline upstream of the control section, it can help maintain uncongested flow on the mainline downstream through the control section. An application of mainline metering has been documented in Japan, where it has been made effective by regulating the number of toll booths open, thereby controlling the traffic entering the freeway. Another application is the San Francisco-Oakland Bay Bridge mainline metering in Oakland, where controls are used after vehicles pass through the toll plaza at a point prior to entering the ridge.[15] Other applications of mainline metering on controlled-access facilities such as terminals, bridges, and toll roads have been found to be effective, but the concept has yet to be applied to a typical metropolitan freeway system.

Table 4-3. Primary Advantages and Disadvantages of Shoulder Removal. [14]

Design Alternative	Advantages	Disadvantages
Use of Left Shoulder	• Left shoulder not used as much for emergency stop/or emergency enforcement • Least expensive if width is available • Trucks often restricted from left lane	• Usually requires restriping • Sight distance problem with some median treatments
Use of Right Shoulder	• Often the easiest to implement	• Right shoulder is preferred area for emergency stops and enforcement • Sight distance changes at merge and diverge areas of ramps
Use of Both Shoulders	• Not recommended • Use ONLY in extreme cases	• Requires restriping • Safety concerns (no refuge) • Enforcement is difficult • Incident response longer • Maintenance more difficult and expensive

Another potentially effective use of mainline metering that has not yet been applied is in a construction zone where traffic demand greatly exceeds the capacity available, and some reserve capacity for vehicles entering at downstream ramps needs to be provided.[1]

Another application of mainline metering involves using DMSs to display reduced advisory speed limits over sections of freeway. This technique is commonly used on portable DMSs upstream of work zone lane closure activities.[16] However, its application to freeway management in the U.S. has been less favorable. Nonetheless, this approach is used with reasonable success outside of the U.S.[17]

FREEWAY-TO-FREEWAY RAMP METERING

The primary benefit of ramp metering is that it reduces congestion and shockwaves on freeways. Metering eliminates the heavy surges or platoons of entering traffic and allows the freeway to carry substantially higher volumes at higher speeds. It also substantially reduces accidents, especially the rear-end type crashes that result from stop-and-go driving. Reduction in accidents and congestion also results in overall reductions in fuel consumption and air pollutant emissions. Freeway-to-freeway ramp metering uses a meter on a ramp from another freeway to control the entrance of vehicles onto the new freeway. Minnesota Department of Transportation (MnDOT) has been successfully metering freeway-to-freeway ramps for over 20 years and is currently metering 74 ramps. Although there is some concern over metering these high volume ramps, MnDOT believes it is desirable to do so because heavy surges of traffic, if left unmetered, can severely affect the operation of the receiving freeway by causing congestion and accidents.[18]

CHANNELIZING DEVICES FOR WORK ZONES

Traffic management in construction and maintenance work zones is important to the safety of both workers and motorists. Time is required to properly develop and implement the traffic control when lanes must be closed to complete the work. No one sequence of traffic control devices can be designed for all situations. The traffic control plan should be designed to provide the same number of lanes of traffic during construction as before and ideally, be designed for the same free-flow traffic speed that existed before freeway construction began. A work zone cannot always maintain the same number of lanes and, in addition, where motorists drive in a work zone can be influenced by the traffic control devices present.

Static signs are used for directing traffic in advance of and within a work zone. However, variable message signs and arrow panels supplement channelizing devices and provide additional target value and suitable messages that attract motorists' attention as they approach a work zone. Highway Advisory Radio (HAR) can also be used to provide more information, including route detours. Newspaper articles and traffic broadcasts can also be employed to alert motorists to general construction and maintenance work zone locations, but provide limited detailed information about specific lane closures and traffic delays.[1]

Within the work zone itself, traffic must be channeled from the lane(s) being closed to one that is open. A number of different types of channelizing devices can be used, depending on the duration of the closure, traffic speeds, etc. These devices include but are not limited to the following:[2]

- Cones.
- Tubular markers.
- Vertical panels.
- Drums.
- Barricades.

Regardless of the device used, it is critical that proper spacing and length of taper be employed to safely transition motorists from the closed lane(s) to the open lane(s).[2]

Portable barriers may be used to separate traffic from the work area and to protect the construction workers. Special signing and temporary delineation and/or route detours may be needed when these barriers are moved and traffic is shifted. Portable barriers have been used to create HOV lanes in Dallas and Boston. This device could also be used as a lane control technique in a construction area. (See the discussion in **Module 6** for additional information).

TOLL FACILITIES/CONGESTION PRICING

Toll facilities are fully controlled access roadways designed to the same high standards of design as freeways. However, because of both the economic influence they exert on traffic demand for the facility and the traffic metering effect that occurs at the toll collection plazas, toll facilities can also be considered another form of lane use control. Toll facilities form the most direct user charge for providing revenues based on the costs of travel. Often, they can be implemented more quickly, because the capital funding is available up front and because toll roads often do not have to comply with federal regulations.[19] Also, toll facilities provide adequate funding for ongoing operations and maintenance.

In recent years, legislation has been enacted to facilitate the development of toll facilities through innovative financing. For example, the Federal Highway Act of 1987 provided for eight demonstration projects across the nation, allowing a mixture of toll revenues with State and federal funds on new projects.[20] California enacted legislation that allows the development of joint-power authorities to collect developer fees for transportation projects, and awarded four franchises to private entities, allowing private designing, financing, construction, and operation of toll facilities for 35 years.[20]

Two basic types of collection methods are used: mainline barriers at intermittent spacings, and toll collection at interchanges. Where mainline barriers is used, the location of the barrier should be far enough from exit or entrance ramps to avoid weaving problems. Toll plazas should be located on tangent alignment with decision sight distance provided on the approach. Grades approaching the plaza should not exceed 0.5 percent. The design of the plaza itself should be based on the expected number of peak-period arrivals and the rate at which they can be processed. Sufficient toll collection lanes of great enough length should be provided to minimize the length of queuing at the plaza. Where toll collection occurs at exit and/or entrance ramps, care should be taken in interchange ramp design. Plazas should be placed far enough upstream from the ramp diverge to provide for normal deceleration and braking to a queue.[1]

A new technology experiencing increased use is Automatic Vehicle Identification (AVI) technology for automatic toll collection. The technology is being implemented to increase capacity and decrease delays and congestion at toll plazas. Figure 4-4 illustrates the proposed use of the AVI technology on the toll roads. An AVI system speeds the toll collection process by having a device identify each vehicle as it approaches a toll plaza or passes a check point, and charging the proper toll to the user's account, eliminating the need for vehicles to stop.

Congestion pricing is a transportation management technique similar in concept to toll facilities, but which attempts to spread peak traffic demands to less congested segments of the network and to less congested periods of the day. The application of congestion pricing has been very limited within the U.S. Experience in Hong Kong in the mid-1980s proved the program to be a technological success, although not widely accepted by the public.[22]

Recent advances in technology are making congestion pricing a viable option in the U.S. Automatic fare collection systems can be used for this purpose, including optic scanners and radio frequency technology. The system would automatically charge the user by prepayment, direct billing, or credit card. A billing statement would be received by the user each month. Typically, the user would receive advance notification of billing rates, ideally one month prior to charging. Table 4-4 shows a typical user fee schedule.

Key issues relative to congestion pricing in the U.S. are as follows:[23]

- Technology compatibility — between toll collection systems across the country and across travel modes.

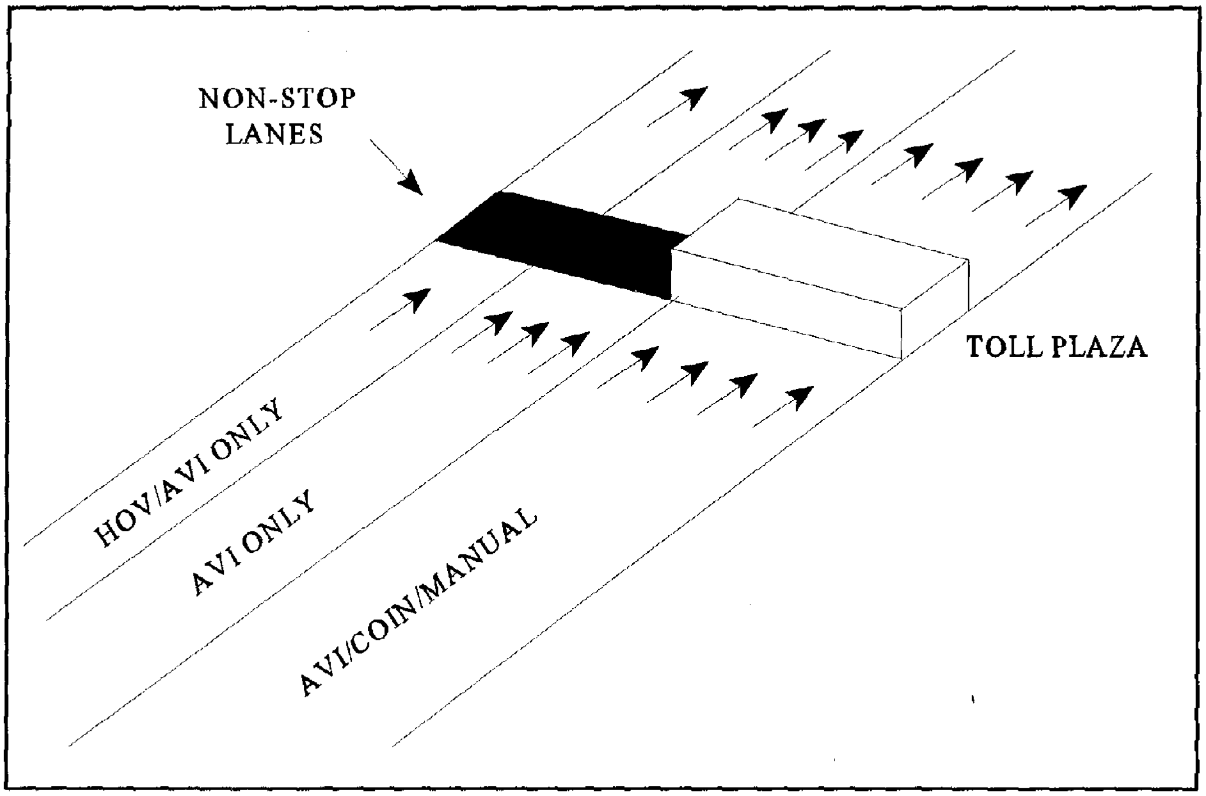

Figure 4-4. Schematic of an AVI Toll Plaza. [21]

- Enforcement — concerns about legislative changes needed to allow vehicle owners to be ticketed, rather than drivers. Also, verification of occupancy requirements (if implemented) needs to be accommodated without unduly affecting the overall operations of the facility.

- Privacy — concerns about the potential tracking of individuals through the AVI technology. One alternative proposed is the use of "Smart" cards which maintain their own internal data about the individual's account.

- Price determination — questions have to be resolved (should charges be based on short-term marginal road user costs of an additional vehicle added to the traffic stream, or on long-term costs of providing an equivalent amount of extra capacity to the facility to accommodate that alternative pricing structures upon traffic demand, air quality, land use, etc. are difficult to estimate at this time.

AUTOMATED HIGHWAY SYSTEMS

Automated Highway Systems (AHS), a component of the Intelligent Transportation Systems (ITS), is seen as the next major performance upgrade of the United States vehicle-highway system. It should be mentioned, however, that AHS is still in its infancy and is many years from being an operational reality. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 established a program to determine the feasibility of an AHS. Research has shown that AHS has the potential to double or triple the nation's roadway capacity and reduce the frequency and severity of incidents while providing more stable traffic flow.[24,25] The increased capacity will result from the closer longitudinal and lateral

Table 4-4. Typical User-Fee Schedule.[22]

Route Segment Number	Peak Period (6:01 am - 9:00 am; 3:01 pm - 7:00 pm)				Off-Peak Period (9:01 am - 3:00 pm; 7:01 pm - 6:00 am)			
	1	2	3	4	1	2	3	4
A	$0.09* 45 mph	$0.09 45 mph	$0.09 45 mph	$0.07 50 mph	$0.05 55 mph	$0.05 55 mph	$0.05 55 mph	$0.04 55 mph
B	$0.04 60 mph	$0.04 60 mph	$0.04 60 mph	$0.04 60 mph	$0.02 60 mph	$0.02 60 mph	$0.02 60 mph	$0.02 60 mph
C	$0.06 25 mph	$0.06 25 mph	$0.05 30 mph	$0.05 30 mph	$0.04 35 mph	$0.04 35 mph	$0.02 40 mph	$0.02 40 mph
D	$0.10 40 mph	$0.10 40 mph	$0.08 45 mph	$0.08 45 mph	$0.08 45 mph	$0.08 45 mph	$0.06 50 mph	$0.06 50 mph
E	$0.10 20 mph	$0.10 20 mph	$0.08 25 mph	$0.08 25 mph	$0.08 25 mph	$0.08 25 mph	$0.06 30 mph	$0.06 30 mph
F	$0.05 30 mph	$0.05 30 mph	$0.08 30 mph	$0.08 30 mph	$0.04 35 mph	$0.04 35 mph	$0.06 35 mph	$0.06 35 mph
G	$0.04 45 mph	$0.04 45 mph	$0.07 40 mph	$0.07 40 mph	$0.03 55 mph	$0.03 55 mph	$0.05 55 mph	$0.05 55 mph

* Dollar amount indicates user-fee rate (dollars per mile) for using a specific route. The mile-per-hour figure indicates anticipated travel speed when using a specific route. For example, travel on Route B/Segment 3 during the peak period would cost $0.04 per mile, with an anticipated average travel speed of 60 mph.

spacing that will be allowed due to the full control of the AHS expressway. The Federal Highway Administration (FHWA) has established an AHS program that will be able to carry out the following:

- Identify and analyze alternative AHS concepts.
- Demonstrate the potential feasibility of AHS in 1997.

Concept

AHS refers to the use of modern electronics, sensors, and communications on highway vehicles to provide "fully automated" vehicle operation. The automated system of roadways will run adjacent to the existing infrastructure providing an option to choose the AHS facility or remain on the conventional freeway. As a vehicle approaches and accesses an AHS lane of an AHS expressway, the vehicle's steering, braking, and acceleration are controlled until the vehicle exits the lane, after which the driver once again assumes control of the vehicle. An AHS expressway will have four major components that are fundamentally different from a conventional expressway. These segments are as follows:[26]

- Vehicle characteristics.
- Roadway infrastructure.
- Command and control.
- Entry and exit infrastructure.

The functional characteristics of each of these segments are discussed in the paragraphs below.

Vehicle Characteristics

The function of the AHS vehicle is to carry the driver, passengers, and goods as they are moved through an AHS system. The vehicle must do the following:

- Provide for controlled vehicle movement.
- Interact with the AHS roadway infrastructure component to obtain traction and support for operation while in the system, and to obtain lane boundary indications.
- Interact with the entry and exit infrastructure component to provide smooth and rapid entry and exit to AHS.
- Provide accurate control responses to directions received from the command and control component regarding vehicle braking, steering, throttle, and lights.
- Detect and maintain the status of critical vehicle functions.
- Support access to and from the command and control component.
- Interact with the driver, on a user-friendly basis.

Roadway Infrastructure

The primary function of the roadway infrastructure is to:

- Provide traction and support for vehicle operation, including vehicles operating properly and those that are malfunctioning.
- Enable safe vehicle operation by ensuring vehicle separation in case of severe system malfunction.
- Provide connectivity for entering and exiting vehicles and connectivity to other AHS systems.
- Provide passive or active indication of lane boundaries.
- Provide sensing of environment or obstacles, or both.
- Support/enable command and control and communication access to AHS vehicles and to roadway conditions.
- Support access to roadway by emergency and maintenance vehicles.

Command and Control

The AHS expressway is controlled primarily by the command and control component. The approach that is taken to accomplish the AHS command and control functions will have a strong influence on how the entire system is to be implemented. The five primary functions of the AHS command and control segment are listed below:

- Traffic flow management.
- Intervehicle coordination.
- Incident management.
- Vehicle control.
- Vehicle management.

Entry and Exit Infrastructure

The entry and exit infrastructure refers to the component of the system that transitions to and from the AHS expressway onto or from the regular freeway lanes. There are several methods for making this transition, but it is hypothesized that these transitions will include separation by vehicle classification and type of in-vehicle AHS technology. The classification separation is made so that lateral space can be optimized.

Goals

In order for an Automated Highway System to be successful, it must provide positive and noticeable benefits. Benefits must be realized in the areas of capacity, safety, energy, level of service, and environmental and community impacts. AHS will provide a more efficient utilization of right-of-way by decreasing lateral and longitudinal spacing of vehicles, thus increasing capacity. Safety improvements will be realized through the implementation of AHS due to the automation of usually manual tasks that create the possibility for driver error. Due to the smooth operation and flow of the vehicles along an AHS expressway, increased energy efficiency will be experienced. By decreasing total trip time, increasing level of comfort, and maintaining flexibility, the level of service of the system can be increased. The AHS system is expected to improve each of these components. Lastly, the AHS will aid realization of environmental goals related to noise and air pollution, community disruption, and user acceptance.[27]

4.4 LESSONS LEARNED

PLANNING

Freeway-to-Freeway Ramp Metering

In considering whether to implement a freeway-to-freeway ramp metering system, several concerns must be examined (e.g., whether or not to provide a dynamic warning device to alert approaching motorists that there is a ramp meter in operation, and possibly a substantial queue downstream). MnDOT, which is currently metering 74 ramps, bases its analysis upon available sight distance, approach speeds, and queue lengths. In general, MnDOT uses ramp meters at most freeway-to-freeway ramps, except loops. If an advance warning device is used, it is a 30 cm (12 in) flashing yellow signal head, accompanied by a standard symbolic "traffic signal ahead" sign, mounted on a 3 m (10 ft) traffic signal pedestal. It is placed in flashing operation when the ramp meter is cycling.[18]

In the operation of the MnDOT freeway-to-freeway ramp meters, metering rates and geometrics are carefully analyzed. Freeway-to-freeway ramps use different timing parameters than other meters. A narrower range of rates is used so that under severe incident conditions ramp flow is reduced by 25 percent, as compared to a 50 percent reduction at other ramps. These parameters help to guard against long queues. When necessary, MnDOT constructs an extended storage lane upstream of the meter to prevent queuing from backing up onto the intersecting freeway. Also, signing is used to encourage motorists to wait in line on shoulders, rather than in the through lanes of intersection freeways.

MnDOT has noted that there are several major concerns at freeway-to-freeway ramps that do not exist at other metered ramps, and they may be the reasons why some traffic management agencies have been reluctant to meter these ramps. The biggest concern is over accidents on freeway-to-freeway ramps, or upstream on the approaching freeway. This concern is related to stopping high speed/high volume ramp traffic, and the resulting queues. Experience over the past 25 years in Minnesota has indicated that there have actually been very few accidents at these ramps and that there is a net reduction in crashes.

Another concern over freeway-to-freeway ramp meters is that they may result in motorists being metered several times while making one trip. For example, a motorist entering the freeway from a metered ramp at an arterial street may also use several other freeways on a trip, thus encountering several ramp meters. There is also concern over negative reaction from the public when freeway-to- freeway ramp meters are deployed. The faster metering rates used at freeway-to- freeway ramps, however, have resulted in substantially fewer complaints about freeway-to-freeway ramp meters as compared to other ramp meters.

Toll Facilities

Toll road facilities are a means of financing roadway improvements. The intent is to finance roadway construction only if there is sufficient demand willing to pay a premium for services rendered by the facility. Furthermore, the user population must be willing to pay for the opportunity to save time in the system because toll road facilities are generally less congested. Currently, the concept of toll roads is being considered as a realistic procedure to finance the construction of needed facilities in a short time period. There are several advantages and disadvantages involved in the implementation of toll roads as opposed to free roads. Table 4-5 lists some of the advantages and disadvantages of financing a road via user tolls.

Congestion Pricing

There are logistical, institutional, and attitudinal barriers that must be addressed when implementing a congestion pricing system. A feasibility study must therefore be undertaken prior to implementation. The following tasks should be conducted:[22]

- Review of appropriate state-of-the-art technology.
- Attitudinal surveys of the system users.
- Organization of participating agencies and private-sector partners.
- Conceptual design for select U.S. cities.
- Preliminary capital and operational and maintenance cost estimates.
- Development of a conceptual implementation plan (i.e., time frame, lead agency, potential funding sources, institutional requirements).

Congestion pricing has seen very limited use in the United States, though already proven successful in efforts to reduce congestion in Singapore and several Norwegian cities. Implementation of roadway pricing has been discouraged in the U.S. due to technical and political problems. The use of AVI technology overcomes some of the technical barriers such as congestion at toll booths. In order to overcome political barriers, demonstration projects can be performed to introduce the concept. Congestion pricing should not be introduced on a facility that traditionally has no charge. Two recommended facilities that should be used to introduce this concept are as follows:[29]

Table 4-5. Advantages and Disadvantages of Toll Road Financing. [28]

Advantages	Disadvantages
• Timely construction, no delays. • Reduced construction costs. • Earlier realization of benefits, such as lower fuel costs, greater safety, comfort and convenience. • Regular inspections and maintenance required by lenders. • Inclusion of operating costs in financing and income plans; costs include police, emergency services, snow and ice control. • Ability to free tax funds for "free" roads.	• Higher maintenance and operations costs, in most cases. • Infrequent access. • Possible adverse effect on other roads in corridor. • Delays at toll booths. • Added costs of borrowing, collecting tolls.

- Existing toll facilities, where off-peak discounts and peak-hour surcharges can be introduced in order to increase ride-sharing incentives and reduce congestion.

- Completely new facilities.

A pricing schedule should be designed so that initial costs are fairly low. These costs should be maintained for a period of 6 to 12 months to "permit behavior patterns to stabilize," after which the cost should increase. This process should continue until the cost is at the desired level. The use of congestion pricing is expected to improve the traffic flow, ridesharing, and emission-reduction experienced on the roadway. These improvements should be quantified in the demonstration project to prove these benefits.

Table 4-6 presents barriers to the implementation of congestion pricing using AVI technology, and recommended strategies. Three arguments that justify the use of congestion pricing are:[30]

- Economic argument—automobile users should pay the full cost of the congestion their use of the road imposes on the public.

- Congestion is reduced.

- Environmental improvement—less congestion means less air pollution due to slow moving traffic flows.

Channelizing Devices for Work Zones

There is a wide variety of channelizing devices currently available for use in highway work zones. The MUTCD presents basic design standards for these devices and general guidelines for their use; however, it is the highway agency's choice where and when to use particular devices or sets of devices. Typically, work zone channelizing devices are chosen on the basis of one of the following practices:

1. Select the device with the lowest initial cost.

2. Select the device that is normally used by the agency.

Table 4-6. Barriers to Congestion Pricing Implementation. [30]

Barrier	Description	Recommended Strategies
Technical		
AVI technology	• Equipment unreliability.	• More research.
Logistical Problems	• Numerous structures at checkpoints needed. • Equipping vehicles with proper equipment. • Geography of the city.	• Provide financial incentive for equipment installation on vehicles. • Many problems solved with time.
Uniformity	• Different AVI technologies used by each agency.	• Develop standards for AVI systems. • Will require legislation but should not be a problem.
Social and Political		
Congestion Pricing as an Additional Tax	• Public perceives it as another form of taxation instead of a price to use the road.	• Stress that this is a user fee to support roads, not a tax. • Stress that revenues from the system will be linked to further expenditures on the system. • Describe lower rates at non-peak periods as a reward for traveling at that time.
Privacy	• Public does not want their vehicular movements monitored.	• Stress that a congestion pricing payment is no different than an itemized telephone bill. • Information not used for enforcement. • Pictures only taken of license plates. • Not looking at individuals, just tags.
Equity	• Forces poorer drivers off the road--politically undesirable.	• Show that it would not be any more equitable or inequitable than present system.
Business Interests	• May create decreased interest in downtown shopping areas.	• Effects not certain--need demonstration project.

3. Select a device already in stock.

4. Select the "very best" device just in case.

Each of these approaches has drawbacks, and collectively they have resulted in inflated job costs, unnecessarily large inventories, lack of uniformity, and in some cases, improper device use. As an alternative to the typical methods used for selecting channelizing devices for work zones, the value engineering approach (see **Module 11**) can be used. The approach involves 7 steps:[31]

- Determine the intended purpose of the devices.

- Identify available alternative devices.
- Select appropriate measures of device performance.
- Determine the performance of the alternative devices on the basis of selected performance measures.
- Estimate the total cost of each acceptable alternative.
- Calculate the relative value of each acceptable alternative, where value equals performance divided by cost.
- Select the alternative with the greatest value.

The following recommendations should be followed when using this approach:[31]

- Base value engineering study on comprehensive and accurate information.
- Use a team approach—team members are well trained and diverse in experience and technical background.
- Consider value engineering approach most appropriate for central office use—through pooling central office staff and data-gathering resources.

DESIGN/CONSTRUCTION

LCS and DMS Placement

A panel of eight TxDOT managers and engineers with expertise in Lane Control Signal (LCS) design and operation in freeway traffic discussed problems and potential solutions regarding LCS. Their recommendations included the following:[13]

LCS Visibility

- Drive throughs should be performed by TxDOT personnel when a red X is displayed due to its low legibility distance.
- If the department chooses to require double-stroked symbols for LCS displays, a maximum pixel spacing and/or effective stroke-width-to-letter-height should also be specified.
- A regular cleaning and bulb replacement schedule should be implemented.
- Back plates or back panels should be considered for placement behind LCS on overhead sign structures.

LCS Spacing and Mounting Locations

- LCS should be placed every 0.8 to 1.6 km (0.5 to 1.0 mi), but special geometric characteristics and driver decision points should also be considered during this placement.
- Mounting LCS on a cross-street bridge structure rather than on an overhead sign structure is desired.
- Positive guidance principles should be employed when determining the placement of the LCS.

DMS Placement

It is recommended that the following points should be considered when placing dynamic message signs for freeway management:[32]

- Signs should be targeted at an audience that is made up of local drivers generally familiar with the surrounding street system. This allows less detail in the messages presented.

- A 3-line sign with 18 characters per line is recommended.
- A letter height of 46 cm (18 in) is recommended to allow sufficient legibility distance.
- The minimum spacing between a DMS and other guide signs not co-located with the DMS should be 305 m (1000 ft).
- The maximum distance from a detour exit that a DMS should be placed is 1220 m (4000 ft).
- DMS located upstream from an interchange should not be used for messages requiring a detour maneuver beyond the interchange.
- Placing DMS on the far side of a sharp horizontal or vertical curve may limit the driver's ability to read the sign.
- An unrestricted visibility distance of 183m (600 ft) should provide the driver plenty of time to read and comprehend the message.

Use of Narrow Lane and Shoulders

Design guidelines for the implementation of projects involving the use of shoulders and narrow lanes were developed in a recent NCHRP research study based on the experience of agencies that participated in the study. Additional details are provided in the NCHRP report. The guidelines developed in the research represent more of a guide for *applying* design standards. They are intended to supplement, rather than supersede, existing standards. Following is a selection from the guidelines: (14)

- Field observations indicate that operational impacts of reduced shoulder or lane widths are most notable in the transition area. It is recommended that the transition area be located on a tangent, preferably in an area where there are no crossing structures, retaining walls, or other roadside appurtenances.
- On facilities with high truck percentages, it is recommended that trucks be restricted from using a right shoulder lane, which typically does not have adequate pavement structure to support heavy trucks.
- Emergency turnouts and crossovers should be provided along altered sections. It is recommended that enforcement and emergency response personnel be involved in selecting locations. These turnouts should be large enough to accommodate a tractor trailer unit and at least one piece of emergency equipment. The location of crossovers should be considered in conjunction with incident management plans.

4.5 EXAMPLES

SAN ANTONIO (TRANSGUIDE)

Description of System

In late 1995, the Texas Department of Transportation began operation of an advanced traffic management system on approximately 41.6 km (26 mi) of freeway in San Antonio, Texas. The system, labeled TransGuide, includes inductive loop detectors and closed-circuit television cameras for traffic surveillance, and a combination of dynamic message signs and lane control signals to convey freeway traffic conditions and lane status information to motorists on or approaching the freeways.

Other components are being introduced as the technology is developed. The system is also being expanded to include additional freeways in the San Antonio area.[34]

Lane control signals are placed approximately 1.6 km (1 mi) apart between major freeway-to-freeway interchanges. Signal spacings are then reduced to about 0.8 km (0.5 mi) spacing near the interchanges. Dynamic message signs are located upstream of major detour points on the freeway, and on the entrance ramps to the freeway. When an incident or work zone activity requires one or more lanes to be closed anywhere within the limits of TransGuide operations, predefined information dissemination plans are called from the computer database and implemented on the lane control signals and dynamic message signs. The actual plan (termed a scenario) selected is based on the expected duration of the incident, the time of day, and the number of lanes blocked.

A scenario consists of changes in up to three sets of lane control signals upstream of the incident. The two sets of signals closest to the incident and over the lane(s) that are blocked display a red X, and the open lanes display a green downward arrow. At the third signal location (the farthest upstream), signals over the lanes that are blocked display a downward diagonal yellow arrow to the left or the right. These diagonal arrows are not currently specified in the MUTCD as acceptable lane control signal symbols.[5] However, they are utilized extensively in Canada and other countries for this purpose. Also, recent research suggests that diagonal arrows may be better understood as a transition symbol than the yellow X that is currently allowed by the MUTCD for this purpose.[33]

Effects of Information

Recent evaluation of the TransGuide system indicates that drivers are obtaining and responding to the overall dynamic information system. For example, the number of drivers reportedly diverting to alternative routes in response to available information (primarily radio traffic reports before TransGuide, reports plus the dynamic message signs and lane control signals after TransGuide implementation) has increased from 33 to 80 percent.[34] However, the effect of the dynamic information system upon driver lane usage upstream of the incident has not been as well defined to date. Limited data suggests that a small portion of motorists do move from the closed lane to the open lane farther upstream of an incident when the lane control signals indicate a downstream blockage.[35] Survey results also suggest that the signals are seen and correctly interpreted by most drivers.

Operators of the TransGuide system have indicated the importance of providing accurate and useable information on the dynamic message signs in conjunction with the lane control signal displays in order to obtain appropriate driver responses. In one instance, operators closed two lanes where glass had been dropped on the road. They indicated "debris in left two lanes" and activated the appropriate lane control signal sequences, but saw drivers continuing to utilize the left lanes for travel (through the area of glass). They then switched the sign to read "glass in left two lanes." Nearly all drivers vacated those lanes and remained out of those lanes until the lane control signals indicated that all lanes were open.[35]

SR 91, ORANGE COUNTY, CALIFORNIA CONGESTION PRICING

Recent construction of four express lanes (two each way) in the median right-of-way of State Route 91 in Orange County, California, was a $126 million undertaking that was accomplished through an innovative franchising agreement between the public sector and private enterprise (California Private Transportation Company, CPTC). To pay for construction, CPTC will collect tolls from the facility for the next 35 years, after which it will revert to State operation. The project has received extensive publicity as the first implementation of congestion pricing in the U.S. Users of the facility will be charged a toll ranging from $0.25 to $2.50, depending upon the time of the day and traffic demand levels.

A key component of the SR 91 system is the sole use of electronic toll collection equipment. No toll booths are present along the facility. Instead, only overhead radio receivers, which read small transponders that motorists place in their windshields are used to approve approaching vehicles to enter the express lanes and make appropriate toll charges to the motorist's account. Toll violators may be ticketed by the California Highway Patrol or via the mail and receive a $100 to $300 fine.[36] The revenues from toll collections are used to pay for the costs of enforcement. At the same time, the facility is designed to encourage carpooling. Buses, vehicles with three or more occupants, motorcycles, and vehicles designated as emission-free can use the express lanes for free (although they must still have a transponder in their vehicle).

Because of the system's recent initiation, experiences to date are limited. However, it was reported that within just a few weeks of its opening, the toll lanes and nearby Metrolink trains drew so many commuters that congestion levels on the mixed-use lanes on SR 91 dropped to levels not seen in 15 years.[36] After only a few months of operation, over 50,000 transponders are in use in the SR 91 corridor.

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MODULE 5. RAMP CONTROL

TABLE OF CONTENTS

MODULE 5. RAMP CONTROL

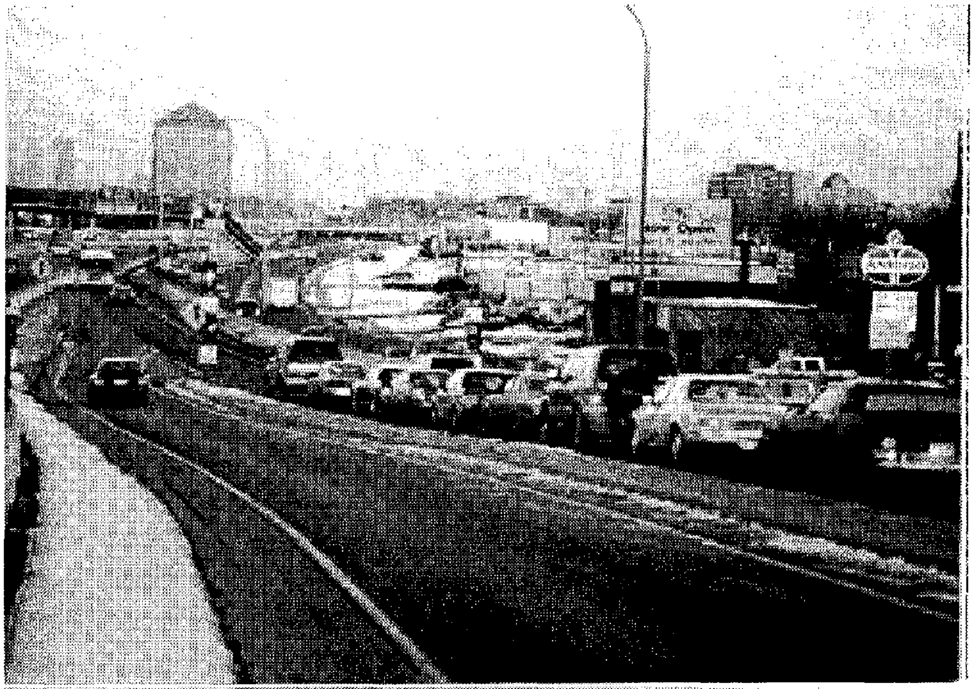

Figure 5-1. Ramp Meter with HOV By-Pass in Minneapolis, MN.

5.1 INTRODUCTION

The geometric design of a freeway ramp (width, curvature, vertical alignment, etc.) can have a positive or negative influence on both the operation of the ramp itself and on the freeway at, or upstream of, the merge point. Freeway design standards generally address those considerations. Ramp control, on the other hand, seeks to regulate the flow of vehicles at freeway ramps in order to achieve some operational goal such as balancing demand and capacity or enhancing safety. Other than freeway-to-freeway interchanges, freeway ramps represent the only opportunity for motor vehicles to legally enter or leave a freeway facility and, therefore, the only point at which positive control can be exercised. Freeway ramp control systems have been in operation at various locations throughout the country since the early sixties. It is estimated that ramp control systems are operated in over 20 geographical areas at present, with individual metered ramps numbering over 2300.[(1)]

Most ramp control systems have been proven to be successful in terms of reduced delay and travel time (and the concomitant reductions in fuel consumption and vehicle pollutants, and in accident reduction.) They are more effective when they are part of an integrated transportation management plan that incorporates other systems as described in other modules of this document. Deployment of ramp control systems has been somewhat limited due to some public resistance to being stopped on a freeway ramp for no readily apparent reason, although the ramp metering rate may reflect a downstream bottleneck such as an incident.

DEFINITION OF RAMP CONTROL

Freeway ramp control is the application of control devices such as traffic signals, signing, and gates to regulate the number of

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vehicles entering or leaving the freeway, in order to achieve some operational objective. Typically, the objective will be to balance demand and capacity of the freeway in order to maintain optimum freeway operation and prevent operational breakdowns. Ramp metering may also be applied for safety considerations where certain geometric inadequacies or other constraints exist.

APPLICATION OF RAMP CONTROL

The primary application of ramp control, commonly known as ramp metering, has been on freeway entrance ramps. However, ramp control has been applied in other situations as well.

Entrance Ramp Metering

Metering on entrance ramps involves determination of a metering rate (typically "4 to 15 vehicles per minute" are minimum and maximum rates for single lane metering) according to some criteria such as measured freeway flow rates, speeds, or occupancies upstream and downstream of the entrance ramp. The rates may be fixed (pre-timed) for certain periods, based on historical data, or may be variable minute-by-minute (traffic responsive) based on measured traffic parameters. The entry of vehicles at that rate is regulated by one or more traffic signals beside the ramp at driver's-eye height. Vehicle sensors may be located at points along the ramp to signal the blockage of the merge area or backing of the ramp queue into a cross street.

Entrance Ramp Closure

Typically lower metering rates (say 2 to 4 vehicles per minute) over a sustained period of time are not acceptable to drivers, and they will tend to disregard the signal. In the extreme case where the metering rates must be sustained at lower levels, it may be necessary to physically close the ramp with automatic gates or manually placed barriers. Obviously, this extreme case may cause negative public reactions and should be applied only after considerable planning and a public information program.

Exit Ramp Closure

Metering of exit ramps is obviously not appropriate but closure with automatic gates or manually placed barriers, with adequate freeway warning signs, may be used to accomplish certain operational objectives. For example, if the exit ramp terminus at the cross street has such inadequate capacity that exit ramps queue onto the freeway, the ramp may be closed to encourage drivers to exit upstream or downstream where more capacity is available.

Systemwide Ramp Control

Although individual ramps may be metered or closed for specific reasons, ramp control is most effective when ramps are metered in an integrated system manner. Individual metering rates are determined by conditions over a larger portion of the freeway, not just in the immediate area of the ramp. Although local controllers may suffice in individual ramp metering as described above, system-wide control requires a central or distributed control system master with control algorithms and interconnection by some communications media.

RELATION TO OTHER FREEWAY MANAGEMENT FUNCTIONS

Ramp control is closely related to other infrastructure elements in a freeway management system. The widespread, widely embraced Intelligent Transportation Systems (ITS) movement has further emphasized the benefits of integrated system elements. Other modules in this handbook describe specific subsystems of a freeway management system. The following paragraphs briefly describe the relationship of those elements to freeway ramp control.

Surveillance

The surveillance subsystem includes various techniques for determination of freeway and ramp operating conditions that may have an influence on metering rates or operational overrides. Specific information on surveillance technology can be found in **Module 3** of this handbook. The paragraphs below provide a description of the types of surveillance used in conjunction with ramp control.

Vehicle Detection

Vehicle sensors located on the freeway can serve multiple purposes if located correctly during the design and construction phase. Detectors located in the freeway lanes generally have the purpose of input to incident detection algorithms and for system operation evaluation. Freeway detectors can also be used as input data in determining metering rates in traffic responsive operations. Counting detectors located on entrance and exit ramps serve as input and output data in defining a closed system operation for estimating average delay in the system.

Closed-Circuit Television

Closed-circuit television (CCTV) are used to detect and verify incidents in the overall surveillance subsystem. Cameras can also be used to fine tune and monitor operation of individual metered ramps, precluding the necessity for on-site field observation.

Environmental Sensors

Due to grades on ramps it is often necessary to adjust ramp metering rates or terminate operation during extreme weather conditions such as icy or extremely wet roadway surfaces. Environmental sensors will give early warning when such conditions exist.

HOV Treatments

Preferential treatment of high-occupancy vehicles at entrance ramps has been used successfully in several locations on entrance ramps. These systems have primarily involved a separate lane to bypass the ramp signal, and single occupant vehicle queue.

Information Dissemination

Notification of travelers of ramp closures can be effected by either pre-trip information dissemination devices such as kiosks, Web site, and Community Access Television (CATV), or by on-road devices such as variable message signs or highway advisory radio. Other operational changes in ramp operations that may be of interest or assistance to travelers may also be communicated.

Communication

Unless the controlled ramps are isolated and operate in a nonsystem mode, the communication subsystem must accommodate for the control, detection, and signal hardware.

Control Center

While ramp control systems generally have the capability to operate in an isolated manner without supervision from a central or distributed master, most are interfaced to a central management system through the communication system.

BENEFITS OF RAMP CONTROL

Positive benefits of ramp control have been documented widely and can be found in the general literature.[1] Benefits have been most commonly reported in typical measurable traffic operations parameters such as reduced delay and travel time, increased throughput and operating speeds, and reduced accident experience. Other benefits less easily quantified may also accrue from ramp control. The case studies in the following section summarize some reported benefits of ramp control. The following paragraphs describe typical benefits, both quantifiable and less easily quantified.

Improved System Operation

Freeway traffic operating characteristics that can be expected to be influenced by ramp control systems are: speed, travel time, and delay. Typically, freeway operation has been described as a series of relationships between volume, speed, and density (or occupancy). The general objective of most freeway management systems is to optimize throughput while maintaining freeway operation in the non-congested area of the curve. By controlling the number of vehicles entering the freeway based on available downstream capacity to accommodate upstream freeway vehicles and entering ramp vehicles, freeway operation is enhanced. In another scenario, the objective may be to maintain some target level of service (as indicated by speed.) Again, by controlling the rate at which vehicles are metered onto the freeway, a target operating condition is maintained. Improvements on the freeway must be weighed against ramp delays and travel times which may be increased for travelers who choose to divert to other facilities.

Improved Safety

Freeway ramp control can effect decreased vehicle crash experience on both the ramp (and merging area) and on the freeway. By breaking up platoons of vehicles, which may enter the ramp from discharge at an adjacent intersection or traffic generator, the incidence of rear end vehicle crashes is decreased in the merging area, where multiple vehicles compete for gaps. Vehicle crashes on the freeway are also reduced as the merge becomes smoother, and freeway drivers in the outside (merging) lane are less likely to have to brake abruptly or make lane-change maneuvers. Finally, in system-wide operation the overall freeway is maintained in a more stable, uniform operational mode and vehicle crashes resulting from stop and go operations are reduced.

Reduced Vehicle Operating Expense

Improved system operation has the direct and quantifiable result of reduced vehicle operating expense. Reductions in the number of stops and speed changes translate to related reductions in vehicle operating expense. The most significant savings are related to the reduction of vehicle crashes.

Means for Positive Freeway Traffic Control/Management

There are few opportunities to actively "control" freeway traffic on a routine basis. Obviously, police officers working freeway incidents control freeway traffic, but not on an everyday basis at the same location. Passive control, such as suggestions or advisories via pre-trip planning information sources or en route signing, may either be followed or ignored. Ramp control offers a means to regulate or control freeway bound vehicles.

Reduction in Vehicle Emissions and Fossil Fuel Consumption

The direct correlation between improved traffic operations and the reduction of fuel consumption and vehicle emissions is well-known. Reductions in delay and numbers of stops, together with the maintaining of more uniform speeds as described previously will, in virtually every situation, result in a similar reduction in fuel consumption and vehicle pollutants. An exception might be where speeds are in higher ranges than is typically experienced during peak periods on metropolitan freeways.

Coordination With Other Corridor Management Elements

Intelligent Transportation Systems (ITS) defines certain core infrastructure elements known collectively as an intelligent transportation infrastructure. The importance of the interrelationship of the various subsystems applies to ramp control as a subsystem of Advanced Transportation Management Systems (ATMS) as well. Examples include the following:

- Ramp metering systems should be coordinated with surface street traffic signals to account for spill back of ramp queues.
- Information on ramp closures may be communicated by off-freeway information devices.
- High Occupancy Vehicle programs may involve special treatment of HOV at entrance ramps.
- Special ramp operating procedures may be instituted during incident conditions.

Promotion of Multimodal Operation

By giving preferential treatment to High Occupancy Vehicles at entrance ramps, the ramp control subsystem can promote travel mode shifts and reduction of single occupancy vehicles.

MODULE OBJECTIVE

The objective of this ramp control module is to provide insights into and guidelines on the issues associated with planning, designing, constructing, operating, and maintaining a ramp control subsystem in a freeway management system. This module also gives guidance to planners, designers, managers, and operators in public relations aspects of freeway ramp control.

MODULE SCOPE

The scope of this ramp control module is intended to include general guidelines as well as serving as a guide to references and other documentation that may be of benefit to planners, designers, and operators of freeway management systems. It is not intended to provide detailed design specifications or other construction documents. Typical plans, specifications, and estimates documents can usually be obtained from agencies already operating ramp control systems.

5.2 DECISION PROCESS

Freeway ramp control is one of the few direct means of controlling access to the freeway main lanes. Indirect control would include such methods as encouraging diversion to other facilities, or mode changes through communications with travelers prior to their trips or en route. However, direct limiting of access through ramp control can be effective and accepted by the driver only if it is applied in those circumstances where traffic characteristics, demand patterns, and infrastructure are conducive to the technique.

PROBLEM IDENTIFICATION

Traffic engineers and other professionals will no doubt have an intuitive feel for where freeway operational deficiencies exist in a congested freeway environment. However, in order to address potential solutions to alleviate such problems, it will be necessary to quantify deficiencies in both time and space, i.e. during what portions of the day, and at which locations within the freeway system, are such deficiencies present. It is important to document the freeway operations from a traffic characteristics and infrastructure aspect in order to identify and define the problem as well as to provide a basis for measurement of effectiveness and to monitor for future changes. Several techniques may be used to illustrate a systemwide picture of freeway traffic characteristics, design features, capacity deficiencies, vehicle crash experience, and other features of interest, including the following:

- Schematic maps, color coded or otherwise delineated to show various levels of operation, other traffic characteristics, and crash experience at various periods of the day.
- Schematic maps, color coded or otherwise delineated to show various infrastructure characteristics.
- Spreadsheet or other tabular format.
- Descriptive write-up.
- A combination of the above items.

Level of Service / Capacity Deficiency / Bottlenecks

The *Highway Capacity Manual* provides definitive guidance in determining qualitative and quantitative pictures of freeway operations. Capacity deficiencies, or freeway bottlenecks, will be a function of traffic demand and characteristics as well as the geometrics and other design features of the roadway itself. It will be necessary to pinpoint where such deficiencies exist, and the contributing factors. Subsequent sections of this module provide a detailed listing of data required for analysis of capacity and level of service in relation to ramp control, as well as other analyses. **Module 2** provides more guidelines for capacity and level of service analyses.

Capacity and Level of Service (LOS) should be determined for existing traffic characteristics and infrastructure as well as those parameters for future conditions in some horizon or build-out year. Planned additions to the freeway section under consideration, or to alternative routes or modes, may either obviate the need for ramp control or influence its implementation schedule.

Vehicle Crash Experience

The occurrence of vehicle crashes on freeways may be attributed to a variety of factors, some of which may not be correctable by ramp control techniques. Those types of accidents most likely to be alleviated by ramp control include:

- Rearend crashes on freeway main lanes due to over-capacity operation (bottleneck conditions).
- Lane change crashes on freeway lanes due to over-capacity merging conditions.

- Lane change crashes on freeway lanes due to inadequate sight distance or to other geometric deficiencies in the merge area.

- Run-off-the-road crashes caused by drivers avoiding shock waves.

- Rearend crashes on the entrance ramp due to queuing in the merge area.

Crash records may be summarized by section of freeway, location, time of day, and type of crash to determine if ramp control has the potential to reduce collision experience.

Inventory of Infrastructure

Except in the case of an isolated, single entrance ramp location, a ramp control system is generally a subsystem of a comprehensive freeway management system. Much of the infrastructure data required for problem identification will likely be available. The following types of data should be assembled for the freeway system under consideration.

Freeway System

- **Lane Configuration.** Number and types of freeway lanes (through, weaving, acceleration, deceleration) should be determined and tabulated and/or graphically displayed.

- **Ramp Locations.** Entrance and exit ramps should be located, with link distances between ramps determined.

- **Geometrics.** Typical geometrics such as freeway lane and entrance ramp width, vertical and horizontal alignment, ramp length, ramp storage capacity, merging area, and sight distance restrictions should be determined and tabulated. Type of ramp design (loop, linear) should be noted.

- **Frontage Roads.** Presence of frontage roads and their lane configurations should be determined and tabulated.

- **Interface to Crossing Freeways.** Freeways will generally be interfaced or connected via a freeway interchange. The proximity of another freeway's connections to the entrance ramps being considered for ramp control should be noted to determine if any special measures are needed.

- **Interface to Crossing Arterials.** The relationship of entrance ramp metering to an upstream cross street is critical. If not properly considered, queuing from the ramp signal into the cross street can cause concerns to the agency responsible for arterial street operation, as well as public resentment. Type of crossing roadway, traffic control, mix of traffic, ramp storage area, and other factors should be noted for each ramp.

Existing Freeway Management Systems

Normally there will be only one agency responsible for freeway operations in a particular geographic area, but there are some situations where more than one agency may be involved. For example, a dense metropolitan area may extend into two States or a tollway operated by a toll authority may interface to a state-operated freeway. As part of the inventory, the existence of such systems should be confirmed and documented to include the following:

- Participating agencies.

- Type and location of control center facility.

- Type of control system (central, distributed, hybrid, local).
- Surveillance and detection.
- Information dissemination (pre-trip, en route).
- Communication system (medium, leased, or owned).

Existing Ramp Control Systems

In lieu of a full blown freeway management system, some entrance ramps may be metered in an isolated manner with a local, non-system controller. Inventory should include the following:

- Responsible agency.
- Type of controller.
- Surveillance and detection.
- Communication system.

Other Relevant Field Systems

Other relevant field operational systems that may have an effect on freeway operation should also be identified. Such systems would include the following:

- High occupancy vehicle lanes or ramps.
- Incident management teams.
- Accident investigation sites.
- Courtesy and motorist assistance patrols.
- Hazardous material routing and restrictions.

Inventory of Traffic Characteristics

Certain traffic and flow characteristics will influence the potential success and the design of freeway ramp control systems. Typical traffic characteristics are listed below. **Module 2** provides a more detailed description of individual traffic parameters.

Traffic Composition

The composition of the traffic stream on the freeway main lanes and the entrance ramp will influence both the type of control and the design of the system. A determination of the percentage of passenger vehicles, commercial vehicles, and transit vehicles should be made for peak periods.

Traffic Flow

Traffic volumes and traffic flow rates during peak periods will be required for capacity and level of service determinations to define the operating conditions and problem locations that might be addressed by ramp control techniques. Traffic flow data will also be used in determining metering rates and periods of operations. Traffic flow data requirements will include the following:

- Traffic volumes and flow rates, generally by 15-minute periods, on freeway lanes and entrance and exit ramps.
- Distribution of freeway vehicles by lane.
- Traffic volumes and flow rates on adjacent service roads.
- Traffic volumes and flow rates on cross streets served by the freeway ramps.

Other Traffic Parameters

Other typical traffic parameters that may be of value either in defining operating conditions and problem locations or in developing control strategies include the following:

- **Lane Occupancy.** Defined as the percentage of time a particular sampling "spot" on the freeway is occupied, this parameter may not be economically measured until such time as a surveillance system is in place. Its primary use is in selecting metering rates, although it can identify operational problems if reasonably available. It may be derived from speed and volume data, which may be more readily available prior to system implementation. The reader is referred to **Module 2**, or the *Highway Capacity Manual*, for a discussion of the relationship of lane occupancy to freeway level of service.[2]

- **Traffic Density.** Defined as the number of vehicles per lane per mile, traffic density may be determined with aerial photos or by freeway input/output counts. The reader is referred to **Module 2** or the *Highway Capacity Manual* for a discussion of the relation of traffic density to freeway level of service (LOS).[2]

- **Speed.** Vehicle speeds are another indicator of freeway LOS and may be determined by traditional speed measurement techniques prior to system installation.

- **Vehicle Occupancy.** As opposed to *lane* occupancy, *vehicle* occupancy is generally defined as passengers per vehicle and is usually determined by manual observation. This parameter may be useful in determining the viability of preferential treatment of high occupancy vehicles (HOV) at entrance ramps.

Temporal Variations

As previously mentioned, it is important that traffic operations characteristics be collected and analyzed in incremental time periods so that ramp control operation schedules can be developed optimally. Even though the system may be traffic responsive, it may be advantageous to operate either on a predictable schedule or with limited variations in schedule. Plotting various parameters by time period in 15-minute increments will help predefine those operational periods. Although ramp control is usually associated with peak periods, plotting data over a longer period may indicate other times when ramp metering may be appropriate.

Ramp Geometric Limitations

Inventory of infrastructure elements and field observations will provide information to evaluate the physical viability of individual ramps to support ramp metering. The following physical factors should be considered:

- **Ramp Storage.** How many vehicles can reasonably be stored or queued on the ramp upstream of the metering signal without interfering with cross street traffic?

- **Ramp Width.** Is there adequate width for side-by-side metering and/or preferential HOV bypass lanes?

- **Grade.** Are ramp grades restrictive during adverse weather or for certain types of heavy vehicles?

- **Merge Area.** Does the present design facilitate a smooth merge?

Cross Streets

Limited vehicle storage for queuing at ramp signals may adversely affect operation of an upstream cross street. Presence of such conditions should be noted so that they can be considered during design of control strategies.

Service Roads

As with cross streets, limited vehicle storage for queuing at ramp signals may adversely affect operation. The type of cross street (major arterial, collector, etc.), traffic demand, presence of signals, and their operation must be considered.

Summary of Problem Definition

Traffic characteristics and demand, as well as geometric factors, are important in evaluating existing and future conditions and the potential applicability of freeway ramp control. While not all data items listed above may be available to the designers and planners, it is important to collect and assemble as much relevant data as feasible for the analysis. Many of the data items noted above may also be used during the design of the system and development of the control strategies and software.

IDENTIFICATION OF PARTNERS AND CONSENSUS BUILDING

Freeway ramp control is the primary method of managing demand once drivers have committed to use the freeway for their trip. It has been proven to be an effective means of balancing capacity and demand and reducing delay and vehicle crashes. It can also be one of the most controversial traffic control techniques. Delay at ramp signals or closing of a ramp may be considered too drastic by some drivers, and even an infringement on their rights. Such delays will be offset by overall system improvement, but this is not always apparent to the driver. Without ramp control, drivers may experience even more delay on the freeway than they would have experienced at the signal. Again, this may not be readily discernable to the driver.

In most instances, a State Transportation Department or Toll Authority will have the responsibility for operation, but not necessarily enforcement, of a ramp control system. It is important for the agency responsible for operation of the ramp control system to identify and establish relationships and communications with all agencies that may have a role in operation and enforcement so that they may be brought into the planning and design process. It is also important that the benefits of ramp control, which are realistic and measurable, be fully explained and that it not be oversold as adding capacity (such as adding a lane). It should be characterized as a means to make maximum use of available capacity by managing capacity and demand.

Relation to Other Agencies

City/County Traffic Operations Agencies

Because of the close relationship and interface between surface street traffic operation and signalization and access to and from freeway ramps, it is important to involve those agencies and build a consensus for the system at all levels, from the agency head to the operations engineers to the control system operators. To the extent possible, system goals and objectives should be developed mutually.

Enforcement Agencies

Depending on State and local ordinances or interagency agreements, State, local, or transit police may be responsible for enforcement of ramp control devices. Compliance with ramp control signals is essential if the system is to operate efficiently. Enforcement agencies must be brought into the process early and must understand the goals and objectives of the system and the operating philosophies. The signals must be enforced, but over-enforcement can have a detrimental effect on driver attitude and, in fact, cause deterioration of operation as drivers are stopped on the freeway shoulder. Compliance with the signals must be established early and monitored to ensure that an acceptable level is maintained. A program of public information and police support is essential.

Emergency Management Agencies

Fire, police, medical, hazardous materials, motorist assistance patrols, and other agencies responsible for emergency management on the freeway system should be aware of the proposed system and be fully informed as to its operation and benefits. Any special support required of the particular agency should be solicited.

Public Transportation Agencies

Public transit agencies that access freeways via metered ramps, or that exit on ramps which may be closed during certain periods of the day, should be also be brought into the planning and design process at an early stage. This is particularly important where preferential treatment of high-occupancy vehicles such as buses is being considered.

Relationship to Elected Official / Political Environment

Although a support base and consensus may be built at the staff and agency level, it is important to build support with elected officials as well. As stated above, benefits of ramp control are real and measurable in the overall system, but may not be apparent to the individual driver who experiences delay at an entrance ramp or must reroute due to a ramp closure. Citizen (voter) complaints can have an adverse effect on the success of ramp control projects. System planners, designers, and operators must help those in office understand the goals, objectives, and operating characteristics of the system prior to system turn-on.

Importance of Enforcement / Judicial System

The importance of enforcement of ramp control has been previously stated. Accordingly, enforcement must be supported by the judicial system. A standard ramp traffic signal that meets the requirements of the *Manual On Uniform Traffic Control Devices* (MUTCD) is a legally enforceable device.[3] However, because ramp control systems are not as familiar as intersection signals, certain judges may be inclined to dismiss related citations. It is important to ensure that the proper laws and ordinances are in place and that judges to whom appeals of citations may be taken are informed of the system goals, objectives, and operating characteristics prior to system turn-on.

Relationship With Media

Local news media, both print and electronic, can have a profound effect on the success of ramp control systems. It is important that a media relations plan be developed to help ensure that positive support is secured. Methods for disseminating information about ramp control system include brochures, town meetings, and handouts.

As stated previously, it is important that the benefits of ramp control, which are realistic and measurable, be fully explained and that they not be oversold as adding capacity (as in the case of adding a lane). It should be characterized as a means to make maximum use of available capacity by managing capacity and demand.

ESTABLISHING GOALS AND OBJECTIVES

Module 2 describes the process of establishing system goals and objectives. Goals and objectives of the ramp control system should complement and not conflict with overall system goals. In the rare case of stand-alone ramp control system, the goals and objectives may differ from those in an integrated system.

Typical overall system goals and objectives and how they may be supported by a ramp control system are listed below.

- **Reduced Accident Experience.** Maintaining smoother freeway flow by metering and improving merge conditions on the ramp.

- **Maintaining Acceptable Freeway Level of Service.** Metering on entrance ramps to maximize freeway flow rates within acceptable ranges.

- **Balancing Demand/Capacity in Freeway Corridor.** Metering on entrance ramps to encourage drivers to shift to other ramps or facilities with available capacity, or to change trip time.

- **Reduction of Single-Occupancy Vehicles.** Preferential treatment of car pools on entrance ramps.

- **Reduced Vehicle Delay.** Metering on entrance ramps to limit freeway flow rates within acceptable ranges.

- **Incident Management.** Closing ramps upstream of a freeway incident and increasing metering rates downstream.
- **Promotion of Multimodal Operation.** Preferential treatment of buses on entrance ramps.

- **Reduced Noise.** Smoother Traffic Flow Reduces Engine Revving.

- **Reduced Vehicle Operating Costs.** A result of smoother traffic flow and reduced stops.

- **Reduced Fuel Consumption.** A result of smoother traffic flow and reduced stops.

- **Reduced Vehicle Emissions.** A result of smoother traffic flow and reduced stops.

ESTABLISH PERFORMANCE CRITERIA / MEASURES OF EFFECTIVENESS

Performance criteria express broad goals in tangible or measurable terms. Better operation is obviously a goal to be strived for, but is difficult to measure and may have different meanings for different people. With the exception of the first goal (balancing capacity and demand), the goals and objectives listed above are tangible and measurable in readily understandable terms both before and after system turn-on. Level of service can be calculated, vehicle crash rates can be tabulated from law enforcement data bases, speed and delay studies can determine operating conditions that can be used to calculate delay, fuel consumption, and vehicle emissions. Transit records are available to establish changes in bus patronage, and field studies can measure vehicle occupancy.

DEFINE FUNCTIONAL REQUIREMENTS

Functional requirements for the ramp control subsystem are fairly straightforward and are summarized below:

- **Displays.** Signals on the ramp for vehicle drivers and advance warning signs.
- **Local Controller.** Device to receive and store vehicle detector information and operate signals according to internal logic or according to a central supervisory system.
- **Vehicle Detectors.** Devices to measure conditions on the freeway and ramp.
- **Control Logic.** Programs residing in the local controller for non-system operation, or at a central system processor for system operation.
- **Communications.** Leased or owned communication link between field location and central management site for data and control command transmission.
- **Central Control System.** Computer, peripherals, and operator interface devices.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The June 1996 ITS Architecture Executive Summary states (italics indicate adaptation to ramp control systems):

> The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It is not a system design concept. What it does is define the framework around which multiple design approaches may be developed, each one meeting the needs of the user, while maintaining the benefits of a common architecture. The architecture design defines functions (*e.g., collect data from freeway and ramp detectors; and operate and monitor ramp meter signals*) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (*e.g., detectors on the freeway and ramp, signals on ramps, and local controller near the ramp*), the interfaces/information flows between the physical subsystems and the communication requirements for the information flows (*e.g., signal wirelines from the detector to the local controller and from the controller to the ramp signal; two-way wideband communication between the field controller and the central management site.)* In addition, it identifies and specifies the requirements for the standards needed to support national and regional interoperability.

In all likelihood, the functional relationships, data requirements, and information flows for a ramp control system will be dictated by the design of the broader freeway management system. However, in the case of an isolated ramp control system, the architecture will be more in the realm of typical signal design at an arterial street intersection. In any event, an open architecture (one that can be interfaced with in the future) should be employed.

5.3 TECHNIQUES AND TECHNOLOGIES

The great majority of improvements and innovations in freeway traffic management have been in the area of computing and communications technology capability. Computers are faster, have more memory and storage capability, and are more user friendly, and virtually every person involved in freeway management has ready access to a personnel computer. Development of improved communications technology has paralleled development of the more capable computers. Broad band fiber optic cable, which accommodates both high speed digital data and video, has become the standard in most freeway management systems, rather than twisted-pair and coaxial cable for hub-to-hub transmission. Wireless technology (such as cellular, microwave, packet radio, and other media) has provided a means for quick implementation until the more capital intensive construction of fiber can be funded. Many systems operate with a hybrid communication system that combines multiple media including leased telephone lines and fiber cable. The freeway management techniques and strategies documented in the 1983 *Freeway Management Handbook* were much the same as those documented in the 1985 *Traffic Control Systems Handbook,* although newer technologies were described.[5,6]

The 1996 *Traffic Control Systems Handbook* documented further developments in computing and communications hardware which had application in freeway management.[7] Other modules of this handbook specifically address hardware and software that have application in the freeway management arena.

The basic freeway ramp control techniques have not changed appreciably. Field displays and control strategies such as pretimed metering, traffic responsive metering, and system metering algorithms are still valid but with the increased computing and data transmission techniques, those algorithms can operate faster and virtually in real-time leading to more efficient control and evaluation. The techniques described below have been drawn from previous handbooks and updated as necessary to reflect changing techniques.

ENTRANCE RAMP CONTROL

Ramp Closure

Entrance ramp closure is a seldom-used technique except on a short term basis, and is included here for information purposes, and should not be considered comparable to other ramp control techniques. The closure of an entrance ramp during peak traffic conditions is the simplest and most positive form of entrance ramp control. It is also the most restrictive. Therefore, it is usually the least popular and it is also subject to considerable public opposition. However, it has been used successfully as part of a system in a number of cities in the United States and Japan (e.g., Houston, Los Angeles, San Antonio, and Fort Worth, and Osaka and Tokyo, Japan). Closure has also been effectively used in single spot improvements at entrance ramp applications, such as on freeways in Beaumont and Corpus Christi.[6] Closure may be the appropriate measure where an entrance ramp introduces serious weaving problems. Although this type of entrance ramp control can provide the same operational benefits to freeway traffic as the other types, it lacks flexibility. Consequently, if applied inappropriately, it can result in underutilizing freeway capacity, with the consequent overloading of alternate routes.

Application

Because of its limitations, entrance ramp closure should not be considered except under the following circumstances:

- Adequate storage is not available at the entrance ramp to prevent queues of vehicles waiting to enter the freeway from interfering with surface street traffic. The closure of the entrance ramp would eliminate the storage problem.

- Traffic demand on the freeway immediately upstream of the entrance ramp is at capacity, and an alternate route with adequate capacity is available. The closure of the entrance ramp would prevent demand from exceeding capacity on the freeway section immediately downstream from it, and it would divert the traffic demand at the ramp to an alternate route. Even if the upstream traffic demand is less than downstream capacity, the rate at which traffic could be allowed to enter the freeway might be so low that it would not be possible to control the entrance of ramp traffic without a large number of violations. In this case, it would be more practical to close the ramp in order to prevent congestion on the freeway.

With regard to the second circumstance, it should be noted that the required demand-capacity relationship could occur because of nonrecurrent congestion as well as because of recurrent conditions. Therefore, closure might be used as a response to incidents on the freeway, as is done in Japan.[8,9]

Ramps may be closed on a temporary basis, on a scheduled basis, or permanently.

- **Temporary Closures.** Entrance ramps may be closed temporarily in response to maintenance or construction activities either on the freeway or the adjacent frontage road or surface street. It is not uncommon for a ramp to be closed by police during management of a downstream incident.

- **Variable Schedule.** Because of extreme recurring downstream capacity deficiencies, ramps may be closed during certain peak periods and open at off-peak times.

- **Permanent Closure.** A ramp may be closed on a permanent basis due to changes in the freeway systems or demand patterns. Concrete barriers or other physical constraints are recommended.

Methods

Methods of entrance ramp closure that have been used in current systems include the following:

- Manually placed barriers such as cross bucks, barrels, or cones.

- Automated barriers such as those used at railroad crossings.

- Signing.

Experience in Detroit and Los Angeles has indicated that signs alone cannot effect a positive entrance ramp closure.[10,11] Automated barriers enable an entrance to be closed and opened automatically, which tends to increase the flexibility of closure as a means of control. Since manual placement of barriers is labor intensive, this approach is best suited for short-term or trial control projects.

Ramp Metering

Metering is a method of regulating traffic flow. When applied as a form of entrance ramp control, metering is used to limit the rate at which traffic can enter a freeway. Maximum practical single lane rate is generally at 900 vph, with practical minimum of 240 vph. When the metering rate is not directly influenced by mainline traffic conditions, the control is referred to as "pretimed metering." This does not, however, necessarily imply the absence of vehicle detectors.

Metering Rates

The calculation of metering rates depends on the purpose for which the metering is being used. Normally, metering is used either to eliminate congestion on the freeway or to improve the safety of the merging operation as follows:

Congestion. If the metering system is intended to eliminate or reduce congestion, demand must be kept at less than capacity. Therefore, the calculation of the metering rate at a ramp would be based on the relationship between upstream demand, downstream capacity, and the volume of traffic desiring to enter the freeway at the ramp. Downstream capacity may be determined by the merging capacity at the ramp or by the capacity of the freeway section downstream. Of course, if the sum of upstream demand and ramp demand is less than or equal to downstream capacity, metering is not needed to prevent congestion. On the other hand, if the upstream freeway demand alone is greater than downstream capacity, metering at the ramp would not eliminate congestion. Otherwise, the desired metering rate is set equal to the difference between upstream demand and downstream capacity (assuming upstream demand is less than downstream capacity and the metering rate does not create excessive queuing).

For example, in the situation shown in figure 5-2, the upstream demand is 5,100 vph, the downstream capacity is 5,400 vph, and the ramp demand is 500 vph. Since the total demand (5,600 vph) is greater than the downstream capacity, ramp metering might be a feasible solution. Therefore, if a metering rate equal to the difference between upstream demand and downstream capacity (300 vph) were used, the freeway would be able to accommodate the upstream demand and maintain uncongested flow while also handling 300 vph of the ramp demand.

However, the ultimate test of the feasibility of ramp metering at a rate of 300 vph would involve consideration of the following questions:

- Is adequate additional capacity available in the corridor for the 200 vph that are likely to be diverted? And, if so, is it likely that the 200 vph would utilize that extra corridor capacity? If not, capacity would have to be added to the corridor and/or made more attractive for this number of vehicles per hour to be diverted. Otherwise, ramp metering would solve only the problem on the freeway.

- Is adequate storage available at the ramp to accommodate the queue of vehicles that would have to wait at the ramp before entering the freeway? If adequate storage could not be provided at the ramp, alternatives to be considered would be closure of the ramp, or metering at other ramps upstream to reduce upstream demand, which would in turn permit a higher metering rate and require less storage at the ramp.

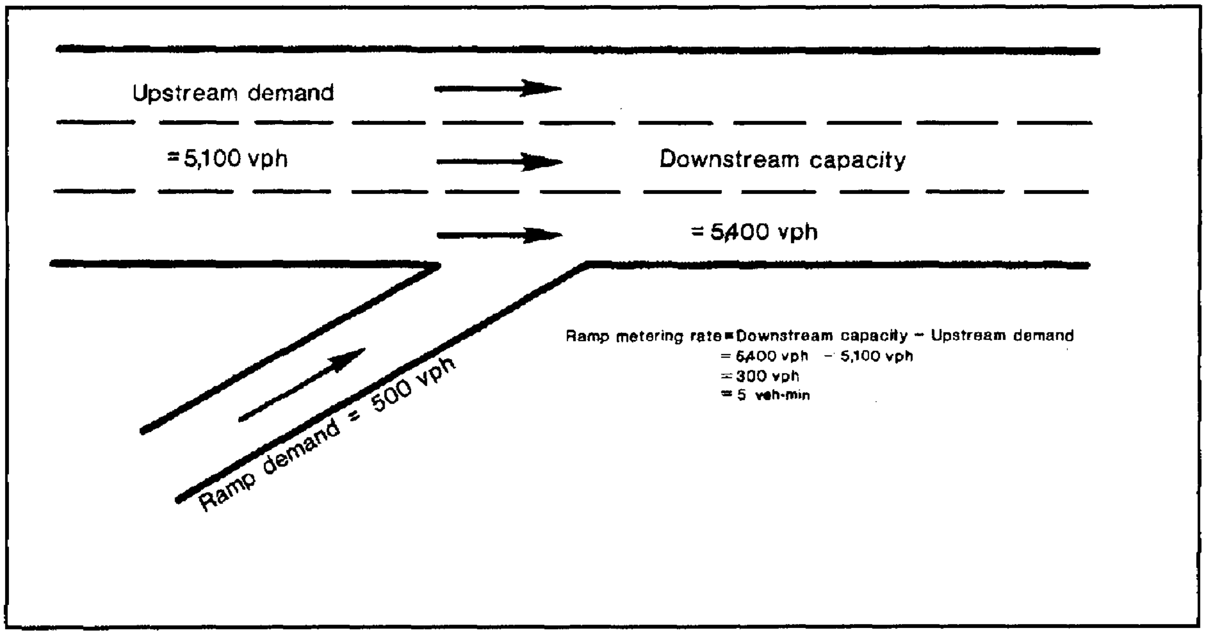


Figure 5-2. Example of Pretimed Entrance Ramp Metering Rate Calculation.

- Is the specified metering rate (300 vph) too restrictive? If so, consideration should be given to closing or metering other ramps upstream to reduce upstream demand, which would permit a higher metering rate at the ramp. However, metering other ramps upstream might lead to the underutilization of the freeway.

Signal Timing. Given that a metering rate has been set, specific signal timing parameters must be determined. (See figure 5-3 for general detector positioning.)

- **Signal Cycle.** Cycle is the inverse of the metering rate or forced headway between released vehicles. For example, a 10-second metering rate results in a 6-second cycle or headway between released vehicles.

- **Minimum Green.** The green interval is just long enough to allow one vehicle to cross the stop line at the signal, usually 0.5 to 1.3 seconds. Some systems use the checkout detector (a pulse detector) to signal the controller to terminate green.

- **Clearance Interval.** If a yellow clearance interval is used, it is typically 0.7 to 1.0 seconds, making the total green plus yellow 1.2 to 2.3 seconds. If no yellow clearance is used, the 1.0 second clearance is added to the minimum green to ensure safe clearance.

- **Red Interval.** The red interval is, then, the difference between the total cycle length and the green plus yellow or the green only interval.

- **Queue Detector.** If the queue defector (a presence loop) is occupied more than some maximum length of time (say 2.0 seconds) indicating an excessive queue, the controller may increase the metering rate in order to reduce or clear the queue.

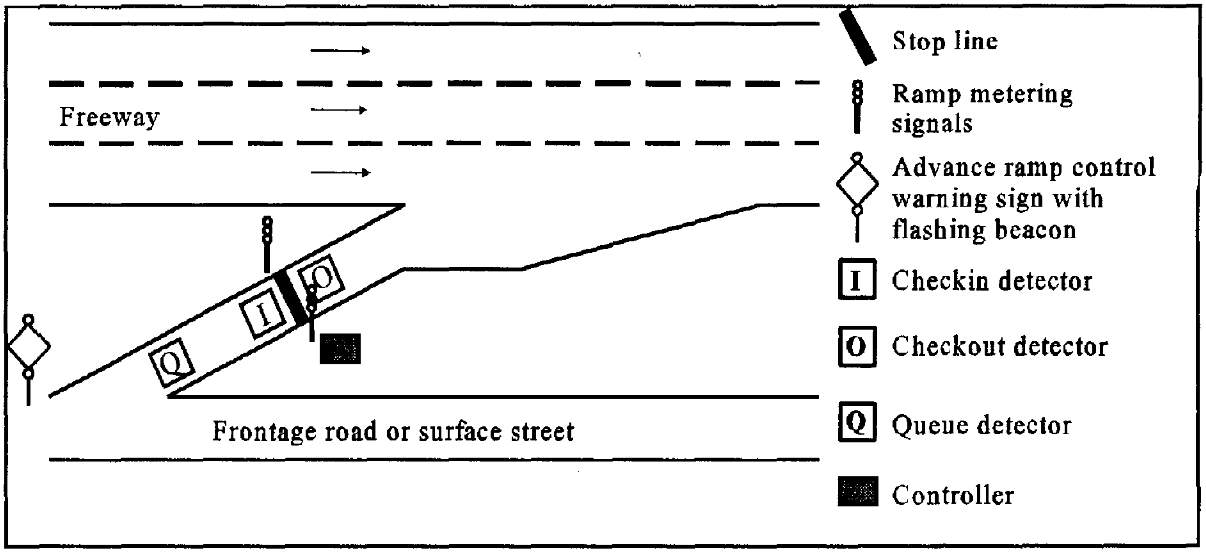


Figure 5-3. Pretimed Ramp Metering Layout.

- **Merge Detector.** If the merge detector (a presence loop) is occupied more than some maximum length of time (say 3.0 seconds), indicating the merging area is blocked, the controller may hold the ramp signal in red to avoid stacking on the ramp.

The settings given above are typical but should be fine tuned in the field to account for unique geometrics, grades, driver characteristics, vehicle mix, and other factors.

Safety. If metering is to be used primarily as a means of improving the safety of the merging operation, then the metering rate is simply set at a maximum consistent with merging conditions at the particular ramp. The primary safety problem of the merging operation is incidence of rearend and lane-change collisions caused by platoons of vehicles on the ramp competing for gaps in the freeway traffic stream. Therefore, metering is used to break up these platoons and to enforce single-vehicle entry. For this to happen, the metering rate selected must ensure that each vehicle has time to merge before the following vehicle approaches the merge area. The time it takes a vehicle to merge depends on the following factors:

- Distance the vehicle is stopped from the freeway.
- Geometrics of the ramp (grade, sight distance, and length of the acceleration lane).
- Type of vehicle.
- Availability of acceptable gaps in the freeway traffic stream.

If the average time to merge is 6 seconds, the metering rate will be 600 vph or 10 vpm.

Pretimed Metering

Pretimed metering refers to a fixed metering rate that is not influenced by current mainline traffic conditions. The rate will normally be set on the basis of historical data. However, pretimed metering does not necessarily imply the absence of detectors.

System Components

Pretimed metering is the simplest form of entrance ramp metering. Typical components are shown in figure 5-3 and are described below.

- **Ramp metering signal.** Usually a standard 3-section (red-yellow-green), or 2-section (red-green) signal display that controls the ramp traffic.

- **Local controller.** Frequently a standard pretimed or Type 170 controller with capability to vary metering rates by time of day or to accept detector inputs. However, national cooperative efforts among industry, operating agencies, and FHWA have developed a design for an open architecture protocol for local controller. This controller, more properly termed a "field processor,"acts as a communication processor with extended capability for other freeway management functions such as control of variable message signs, detector processing, and closed-circuit television cameras.

- **Advance ramp control warning sign with flashing beacon.** A sign which indicates to traffic approaching the ramp that it is being metered. In California, a blank-out type "METER ON" sign is used at many installations in lieu of the flashing beacon.

- **Vehicle Detectors.** There are four types of detectors that are generally used with this type of ramp metering strategy:

    - Check in (demand) detectors.

    - Checkout (passage) detectors.

    - Queue detectors.

    - Merge detectors.

In some applications of pretimed metering a check-in detector is placed on the approach to the ramp metering signal so that the signal will remain red until a vehicle is detected at the stop line, as shown in figure 5-3.[12] When a vehicle is detected by the check-in detector, the ramp metering signal will change to green, provided the minimum red time has elapsed. With this type of operation, it is desirable to have a minimum metering rate (e.g., 3 vpm) at which the signal is set in case there is no detector actuation, because of possible detector failure or because of vehicles stopping too far back from the stop line to actuate the detector. In some cases, two detectors are used to provide redundancy to reduce the impact of detector failures.

In some systems, a checkout detector has been used to ensure single-vehicle entry. When a vehicle is permitted to pass the ramp metering signal, it is detected by the checkout detector, which is installed just beyond the stop line (usually about half a car length past it). The green interval is then terminated as soon as the vehicle is sensed by the checkout detector. In this way, the length of the green interval is made sufficient for the passage of only one vehicle.

In some pretimed metering systems, a queue detector is used to detect backing of ramp traffic into frontage roads or surface streets. The queue detector is placed at a strategic point on the ramp, or on the frontage road, in advance of the ramp metering signal. When a queue is sensed by a vehicle occupying the loop for a selectable period of time, indicating that the queue of vehicles waiting at the ramp metering signal is sufficient to interfere with traffic on the frontage road or surface streets, a higher metering rate may used to shorten the queue length. This can be self-defeating, however, since shorter queues often attract higher demands.

A merge detector is a device that senses the presence of vehicles in the primary merging area of the ramp and freeway mainlanes. When the merge detector senses that a vehicle has stopped, blocking the merge area, the signal may be held in red for some preset maximum time in order not to clog the area and to reduce the possibility of a rear end collision. On a well designed entrance ramp with adequate acceleration and merging distance, a merge detector is not necessary or practical.

Placement of these auxiliary detectors is discussed in more detail in the subsequent section on traffic responsive metering. Figure 5-4 shows ramp metering signals and advance warning signs that have been used. Also, for a discussion of standards for various system components, refer to the recommended practice for freeway entrance ramp displays prepared by the Institute of Transportation Engineers (ITE).[13]

System Operation

In the operation of a pretimed metering system, the ramp signal operates with a constant cycle in accordance with a metering rate prescribed for the particular control period. However, timing the red, yellow, and green intervals of the cycle (many systems use ramp signals that have only red and green intervals) depends on whether the type of metering used is single-entry metering or platoon metering.

Single-entry metering. In the case of single-entry metering, the ramp metering signal is timed to permit only one vehicle to enter the freeway per green interval. Therefore, the green-plus-yellow (or just green if yellow is not used) interval is just long enough (usually about 1.5 to 2 seconds) to allow one vehicle to proceed past the signal. The red interval varies with the number of vehicles being metered. For instance, if a metering rate of 600 vph or 10 vpm were to be used, and the green-plus-yellow interval were 2 seconds, a red interval of 4 seconds would be used. If the metering rate were 300 vph, or 5 vpm, and the green-plus-yellow interval were 2 seconds, a red interval of 10 seconds would be used.

Platoon metering. When metering rates greater than 900 vph are required, platoon metering, which permits the release of 2 or more vehicles per cycle, may be used to achieve such high metering rates. For pretimed platoon metering, the cycle length is determined on the basis of the desired metering rate and the average number of vehicles to be released per cycle. For example, in the case of a metering rate of 1,080 vph, or 18 vpm, and a release of 2 vehicles per cycle, 9 cycles per minute would be required. Therefore, the cycle length would be 6.67 seconds. Similarly, if a release of 3 vpc were used instead, the cycle length would be 10 seconds. However, the timing of the cycle intervals (i.e., green, yellow, red) would depend on the form of platoon metering used, tandem or 2-abreast.

Tandem Metering. In the case of tandem metering, the vehicles are released one after another. Therefore, the green-plus yellow time is made long enough to permit the clearance of the desired number of vehicles per cycle. A yellow interval should be used to minimize the rearend collision potential. Thus, for the 7-second cycle with 2-vehicle platoons, a 4-second green-plus-yellow and a 3-second red might be used. And for a 12-second cycle with 3-vehicle platoons, a 9-second green-plus-yellow and a 3-second red might be used. Experience indicates that 2-vehicle platoons can be handled satisfactorily and that 3-vehicle platoons are a practical maximum. In either case, a

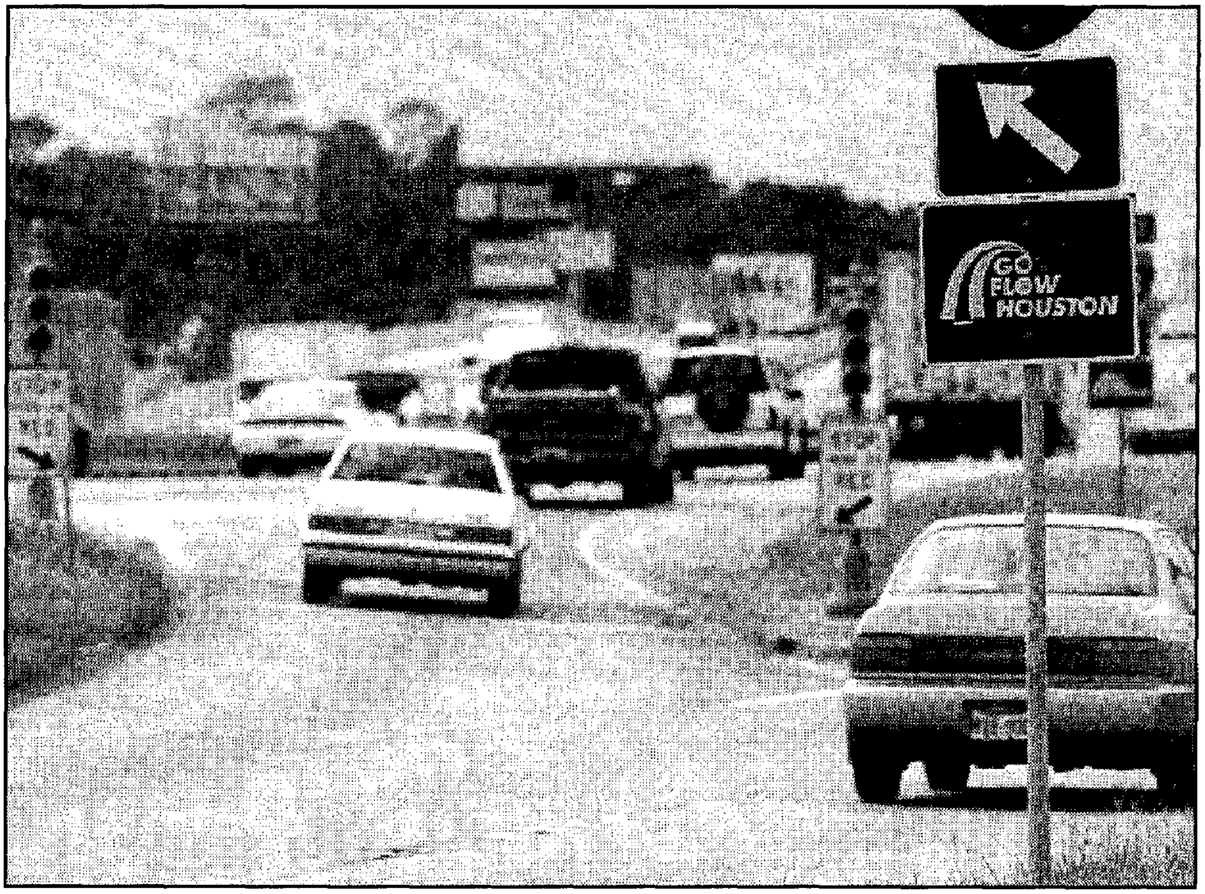


Figure 5-4. Typical Field Displays for Ramp Meter Installations.

maximum metering rate of 1,100 vph can be expected.[14]

Two-abreast Metering. With two-abreast metering, two vehicles are released side by side per cycle. This form of metering requires two parallel lanes on the entrance ramp plus a sufficient distance beyond the ramp metering signal for the two vehicles to achieve a tandem configuration before merging with freeway traffic. The more common practice in two-lane situations is to alternate the release—one from the left lane followed by one from the right. The timing of the cycle intervals for multiple-lane metering is similar to that for single-entry metering in that the green-plus-yellow interval is just long enough (usually about 3 seconds) to allow one vehicle in each lane to proceed past the ramp metering signal. The remainder of the cycle is red. With alternate release metering, maximum metering rates of about 1,700 vph may be achieved.

Compared to single-entry metering, platoon metering is a more complex operation and may cause some drive confusion which may lead to disruptions of ramp flow. Therefore, single-entry metering should always be given first consideration, and platoon metering should not be used unless it is necessary to achieve higher metering rates. However, platoon metering has been successfully used in several locations and drivers can adapt with proper design and pre-operation publicity.

It has been shown that entrance ramp control can be extremely cost effective.[1] Experience has indicated that the biggest net gain in benefits is realized in going from no control to pretimed metering. Pretimed metering offers both advantages and disadvantages. The most important advantages are that it gives the driver a dependable situation to which he can readily adjust, and that it tends to be associated with lower costs. The major disadvantage is that the system can neither respond automatically to significant changes in demand, nor adjust to unusual traffic conditions resulting from incidents. Because of this inability to automatically respond to changes in traffic conditions and the relative difficulty of dissipating resultant congestion, pretimed metering rates have usually been set so that operation will be at volumes slightly below capacity at the desired LOS.

Traffic-Responsive Metering

In contrast to pretimed metering control, traffic-responsive metering is directly influenced by the mainline and ramp traffic conditions during the metering period. Metering rates are selected on the basis of real-time measurements of traffic variables indicating the current relation between upstream demand and downstream capacity.

Fundamental Traffic Flow Relationships

In order to determine or predict demand-capacity conditions on the basis of real-time measurements of traffic variables, a description or model of traffic is necessary. Most frequently used as indicators of operating conditions for traffic-responsive metering are functional relationships between flow rate, q; space-mean speed, u; and density, k.[15]

A generalized relationship between each of the variables is depicted in figure 5-5 and can be summarized as follows:

- At zero density, or when no vehicles are on the roadway, the flow rate is zero. and traffic is permitted to travel at its free speed, u_f.
- As density increases to a value, k_m, the flow rate increases to a maximum value, q_m, which is the capacity of the roadway, and speed decreases to a value, u_m.
- As density increases from a value, k_m, to a maximum value, k_j (jam density), the flow rate decreases to zero because the roadway is blocked with too many vehicles for traffic to move.

The values of q_m, u_f, u_m, k_m, and k_j—and the shapes of the curves—depend on several factors including geometrics of the roadway, composition of traffic, and weather conditions. Therefore, these values may be different for different sections of the roadway, and each section may have more than one set of these values. Although these are theoretical relationships based on the assumption of uniform traffic flow, the trends expressed by these relationships do exist.[16]

Basic Strategy

As explained earlier, congestion occurs whenever demand exceeds capacity. Therefore, as indicated in figure 5-5, the values of q_m, u_m, and k_m define boundaries between congested flow and uncongested flow. The purpose of metering is to prevent or reduce congestion, or in other words, to keep the values of the fundamental traffic flow variables at levels that define points on the uncongested-flow portions of the traffic flow curves. Thus, the basic strategy of traffic responsive metering is as follows:

- Obtain real-time measurements of traffic variables on the freeway.

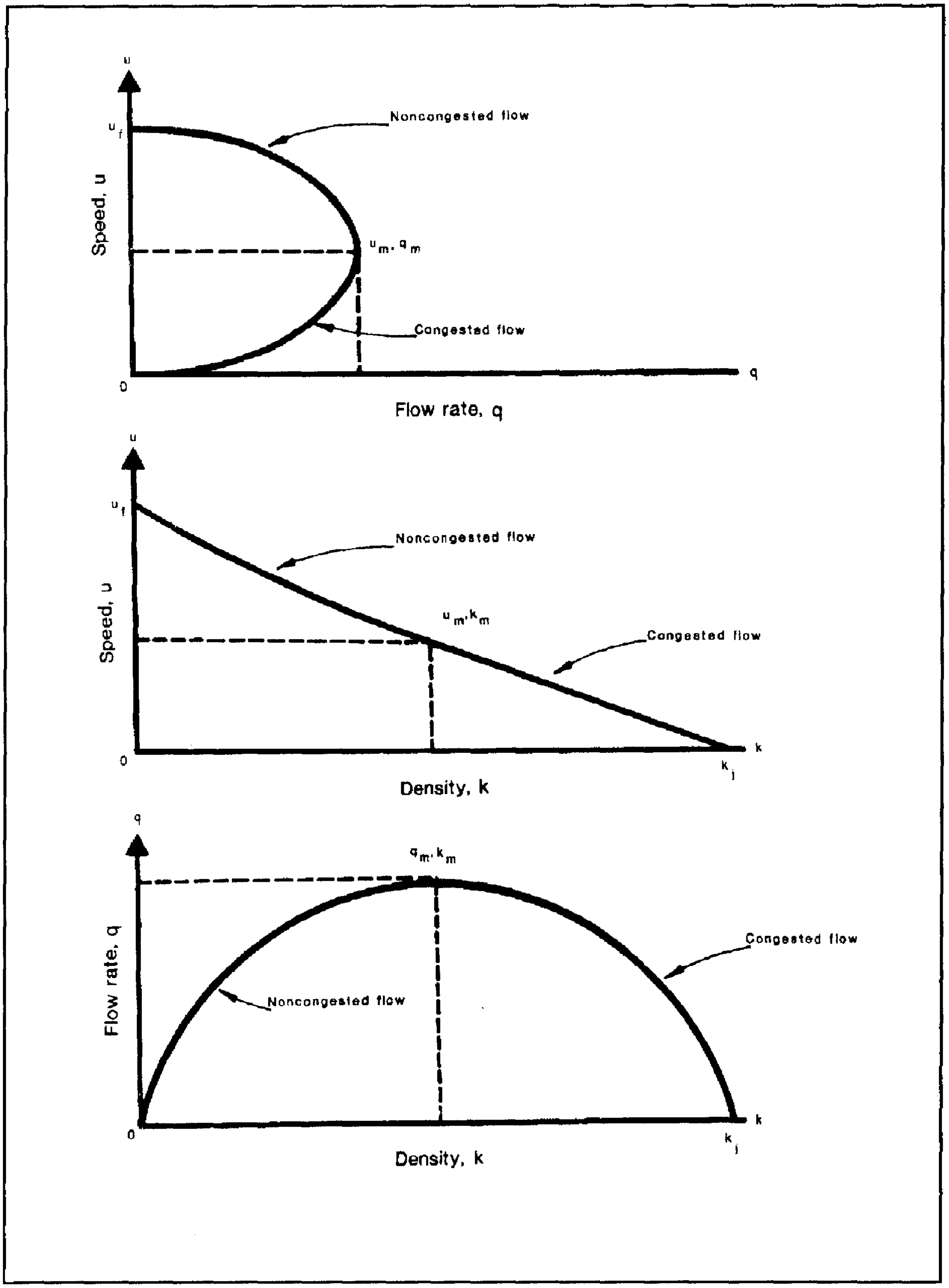


Figure 5-5. Fundamental Flow Rate-Speed-Density Relationships.

- On the basis of these measurements, determine where on the fundamental traffic flow curves the freeway section is operating with respect to capacity.
- Determine the maximum ramp metering rate at which vehicles can be permitted to enter the freeway.

A refinement that is often made to this strategy is to select the traffic flow curves on the basis of traffic composition and weather conditions.

Lane occupancy (a surrogate measure for density) and flow rate (volume) are the two traffic variables generally used to describe freeway traffic conditions for traffic responsive metering. These are the control parameters usually used, because they can be measured in real time using vehicle detectors.

Several variations on the basic strategy of traffic-responsive metering utilize different combinations of traffic variables. Although most are reported as having positive effects on freeway operations, none has been generally accepted as being superior to the others. In fact, new strategies are still being formulated to find better modes of control. However, the principal traffic-responsive strategies remain demand-capacity control and occupancy control.

Demand-Capacity Control

Demand-capacity control features the selection of metering rates on the basis of a real-time comparison of upstream volume and downstream capacity. The upstream volume is measured in real time and compared with either a preset value of downstream capacity determined from historical data or a real-time value computed from downstream volume measurements. To be most effective, the downstream capacity used should account for the effects on capacity of weather conditions, traffic composition, and incidents.

The difference between the upstream volume and the downstream capacity is then determined and used as the allowable entrance ramp volume. This ramp volume is expressed as a metering rate to be used during the next control interval (usually 1 min). If the upstream volume is greater than the downstream capacity, a minimum metering rate is used (e.g., 3-4 vpm). Theoretically, if the upstream volume were greater than the downstream capacity, a zero metering rate, or ramp closure, should be used in order to prevent congestion. It has generally been found that metering rates lower than 3 vpm are not effective, because vehicles waiting at the ramp will judge the ramp metering signal to be malfunctioning and will proceed through on red.

Downstream capacity may also be measured directly from freeway detector(s) to reflect for variations in traffic composition, weather, or other limiting factors which would not be accounted for in a fixed value of capacity.

Since a low upstream volume could occur in congested as well as uncongested flow, volume alone does not indicate degree of congestion. Therefore, an occupancy measurement also is usually made to determine whether uncongested or congested flow prevails. If the occupancy measurement is above a preset value (e.g., 18 percent, as used in Los Angeles).[17] which is determined from historical data, congested flow will be assumed to exist and a minimum metering rate used.

Occupancy Control

Occupancy control utilizes real-time occupancy measurements generally taken upstream of the entrance ramp. One of a number of predetermined metering rates is selected for the next control interval (usually 1 min) on the basis of occupancy measurements taken during the current control interval. For a given entrance ramp, the metering rate to be used for a particular value of occupancy would be based on a plot of historical volume-occupancy data collected at each measurement location. An example of a typical plot from Chicago is shown in figure 5-6.[18] From such a plot, an approximate relationship between volume and occupancy at capacity is determined. For each level of occupancy measured, a metering rate can be determined that corresponds to the difference between the predetermined estimate of capacity and the real-time estimate of volume. If the measured occupancy is greater than, or equal to, the preset capacity occupancy, a minimum metering rate will be selected instead of a zero rate or ramp closure. This choice would be based on effective and practical entrance ramp control considerations, as explained earlier for demand-capacity control. Table 5-1 shows a recommended range of metering rates based on measured occupancy.[19]

System Components

A traffic-responsive metering system contains the same components as described for pretimed metering. These include ramp metering signal(s), local controller, advance warning sign with flashing beacon, and detectors. The local controller unit for traffic-responsive metering requires additional logic over and above that required for pretimed metering in order to monitor traffic variable measurements, select or calculate metering rates, and respond to override-type conditions such as excessive queues. Queue, check in, checkout, and merge detectors are normally also included in traffic-responsive metering systems.

Some traffic-responsive metering systems have also included detectors used to determine traffic composition and weather conditions.[9, 17] Input from these detectors enables the system to account for the effects of these factors on traffic flow.

Table 5-1. Local Actuated Metering Rates as Function of Occupancy. [19]

Occupancy (%)	Metering Rate(Vehicles/ Minute)
≤ 10	12
11-16	10
17-22	8
23-28	6
29-34	4
> 34	3

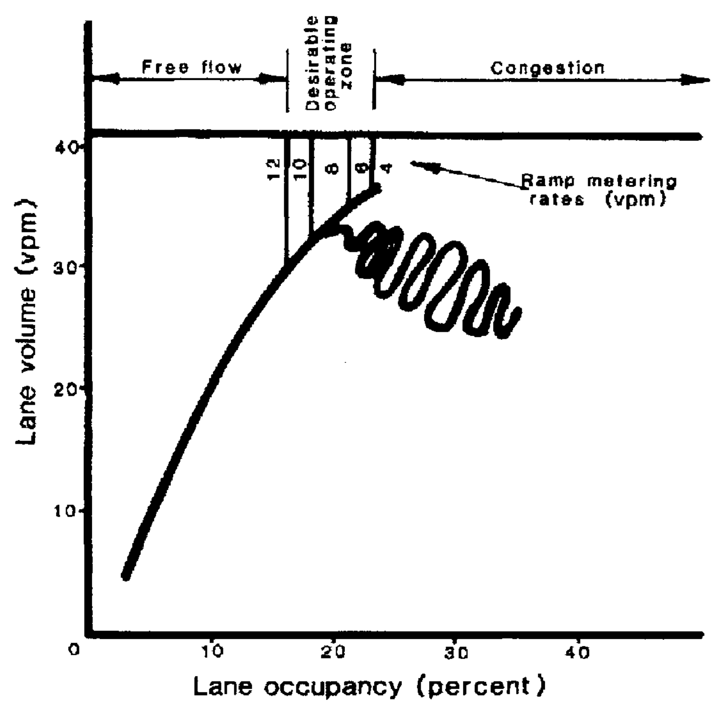


Figure 5-6. Typical Volume-Capacity Plot Related to Ramp Metering Rate. [18]

The typical location of these components on a ramp is shown in figure 5-7. For a discussion of standards for various components, the reader is referred to the publication on recommended practice for freeway entrance ramp control displays prepared by the Institute of Transportation Engineers (ITE).[13]

System Operation

The operation of a traffic-responsive metering system is similar to that of a pretimed metering system, except in regard to the following:

- **Metering Rate Selection.** Single-entry metering is normally used to time the red-yellow-green (or red-green) intervals for a given metering rate. However, if high metering rates (e.g., higher than 13 vpm), are required, platoon metering might be used. Single-entry metering and platoon metering should not both be used at any one ramp.

In a traffic-responsive metering system, the selection is based on real-time measurements of traffic variables which describe traffic flow conditions on the freeway. The control interval, which is the time period during which a selected metering rate remains in effect, is much shorter for a traffic-responsive metering

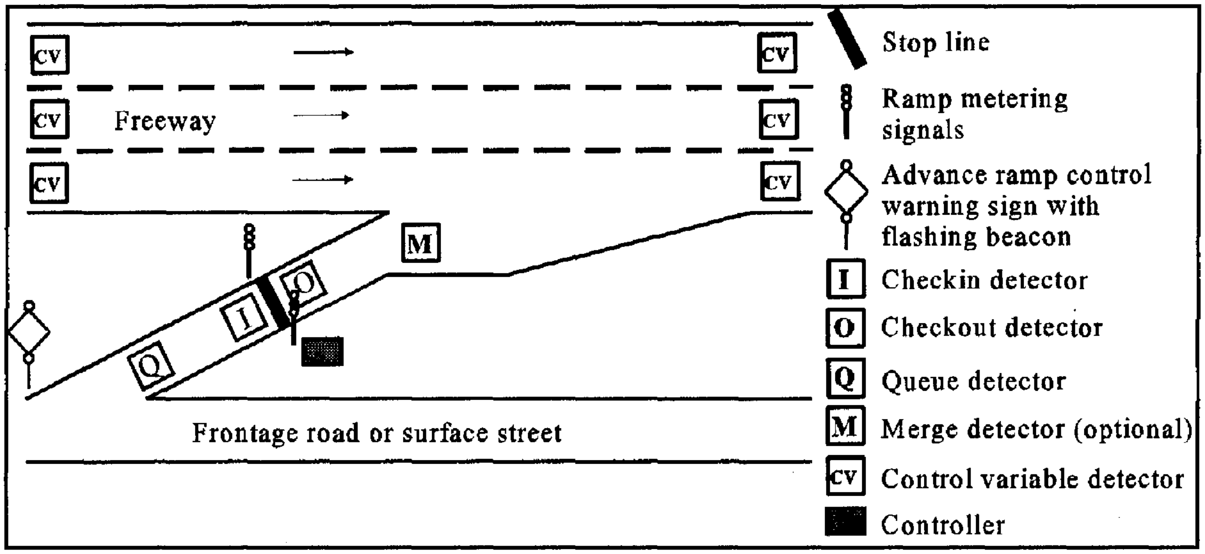


Figure 5-7. Traffic Responsive Ramp Metering Layout.

system (e.g., 1 min) than for a pretimed metering system (e.g., 30 min., 1 hr., or the entire peak period).

- **Override Features.** Override features of a traffic responsive system adjust metering rates in accordance with certain operational considerations as follows:

- **Continued Actuation of the Queue Detector.** Indicates that the queue of vehicles waiting at the ramp metering signal is approaching the frontage road or surface street and is likely to interfere with traffic on either or both. Therefore, a higher metering rate may be used to shorten the queue length.

- **Actuation of the Merge Detector.** Indicates that a vehicle is still in the merge area. Therefore, in the case of single-entry metering, subsequent green intervals are preempted until the vehicle merges.

- **No Actuation of the Checkout (Passages Detector After a Green Interval).** Indicates that a vehicle has missed the green signal. Therefore, the ramp metering signal is returned to or left in green.

- **Continued Actuation of the Queue Detector With No Actuation of the Check in (Demand) Detector.** Such a condition indicates that a vehicle on the ramp has stopped short of the check in detector. Therefore, the ramp metering signal is turned to green to allow this vehicle to proceed.

Gap-Acceptance Merge Control

Gap-acceptance merge control has been implemented and tested, but is little used, if at all, today. The concept of matching a merging vehicle to a specific freeway gap is attractive, but many variables can cause it to fail. Certain elements, such as slow vehicle detection, may have application in other types of ramp control operation. Gap-acceptance merge control might have application where geometries are substandard and the primary concern is safety.

The merge-control concept of entrance ramp metering is intended to enable a maximum number of entrance ramp vehicles to merge safely without causing significant disruptions in freeway traffic. The concept involves maximum utilization of gaps in the traffic stream of the freeway lane into which ramp vehicles are to merge. It may or may not involve the calculation of ramp metering rates in accordance with the demand-capacity constraint. The problem is mainly one of inserting entrance ramp vehicles into freeway gaps. However, a provisional metering rate based on system calculations may be established. If a gap is found in a "window", say 3 seconds either side of the calculated release point, it is considered to have satisfied the metering rate, and a vehicle is released.[20] Gap acceptance metering has not been widely used, but may be warranted where geometrics are substandard or the safety of the merging operation can be improved.

Basic Concepts

The concepts of gap acceptance at freeway entrance ramps are important in describing the interaction of the freeway and ramp traffic. It is assumed that the ramp driver measures each gap in the adjacent freeway lane and compares it with an acceptable gap which he/she judges as large enough for a safe merge.

The minimum acceptable gap is dependent on several factors, such as the following:[20]

- Entrance ramp and freeway geometrics.
- Vehicle performance characteristics.
- Driver behavior.
- Traffic conditions.
- Weather conditions.

Merge-control systems are designed to improve the merging operation at the entrance ramp by providing the driver with the information needed to coordinate in time and space entry onto the freeway. These systems operate according to the following basic guideline procedures:

- Detection of an acceptable gap on the freeway into which a ramp vehicle could merge.
- Projection of the arrival of the acceptable gap at the merging point of the entrance ramp.
- Release of the ramp vehicle in sufficient time for it to accelerate and merge into the moving gap.
- If a gap is not detected within some maximum time, say 60 seconds, the vehicle is released.

System Components

Gap-acceptance merge-control systems use many of the same components as those described for pretimed metering, which include ramp metering signals, local controller, advance warning sign with flashing beacon, and detectors. A mainlane gap/speed detector is located in the shoulder lane of the freeway upstream of the ramp merge to provide data from which the controller unit can determine presence and speed of available gaps in which to insert merging ramp traffic. Queue, check in, checkout, and merge detectors are normally included in gap-acceptance merge-control systems.

Another override-feature component that might be added to the system is a slow-vehicle detector, which senses the presence of a slow-moving vehicle on the entrance ramp between the ramp metering signal and the merge detector. A schematic layout for gap-acceptance operation combined with traffic responsive operation as implemented in the Dallas Corridor Study is presented in figure 5-8.[22] Also, for a discussion of standards for various system components, the reader is referred to the publication on recommended practice for freeway entrance ramp control displays prepared by the Institute of Transportation Engineers (ITE).[13]

System Operation

A gap-acceptance merge-control system does not normally operate in accordance with a constant metering rate for a specified control interval as do pretimed and traffic-responsive metering systems. Instead, it operates in response to the availability of acceptable gaps in the lane of the freeway into which ramp vehicles are to merge.

Usually, the system is designed to operate in a single-entry metering mode, with the ramp metering signal resting on red when no vehicles are waiting on the ramp. Experience on the Gulf Freeway in Houston has indicated that it is usually not desirable to operate the ramp metering signal in either of the following two ways:[24]

- If it gives a green indication at the proper time, whether or not there is a vehicle waiting.
- If it normally rests on green when there are no vehicles waiting.

Procedures can be summarized as follows for the nominal operation of a gap-acceptance merge-control system, with single-entry metering and the ramp metering signal resting on red:

- A vehicle stops at the ramp metering signal and actuates the check in detector.
- The controller begins to measure gaps and vehicle speeds which are sensed by the gap/speed detector that is located upstream from the ramp in the lane of the freeway into which ramp vehicles are to merge.
- The controller compares each measured gap to a preset minimum gap size to determine whether or not it is an acceptable gap.
- If the system includes demand-capacity features as described above, the controller determines if the gap falls within a "window" and adjusts the release time accordingly.
- If a gap is not acceptable, the controller considers the next gap. If it is acceptable, the controller computes the time at which the vehicle at the ramp metering signal should be released in order to arrive at the merge point at the same time as does the acceptable gap. This calculation involves the following factors:
  - Speed of the traffic flow measured in the lane of the freeway into which ramp vehicles are to merge.
  - Distance of the gap/speed detector location from the merge point.
  - Predetermined ramp travel time of a vehicle stopped at the ramp metering signal to the merge point.
- At the proper instant, the controller causes the ramp metering signal to change to green.
- The ramp metering signal remains on green for a fixed interval long enough to release a single vehicle. Then, it changes to yellow for a short fixed interval before

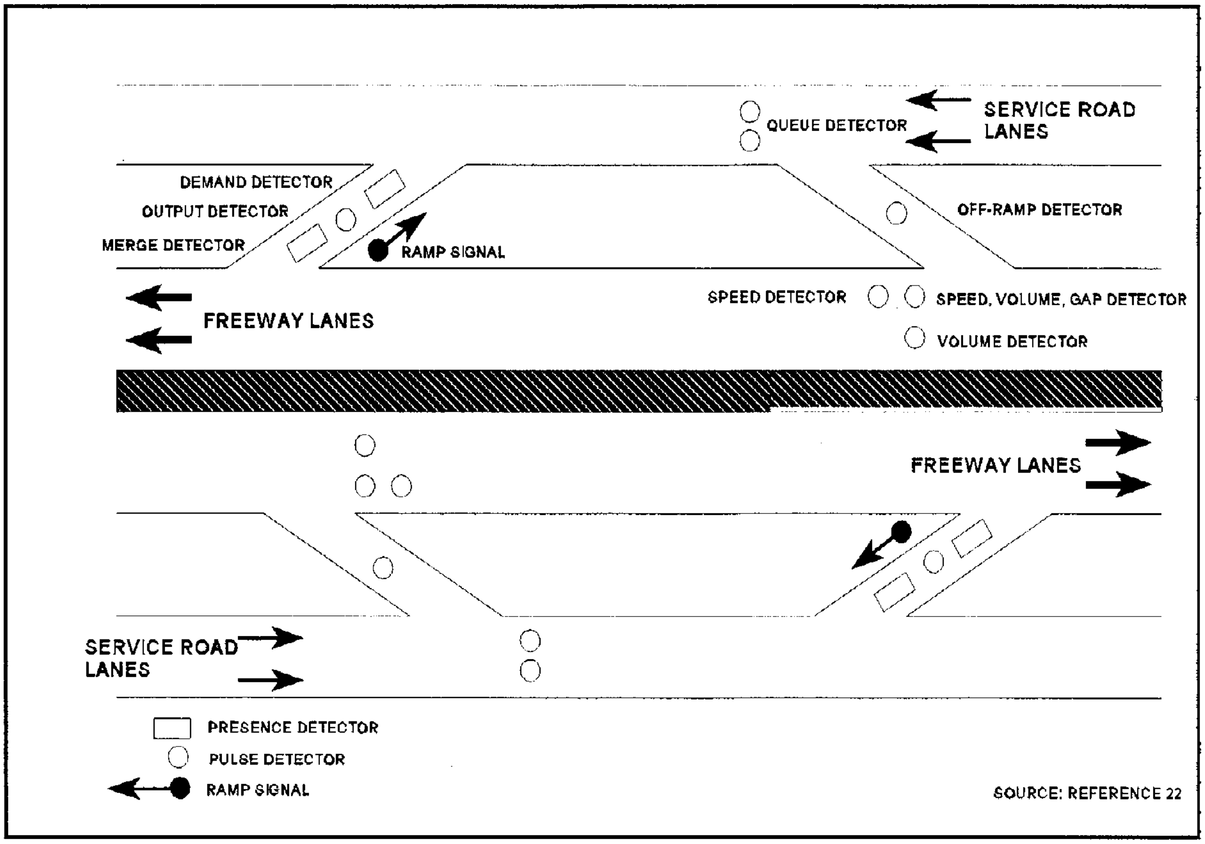


Figure 5-8. Gap Acceptance / Traffic Responsive Ramp Metering Layout.

it changes to red. (Where permitted by State law, the yellow interval may be omitted.) The green plus yellow (or green only) interval is usually about 3 seconds long. It is necessary that the ramp metering signal remain on red long enough to give the next vehicle in line time to pull up to the signal. Thus, the minimum time for a full green-yellow-red (or green-red) cycle should be 4 to 5 seconds.

The operation of the override features of a gap-acceptance merge-control system is essentially the same as for a traffic-responsive metering system. However, a gap-acceptance merge-control system may have the following additional override features:

- **Low-speed, Fixed-rate Metering.** When congested flow develops on the freeway, small space headways between successive vehicles constitute large time headways because of the low speeds. For example, if traffic on the freeway should come to a complete stop, the measured time headways will be infinitely large. Thus, unless an appropriate override were provided, the controller would release a number of entrance ramp vehicles to enter the freeway during the congested flow, a response which would be contrary to the objective of improving freeway operations. Therefore, if the speed of the freeway traffic drops below a preset value (e.g., 25 mi/h), ramp vehicles are metered at a minimum fixed rate {usually 3 to 4 vpm).

- **Slow-vehicle, Red-interval Extension.** At entrance ramps where there are relatively high percentages of trucks and buses, it might be desirable to make special allowances for their performance characteristics. Accordingly, a slow-vehicle detector might be provided to measure the travel time of vehicles from the ramp metering signal to their location. If the travel time is greater than a preset value, the ramp metering signal is held on red until the vehicle has cleared the merge detector or until the merge detector is actuated.

Benefits to be realized from a gap-acceptance merge-control system are similar to those realized from traffic-responsive metering system. A study conducted by the Texas Transportation Institute, which compares a gap-acceptance merge-control system with a demand-capacity-control, traffic-responsive metering system, has reported the following results:[(23)]

- Gap-acceptance merge-control resulted in a higher percentage of ramp-metering-signal violations by ramp vehicles, which was probably due to its irregular pattern of operation and longer queue delays (metering rates ranged from 1 veh/4 seconds to 1 veh/25 seconds).

- Gap-acceptance merge-control resulted in lower travel times from the ramp metering signal to the merge area, which indicates a smoother merging operation.

- Demand-capacity control resulted in higher metering rates and higher peak-hour entrance ramp volume.

In general, for entrance ramps that have well-designed geometrics, a gap-acceptance merge control is less cost-effective than either pretimed or traffic-responsive metering systems. However, gap-acceptance control might be warranted at locations where the geometrics are substandard and the primary concern is to improve the safety of the merging operation.

System Ramp Control

System ramp control refers to the application of ramp control to a series of entrance ramps where a single ramp meter cannot address the excess freeway demand. The primary objective of system ramp control is to prevent or reduce the occurrence of congestion on the freeway. Therefore, the control of each ramp in the control system is based on the demand-capacity considerations for the whole system rather than on the demand-capacity constraint at each individual ramp. This concept does not necessarily imply the use of large computer control systems, since small subsystems may be coordinated by the use of mutual coordination of adjacent ramp meter controllers.

If congestion is to be prevented or reduced on the freeway system, the concept of system ramp control must be used in the design of a system of controls for a section of freeway with more than one entrance ramp. It may be applied in the following types of systems:

- System pretimed metering (including ramp closure).

- Traffic-responsive metering.

- Gap-acceptance merge control.

A discussion of system ramp control applied to each of these systems follows.

System Pretimed Metering

System pretimed metering refers to the application of pretimed metering to a series of entrance ramps. The metering rate for each of these ramps is determined in accordance with demand-capacity constraints at the other ramps as well as its own local demand-capacity constraint.

Determining these metering rates, which are computed from historical data pertaining to each control interval, requires the following information:

- Mainline and entrance ramp demands.
- Freeway capacities immediately downstream of each entrance ramp.
- Description of the traffic pattern within the freeway section to be controlled.

This information provides the basis for establishing the demand-capacity constraints of the entrance ramps and their interdependencies.

Fundamental metering rate calculations—given the required data, the fundamental procedure for computing metering rates involves five steps:

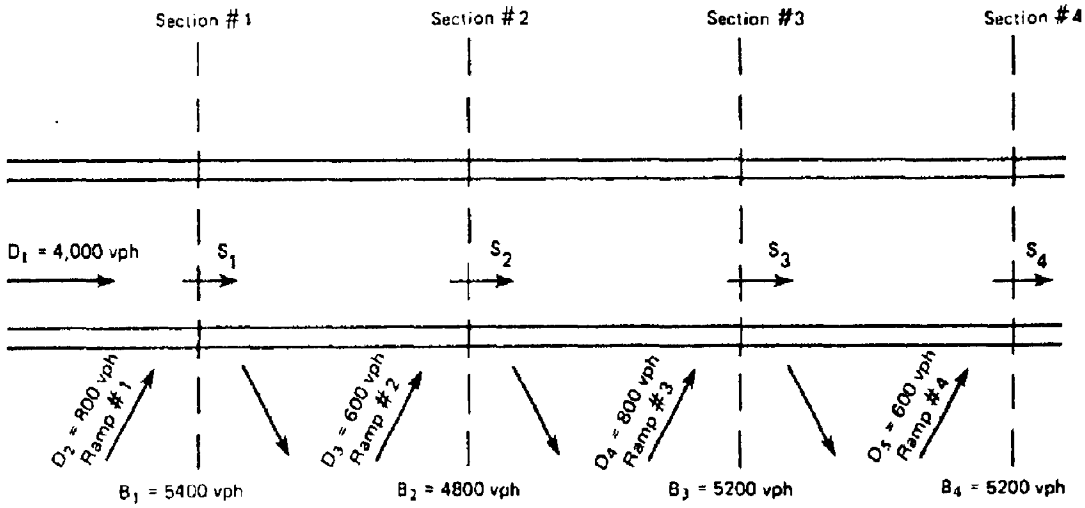
1. Start with the entrance ramp that is farthest upstream.
2. Determine the total demand (upstream mainline demand plus ramp demand) for the freeway section immediately downstream of the ramp.
3. Compare the total demand to the capacity of the downstream section, and proceed as follows:
   a. If the total demand is less than the capacity, metering is not required at this ramp by this demand-capacity constraint. Therefore, skip step 4 and go immediately to step 5.
   b. If the total demand is greater than the capacity, metering is required at this ramp by the demand-capacity constraint. Therefore, proceed to step 5.
4. Compare the upstream mainline demand to the capacity of the downstream section and proceed as follows:
   a. If the upstream mainline demand is less than the capacity, then the allowable entrance ramp volume (or metering rate) is set equal to the difference between the capacity and the upstream mainline demand.
   b. If the upstream mainline demand is greater than or equal to the capacity, then the allowable entrance ramp volume is zero, and the ramp must be closed. If the upstream mainline demand is greater than the capacity, the volumes permitted to enter at ramps upstream must be reduced accordingly. The total reduction in the allowable entrance ramp volumes upstream is equal to the difference between the upstream mainline demand and the capacity, adjusted to account for that portion of the traffic entering upstream that exits before it reaches the downstream entrance ramp being closed.
5. Select the next entrance ramp downstream and go back to step 2.

This procedure is illustrated by the following examples.

Example 1 [5,6]

In the example case shown in figure 5-9, pretimed metering rates are calculated for an integrated, pretimed control system comprised of four entrance ramps. In reviewing this example, the following points should be noted:

- Since only entrance ramp control is being considered and not mainline control, the allowable mainline volume at



X_i = allowable volume at input i

D_i = demand at input i

B_j = capacity at section j

A_{ij} = decimal fraction of vehicles entering at input i which pass through section j

S_j = demand at section j

A_{ij} Values

i \ j	1	2	3	4
1	1.00	0.95	0.90	0.85
2	1.00	0.75	0.70	0.60
3	–	1.00	0.90	0.85
4	–	–	1.00	0.90
5	–	–	–	1.00

Compute X_i's starting at section #1

- Set $X_1 = D_1$ = 4000 vph
- $S_1 = A_{11}X_1 + A_{21}D_2$ = (1.00)(4000)+(1.00)(800) = 4800 vph < B_1 = 5400 vph; ∴ X_2 = 800 vph
- $S_2 = A_{12}X_1 + A_{22}X_2 + A_{32}D_3$ = (0.95)(4000)+(0.75)(800)+(1.00)(600) = 5000 vph > B_2 = 4800 vph; ∴ X_3 = 400 vph
- $S_3 = A_{13}X_1 + A_{23}X_2 + A_{33}X_3 + A_{43}D_4$ = (0.90)(4000)+(0.70)(800)+(0.90)(400) + (1.00)(800) = 5320 vph > B_3 = 5200 vph; ∴ X_4 = 680 vph
- $S_4 = A_{14}X_1 + A_{24}X_2 + A_{34}X_3 + A_{44}X_4 + A_{54}D_5$ = (0.85)(4000) +(0.60)(800) +(0.85)(400) + (0.90)(680) + (1.00)(600) = 5432 vph > B_4 = 5200 vph; ∴ X_5 = 368 vph

Conclusion:

- Ramp # 1: No control needed.
- Ramp # 2 : Meter at a rate of 400 vph.
- Ramp # 3: Meter at a rate of 680 vph.
- Ramp # 4: Meter at a rate of 368 vph.

Figure 5-9. Integrated Entrance Ramp Control: Example No. 1 Calculation of Pretimed Metering Rates. [5,6]

Section 1, Xj is set equal to the mainline demand Dj.

- With the notation given in figure 5-9, the demand, S_j, at a section, j, is computed by the following equation:

$$S_j = (\sum_{i=1}^{j} A_{ij}X_i) + A_{j+1}D_{j+1}$$

where:

X_i = Allowable volume at input i

D_j = Demand at input i

A_{ij} = Decimal fraction of vehicles entering at input i which pass through Section j

S_j = Demand at Section j

As it happens, the metering rate computed for each entrance ramp in this particular example is determined solely by the demand-capacity constraint at the section immediately downstream and is not influenced by the demand-capacity constraints at other ramps.

Example 2[5,6]

The data given in the example shown in figure 5-10 are the same as those given in the previous example. except that the mainline demand, D_1, is 4,600 vph instead of 4,000 vph. In this case, the metering rates at Ramps 2, 3, and 4 are determined solely by their respective downstream demand-capacity constraints, as was the case in the previous example. However, the metering rate at Ramp 1, rather than being determined by the demand-capacity constraint at Section 1, is established in accordance with the demand-capacity constraint at Ramp 2, as is described below.

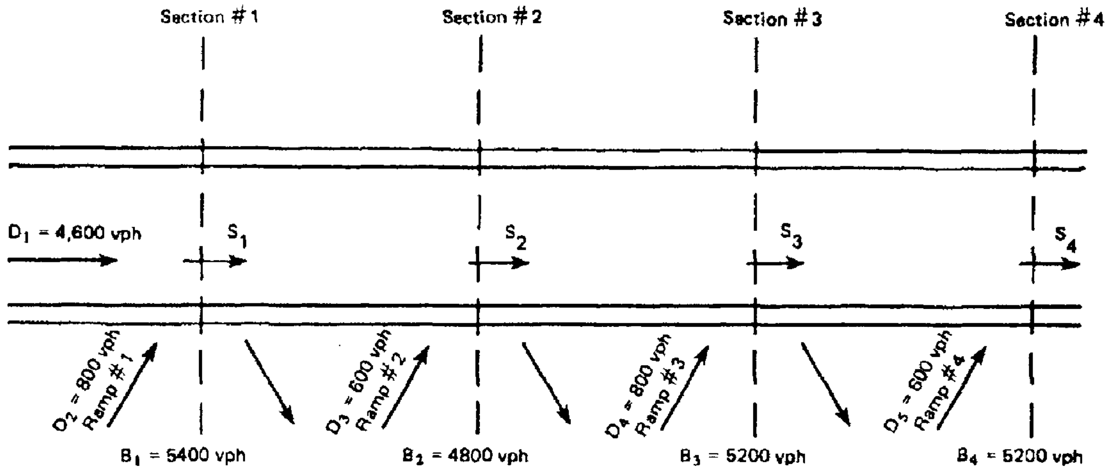
The demand, S_2, at Section 2 is 5,570 vph, which is 770 vph greater than the capacity, B_2, at Section 2 (4,800 vph). If Ramp 2 is closed, the demand at Section 2 is reduced to 4,970 vph, a volume which also exceeds the capacity, B_2. Therefore, it is necessary to reduce the allowable volume, X_2, entering at Ramp 1 (input 2). The allowable volume, X_2, must be reduced enough to reduce the demand, S_2, by 170 vph. The amount of the reduction is equal to the 170 vph divided by the decimal fraction, A_{22}, of the vehicles entering at Ramp 1 and passing through Section 2 (170 vph/0.75 - 227 vph). Therefore, the allowable volume, X_2, at Ramp 1 would be 573 vph instead of 800 vph.

In this procedure, excess demand, $S_j - B_j$, at any section, j, is removed by reducing the allowable volume on the entrance ramp immediately upstream. If' instead, the allowable volumes on entrance ramps farther upstream were reduced, a large number of vehicles would have to be removed from these ramps in order to reduce the demand, S_j, sufficiently at any section, j. This is necessary because some of the vehicles that enter at these ramps will exit the freeway before they reach Section j.

Example 3

Again, in the situation presented in table 5-2, allowable ramp volumes would be calculated as follows. If the excess demand, 1200 vph, at Section 2 were to be removed by reducing the allowable volume, X_2, at Ramp 1, the volume at Ramp 1 would have to be reduced by 267 vph. The allowable entrance ramp volumes are summarized accordingly in table 5-2.

The total input of 2,172 vph, however, is less than that of 2,248 vph, the volume obtained if Ramp 2 is metered as in Example 1. Thus, the fundamental approach



X_i = allowable volume at input i

D_i = demand at input i

B_j = capacity at section j

A_{ij} = decimal fraction of vehicles entering at input i which pass through section j

S_j = demand at section j

A_{ij} Values

i \ j	1	2	3	4
1	1.00	0.95	0.90	0.85
2	1.00	0.75	0.70	0.60
3	–	1.00	0.90	0.85
4	–	–	1.00	0.90
5	–	–	–	1.00

Compute X_i's starting at section #1

- Set $X_1 = D_1 = 4600$ vph
- $S_1 = A_{11}X_1 + A_{21}D_2 = (1.00)(4600)+(1.00)(800) = 5400 \text{ vph} = B_1 = 5400 \text{ vph}; \therefore X_2 = 800 \text{ vph}$
- $S_2 = A_{12}X_1 + A_{22}X_2 + A_{32}D_3 = (0.95)(4600)+(0.75)(800)+(1.00)(600) = 5570 \text{ vph} > B_2 = 4800 \text{ vph};$

  $\therefore X_3 = 0$ and volume entering upstream must be reduced by 170 vph;
  $\therefore X_2 = 800 - 170/A_{22} = 800 - 170/0.75 = 573 \text{ vph}$
- $S_3 = A_{13}X_1 + A_{23}X_2 + A_{33}X_3 + A_{43}D_4 = (0.90)(4600)+(0.70)(573)+(0.90)(0) + (1.00)(800) = 5341 \text{ vph} > B_3 = 5200 \text{ vph}; \therefore X_4 = 659 \text{ vph}$
- $S_4 = A_{14}X_1 + A_{24}X_2 + A_{34}X_3 + A_{44}X_4 + A_{54}D_5 = (0.85)(4600) + (0.60)(573) + (0.85)(0) + (0.90)(659) + (1.00)(600) = 5447 \text{ vph} > B_4 = 5200 \text{ vph}; \therefore X_5 = 353 \text{ vph}$

Conclusion:

- Ramp #1: Meter at a rate of 573 vph.
- Ramp #2 : Close.
- Ramp #3: Meter at a rate of 659 vph.
- Ramp #4: Meter at a rate of 353 vph.

Figure 5-10. Integrated Entrance Ramp Control: Example No. 2 Calculation of Pretimed Metering Rates. [5,6]

Table 5-2. Allowable Entrance Ramp Volumes for Example 3.

Ramp No.	Volume (vph)
1	533
2	600
3	687
4	352
Total Input	2172

described will result in the optimal utilization of the freeway. It maximizes the sum of the allowable entrance ramp volumes, a procedure which corresponds to maximizing system output for steady-state, uncongested flow conditions.[26] It also maximizes the total travel in the system.[27]

Linear Programming Formulation—The fundamental procedure described in Examples 1 and 2 can be formulated as a linear programming model.[26] This model may be used to compute optimal allowable entrance ramp volumes. In terms of the notation defined in figures 5-8 and 5-9, the linear programming model would be as follows:

- Maximize ΣX_j, where n is the number of inputs
- Subject to the following constraints:
  - Demand capacity:

$$\sum_{i}^{n} A_{ij} X_i \quad B_j;\ j=1,.....n-1$$

  - At Section 1, allowable mainline volume $\leq$ mainline demand:

$$X_1 = D_I$$

  - Allowable entrance ramp volume $\geq$ entrance ramp demand:

$$X_1 \leq D_I;\ i=2,.....,n$$

  - Allowable entrance ramp volume equals minimum allowable ramp volume:

$$X_1 \geq \min x_i \geq 0;\ i = 2,.....n$$

The use of the linear programming model yields allowable entrance ramp volumes identical to those obtained by using the fundamental procedure described above.

Practical Considerations

The allowable entrance ramp volumes (or metering rates) calculated for an integrated ramp control system should be evaluated with respect to the following practical considerations:[6]

- Metering rates of less than 180 to 240 vph (3 to 4 vpm) are not feasible because drivers required to wait longer than 15 to 20 seconds at a ramp metering signal often believe that the signal is not working correctly. They will, therefore, proceed on a red indication by the signal. Thus, if a metering rate of less than 180 to 240 vph is calculated, consideration should be given either to closing the ramp or to metering it at a higher rate.

- Practical maximum metering rates are about 900 vph for single-entry metering and approximately 1,100 vph for platoon metering. Therefore, for a metering rate greater than the maximum for the metering type to be used, the setting should be less than or equal to the practical maximum rate, and the metering rates at the other entrance ramps should be adjusted accordingly.

- Metering rates at each entrance ramp should be evaluated with regard to available storage at the ramp and potential resulting congestion on the adjoining surface street system. If the storage is not sufficient, it may be necessary either to close the ramp or to increase the metering rate.

- Metering rates equal to zero indicate that an entrance ramp closure is necessary. However, the closure of a particular entrance ramp may not be acceptable. Therefore, it may be necessary to increase a zero metering rate to some minimum acceptable rate.

- The procedure described for computing metering rates gives preference to traffic entering the system near the upstream end. Consequently, metering rates at entrance ramps downstream may be too restrictive to be acceptable to the motoring public. Therefore, it may be necessary to increase the metering rates computed for some of the downstream entrance ramps, and thus to reduce accordingly the metering rates for some of the upstream entrance ramps.

If any of the computed metering rates were to be altered because of one or more of the practical considerations mentioned above, the metering rates at the other entrance ramps would have to be adjusted accordingly to ensure both an optimal utilization of the freeway and an uncongested flow.

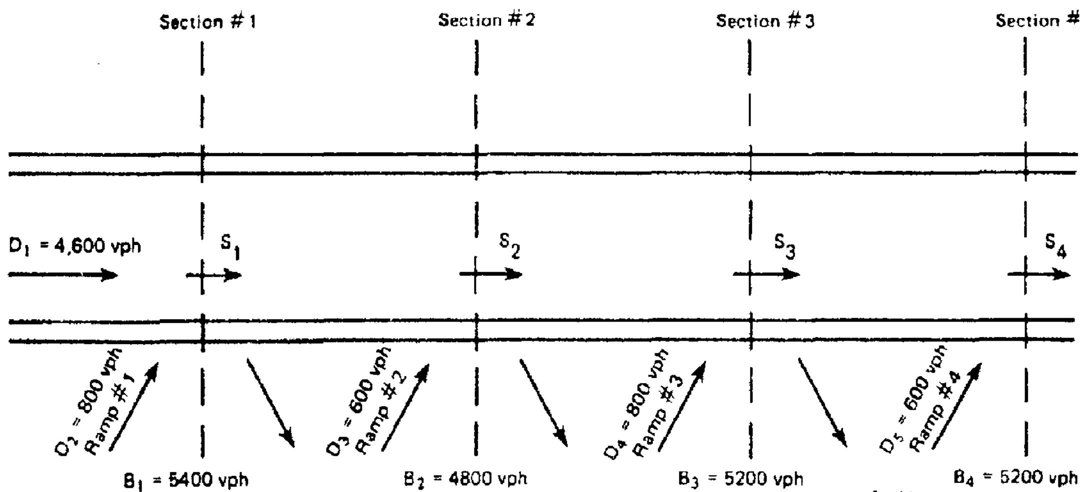
Example 4 [5,6]

If it were necessary to maintain a metering rate of at least 240 vph at Ramp 2 in the example presented in figure 5-10, it would be necessary to follow the adjustment procedure for the metering rates at the other entrance ramps (as shown in figure 5-11). The allowable volume. X_2 (573 vph), at Ramp 1 would have to be reduced by 320 vph in order to allow 240 vph to enter at Ramp 2 and still satisfy the demand-capacity constraint at Section 2. This reduction also decreases the mainline demand at Sections 3 and 4. Thus, the allowable volumes at Ramps 3 and 4 are increased to maximize the utilization of the freeway at these sections.

It is usually difficult to obtain reliable estimates of the A_{ij} values, because these vary with time and generally exhibit a high variance. Also, the O/D type studies used to collect these data are expensive and do not provide real-time data.

As indicated in the 1996 *Traffic Control System Handbook*, it may be unfeasible to reduce ramp volumes sufficiently to effect changes on freeway main lanes because of circumstances such as the following:[7]

- Minimum metering rate constraints.



X_j = allowable volume at input i

D_i = demand at input i

B_j = capacity at section j

A_{ij} = decimal fraction of vehicles entering at input i which pass through section j

S_j = demand at section j

A_{ij} Values

i \ j	1	2	3	4
1	1.00	0.95	0.90	0.85
2	1.00	0.75	0.70	0.60
3	–	1.00	0.90	0.85
4	–	–	1.00	0.90
5	–	–	–	1.00

Compute X_i's starting at section #1

- Set $X_1 = D_1$ = 4600 vph
- $S_1 = A_{11}X_1 + A_{21}D_2 = (1.00)(4600)+(1.00)(800) = 5400$ vph $= B_1 = 5400$ vph; $\therefore X_2 = 800$ vph
- $S_2 = A_{12}X_1 + A_{22}X_2 + A_{32}D_3 = (0.95)(4600)+(0.75)(800)+(1.00)(600) = 5570$ vph $> B_2 = 4800$ vph;

  Since X_3 must equal at least 240 vph; $X_3 = 240$ vph and volume entering upstream must be reduced by 410 vph;
  $\therefore X_2 = 800 - 410/A_{22} = 800 - 410/0.75 = 253$ vph
- $S_3 = A_{13}X_1 + A_{23}X_2 + A_{33}X_3 + A_{43}D_4 = (0.90)(4600)+(0.70)(253)+(0.90)(240) + (1.00)(800) = 5333$ vph $> B_3 = 5200$ vph; $\therefore X_4 = 667$ vph
- $S_4 = A_{14}X_1 + A_{24}X_2 + A_{34}X_3 + A_{44}X_4 + A_{54}D_5 = (0.85)(4600) + (0.60)(253) + (0.85)(240) + (0.90)(667) + (1.00)(600) = 5466$ vph $> B_4 = 5200$ vph; $\therefore X_5 = 334$ vph

Conclusion:

- Ramp #1: Meter at a rate of 253 vph.
- Ramp #2: Meter at a rate of 240 vph.
- Ramp #3: Meter at a rate of 667 vph.
- Ramp #4: Meter at a rate of 334 vph.

Figure 5-11. Integrated Entrance Ramp Control: Example No. 4 Calculation of Pretimed Metering Rates. (5,6)

- Lack of vehicle queuing storage.
- Too large a capacity deficiency.

The reader is referred to the handbook for a detailed example demonstrating the interaction among ramp metering requirements, diversion impacts, and ramp storage requirements. A detailed procedure can be found in reference 19.

Systemwide ramp metering strategies provide the opportunity to distribute vehicle demands over a larger number of ramps.

System Traffic-Responsive Metering

System traffic-responsive metering is the application of traffic responsive metering to a series of entrance ramps where the metering rates at each ramp are selected in accordance with both system and local demand-capacity constraints.

System Operation

During each control interval, real-time measurements are taken of traffic variables (usually volume, occupancy, and/or speed). The data are used to define the demand-capacity conditions at each ramp. Then, on the basis of these measurements, both an independent and an integrated metering rate are calculated for each entrance ramp. Of these two metering rates, the one that is the more restrictive is selected to be used during the next successive control interval.

Metering Rates

The methods used to calculate independent and integrated traffic-responsive metering rates are basically the same as those used to compute independent and integrated pretimed metering rates. Instead of calculating metering rates in real time, a set is precomputed for the range of demand-capacity conditions expected from which the metering rates are then selected in real time. The linear programming model is often used to calculate predetermined sets of integrated, traffic-responsive reentering rates. Also, the metering rates are usually subject to the merge-detector, queue-detector, and maximum-red-time overrides used in traffic-responsive metering

System vs. Independent Ramp Control

Comparisons of system and independent entrance ramp control indicate that increased benefits are realized with system ramp control.[26,27] Improvements occur in terms of the following:

- Lower travel time.
- Higher total travel.
- Fewer crashes.

In traffic-responsive metering, the greater system flexibility provided by system ramp control enables an optimal system response to individual variations in traffic demands and capacities resulting from incidents on the freeways.

Controller Interconnection

A significant feature of system ramp control is the interconnection among local ramp controllers, which permits conditions at one location to affect the metering rate imposed at one or more other locations. Real-time metering plans are computed and updated by a central master computer which issues metering rates to the respective local ramp controllers on the basis of freeway traffic information obtained from vehicle detectors throughout the system.

Although the decision-making capabilities are centralized within the central computer system, the processing of control intelligence may be distributed among the individual entrance ramps. For economic (and possibly reliability) reasons, there is a trend toward decentralized decision-making, distributed computation, and hierarchical control.[28]

RAMBO (Ramp Adaptive Metering Bottleneck Optimization) is a suite of programs developed for the Texas Department of Transportation by the Texas Transportation Institute.[29] RAMBO I is a software tool designed to assist in developing ramp metering plans using the TxDOT ramp meter specification, while operating either in the isolated mode or in local control. The program provides Transition Point Patterns for each metering level and evaluates traffic operations. RAMBO II likewise develops and evaluates ramp metering plans based on forecasted traffic conditions along an extended section of freeway containing up to 12 metered entrance ramps and 12 exit ramps operating either in the system mode, or in a hierarchically distributed system having real-time local control with systems-based metering objectives. The program was implemented in Houston, TX, in 1996.

The total software package can perform capacity analysis of the freeway system, assess projected metering operation, and assist in developing optimal ramp metering plans for either local ramp metering operations (using RAMBO I) or system ramp metering operations (using RAMBO II). RAMBO II can translate system-based results into local metering control parameters that can be downloaded into the local ramp meters if some minor modifications are made to the current ramp meter specifications. The programs include extensive interactive graphic screens.

Incremental Benefits of Various Levels of Control

As discussed earlier, the benefits offered by pretimed metering (including ramp closure) versus no access control include increased mainline speeds (reduced travel time), higher service volumes, less delay, safer merging operations, and reduced user costs. Beyond pretimed metering, the incremental benefits gained from traffic-responsive metering (local or systemwide) depend on the factors discussed below.[21]

Variations in the Ratio of Mainline to Entrance Ramp Demand

As mainline demand approaches capacity, the permissible metering rates become more and more constrained. On the other hand, as the mainline demand decreases. more traffic can be allowed onto the freeway from entrance ramps, and ramp metering control can exert greater impact on the quality of freeway flow, thus producing greater benefits.

Variations in Overall Traffic Demand Pattern

Traffic demand on the freeway and entrance ramps exhibits two types of variations: (1) shift in demand level, and (2) short-term fluctuations. The larger the magnitude of these types of demand variation, the higher the potential for benefits from traffic-responsive metering.

Mainline Capacity Reductions

Reductions in mainline freeway capacity result from accidents, traffic incidents, and adverse weather conditions. As the frequency and impact of these capacity-reducing factors increase, more need develops for traffic-responsive metering to cope with the variations in available capacity. To determine the appropriate level of ramp metering control for a given freeway, the incremental benefits produced by local and systemwide traffic-responsive metering (relative to a base of pretimed metering) must be estimated. Computer simulation can be effectively used in evaluating control benefits. In addition, the incremental system costs (installation, operation, maintenance) and the incremental user costs (travel time, vehicle operating costs, accidents, air pollution emission) must be estimated. Incremental benefits and incremental costs can then be used to conduct a benefit/cost or utility/cost analysis to decide upon the most desirable type of ramp metering.

The growth in traffic demand over the lifetime of a ramp metering project may reduce the incremental benefits of a traffic-responsive type of ramp metering control (local or systemwide). As traffic demand grows substantially over the lifetime of the project, the controllability index of the freeway decreases. Since the benefits are nonlinearly related to the controllability, it is possible that the benefits could decrease faster than the growth rate in demand. In planning ramp metering installations, the engineer should be aware of this effect. It is recommended that the analysis be repeated for as many years as are in the expected project-life duration.

The incremental benefits analysis is but one component of a system selection process which, in turn, is a component of a freeway traffic management decision process. The major components of this decision process include the following:

- Developing a basic analysis of freeway operations.
- Making a detailed analysis of freeway operations and determining improvement alternatives.
- Examining the feasibility of ramp control as an improvement alternative.
- Analyzing the site conditions and selecting the control level.

A detailed discussion of the incremental benefits of different types of ramp metering control is provided in NCHRP Report 232.(19)

EXIT RAMP CONTROL

Exit ramp control is seldom used as a means of freeway traffic control because the opportunities for its effective application are limited. In many situations, the use of exit ramp control may actually be contrary to the objective of safe and efficient freeway operations. Also, it should only be used where destinations can easily be reached by using alternate exits.

Exit ramp closure can be used effectively to reduce safety hazards and congestion caused by excessive weaving between closely spaced ramps and long queues on exit ramps. Also, exit ramp closure can be used at a lane drop location by closing downstream exit ramps in order to encourage more traffic to leave the freeway at the exit ramps before the lane drop and thus decrease the demand on the freeway section beyond the lane drop. However, as in the case of entrance ramp closure, exit ramp closure might not be acceptable because of the increased travel it creates for some motorists.

EMERGING TECHNOLOGIES

As mentioned in the opening paragraph of this section, most of the advances and emerging technologies in freeway management systems are in the computing hardware and communications technologies. While development of those fields will continue to enhance the ramp control process, there will be emergence or at least advancement, from preliminary stages of freeway ramp control systems. Such advancements include:

- **System Operation.** As freeway systems expand with more communications links, and detector data become available, there will be increased system operation of entrance ramp meters, with metering rates being determined on a system or subsystem basis.

- **Integrated Systems.** Earlier freeway management systems generally operated independently of the operation of surface street signal systems. In lieu of actually being integrated through hardware and communications links, traffic state and local system managers sometimes communicated informally to bridge the two systems. Future systems will likely be fully integrated, with data exchange and control decisions being made automatically with real-time data.

- **Information to Motorists.** Advanced information systems being installed or planned as part of the ITS deployment and expansion will assist motorists in selecting or bypassing entrance ramps where metering rates may be restrictive. Such diversion can be considered in integrated freeway and surface street systems.

- **Advanced Control Algorithms.** The National ITS Architecture Implementation Strategy provides an evaluation of ITS Technology Areas as to their maturity (mature, immature, mixed) to assess their potential deployment horizon.(2) While most of the elements are hardware oriented,"processing technology and advanced algorithms that enable advanced vehicle and traffic control application" are designated as mixed, meaning that there is opportunity for emerging applications.

- **Advanced Ramp Metering Concepts.** Because queues become critical under heavy ramp demands conditions, improved queue management algorithms based on multipoint detection are under development. Also, traffic responsive activation of ramp control will likely be used to manage traffic during off-peak or weekend incident conditions.(7)

5.4 LESSONS LEARNED

Although ramp control systems have been in operation in various metropolitan areas throughout the country for over a quarter of a century, they are still sometimes viewed as a "new or radical" approach to traffic control and management. Intersection traffic signals, on the other hand, are accepted by most drivers as necessary and, in fact, their installation is often requested by citizens. The two systems essentially perform the same function: **Facilitate use of available capacity between conflicting vehicular movements on the basis of demand levels and safety considerations with traffic signals.** However, the ramp signal may be viewed negatively by drivers, because freeways have been traditionally designed for unrestricted flow. In reality, the flow is often restricted by recurring and non-recurring congestion that may have a greater effect than that of the meter signal, which may encourage the driver to divert. For these reasons, there are certain "lessons learned" associated with ramp control which may not be a factor in other traffic and freeway control elements.

IMPLEMENTATION

Public Relations

Ramp metering systems can be successful only if they receive public support from political leaders, enforcement agencies, and the motoring public. To gain this support in advance of implementation, a comprehensive public relations and information program should begin well in advance. To the public, ramp meters are often seen as a constraint on a roadway normally associated with a high degree of freedom. Although definite benefits may be achieved by metering and have been demonstrated statistically, the benefits may not be recognized by individual motorists. A 3-minute wait at an entrance ramp, however, is easily recognized. A proactive public relations program should be an integral part of every metering project.[1]

It is important not to oversell the benefits of ramp metering. It is not a substitute for a new freeway lane. The benefits are measurable systemwide, but may not be readily discernable to the individual driver at the ramp signal. Successful public relations campaigns will explain the difficulties of mitigating freeway congestion problems and the cost effectiveness of management techniques such as ramp metering.[1] The campaigns should also provide realistic expectations of the system's benefits, and show how taxpayers will experience improved freeway conditions. The most common method of disseminating ramp metering information is through brochures or media advertisements on television and radio. Some examples of public relations brochures are shown in reference 1. In Minneapolis and Los Angeles, the "public" has actually requested additional metered ramps. This public input has become one of the factors in evaluating and selecting new metered locations.

Public relations aspects of the ramp control system should begin well in advance of turn-on. In Seattle, the Washington State DOT (WSDOT) has developed a methodical approach to implementing ramp metering.[30] Their process describes what needs to be accomplished starting five years prior to ramp metering all the way up to one week before, and continuing through six months after start-up. The procedure includes public input, the design process, and the public relations focus. In Tacoma, Washington, the WSDOT went beyond the typical public relations campaign of brochures and media advertisements. WSDOT has incorporated a ramp metering lesson into both public and private driver education school curricula. The lesson, which lasts about 30 minutes, helps students to understand what ramp meters are and what they mean to the driver. The information packet for this lesson includes a lesson plan, information sheets, brochures, key chains, and a well-developed 12 minute video entitled "Ramp Meters: Signals for Safety."

A promotional videotape from the FHWA entitled "Ramp Metering: Signal for Success" is another example of how the merits of ramp metering can be presented to the public.[1] This 17-minute videotape, which is intended for citizens and public officials, explains the principles and benefits of ramp metering. It addresses key issues such as safety, efficiency, equity, and public relations. Copies are available through the FHWA or the Institute of Transportation Engineers (ITE).

Media Relations

The print and electronic media can be great allies or great deterrents to the success of ramp control systems. When the Dallas

Corridor Study metering system was implemented in 1974, a radio reporter in the control center (with CCTV and other displays) reported that the system was working great, while a television reporter interviewing the 20th vehicle in a ramp queue proclaimed the system a failure.[31] The system perspective (which was understood by the reporter in the control center) must be stressed. As with the general public, the media must be informed as to system goals and expectations, schedules, operations, and results. It is also important to maintain communication with the media after system turn-on. Beat reporters are often reassigned, and the new reporter may need to be briefed before an uniformed, negative story is written.

Implementation Strategies

Scheduling of ramp control turn-on should be carefully considered. Incremental implementation of individual sections should be considered, rather than a total system launch. In particular, locations that have the best alternate routes and the highest probability of disruption of traffic flow should be considered first. Ramps should be operated with metering rates that cause little disruption. As drivers become familiar with and accustomed to the system, metering rates can be tightened and other locations implemented.

An interesting approach has recently been employed in Houston. Some of the pioneering efforts in ramp control took place in the mid-sixties.[12] However, due to reconstruction of freeways, ramp metering had not been in operation for some time. When ramp metering was recently reimplemented, a conservative philosophy was developed. The Implementation philosophy was as follows: [32]

> *... drivers and their views are important and a very high priority. No ramp delays (for a while at least) will be more than 2 minutes, and this must be verified. When queues or delays get too long, the signals are shut off until the queues clear, no matter what happens to the freeway. For the first three months, metering during the peak of the rush hour was sometimes terminated. No written complaints were received. However, continuous quality improvement for the freeway traffic flow is stressed. Freeway drivers have called by cell phone and by Internet asking TranStar (the freeway management center) for "more" ramp metering. Now, the simple explanation for this is that we have "teased" the freeway traffic into this position. But we have not followed any ramp control strategy mentioned in the traditional freeway ramp control manuals. The traditional demand/capacity methods are for marginally overloaded well-disciplined systems, and that goal of demand/capacity control is only a faint vision in Houston at the moment. We are simply pushing back up the q/k curve toward capacity from stop-and-go conditions, and not from the other side.*

Implementation Summary

The successful implementation of a freeway ramp control system is dependent on many factors outside of the hardware, software, and control algorithms. The implementation plan must include involvement, education, and support by the public, media, and political leaders. Additionally, the strategy with which individual ramps and subsystems are "turned on" must be carefully considered, planned, and executed.

OPERATIONS AND MAINTENANCE

Operations and maintenance considerations are not unlike those for other freeway control subsystems or for other traffic signal control systems. While the strategies may differ, there is still a necessity for operating agencies to commit the funds for personnel to operate, maintain, evaluate, and update the control system.

- **Personnel.** Adequate personnel for system operation and maintenance are essential if systems are going to succeed and continue to succeed. While improved hardware and software capabilities have allowed many tasks to be automated in system operation, personnel must be assigned to ensure continued efficient operation.

- **Training.** Training for system operations and maintenance is usually provided by the systems contractor. Continuing training programs will be essential as new personnel are assigned and as hardware and software upgrades are implemented.

- **Documentation.** Initial documentation for system operation and maintenance should (**must**) be provided by the systems contractor. Operations and maintenance personnel must also ensure that documentation is updated as system changes or hardware upgrades are made. Detailed logs should be kept for such changes. Modern systems often incorporate automated logging capability to facilitate the task and ensure that records are consistent.

- **Evaluation.** Although effectiveness of ramp control techniques has been well documented in the literature, it is usually necessary to perform "before and after" studies to document results of each system. It will also be important to continue to sample system operation with the same type data used in the initial evaluation to detect changes in system operation performance.

- **Updating Initial Strategies.** Based on continued system monitoring, as mentioned above, changes in individual control parameters or control strategies may be warranted. These may require minor changes to the data base or more significant changes to the control programs. Changes in the roadway system, both freeway and surface streets, must also be monitored and considered.

- **Incorporating New Strategies.** As ramp control systems continue to grow and mature, new ramp control algorithms will likely also be developed and tested. Continued communications among system operators and participation in professional organizations such as the Transportation Research Board (Freeway Operations Committee), Institute of Transportation Engineers, and Intelligent Transportation Society of America will be beneficial in becoming aware of such strategies.

- **Hardware and Software Maintenance.** Hardware maintenance may be performed either by the agency or by contract, or by a combination of the two. The responsible agency will likely maintain standard traffic control equipment and communications cables. Computer and communications hardware will usually be maintained by contract. Software data bases will normally be maintained by the responsible agency, while applications and system software will be maintained by contract. Whatever the method, agency or contract, maintenance responsibilities should be clearly defined and understood in advance of system implementation. Sufficient funding must continue to be committed for hardware and software maintenance.

DIVERSION OF TRAFFIC

A major issue that is raised in connection with metering is the potential diversion of freeway trips to adjacent surface streets to avoid queues at the meters. Extensive evaluations of existing metering systems show that adjustments in traffic patterns, after metering is implemented, take many forms.[1] However, it is possible to predict the likely impacts of metering before it is installed. Factors that enter into the analysis include trip length, queue length, entry delay, and especially the availability of alternate routes. The impact of attractive and efficient alternate routes can be a key factor in the effectiveness of a ramp metering system.[33] The probable new traffic patterns, including diversion, can then either be accommodated in the design and operation of the system, or become part of a decision that metering is not feasible.

Metering may, in fact, divert some short trips from the freeway. In concept, freeways are not intended to serve very short trips, and diverting some trips may even be desirable if there are alternate routes that are under-utilized. Diverting traffic from high volume, substandard, or other problem ramps to more desirable entry points should be an objective of metering where it is feasible. Such an action does require a thorough analysis of the alternate routes and the impacts of diversion on those routes, and improvements on the alternate routes when and where they are needed.

In Portland, city officials were very concerned about entrance metering creating problems on parallel streets. Before the meters on I-5 were installed, the city and State agreed that if volumes on adjacent streets increased by more than 25 percent during the first year of operation, the State would either abandon the project or adjust the meters to reduce the diversion below the 25 percent level. Following meter installation, the increase in local street volume was not substantial. Evaluations of the impact of metering on adjacent streets have been conducted in Los Angeles, Denver, Seattle, Detroit, and other cities. Significant diversion from the freeway to surface streets did not occur in any of these locations. Formal and informal agreements are common between State and local jurisdictions in connection with metering projects, and close advance coordination between jurisdictions is highly recommended.[1]

In some cases, there may not be feasible alternates routes, due to barriers such as rivers, railroads, or other major highways. Metering still can and does operate effectively where diversion is not an objective of the system. The systems in Denver, Northern Virginia, and Chicago, for example, operate under a so-called non-diversionary strategy. In these systems, metering is sometimes terminated at least until the queue dissipates. (See discussion of Houston ramp metering above). Significant benefits in freeway flow and accident reduction still result from nondiversionary metering. The onset of mainline congestion consistently begins later in the peak period and ends earlier. On many days, the mainline does not break down at all. Accidents and accident rates are also reduced. For example, in Denver it was observed that many drivers entered the freeway earlier in the morning. Peaks or spikes in volumes were thus leveled out over a longer period of time resulting in better utilization of freeway capacity.[34]

ENFORCEMENT

The effectiveness of ramp metering, like that of any other traffic regulation, is largely dependent on voluntary driver compliance. As part of the public information effort, it should be made clear that ramp meters are traffic control devices that must be obeyed.[1] The laws and penalties should be clearly explained. In cities where the advance publicity has been positive and plentiful, violation rates has been lower. Again, as with any other regulation, enforcement is needed. Cooperation with police agencies is essential. Effective enforcement requires good enforcement access, a safe area for citing violators, adequate staff, support by the courts, and good signs and signals that are enforceable. Enforcement needs must be considered and accommodated **early** in the project development and design stages. Enforcement personnel should also be included **early** on in the planning and design of ramp metering projects. Compliance is critical to the success of a ramp metering system. Compliance rates, have generally been good in most areas across the country. However, violations are contagious and can multiply quickly. The result can be an extremely ineffective ramp metering system.

EQUITY

The complaint that ramp metering favors longer trips at the expense of shorter trips can be a controversial issue.[1] Close-in residents argue they are deprived of immediate access to the freeway, while suburban commuters can enter beyond the metered zone and receive all the benefits without the ramp delays.

Again there are strategies that have been employed to mitigate the equity issue. Initial metering in Detroit operated only in the outbound direction to minimize the city-suburb equity problem. Once the effectiveness of the metering was established, the system was expanded with less objection. This strategy was used in Atlanta where northbound I-75, leaving the city during the evening peak, will be the first section metered.[33] In Seattle, the system was designed to allow more restrictive metering rates farther away from downtown. With the long trip length, motorists originating from the suburbs have the most to gain from improved freeway conditions. The minor additional delay experienced at the meters is more than offset by the reduced mainline travel times. In Milwaukee, where the question of equity has been a limiting factor in the expansion of metering, it is now proposed to expand the system by metering each ramp that contributes traffic to congested freeway segments. Metering rates will be designed to be comparable for all ramps. For example, if it is determined a 10 percent reduction in demand is needed on the freeway segment, metering rates will be established to reduce all ramp volumes by 10 percent. In addition, each ramp metering rate will be adjusted to the extent possible in order to ensure average motorist delays are about equal for outlying ramps and for closer in ramps.[35] In Dallas, there was concern that suburbs were being favored over areas closer to the central business district. Ramp counts and license plate studies revealed that approximately as many vehicles were exiting the freeway before they reached downtown as were entering downstream of the adjacent suburbs, so equity was achieved.[36]

Even if only a few drivers experience increased travel times, there may still be objections simply because some have to wait at the ramps and others do not. A reasonable analogy can be made between a metered freeway and a signalized arterial. Vehicles entering an arterial from a minor street must generally wait at a traffic signal while traffic already on the arterial is given priority. In both cases, the freeway and the arterial, the entering vehicles experience some delay in order to serve the higher volume facility. [1]

5.5 EXAMPLES IN RAMP CONTROL

There is extensive documentation of ramp control systems in the literature, much of which are cited in the reference lists in this handbook. An excellent summary of ramp control status, Ramp Metering Status in North America, was published by FHWA in 1995.[1] The history and case studies cited below were adapted from that report.

HISTORY OF RAMP CONTROL

The first metered ramp, as we know it today, was installed in Chicago on the Eisenhower Expressway in 1963. This first application, however, was preceded by successful tests of the effectiveness of metering traffic entering New York tunnels, and by ramp closure studies in Detroit. In Los Angeles, ramp metering began in 1968. That system has been expanded continually until there are now over 800 ramp meters in operation in L.A. County—the largest system in North America. Currently ramp meters are in operation in 23 metropolitan areas in North America These metering systems vary from a fixed time operation at a single ramp to computerized control of every ramp along many kilometers of a freeway.

Many reports have been written that document the potential successes and benefits of ramp metering. However, the true measure is in the continued growth of ramp metering installations. Since 1989, the number of operating meters in North America has increased from about 1600 to more than 2300, an increase of about 45 percent. Additionally, many existing systems are proposing expansions and/or upgrades. On the planning side, new ramp metering is being considered in numerous other cities as part of ITS early deployment plans or feasibility studies. By the year 2000, at least 33 cities in the United States and Canada will have functioning ramp meters. This will be 11 more systems than existed in 1989.

ENTRANCE RAMP METERING CASE STUDIES

The abbreviated case studies presented here are just a few examples of effective ramp metering operations. The benefit statistics presented are not consistent from city to city as there is no uniform evaluation criteria. Additionally, the measures of effectiveness (MOEs) vary depending on the objectives of the system. Further, complicating the matter, many ramp metering installations are implemented at the same time as other freeway improvements such as increased capacity, high-occupancy vehicle (HOV) lanes, surveillance systems, traffic information systems, and incident management programs. In these cases, it is not always possible to evaluate the individual components of the larger projects. The conditions of the evaluations of these case studies are noted for each discussion.

Portland, Oregon

The first ramp meters in the Pacific Northwest were installed along a 10 kilometer section of I-5 in Portland in January 1981. The meters are operated by the Oregon Department of Transportation. I-5 is the major north/south link, and is an important commuter route through the metropolitan area. This initial system consisted of 16 metered ramps between downtown Portland and the Washington state line. Nine of the meters operated in the northbound direction during the p.m. peak, and seven controlled southbound entrances during the a.m. peak. The meters operate in a fixed time mode. There are currently 58 ramp meters operating on 5 different freeways.

Prior to metering, it was common along this section of 1-5 for platoons of vehicles to merge onto the freeway and aggravate the already congested traffic. The northbound PM peak hour average speed was 26 ki/h. Fourteen months after installation, the average speed for the same time period was 66 ki/h. Travel time was reduced from 23 minutes (but highly variable) to about 9 minutes. Premetered conditions in the southbound a.m. peak were much less severe, hence the improvements were smaller. Average speeds increased from 64 to 69 kph, resulting in only slight reductions in southbound travel times.

Additional benefits that were evaluated for the p.m. peak period included fuel savings and a before-and-after accident study. It was estimated that fuel consumption, including the additional consumption caused by ramp delay, was reduced by 2040 liters of gasoline per weekday. There was also a reduction in rearend and sideswipe accidents. Overall, there was a 43 percent reduction in peak period traffic accidents. [37]

Minneapolis/St. Paul, Minnesota

The Twin Cities Metropolitan Area Freeway Management System is composed of several systems and subsystems that have been implemented over a 25-year period by the Minnesota Department of Transportation. The first two fixed time meters were installed in 1970 on southbound I-35E north of downtown St. Paul. In November 1971, these were upgraded to operate on a local traffic responsive basis and 4 additional meters were activated. This 8-kilometer section of I-35E has been evaluated periodically since the meters were installed. The most recent study shows, that after 14 years of operation, average peak hour speeds remain 16 percent higher, from 60 to 69 ki/h, than before metering. At the same time, peak period volumes increased 25 percent due to increased demand. The average number of peak period accidents decreased 24 percent, and the peak period accident rate decreased by 38 percent.

In 1974, a freeway management project was activated on a 27-km section of I-35W from downtown Minneapolis to the southern suburbs. In addition to 39 ramp meters, the system included 16 closed-circuit television (CCTV) cameras, 5 dynamic message signs (DMS), a 2-km zone of highway advisory radio (HAR), 380 vehicle detectors, and a computer control monitor located at the MnDOT Traffic Management Center in Minneapolis. This project also included extensive "freeway flyer" (express bus) service, and 11 ramp meter bypass ramps for HOV's. An evaluation of this project after 10 years of operation shows that average peak period freeway speeds increased from 55 to 74 ki/h, or 35 percent. Over the same 10-year span, peak period volumes increased 32 percent, the average number of peak period accidents declined 27 percent, and the peak period accident rate declined 38 percent. Over one million dollars a year in road user benefits are attributed to reduced accidents and congestion. This system also has positive environmental impacts. Peak period air pollutant emissions, which include carbon monoxide, hydrocarbons, and nitrogen oxides, were reduced by just under 2 million kilograms per year. [38]

Over 300 additional ramp meters have been implemented from 1988 to 1995, and there are currently 400 meters in operation. Further projects are now in the design and construction phases. The plans are to complete the ramp metering system which will cover the entire Twin Cities freeway network over the next five years.[39] The success of the Twin Cities system has shown that the staged implementation of a comprehensive freeway management system on a segment-by-segment, freeway-by-freeway basis, over a long period of time, is an effective way of implementing an area-wide program.

Seattle, Washington

In September 1981, the Washington State Department of Transportation (WSDOT) implemented metering on I-5 north of the Seattle Central Business District. Initially the system, which is named FLOW (not an acronym), included 17 southbound ramps that were metered during the a.m. peak, and 5 northbound ramps that were metered during the p.m. peak. Currently, the ramp metering system includes 54 meters on I-5, I-90, and SR 520. These meters are all operated under centralized computer control. Future expansion plans include additional ramp meters on SR 520 east of Lake Washington, on all of I-405, and on I-5 south of Seattle.

One evaluation of the initial 22 meter system showed that between 1981 and 1987, mainline volumes during the peak traffic periods increased 86 percent northbound and 62 percent southbound. Before the installation of metering, the travel time on a specific 11-km course was measured at 22 minutes. In 1987, the travel time for the same course was measured at 11.5 minutes. Over the same 6-year time period, the accident rate decreased by 39 percent.[40]

A somewhat unique application of metering was implemented in Seattle on SR-520 in 1986. While diversion caused by metering is often controversial, one of the objectives of metering SR-520 was to reduce commuter diversion through a residential neighborhood. The meters were installed on the two eastbound ramps on SR-520 between I-5 and Lake Washington. One of these ramps, the Lake Washington Boulevard on-ramp, is the last entry onto SR-520 before the Evergreen Point Floating Bridge. Because there were no bottlenecks downstream of this ramp, traffic would normally flow freely on the bridge and beyond. Motorists, especially commuters from downtown Seattle, were using residential streets to reach the Lake Washington Boulevard on-ramp to avoid congestion on SR-520. This on-ramp, however, was a major contributor to congestion on SR-520 because of the high entering volumes. By metering the ramp, it was anticipated that traffic diverting through the adjacent neighborhood from downtown would be discouraged by the delay caused by the meter. Motorists would instead use the Montlake Boulevard on-ramp, which was also metered at the same time. A HOV bypass lane was also installed at the Montlake Boulevard on-ramp. Two other objectives of this project were to improve flow on SR-520 and to encourage increased transit use and carpooling.

An evaluation of this two-ramp meter "system" after four months of operation showed there was a 6.5 percent increase in mainline peak period volume, a 43 percent decrease in the volume on the Lake Washington Boulevard on-ramp, an 18 percent increase in the volume on the Montlake Boulevard on-ramp, and a 44 percent increase in HOVs using the Montlake Boulevard on-ramp.[41] Another indication of the effectiveness of the combination of the HOV bypass and the improved SR-520 flow is a decrease of 3 minutes in METRO (King County Department of Metropolitan Services) transit travel times for buses traveling from downtown to the east, and a 4-minute decrease for buses traveling from University District to the east. The reliability of the bus travel times also improved, and METRO adjusted the schedules for these routes accordingly.

In 1993, the WSDOT implemented weekend ramp metering for the first time. Three ramps north of Seattle on southbound I-5 have been metered several hours due to heavy weekend volumes. Because of this success, in March of 1995, weekend metering was expanded to include four additional southbound ramps.

In April of 1995, WSDOT began operating seven southbound I-5 meters during the evening commute. This is WSDOT's first implementation of metering both directions of a corridor during the same peak period. The motivation behind this operational change is that the traditional reverse commute direction has become increasingly congested. Prior to this change, metering along this section had operated southbound (inbound toward Seattle) during the morning commute and northbound (outbound) during the evening commute.

Denver, Colorado

The Colorado Department of Transportation activated a pilot project to demonstrate the effectiveness of ramp metering on a section of northbound I-25 in March 1981. The initial system consisted of five local traffic-responsive metered ramps operated during the a.m. peak on a 4.7-km section of I-25 south of the city. Periodic after-evaluations revealed significant benefits. An 18-month after study showed that average peak period driving speed increased 57 percent and average travel times decreased 37 percent. In addition, incidence of rearend and side-swipe accidents declined 5 percent due to the elimination of stop-and-go conditions.

The success of the pilot project led to expansion of the system. In 1984, a central computer was installed and a System Coordination Plan was implemented that permits central monitoring and control of all meters. Since 1984, additional ramp meters have been added, until reaching the current number of 28. In late 1988 and early 1989, a comprehensive evaluation of the original metered section was conducted. A number of changes occurred between 1981 and 1989, the most significant of which was the completion of a new freeway, C-470, which permitted more direct access to I-25 from the southwest area and generated higher demand for I-25. Volumes during the 2-hour a.m. peak period increased from 6200 vph in 1981 to 7350 vph in 1989 (on 3 lanes). Speeds measured in late 1988 decreased from the original evaluation, but remained higher than the speeds before metering was implemented: 69 ki/h before, 85 ki/h after, in 1981, and 80 ki/h in late 1988. The frequency of accidents during the a.m. peak period did not increase between the time of original evaluation and 1989. As a result, the accident rate decreased significantly because of the increased volumes. Rearend and sideswipe type accidents decreased by 50 percent during metered periods.

An interesting unplanned "evaluation" of the system occurred in the Spring of 1987. To accommodate daylight savings time, all of the individual ramp controllers were adjusted one hour ahead. Unfortunately, the central computer clock was overlooked. The central computer overrode the local controllers, and metering began an hour late. Traffic was the worst it had been in years. However, this oversight did have a bright side for the Department of Transportation. Since this incident, the media has been even more supportive of ramp metering than before. [34]

In 1988, the Colorado Department of Transportation conducted a study to evaluate different levels of ramp metering control. The study compared ramp meters operating in local traffic-responsive mode versus meters operating under centralized computer control. The results showed that if local traffic-responsive metering could maintain freeway speeds above 90 ki/h, centralized control offered little or no additional benefit. However, if local traffic-responsive metering was unable to maintain speeds near the posted speed limit of 90 ki/h, centralized control was very effective. Data showed speeds increased 35.5 percent, from 50 to 68 ki/h, and vehicle hours of travel were reduced by 13.1 percent.[42] This evaluation shows the importance of implementing operating strategies that correspond to the needs of the freeway network.

Detroit, Michigan

Ramp metering is an important aspect of the Michigan Department of Transportation's (MDOT) Surveillance Control and Driver Information (SCANDI) System in Detroit. The SCANDI metering operation began in November 1982 with six ramps on the eastbound Ford Freeway (I-94). Nineteen more ramps were added on I-94 in January 1984 and three more in November 1985. An evaluation performed by Michigan State University for MDOT determined that ramp metering increased speeds on I-94 by about 8 percent. At the same time, the typical peak hour volume on the three eastbound lanes increased to 6400 vehicles per hour from an average of 5600 VPH before metering. In addition, the total number of accidents was reduced nearly 50 percent, and injury accidents came down 71 percent. The evaluation done by Michigan State also showed that significant additional benefits could be achieved by metering the three freeway-to-freeway connectors on this section of I-94.[44]

Austin, Texas

In the late 1970s, in Austin, the Texas Department of Transportation implemented traffic responsive meters at 3 ramps along a 4.2 km segment of northbound I-35 for operation during the a.m. peak period. This section of freeway had two bottleneck locations that were reducing the quality of travel. One was a reduction from 3 to 2 lanes and the other was a high volume entrance ramp just downstream of a lane drop. Metering resulted in an increased vehicle throughout of 7.9 percent and an increase in average peak period mainline speeds of 60 percent through the section. The meters were removed after the reconstruction of I-35 eliminated the lane drop in this section.[44] This situation shows the versatility of ramp metering in that it can also be used effectively as a temporary solution.

Long Island, New York

At the other end of the spectrum from Austin is the INFORM (Information For Motorists) project on Long Island. The INFORM project covers a 64-km long by 8-km wide corridor at the center of which is the Long Island Expressway (LIE). Also included in the system is an east-west parkway, an east-west arterial and several crossing arterials and parkways, a total of 207 kilometers of roadways. System elements include 70 metered ramps on the LIE and the Northern State/Grand Central Parkway.

In 1989, an analysis of the initial metered segment was conducted after 2 months of operation. For the peak period, the study showed a 20 percent decrease in mainline travel time (from 26 to 21 minutes) and a 16 percent increase in average speed (from 47 to 56 ki/h). Motorists entering at metered ramps also experienced an overall travel time reduction of 13.1 percent and an increase in average speed from 37 to 45 ki/h. The MOEs for this project include vehicle emissions. For this initial segment, the analysis indicates there was a 6.7 percent reduction in fuel consumption, a 17.4 percent reduction in carbon monoxide emissions, a 13.1 percent reduction in hydrocarbons, and a 2.4 percent increase in nitrous oxide emissions. The last is associated with the higher speeds. Initial observations of the effect of metering the 4-lane parkway on the INFORM project indicates the benefits may be even greater than those achieved on wider freeways. Intuitively this makes sense, because the impact of an unrestricted merge on only two lanes (in one direction) can be severe. (45)

A more extensive evaluation of the INFORM project was completed in 1991. Data from this study showed much more conservative results. It is believed that this study is more representative of the true traffic conditions. The main reason for this is related to the "queuing off" (shut-down of the meter due to excessive queuing) of the ramp meters. The original study did not include areas where metering was usually shut off due to heavy ramp volumes, while the later study accounted for all ramps. This evaluation showed that while throughput had increased only about 2 percent, the average mainline speeds had increased from 64 to 71 ki/h, or about 9 percent. However, for two separate bottleneck locations, data showed increases of 53 to 84 and 53 to 89 ki/h, or gains of about 36 and 40 percent respectively. This evaluation also included calculation of a "congestion index." This index is the proportion of detector zones for which speeds were less than 48 ki/h (30 mi/h). While no benefit was shown in the evening peak period, the morning peak period showed an improvement of 25 percent in the congestion index. The accident frequency rate also showed encouraging improvement, with a 15 percent reduction as compared to the control section. (46)

San Diego, California

In San Diego, ramp metering was initiated in 1968. That system, installed and operated by the California Department of Transportation (Caltrans), now includes 134 metered ramps on 110 plus kilometers of freeway. No detailed evaluations of metering have been conducted on the San Diego system since the early installations, but sustained volumes of 2200 vph to 2400 vph, and occasionally even higher, are common on San Diego metered freeways. A noteworthy aspect of the program is the metering of eight freeway-to-freeway connector ramps. Metering freeway-to-freeway connectors requires careful attention to storage space, advanced warning, and sight distance. If conditions allow, freeway connector metering can be just as safe and effective as other ramp metering. (47)

SUMMARY OF RAMP METERING BENEFITS

Metering entrance ramps can significantly improve mainline traffic flow. These case study evaluations, as well as others, show that metering consistently increases travel speeds and improves travel time reliability, both of which are measures of reduced stop-and-go, erratic flow. It should be emphasized that these benefits occurred even though, in most instances, mainline volumes had significantly increased. Metering helps smooth out peak demands that would otherwise cause the mainline flow to breakdown. A strong case can be made from the data reported that metering actually increases the throughput of a freeway. The data from Minneapolis, San Diego, Seattle, Detroit and Denver shows mainline volumes well in excess of 2100 vph per lane on metered sections, and sustained volumes in the range of 5 percent to 6 percent greater than for pre-metered conditions. Improved traffic flow, particularly the reduction in stop-and-go conditions, also reduces certain vehicle emissions. This has been shown in both the INFORM project and in the Twin Cities Freeway Management System.

The other direct benefit, but one that has not been fully quantified, is the reduction in accidents attributed to metering. The Dallas corridor provided a unique opportunity to compare vehicle crash experience in a ramp metering system.[48] Evaluation studies showed significant improvements in system operating characteristics as compared to the "before" conditions. However, during the first year of operation, metering was exercised only in the peak direction of flow. During that year, crashes in the metered direction decreased by 24 percent as compared to the previous year, while crashes in the non-metered direction increased by 12 percent. During the first three years of metering, total weekday (24 hour/day) crashes increased by 8 percent while accidents during ramp metering decreased by 18 percent. The other case studies presented in this report consistently show a reduction in crash rates of 24 to 50 percent. Minnesota Department of Transportation estimates over 1000 vehicle crashes are prevented each year on Minneapolis/St. Paul metropolitan area freeway due to ramp metering.[39] However, the benefits derived from accident reduction go well beyond the direct costs related to medical expenses and vehicle damage. To illustrate, assume an incident blocks one lane of three at the beginning of the peak period on a freeway with a 2-hour peak demand of 6000 vph. Studies show that an accident blocking one of three lanes reduces capacity by 50 percent. A 20-minute blockage would cause 2100 vehicle-hours of delay and a queue over 3 kilometers long, and take 2 1/2 hours to return to normal, assuming there were no secondary accidents or incidents. Clearly the safety aspects of metering are a major benefit.

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MODULE 6. HOV TREATMENTS

TABLE OF CONTENTS

MODULE 6. HOV TREATMENTS

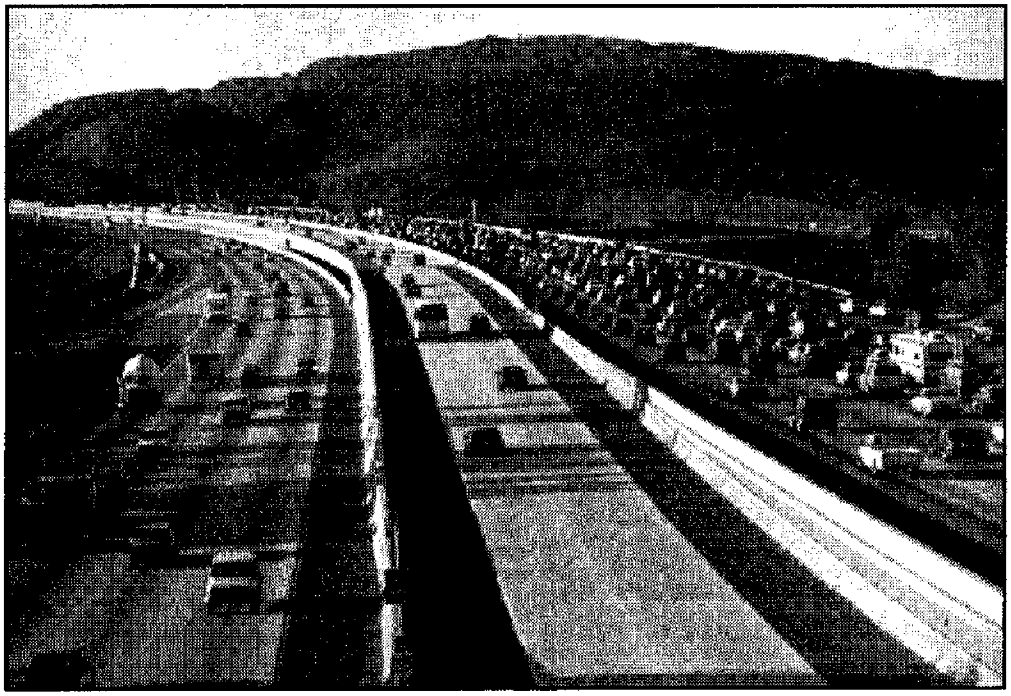

Figure 6-1. HOV Lane in San Diego, CA.

6.1 INTRODUCTION

Preferential treatments for high occupancy vehicles (HOV) have proven to be one of the most flexible, cost effective alternatives for increasing the person-moving capacity of congested metropolitan transportation systems. The concept emphasizes *person movement* rather than traditional *vehicle movement.* It offers multi-person vehicles the opportunity to travel in reserved lanes that allow higher operating speeds and more reliable travel times. HOV treatments are not appropriate in every situation, but their applications are growing as more and more metropolitan areas face the challenge of improving mobility, particularly during peak travel periods.

Constraints on metropolitan mobility have been identified as among the most serious transportation issues affecting the economic and social vitality of the nation. Many regions of the country, recognizing this critical importance of continued mobility, have established the following areawide goals:

- Reduce vehicle-miles of travel.
- Conserve energy.
- Reduce air pollution.

HOV facilities can be a major component in regional efforts to improve the operational efficiency of a freeway by:

- Increasing the people-moving capacity of the facility.
- Offering high-speed travel to a larger number of people (to decrease the average travel time and make it more predictable).

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- Providing an incentive for people to share rides (to increase the number of persons carried per vehicle).

The objective of HOV lanes is, of course, to move more people in fewer vehicles than conventional highway lanes. A dramatic example of the person-moving capability of an HOV lane is on 4 km (2.5 mi.) of I-495 in New Jersey, between the New Jersey Turnpike and the Lincoln Tunnel entering New York City. Here a contraflow lane, a lane in the off-peak direction, separated from the adjacent lane with plastic posts during the morning peak, carries 35,000 people in 750 buses during the peak hour, and more than 70,000 people in 1650 buses in the 3-hour peak period. It would require 15 conventional freeway lanes to move the same number of people in the peak hour. Certainly, no other city has the employment density or transit use of the New York/New Jersey Metro area, but HOV facilities throughout the country are accomplishing the same objective by providing a reduced travel time and travel time reliability incentive for drivers to change mode to HOV. Existing freeway HOV lanes carry the person-equivalent of two to five conventional lanes, and do so at a higher level of service than the conventional lanes. If an HOV lane becomes congested, the occupancy requirement can be raised, or other adjustments can be made to accommodate additional vehicles and thus additional people.[1]

TREATMENTS

Priority treatments may be either dedicated mainline lanes or isolated improvements that bypass a bottleneck. These treatments include the following:

- Exclusive HOV Facility - Separate Right-of-Way.
- Exclusive HOV Facility - Freeway Right-of-Way.
- Concurrent Flow Lane.
- Contraflow Lane.
- Queue Bypass HOV Facility.

These treatments are best served when implemented with a number of other transportation demand management measures to encourage use such as:

- Rideshare matching services.
- Guaranteed ride home.
- Employer incentives through preferential parking.
- Parking cost incentives.
- Supporting facilities that help to collect and distribute passengers.
- Public information.
- Education programs.

MODULE OBJECTIVES

The objectives of this module are to accomplish the following:

- Present the process for developing HOV treatments within a freeway system.
- Provide a summary and description of different HOV treatments in use, including both HOV lanes and supporting facilities such as park-and-ride and preferential parking programs.

- Discuss planning, design, construction, operating, and maintenance issues associated with the different HOV treatments.

MODULE SCOPE

In view of the impressive HOV success stories of Houston, Seattle, and other cities (see **section 6.5**), a high interest exists in implementing HOV treatments within freeway systems. This module presents the basics for HOV treatments associated with freeways. Treatments on arterial roadways can also support the freeway system, however those treatments are not discussed here. Information on the different freeway treatments and their supporting parking-related facilities are presented along with discussion on issues associated with those facilities. An emphasis of this module is on the need for cooperation between the partners and the presentation of issues that need to be considered during the planning process.

6.2 DESIGN PROCESS

IDENTIFY PROBLEMS/NEEDS

High Occupancy Vehicle facilities are viable components of freeway systems. The needs that can be addressed by HOV facilities include the following:

- Increasing person-carrying capacity of a highway corridor.
- Reducing total travel time.
- Reducing or defer the need to increase highway vehicle-carrying capacity.
- Improving efficiency and economy of public transit operations.
- Reducing fuel consumption.
- Improving air quality.
- Inducing mode shift.

Factors that influence consideration of HOV facilities include:

- Congestion.
- Travel time savings.
- Person throughput.
- Vehicle throughput.
- Local agency support.
- Enforceability.
- Physical roadway characteristics.
- Support facilities.
- Environmental mitigation.
- Compatibility with other modes.

The two criteria that most commonly appear to influence HOV viability are *congestion* and *travel time savings*. Without existing or forecasted congestion, the HOV alternative offers no substantial benefits for single-occupant drivers to switch to carpool, vanpool, or bus. Although the definition of "congestion" varies from one locale to another, a good measure of congestion is average freeway speeds of 48 km/h (30 mi/h) or less during the peak hour, or 56 km/h (35 mi/h) or less during the peak period. In some instances, an HOV alternative has been considered for a congested freeway that could operate relatively smoothly with an added mixed-flow lane, but for which future congestion is predicted. Travel time savings has become one of the most reliable predictors of HOV viability, and it must potentially exist to encourage mode shifts. For most treatments, a projected 5-minute or more savings per trip is generally recognized as a prerequisite. Time savings of less than 5 minutes may still justify consideration of queue bypass where a modest investment benefits many drivers.[3]

An assessment of HOV projects in six U.S. cities—Houston, Minneapolis-St. Paul, Pittsburgh, Seattle, Washington, DC, and Orange County, California—found the following common elements in the decision-making process: [4]

- *Corridor and areawide characteristics.* An awareness of the need to address increasing traffic congestion problems in the corridor had developed.
- *Lack of a fixed-guide way transit plan for the corridor.* No decision had been made on the development of a fixed-guide way transit system in the corridor where the HOV facility was ultimately developed.
- *Planned or scheduled highway improvements.* HOV projects were considered and implemented as part of an extensive program of highway improvements. This coordination helped maximize available resources and minimize impacts on implementation.
- *Project champion or champions.* Individuals in positions of authority in highway and transit agencies supported the HOV concept and promoted it throughout the project development process.
- *Legislative direction and policy support.* Legislative or agency policies and directives played an important role in the decision-making process in some HOV projects.

To assist with defining the problems that exist within the freeway system so that appropriate decisions can be made, an inventory of physical and organizational components is needed. Table 6-1 lists some of the specific types of information needed.

IDENTIFICATION OF PARTNERS

The key partners in the development of an HOV facility component of a freeway management system include the following:

- State Department of Transportation.
- Transit Authority (or Authorities).
- Federal Highway Administration.
- Metropolitan Planning Organizations.
- Enforcement Agencies.
- County or City Departments of Transportation.

In addition, the following can be key in developing a successful plan, rather than one that is challenged during the development and/or construction of a facility:

- Elected Officials.
- Media representatives.
- Citizens.
- Representatives from private businesses.
  - Major traffic generators.
  - Businesses with ride-sharing programs.

Table 6-1. Information Needs for Successful HOV Operations.

Person-Moving Capacity of the Roadway Facility
Potential for Support Facilities Such as Park-and-Ride Lots
Origins and Destinations
Activity Centers
Point of Origin
Average Trip Length
Trip Times
Traffic Operation on Freeway Mainlane
Average Delay
Peak Period Volumes
Average Travel Speeds
Travel Time
Bottlenecks
Location
Duration
Causes
Vehicle Occupancy
Percentage of Peak Period 2+ and 3+ Vehicles in the Traffic Stream
Future Demand
Growth Factor of Corridor
Growth Factor of Parallel Routes
Transit and Rideshare Patronage
Types of Operations That Could Benefit from HOV
Existing and Planned Transit Services
General Design Limitations of Existing Freeway Facility
Safety and Accident Data
Violation and Enforcement Data
Information on the Perception of Users, Non-Users, and the General Public

In some cases, for example the development of a park-and-ride facility has included other non-traditional partners. Other important partners that can be involved in the decision-making process include the following:

- Owners/operators of major traffic generators.
- Churches whose parking lots could be used for weekday commuters.

Successful HOV systems requires good coordination between respective governmental agencies. Two examples of areas where effective coordination has occurred include Houston and Seattle.[5] Agencies primarily involved in the implementation of HOV facilities in Houston included:

- Texas Department of Transportation.
- Metropolitan Transit Authority.
- Federal Highway Administration.

Agencies involved in Seattle included:

- Washington State Department of Transportation.

- Puget Sound Council of Governments.
- Seattle Metro Transit.
- Pierce County Transit.
- Municipality of Metropolitan Seattle (Metro).
- King, Pierce, and Snohomish Counties.
- City of Bellevue.
- Federal Highway Administration.

Additional information on the Houston and Seattle systems is provided later in this module.

CONSENSUS BUILDING

Having an overall consensus and developing good working relationships within and between agencies are important in implementing an HOV facility system. During initial meetings, identifying and understanding the differences in operational philosophies and priorities of the different partners will assist in the process. For example, major business associations may be more concerned with the location of ramps to and from an HOV lane, and whether those ramps will go into a parking garage, while a transit agency's priority may be to have the ramps exit to a downtown street.

The importance of public support needs to be recognized early in the process. Extensive public relations and media campaigns may be needed to show the public the benefits of the HOV facilities. An important lesson that has been learned from project failures to date is that the public must be involved and must be able to understand and appreciate the role that HOV systems can serve. Public participation will need to be focused and pursued at various levels.

A multi-agency review group (also called an advisory committee or steering committee) should be formed. Their role includes technical and policy guidance, concurrence powers at major decision points, coordination and liaison with others in the respective agencies, and outreach to greater public participation efforts as needed. Apart from the multiagency review group, focus groups composed of local civic associations, special interest groups, politicians, the media, and others may be necessary to link public participation with the process.[5]

ESTABLISH GOALS AND OBJECTIVES

After the relevant partners are identified, the goals and specific objectives that are to be addressed through this component of the freeway system are developed. Goals are broad statements of the intent of the system or of one of its components, whereas objectives are specific statements about what the system or component of that system will attempt to accomplish. A given goal may have more than one objective specified to reach that goal. Table 6-2 lists examples of goals and objectives that the team might develop for HOV facilities.

ESTABLISH PERFORMANCE CRITERIA / MOES

Performance criteria and measures-of-effectiveness need to be identified in order to assess the extent to which HOV treatments are meeting goals and objectives. Table 6-3 lists suggested objectives and measures of effectiveness.

Table 6-2. Examples of Goals and Objectives for HOV Treatments.

Category	Examples
Goals	• Produce a Better Operating Freeway • Increase the Person-Moving Efficiency of the Roadway Facility • Encourage Mode Change
Objectives	• Reduce User Travel Time • Reduce or Defer the Need to Increase Highway Vehicle Capacity • Improve Efficiency and Economy of Public Transit Operations • Reduce Fuel Consumption • Improve Air Quality by Reducing Air Pollution in a Corridor

Evaluations are necessary to ensure that the improvements are providing the desired benefits and that the expenditure of public funds is justified. Interest exists in the results of these evaluations among many groups, for example, transportation professionals, elected officials, and the general public. While there appears to be general agreement among transportation professionals that HOV facilities should be evaluated, a consensus does not exist regarding the most appropriate measures to use, the performance thresholds the projects should meet to be considered effective, or the preferred data collection techniques. The challenge to transportation professionals is to provide accurate and objective evaluations of HOV facilities that focus on key criteria and that can be easily understood by the different partners. Analyses and findings contained in several reports provide some guidance.[6-8]

DEFINE FUNCTIONAL REQUIREMENTS

The functional requirements of HOV treatments define specific actions or activities that are to be performed in order to achieve one or more of the objectives. The functions should be defined independent of the technology to be employed in the system, so that the focus is on *what* the system is designed to do rather than on *how* the system will be doing it. Table 6-4 presents examples of functional requirements for various objectives.

Example treatments include the following:

- HOV Lanes.
  - Facilities on separate rights-of-way.
  - Long-distance HOV lanes serving buses, vanpools, and carpools, and located within or adjacent to the freeway right-of-way.
- Priority Access at Ramps.
- Terminal Facilities.
- Preferential Parking.

IDENTIFY AND SCREEN TECHNOLOGY

It is appropriate to assess the actual technologies available to meet the functional requirements. The assessment can begin with the discussion of available treatments contained later in this module. Because of the high interest in HOV facilities, the Transportation Research Board, among others, frequently plans meetings to discuss

Table 6-3. Suggested Objectives and Measures of Effectiveness for HOV Facilities. (6)

Objective	Measures of Effectiveness
Improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle	• Actual and percent increase in the person movement efficiency • Actual and percent increase in average vehicle occupancy rate • Actual and percent increase in carpools and vanpools • Actual and percent increase in bus riders
Increase the operating efficiency of bus service in the freeway corridor	• Improvement in vehicle productivity (operating cost per vehicle-mile, operating cost per passenger, operating cost per passenger mile) • Improved bus schedule adherence (on-time performance) • Improved bus safety (accident rates)
Provide travel time savings and a more reliable trip time to HOVs utilizing the HOV facility	• The peak-period, peak-direction travel time in the HOV lane(s) should be less than the travel time in adjacent freeway lanes • Increase in travel time reliability for vehicles using HOV lane(s)
Favorable impacts on air quality and energy consumption	• Reduction in emissions • Reduction in total fuel consumption • Reduction in the growth of vehicle miles of travel (VMT) and vehicle hours of travel
Increase the per lane efficiency of the total freeway facility	• Improvement in the peak-hour per lane efficiency of the total facility
Not unduly impact the operation of the freeway mainlanes	• The level of service in the freeway mainlanes should not decline
Be safe and not unduly impact the safety of the freeway general purpose mainlanes	• Number and severity of accidents for HOV and freeway lanes • Accident rate per million vehicle miles of travel • Accident rate per million passenger miles of travel
Have public support	• Support for the facility among users, non-users, general public, and policy makers • Violation rates (percent of vehicles not meeting the occupancy requirement)
Be a cost-effective transportation improvement	• Benefit-cost ratio

Table 6-4. Examples of Functional Requirements for HOV Treatments.

Objective	Functions
Improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle	To support the HOV facilities, assist in the development of ridesharing programs
Provide travel time savings and a more reliable trip time to HOVs utilizing the HOV facility	Design facility so that incidents are appropriately handled (e.g., quick identification and removal)
Have public support	Involve public at appropriate stages during the process. Develop and execute a public relations campaign

the benefits, challenges, and other aspects of HOV treatments. Publications from these sources can provide additional information on treatments.

Factors that should be considered at this stage include cost (construction, operation, maintenance, replacement, etc.), operations and maintenance requirements, and personnel, equipment, and facility needs. The process for identifying and screening different technologies for inclusion in a freeway management system is often iterative, because there are multiple ways that different technologies can be combined to achieve an objective. For example, decisions made about an HOV treatment can influence decisions made about surveillance techniques.

System Planning

In order for HOV systems and facilities to be properly integrated within the freeway system, system planning needs to occur at all levels, including strategic planning, long-range system planning, short-range planning, and service or operations planning. At the strategic planning level, freeway and transit agencies need to determine their roles, missions, and types of HOV services they want to provide in a metropolitan area. (This type of activity is discussed in detail in **Module 2**.) Through the long-range planning process, agencies can ensure that HOV facilities and services are incorporated into the future design of freeway systems and that funding for capital-intensive facilities are programmed into area transportation improvement plans. The short-range planning process can be used to assess administrative, funding, and service changes that need to occur usually within a 5-year period. Service or operations planning is an ongoing activity—often on a route or corridor basis— and is intended to identify improvements to improve service efficiency and effectiveness of HOV facilities.

Figure 6-2 illustrates a system planning methodology that can be used to identify HOV alternatives designed to service peak-hour person demand at the lowest total cost to the public, while at the same time, providing system continuity.[8] The public costs have been identified as travel delay, construction and right-of-way, and operation costs of the facilities. The methodology also recognizes that some

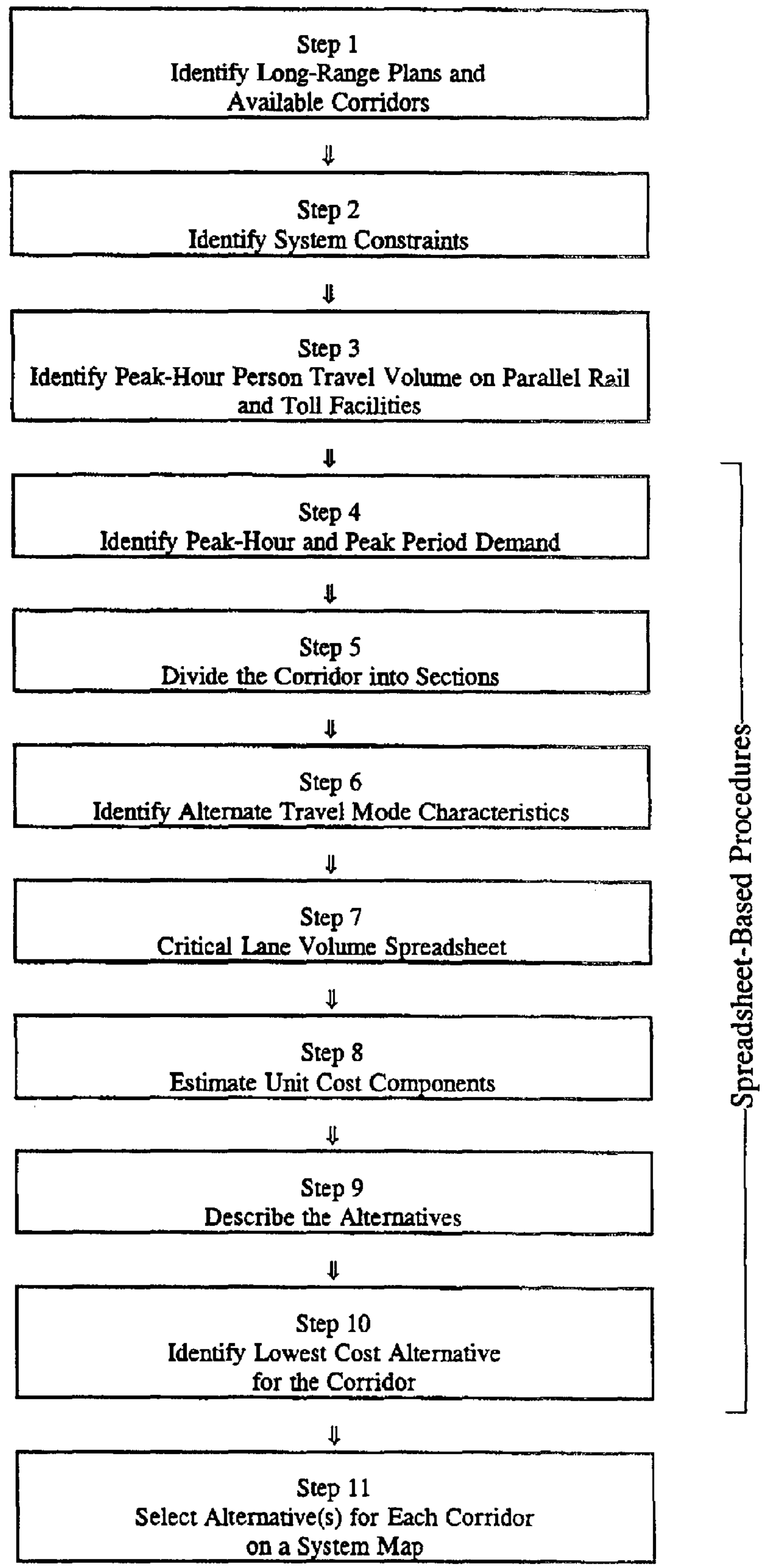


Figure 6-2. Multimodal System Planning Technique—Steps in the Process.[8]

motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use. The methodology can be summarized in the following steps, which begin with corridor and system concerns, become more specific, and conclude with a system-level assessment of the results:

- Identify constraints in the corridor and the system.
- Estimate demand.
- Test alternatives for corridors.
- Examine results of individual corridors for system consistency and adjust improvements.

The methodology includes consideration of facilities such as parallel urban rail transit and toll highways, high-occupancy vehicle lanes, express freeway lanes, and general freeway lanes. The process can also incorporate operational and travel demand management improvements.

The multimodal system planning process includes a spreadsheet-based analytical procedure and several considerations before and after the spreadsheet operation. The technique generally follows an inside-outside geographic arrangement. System constraints (usually most frequent near downtowns) are initially identified. Individual corridors are analyzed and the alternatives optimized, possibly for several factors. The corridors are brought together on a system map, and the match points harmonized.

The system planning methodology provides information to quantify decisions regarding the most efficient expenditure of transportation funds for a multimodal system. It includes operational experience in the framework and provides a balance in difficult concepts such as congestion level and mode shift to ridesharing alternatives. It can optimize transportation systems based on the lowest cost to the public and also optimize within agency construction and operation budgets. The spreadsheet-based analytical program is open to user assumptions, and all default values are supported by documentation.

In practice, the outcomes of the corridor analyses vary depending on travel demand. Low demand corridors (less than 150,000 daily trips) where little or no construction is warranted are usually optimized with freeway general purpose lanes. Moderate demand corridors (up to 200,000 daily trips) may require some limited access express lanes, but the lowest public cost is usually achieved with only general purpose improvements. High demand corridors (in excess of 200,000 daily trips) are usually most efficient with a combination of HOV lane and freeway improvements.

IMPLEMENTATION

A natural result of the system engineering approach is the implementation of the plan. Issues that could be of concern with the implementation of an HOV treatment include the following:[5]

- **Scheduling.** If the HOV project is a retrofit, implementation scheduling can be complicated by a variety of unknowns, generally related to the policies and procedures of the various agencies involved. If the project requires daily monitoring (e.g., contraflow or reversible-flow operations), an additional 1 to 3 weeks following construction completion should be included for pre-operation testing.

- **Design/Construction Packaging.** Proper packaging of the project design can affect quality and cost. There are various reasons to segregate a project's elements into multiple design and construction packages. If the package is too large, competitiveness is reduced in the construction bidding process. If the improvement represents substantially different construction trades (i.e., roadway work versus electronic surveillance), it may also make sense to segregate the improvements to achieve the best responsiveness and quality of work. Conversely, it makes sense in projects involving HOV and adjacent freeway improvements, to combine common elements of work into the same construction packages. This simplifies construction management on the job site.

- **HOV Operation During Construction.** One of the most effective methods of cultivating an early market for an HOV project is to start offering preferential treatment during the construction phase. Additionally, this approach can be a cornerstone of the traffic management plan aimed at preserving corridor flow during construction activities. These benefits often outweigh the complications this approach creates for contractors and throughout the construction period.

- **Pre-Operation Testing.** Some pre-operation testing is desirable for any HOV facility. This period allows police to refine enforcement strategies and the operations team to make minor adjustments in the facility design prior to operation. For reversible-flow or contraflow projects, pre-operation testing is essential. At least 1 to 3 weeks is needed to check out any of the automated features that will be changed on a daily basis and acquaint bus operators, deployment staff, police, and others with how to handle daily operation, maintenance, and emergencies.

- **Operation.** Opening of a project should be preceded by significant public awareness efforts. Target users should be provided information on how to take advantage of the project, including maps, rules and regulations for use, and instructions on how to react in an emergency.

Prior to opening the facility to traffic, a plan must be devised for enforcing the restrictions on the facility. The plan should include how often, how long, and where enforcement activities should be performed.

EVALUATION

The final step in the design process is to evaluate the effectiveness of the HOV treatment. This should not be considered a one-time activity, but should be part of a periodic review of the effectiveness of the component and of the overall system. In addition to providing information to the sponsoring agencies on the effectiveness of the treatment(s), the information would be helpful in communicating the effectiveness of the project to the public and enhancing a general understanding of the role that the HOV project has performed.

Table 6-5 provides an overview of suggested objectives, data collection efforts, and corresponding measures of effectiveness for evaluating HOV facilities. The source of the information in this table contains an approach for conducting evaluations of freeway HOV facilities, including identification of appropriate evaluation objectives, corresponding measures of

Table 6-5. Suggested Objectives, Data Collection Efforts, and Measures of Effectiveness for Evaluating HOV Facilities. [6]

Objective	Veh. & Occup. Counts		Travel Time Runs		Surveys (1)			Corresponding Measure of Effectiveness (MOEs) (3)
	Freeway (2)	HOV Lane	Freeway (2)	HOV Lane	Freeway	HOV Lane	Other	
Increase occupancy	*	*			**	**	** (4)	Percent increase in peak-hour, peak-direction person volume; increase in average vehicle occupancy; and modal shift
Cost effective	**	*	*	*				Benefit-to-cost ratio
Travel time savings			*	*	**	**	**(5)	Amount of travel time saving by HOV users; reliability of trip time for HOV users
Public Support		**			*	*	**(6)	Percent of users, non-users, and general public who approve of HOV facility; violation rates
Energy and air	*	*	*	*	**	**	**(7)	Reduction in CO, HC, and NO emissions; reduction in energy consumption and noise level
Freeway operations	*		*		**			Increase in peak-hour per lane efficiency of freeway
Safety	**	**					*(8)	Number and severity of accidents; accident rate per million vehicle miles of travel and per million passenger miles of travel

* Indicates the top priority data collection efforts needed to evaluate the objectives.
** Indicates data collection efforts which ideally should be conducted, but are not absolutely necessary to evaluate the objectives.
1 Involves periodic use of surveys of HOV users (bus riders, carpoolers, and vanpoolers), non-HOV users in the general traffic lanes, and in some cases, the general public.
2 It is strongly suggested that this data be collected for both the freeway lanes adjacent to the HOV facility and the control freeway.
3 Some, but not necessarily all, of the suggested MOEs associated with gauging the attainment of the objectives are shown.
4 Vehicle and occupancy counts on alternate arterial routes to identify any changes in throughput for the corridor, counts at park-and-ride lots, and vehicle and occupancy counts on a "control" freeway.
5 Monitoring bus on-time performance and schedule adherence before-and-after implementation of the HOV lane(s).
6 Identifying violation rates for the HOV lane (i.e., those vehicles not meeting the minimum occupancy requirement). Monitoring complaints, media, and policy actions.
7 Monitoring air quality and noise levels along the corridor.
8 Identifying freeway accident rates and types before-and-after implementation of the HOV lane(s), as well as obtaining accident rates on the HOV facility.

effectiveness, data collection methodologies, and an evaluation process.[6]

6.3 TECHNIQUES AND TECHNOLOGIES

HOV FACILITIES

There are essentially four different types of high-occupancy vehicle (HOV) facilities used on freeways.

- ***Exclusive HOV Facility - Separate Right-of-Way.*** A roadway or lane(s) developed in a separate and distinct right-of-way and designated for the exclusive use of HOVs (see figure 6-3).

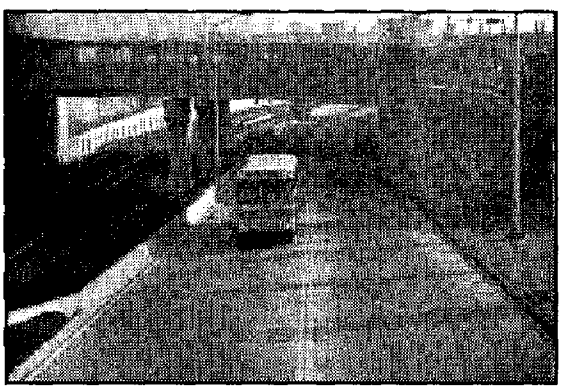
- ***Exclusive HOV Facility - Freeway Right-of-Way.*** Roadways or lanes built within the freeway right-of-way which are physically separated from the other freeway lanes but reserved for exclusive use by HOVs, at least during portions of the day (see figure 6-4).

- ***Concurrent Flow Lane.*** A freeway lane in the peak direction of flow (normally the inside lane) that is not physically separated from the other freeway lanes but is designated for use by HOVs at least for a portion of the day (see figure 6-5).

- ***Contraflow Lane.*** A freeway lane in the off-peak direction of flow (normally adjacent to the median) that is designated for use by HOVs traveling in the direction of peak flow for at least a portion of the day. Normally, the contraflow lane is "separated" from the off-peak (or opposite) flow by insertable cones, pylons (see figure 6-6), or movable concrete barriers.

Operational Considerations

The importance of incorporating operational considerations into both the planning and design process for HOV facilities cannot be overstated. The operation of an HOV facility is critical and should be considered when making planning, design, and implementation decisions. Also, consideration must be given to a range of needs involving support services and facilities, such as park-and-ride lots, bus service planning, marketing rideshare matching, and enforcement. Following is a summary of several operational considerations as discussed in the AASHTO *Guide*.[10]



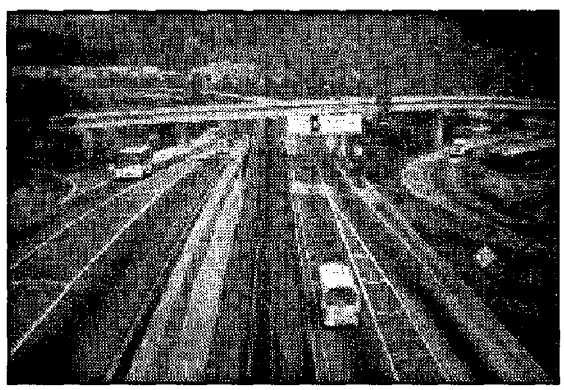


Figure 6-3. Examples of Exclusive HOV Facility - Separate Right-of-Way. [9]

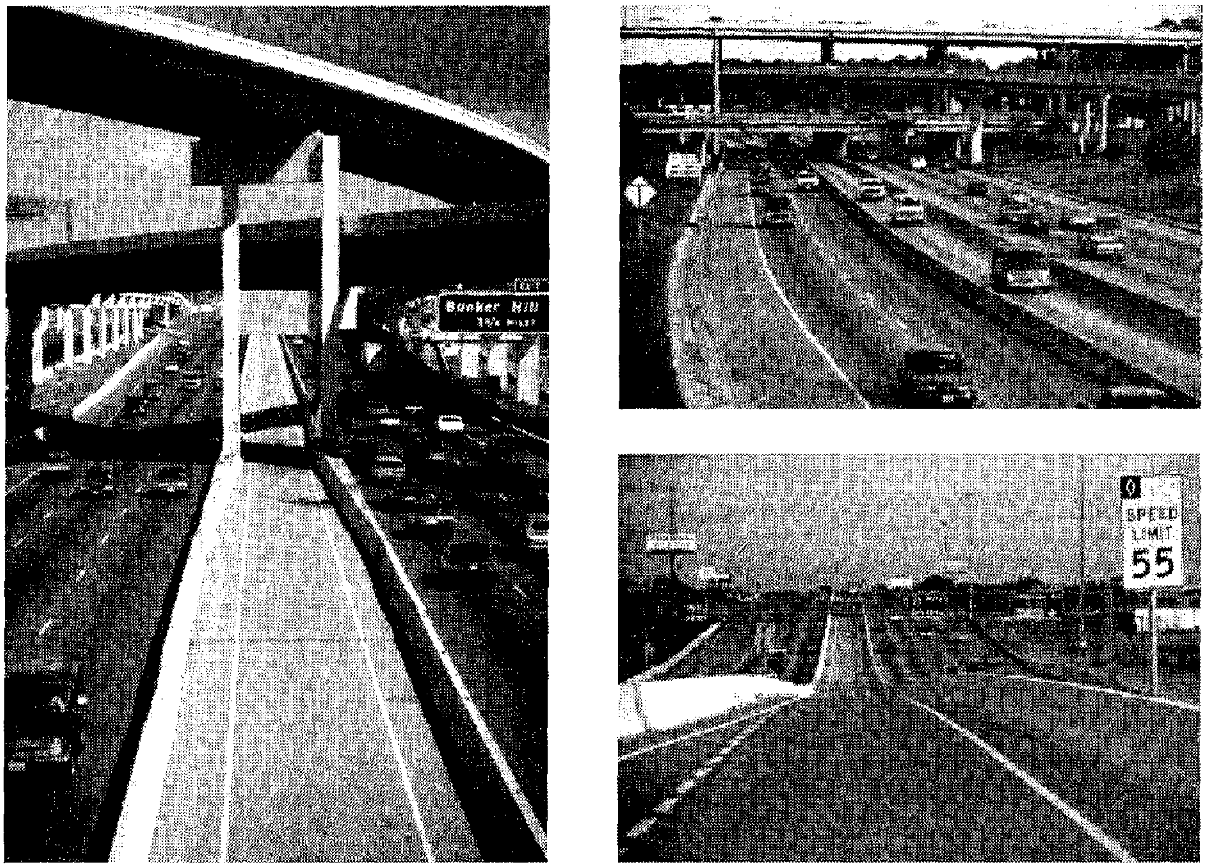


Figure 6-4. Examples of Exclusive HOV Facility - Freeway Right-of-Way. [9]

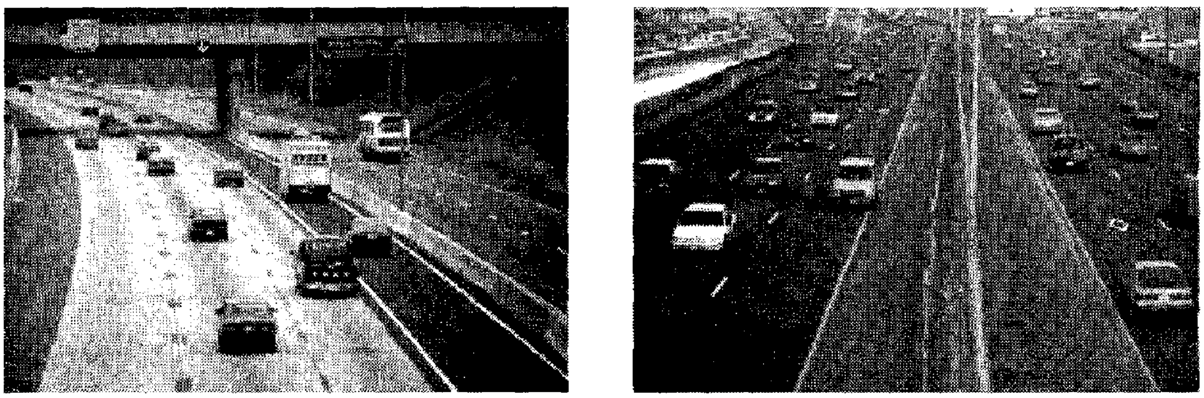


Figure 6-5. Examples of Concurrent Flow Lane. [9]

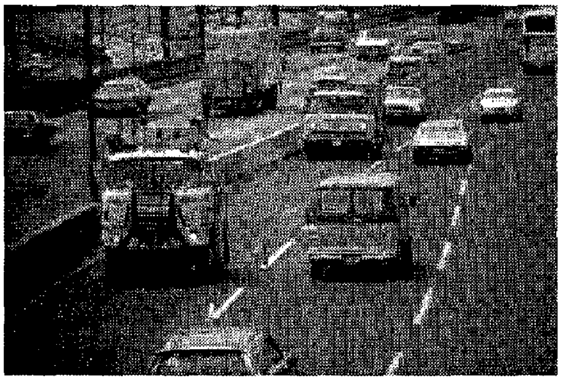



Figure 6-6. Examples of Contraflow Lanes. [9]

HOV Roadway Operations

The operation of separated HOV roadways may be reversible or two-way. The facility can be restricted to HOVs during peak periods only or throughout the day. The latter is less expensive to sign and operate. Limiting access to a reversible HOV facility is crucial if the facility is to be operated in a safe and efficient manner. A system of gates should be considered at each end to prevent wrong-way traffic from entering the facility. In addition to these features, this type of facility should also have a system of variable message signs (VMS) which inform commuters as to the operational status of the facility (open or closed).

Operating Efficiency

The reduction of user travel time is the commonly used measure for assessing the benefits of HOV facility operation. A vehicle breakdown on an HOV facility can be anticipated to occur approximately every 64,000 vehicle-kilometers (40,000 vehicle-miles) traveled. A disabled vehicle will cause a decrease in traveling speeds or, in extreme cases, a total blockage of the facility. Figure 6-7 illustrates the consequences of a 15-minute total blockage on an HOV facility on a separated roadway having a demand of 6,000 persons per hour and a capacity of 12,000 persons per hour. As shown, the 15-minute blockage causes 22,500 person-minutes of delay, and it will take 30 minutes from the time of blockage until the queue totally dissipates.

Considerations for 2+ Versus 3+ Occupancy Requirement

HOV facilities should be implemented in a way that balances the flexibility of HOV growth and the public perception as to the use of a facility. An initial minimum vehicle occupancy requirement must be selected to optimize the efficiency of the facility. The selection must allow for growth in traffic volumes as more commuters choose to switch to carpooling arrangements and take advantage of the travel time and fuel savings. Title 23 United States Code 102(A) allows State departments of transportation to establish the minimum occupancy requirements for vehicles operating on HOV lanes; except that no fewer than two occupants per vehicle may be required and that motorcycles and bicycles shall not be considered single occupant vehicles.

Retaining the potential to carry more people over time offers important operational flexibility. At the same time, though, public perception of the adequacy of HOV lane usage must also be addressed. Peak hour

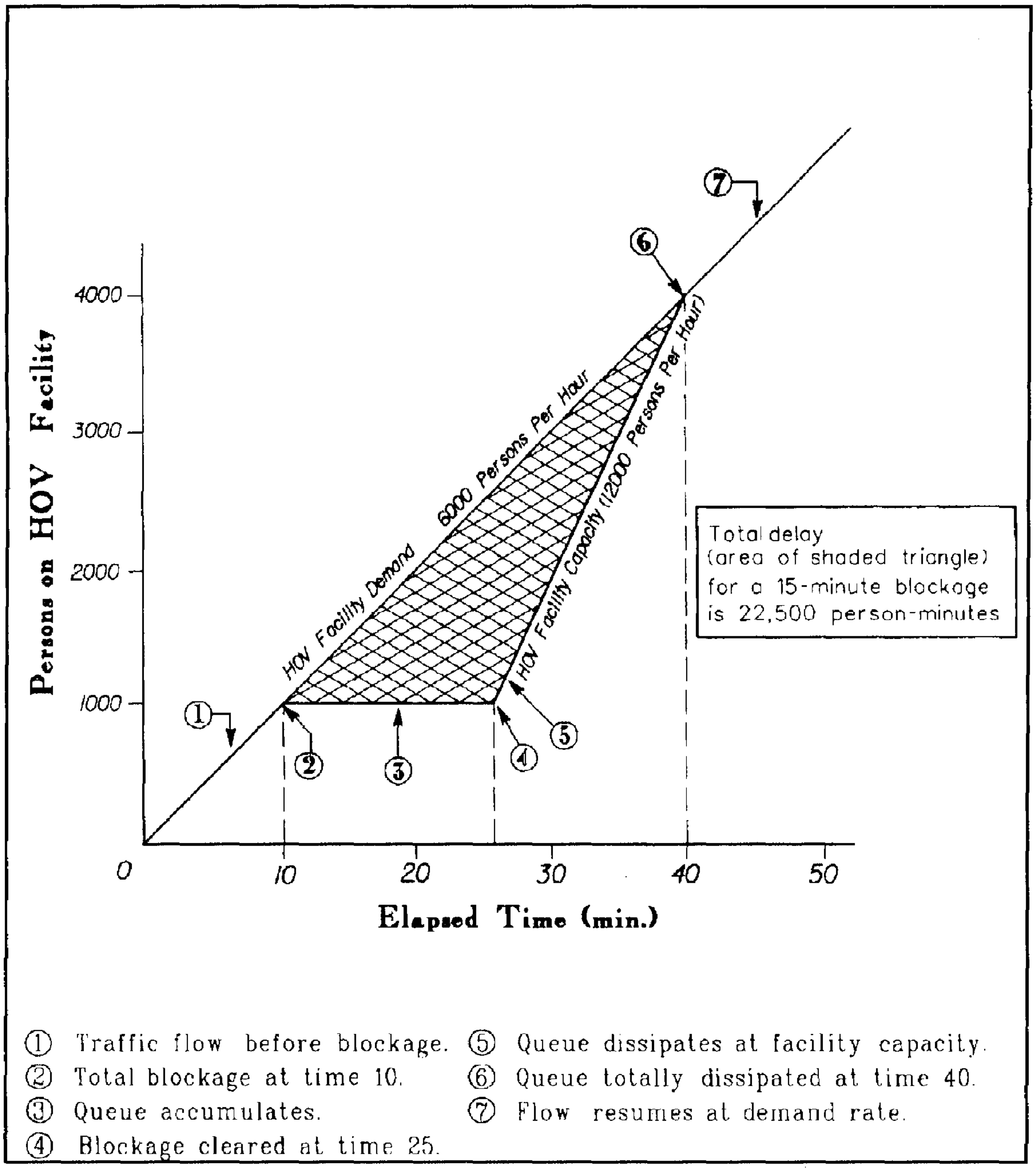


Figure 6-7. Example of Delay on an HOV Facility Due to a Total Blockage Incident. [10]

HOV traffic volumes need to be high enough to help mitigate public concerns over underutilization of HOV facilities. The positive aspect of 2+ eligibility is that a staged resource of commitment to ridesharing is being established. Less work is involved in forming a 2+ carpool versus a 3+ carpool, and the base volume to draw from is considerably greater. There may be less eventual resistance to adding a third passenger than to forming an initial 3+ carpool.

Subsequent changes in occupancy requirements need to be weighed with projected future demand. To go from 2+ to 3+ occupancy could reduce vehicular demand by as much as 75 to 85 percent.

This could be severe if only a 10 to 20 percent reduction in demand is necessary for the near future. A new HOV 3+ lane typically may carry only a few hundred peak-hour vehicles, while an adjacent freeway lane is carrying 1500 to 2000 peak-hour vehicles. Even though the HOV lane may be carrying more peak-hour person trips than an adjacent freeway lane, the traveling public may perceive the lane to be underutilized. Consideration should be given to changing from 2+ to 3+ occupancy when the level of service of the HOV lane is approaching Level of Service D.

In other words, the flexibility to change occupancy requirements is a strong operational management tool. However, changing these requirements frequently or varying the requirement by time of day may create enforcement problems and public resistance.

Hours of Operations

An HOV facility may be operated only during peak periods only or for 24 hours. A number of factors, including geometric design, volumes of HOV and mixed-flow traffic, and hours of congestion will influence HOV operating hours.

Twenty-four hour HOV use of priority facilities is sometimes preferred, because violations tend to be lower and there is less motorist confusion. Also, 24-hour use may provide a greater overall incentive for the formation of new carpools. Some HOV facilities, such as reversible lanes, may not be conducive to 24-hour operation. The hours of operation for reversible facilities must allow time for a variety of necessary functions, such as clearing the lane, moving gates, and changing signing.

Part-time use of a shoulder as an HOV facility should be implemented only after careful consideration of operational and safety problems. The shoulder HOV facility differs from a part-time HOV lane that reverts to mixed-flow use during off-peak periods. The shoulder facility requires special delineation and signing, and involves separate enforcement problems for both peak and off-peak periods. Motorists may tend to use the shoulder as a freeway lane during off-peak hours when it should be used as a shoulder.

Design Elements

Design Speed

A purpose of HOV facilities is to provide a travel time savings for HOVs. Therefore, it is preferable to use a design speed for the HOV facility that is comparable to the adjoining freeway. AASHTO freeway standards for design speed should be used to provide for a high level of service. The design of the facility should consider the specific physical dimensions and operating characteristics of the vehicle types that are expected to be well represented in the vehicle mix. For example, the difference in braking and acceleration characteristics may suggest a different roadway geometry than just using passenger cars.

Cross Section Width

Following is a summary of dimensions used in the design of transit ways.[11] The preferred cross section for single lane at-grade, one-way transitways is a 3.6-m (12-ft) travel mainlane and 1.5-m (5-ft) clearance offsets (shoulders), while the usual cross section is 3.6-m (12-ft) travel mainlane and 1.143-m (3.75-ft) clearance offsets (shoulders). A total minimum width of 6.1 m (20 ft) is recommended for single-lane facilities, as this will allow a disabled vehicle to be passed. Reduced cross sections do not provide the passing capability, and therefore are recommended only for short sections, approximately 610 m (2000 ft) or less, that involve physical constrictions.[12] For multiple lane at-grade, two-way facilities, the travel mainlanes are 3.6 m (12 ft), the center shoulder separations are 3.0 m (10 ft), and the clearance offsets are 0.6 m (2 ft).

HOV lanes should have a minimum pavement width of 3.6 m (12 ft). The pavement should be widened through horizontal curves to account for the offtracking of buses. A minimum width of 4.0 m (13 ft) is recommended for HOV ramps. The typical cross slope for a transitway is two percent, the same cross slope found on most freeway mainlanes.

To allow water to drain, a minimum grade of 0.35 percent should be provided. A maximum grade of 6 percent is recommended to prevent buses from slowing down on the HOV lane. The desirable superelevation is 0.04 to 0.06 for speeds of 64 to 80 km/h (40 to 50 mph) and 0.06 to 0.08 for speeds of 80 to 97 km/h (50 to 60 mph). Vertical clearances are 4.42 m (14.5 ft) minimum and 5.03 m (16.5 ft) desirable, while lateral clearances are 0.6 m (2 ft) minimum and 2.4 m (8 ft) desirable.

Vertical Clearance

Vertical clearance to structures passing over the HOV facility should desirably be the same as for the adjacent freeway at 5.03 m (16.5 ft). While this is more than sufficient allowance for the maximum height of a standard transit bus at 3.429 m (11.25 ft) (double-deck bus is 4.32 m [14.2 ft]), it does allow for the possibility of emergency use or for future use of other types of vehicles, including large commercial trucks. In situations of restricted vertical clearance, a reduced (usual) clearance of 4.42 m (14.5 ft) is generally acceptable. This includes some allowance in vehicle operation and future pavement resurfacing.[4]

Signs and Markings

Signs and markings should conform to the *Manual on Uniform Traffic Control Devices (MUTCD)* to the fullest extent possible.[13] Preferential lane markings should be used to indicate that the lanes are restricted, with supplemental signs or signals conveying the specific restrictions. At the entrance to reversible facilities, particular attention must be paid to the control devices. In addition to static signs, variable message signs may be necessary. These should be supplemented with gates or barriers to further prevent entry by vehicles going in the wrong direction or to allow only authorized vehicles by special designation to enter the facility.

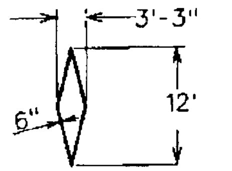
Signs. Regulatory signing for HOV lanes should follow the standard regulatory signing principles (e.g., black legend on white background, rectangular shape, and reflectorized or illuminated). The diamond symbol (white on black background) should be incorporated into the sign format. Guide signing may be necessary on HOV lanes that have designated ingress, ingress/egress, or egress points to inform the motorist of the appropriate HOV lane entry or exit point to use. The guide signing should follow the standard guide signing of the *MUTCD*. The diamond symbol should also be incorporated into the sign format, preferably in the upper left corner of the sign.

Figure 6-8 gives sample signing and pavement markings for HOV lanes used by Caltrans, along with some general applications criteria.

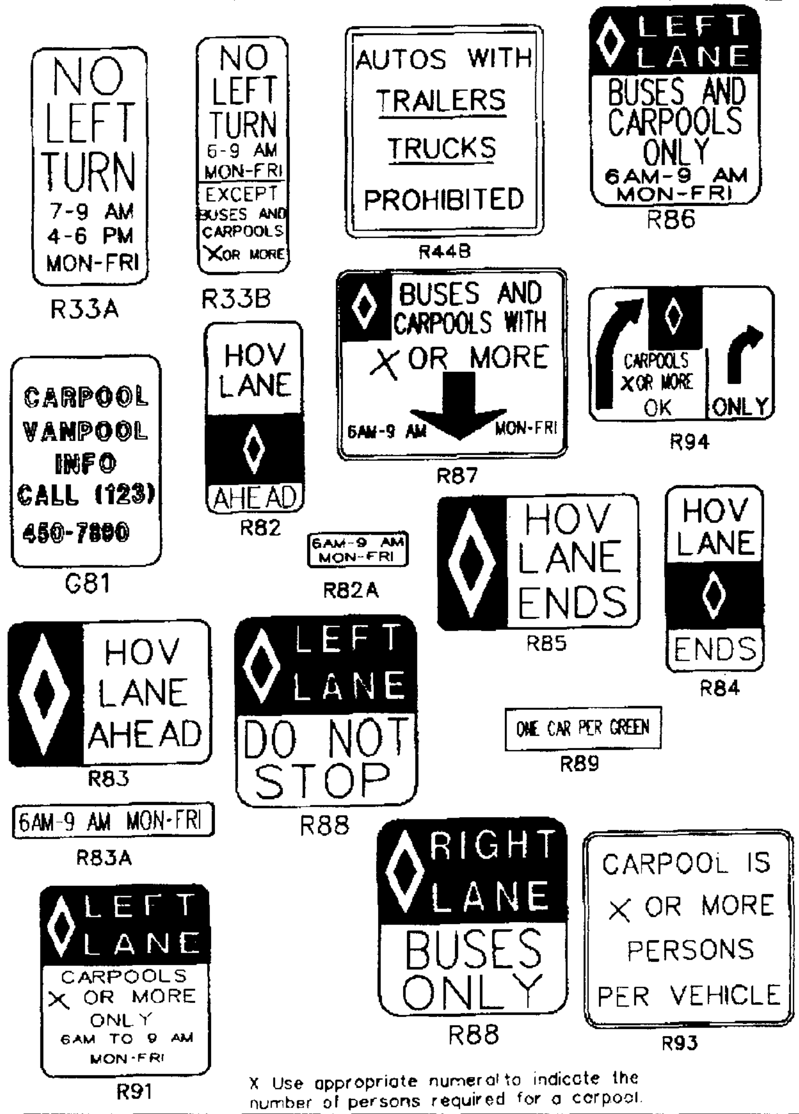
Markings. When a lane is assigned full- or part-time HOV use, HOV lane markings are

HOV PAVEMENT MARKING AND SIGNING NOTES

1. Two advance carpool signs, R94, should be installed on local street when striped for mandatory right turn.
2. Two or more carpool signs, R33B, should be installed on local streets (with concurrence of local agency) wherever left turns are restricted to carpools during peak hours.
3. Two carpool signs, R91, should be installed on extra long entrance ramps with two Detail 'A' pavement markings.
4. Four or more carpool signs, R91, should be installed on extra long ramps with two or more Detail 'A' pavement markings.
5. Spacing of Detail 'A' may be as close as 80 feet on city streets, while a spacing of 1/4 mile may be appropriate for a freeway.
6. Signing and pavement marking details and notes shown on this sheet should be used wherever feasible. Exceptions and proposed experimentation with other signs and markings should be reviewed in advance by the Operations Unit.
7. The bus-carpool lane on the freeway entrance ramp may be either on the left or right side.
8. Additional required signs and markings are shown in the Caltrans Traffic Manual, Section 4-05, Ramp Terminal Signing.
9. A number may be placed in the center of the Detail 'A' pavement symbol to indicate the number of persons required for a carpool.
10. Posted time is not required for ramp bypass lane metered by traffic signals.
11. The pavement legend "CARPOOL LANE" may be used to supplement the Detail 'A' installations on new projects. The word message should then be allowed to wear out.
12. For 24 hour HOV operations, time restrictions are deleted.



DETAIL 'A'
(See Note 9)



X Use appropriate numeral to indicate the number of persons required for a carpool.

Figure 6-8. Sample Signing and Pavement Markings for HOV Facilities.[10]

necessary. The HOV lane marking should be an elongated diamond placed along the longitudinal center of each restricted lane (see figure 6-8). The marking is intended to convey that a restriction on the use of the lane exists, and it is supplemental to the signs or signals conveying the specific restriction. Signs or signals should be used with the HOV lane markings.[10]

The frequency with which the marking is placed is a matter for engineering judgement based on prevailing speed, distance between interchanges and other considerations necessary to adequately communicate with the driver. A spacing of 0.40 km (0.25 mi) would be appropriate for most freeway situations, except on crest vertical curves where a shorter spacing should be used. Initially, the markings "CAR" "POOL" "LANE" may be painted between the diamond symbols on new projects to supplement, but not substitute for, the HOV lane markings. The word markings should then be allowed to wear out once drivers become familiar with the facility.[10]

The striping pattern for the lane line between the HOV lane and the adjacent mixed-flow lane should be in accordance with the *MUTCD.* [13] Typical HOV lane striping and pavement marking schemes are shown in figure 6-9. This figure also provides examples of signing appropriate for concurrent HOV lanes.

Enforcement

Goals and Objectives

An objective of enforcement by police officers on HOV facilities is to maintain the operational integrity and safety of the facility for those high occupancy vehicles designated or authorized to use it. In this regard, detection and apprehension of violators, and effective prosecution of violators, are essential. Therefore, law enforcement personnel with full capability to issue citations must be employed on HOV facilities. In addition, police officers help ensure the safe and efficient operation of the facility. Depending on the type of facility and priority users, the potential safety and operational problems caused by vehicle breakdowns, wrong way movements and/or other vehicles' encroachments into the HOV facility may have an adverse impact on operations and must be a concern of the enforcement authority.

Table 6-6 summarizes selected goals and objectives of enforcement personnel, as well as strategies for implementation and measures of effectiveness.

A 1988 Texas Transportation Institute study of the enforcement procedures for HOV lanes determined the following key concepts related to effective HOV enforcement: [14]

- The level of enforcement needed is dependent upon facility type. In general, concurrent flow facilities require more enforcement than do separated roadway and contraflow facilities.

- To be effective, an officer must have a safe and convenient place to issue citations or warnings. The enforcement activity should be in view of HOV users so that they can see when the lane restrictions are being enforced; however, it should not interfere with traffic on the HOV and mixed-flow lanes.

- To preclude high violation rates, a highly visible enforcement presence has to be maintained at a level where potential violators and legitimate users believe that violators have little chance to use the lane without getting caught.

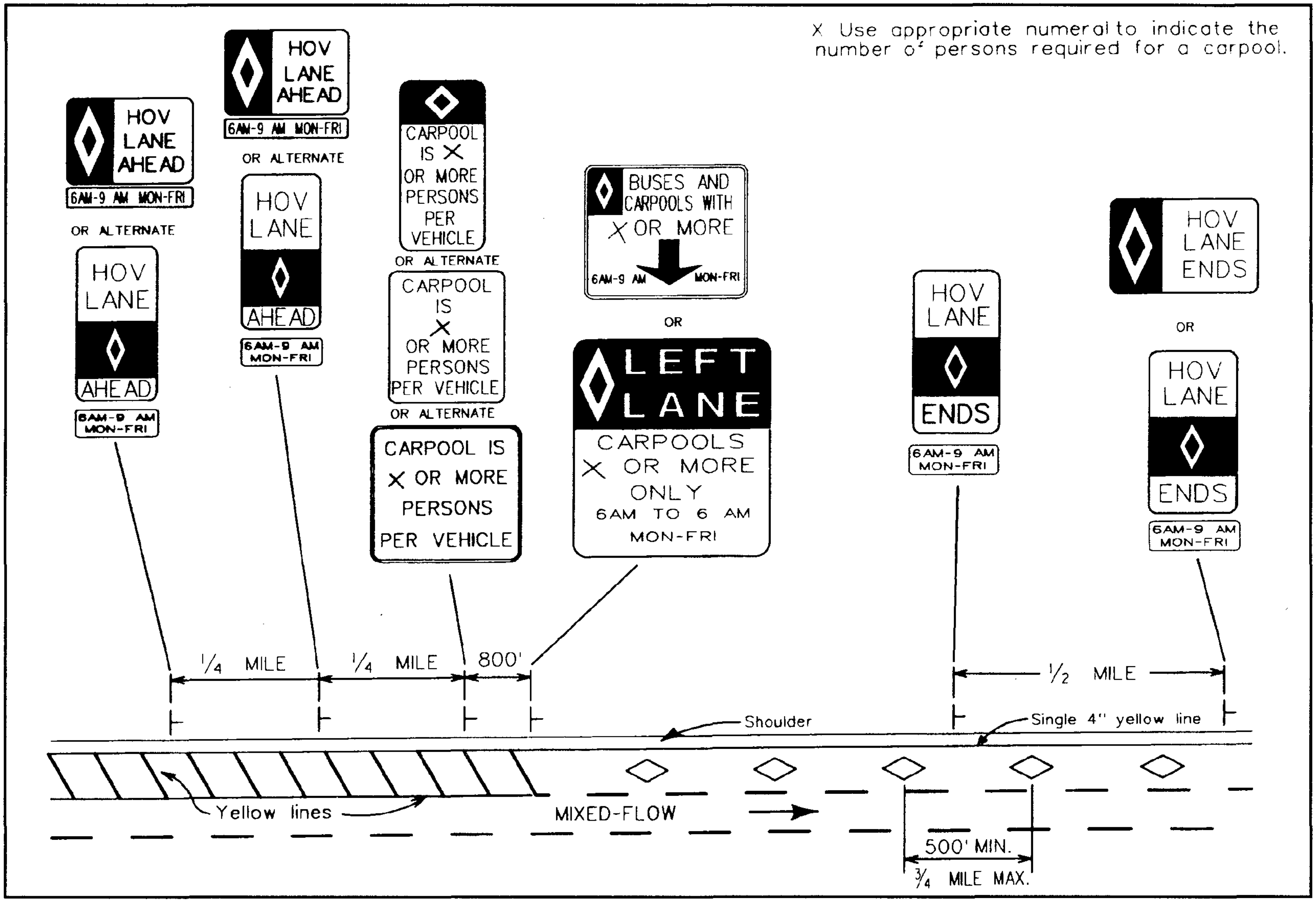


Figure 6-9. Typical Contiguous Concurrent HOV Lane w/o Buffer Signing and Pavement Markings.[10]

Table 6-6. Goals and Objectives of Enforcement Personnel.

Goal	Objectives	Strategies	Measures of Effectiveness
Maintain operational integrity	Help minimize delay	Strict enforcement of occupancy requirements	Violations
	Minimize violation rates	Clear communication of nature of facility	Violation rates
		High visibility of enforcement officers	Travel times
		Swift, safe removal of violators	
Maintain safe operation	Minimize accidents	Strict enforcement of operating rules	Accidents
	Help minimize incident response and clearance times	Clear communication of nature of facility	Accident rates
		Swift, safe removal of violators	Incident response and clearance times

- On limited access facilities, diverting potential violators before they can traverse some part of an HOV lane can be safer and more efficient than apprehending them after the fact. Whenever possible, enforcement areas should incorporate this concept.

Methods

Where enforcement is difficult to accomplish, or perceived as being unsafe, police may avoid apprehending violators, resulting in increasing numbers of illegal vehicles using the lane. Where enforcement has been a problem, 60 percent or more of the vehicles that used the lanes were violators. Experience suggests that steady doses of routine enforcement, combined with moderate application of special enforcement, can generally keep violation rates on exclusive HOV facilities in the 5 to 10 percent range. Heavy, consistent doses of special enforcement would be necessary to have violation rates below 5 percent. There are locations where no amount of enforcement can bring violation rates to an acceptable level.[10]

In some metropolitan areas, programs have been initiated where motorists can call in to report HOV facility violators. Appropriate literature is sent to frequent violators, and enforcement personnel can make a point of watching for these vehicles in the HOV lane. These "so called" HERO programs have been helpful in reducing violation rates. Also, a system of video cameras combined with officer observation may be considered. Another factor that will have a positive

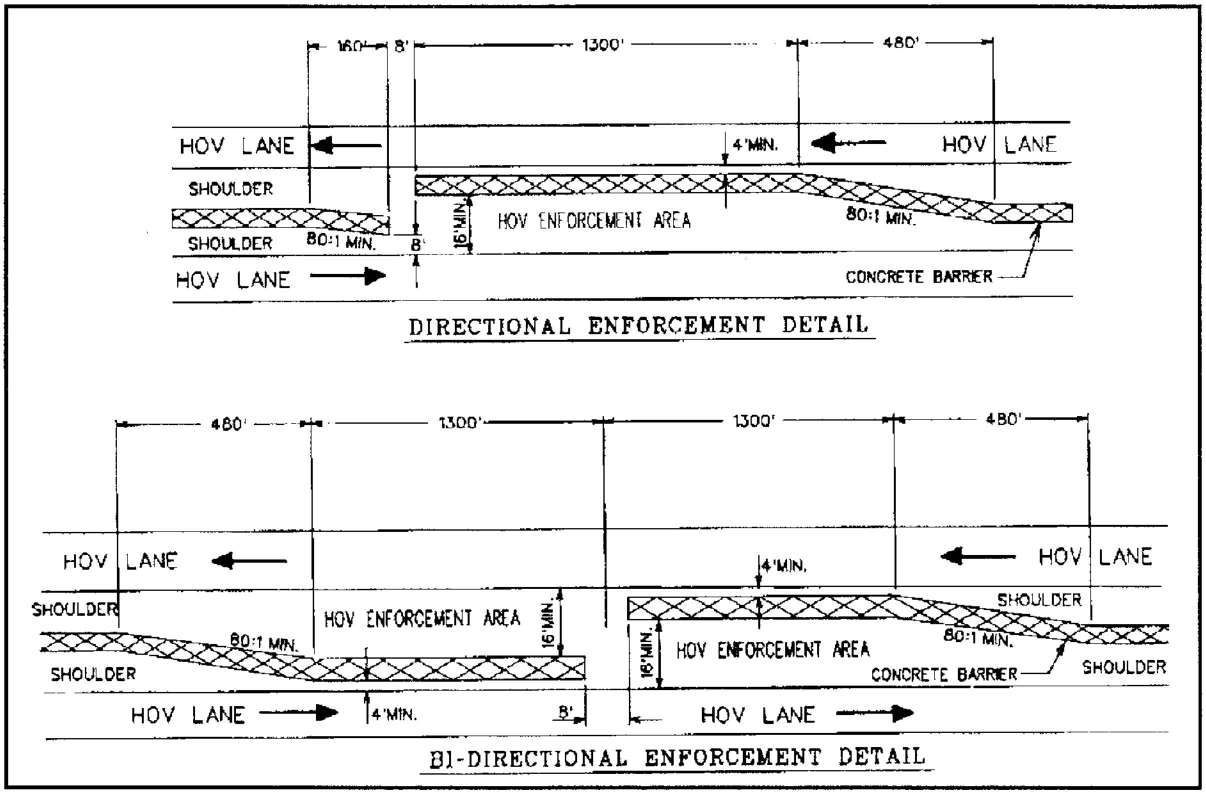


Figure 6-10. Median Enforcement Area for Median 6.7 to 8.8 m (22 to 29 ft) Wide.[10]

impact on the violation rate is the cost of the fine for a violation. Fines exceeding $250 for first offenders have been used, significantly lowering the violation rate.

Enforcement Area Design

When totally new concurrent HOV facilities are to be built and there is adequate width for a median 9 m (30 ft) or wider, consideration should be given to providing a 4.3-m (14-ft), paved median shoulder in both directions as a continuous enforcement area. When facilities are operating at high speeds (81 km/h (50 mi/h) or above), enforcement officers are uncomfortable having to stop and approach another stopped vehicle in less width than this.[10]

On other facilities where the median width is less than 9.2 km/h (30 ft) but equal to or greater than 6.7 m (22 ft) wide, it is possible to accommodate enforcement pockets by narrowing the median shoulder on alternating sides of the center barrier, which permits on-line enforcement. Figure 6-10 shows possible designs for enforcement areas. Closely spaced raised pavement markers could be used to provide added delineation between the enforcement area and the HOV lane in order to improve safety of the enforcement area. California, for example, uses raised pavement markers spaced out at 1.8 m (6 ft) along the edgeline to provide an audible warning to those entering the enforcement area.[10]

Where the median width is less than 6.7 m (22 ft) and enforcement pockets are required, it will be necessary to shift, in one or both directions of travel, away from the centerline in order to obtain the minimum width to accommodate a minimum 4.3-m (14-ft) wide pocket, 0.6-m (2-ft) barrier, and 0.9-m (3-ft) offset to the barrier from the opposing HOV lane. Tapers for lane shifts should be 115:1 or greater. Conceptual design is shown on figure 6-11.

Pockets should be no more than 3.2 to 4.8 km (2 to 3 mi) apart, and should be located between interchanges to avoid interference from interchange structures and also to minimize both the distraction to other drivers and the lane changes taking place at any one time. Pockets should be located to provide minimum sight distance requirements.[10]

ACCESS

Ramp Connections

Types of ramp connections to HOV facilities include the following:

- ***Slip Ramps*** - The at-grade slip ramps are the easiest and least expensive to build. An opening large enough for normal merge/diverge maneuvers is placed in the barrier. This type of ramp is usually from a park-and-ride lot to the frontage road, the freeway, or the HOV lane (see figure 6-12). Elevated slip ramps are also used in some locations (see figure 6-13).

- ***Flyover Ramps*** - The second type of park-and-ride connection is the flyover ramp (see figure 6-14). This ramp resembles an elevated freeway ramp, except that flyover ramps can be either one- or two-way. The elevated flyover ramp is directly connected from the park-and-ride lot to the HOV lane. Because the flyover ramp does not create a tee intersection, fewer conflict points exist.

- ***Grade Separated Interchanges*** - Grade separated interchanges are more expensive than at-grade ramps, but they provide greater flexibility and movement. They are basically aerial tee intersections that can be either one or two directional (see figure 6-15). Acceleration and deceleration lanes should be included. Grade separated interchanges allow vehicles to travel directly from the park-and-ride facility to the HOV lane.

Design

The design of access connections depends on the decision of how to interface high occupancy vehicles with general purpose vehicles on and off the freeway.[10] Several options are available. One option is to connect the HOV facility directly to the freeway with the use of elevated flyover ramps or at-grade slip ramps. Another option is to link the HOV facility directly to the frontage road or surface street system. Of course, transition treatments must be provided in some manner at both ends of the roadway.

If feasible, the terminal connections to HOV facilities from the adjacent freeway mainline should be made with flyover ramps at both terminal end connections. This allows buses and other vehicles using the HOV facilities to exit and enter the freeway mainline on the right instead of having to enter the inner high speed lanes. This eliminates the high-speed lane merge, which is inherently more difficult to execute, especially for HOV traffic such as buses and vans. Depending on the interchange spacing, it could also eliminate the need for the HOVs to make several rapid lane changes in order to access the HOV lane or exit the freeway.

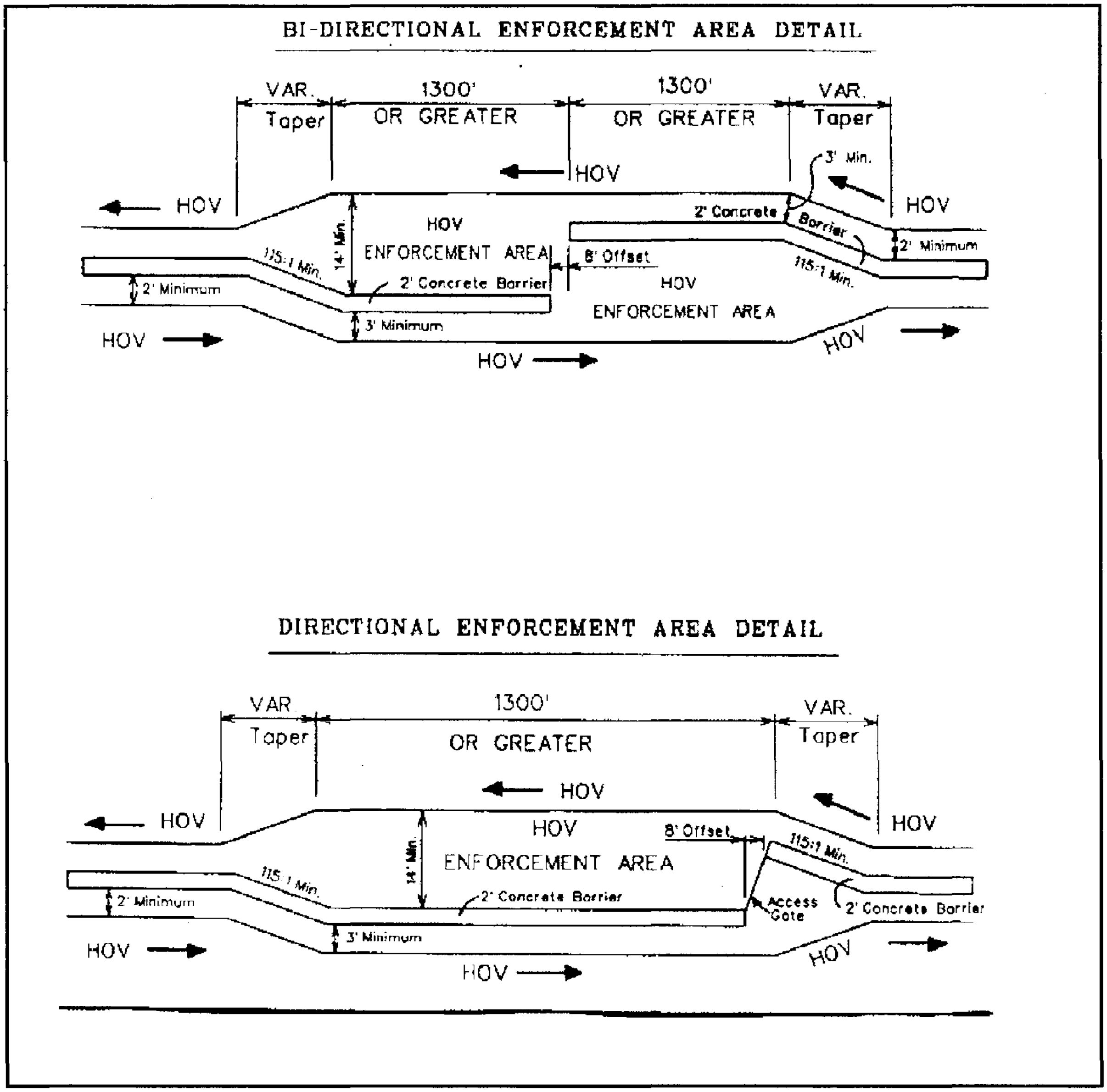


Figure 6-11. Median Enforcement Area for Median Less than 6.7 m (22 ft) Wide.[10]

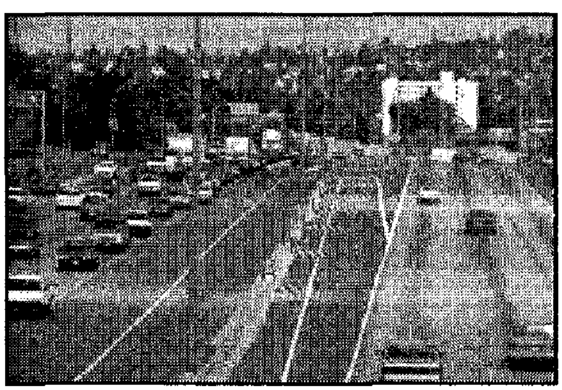


Figure 6-12. Slip Ramp. [9]

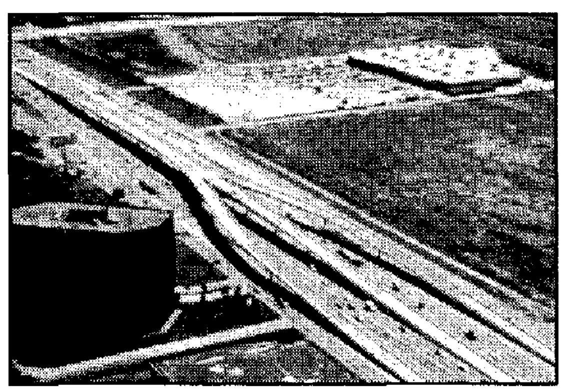


Figure 6-13. Elevated Slip Ramp. [9]

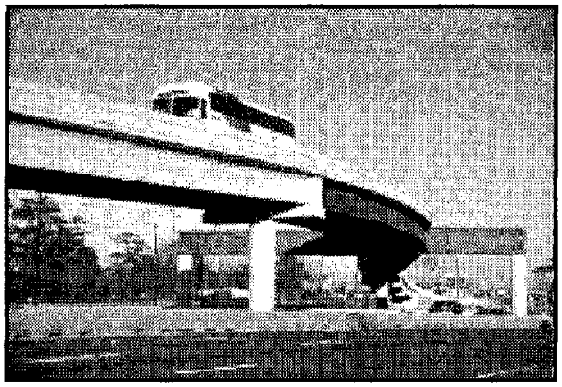


Figure 6-14. Flyover Ramp.[9]

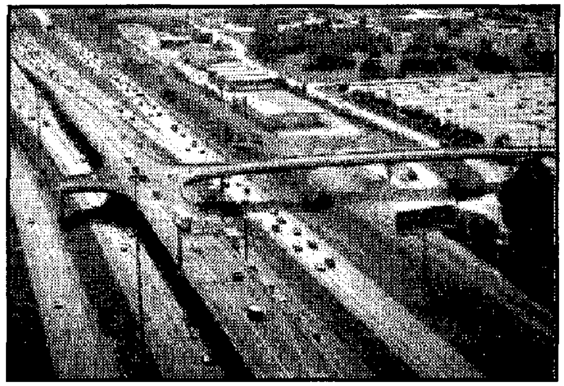


Figure 6-15. Grade Separated Interchange.[9]

Figure 6-16 shows typical flyover ramps connecting the HOV lanes to the righthand lanes of the freeway mainline. Where limited right-of-way and/or high costs prohibit the use of elevated flyover ramps, at-grade slip ramps can be used. At-grade slip ramps are also appropriate where the HOV facilities are reversible. This type of slip ramps terminal is particularly applicable to temporary or phased HOV lane implementation. Figure 6-17 illustrates the general concept of how an HOV facility with slip ramps can be incorporated into the freeway median. Since the HOV lanes shown are reversible, signing and/or barriers will be required to eliminate the wrong-way entry or exit. If traffic patterns warrant, separated HOV facilities should tie in to the existing street system within the central business district.

Direct ramps from a median HOV facility may be expensive and result in operational problems. However, they are preferable to merging HOV traffic with other freeway traffic in advance of the central business district, provided conditions permit. This concept is shown in figure 6-18 with connections into surface streets. It may also be desirable to connect the HOV facility to the through lanes of the freeway to provide for the through movement motorist. From outer areas, connections may be provided into freeway frontage roads for either collection or distribution of high-occupancy vehicles. Figure 6-19 illustrates the use of HOV flyover ramps to the freeway frontage roads. Where the HOV lanes are reversible, signing and/or barriers will be required to eliminate the wrong-way entry.

Intermediate connections to the HOV facility allow access on and off the facility to the through lanes of the freeway at critical locations, transit transfer centers, park-and-ride lots, and park-and-pool areas. These connections may be made at-grade with intermediate slip ramp openings or by grade separated interchanges.

All terminal and intermediate access connections should have high design standards. Tapers on entrance and exit ramps should be designed the same as for other freeway ramps, except that special consideration should be given to the acceleration and deceleration characteristics of loaded buses. This is especially critical where ramp grades are significant. Very long, gradual tapers should be avoided on exit ramps, as traffic may inadvertently follow the taper, assuming it is the main roadway. Ramps that connect to adjacent facilities or to cross streets should be designed to the same standards as comparable facilities that connect freeways to cross roads.

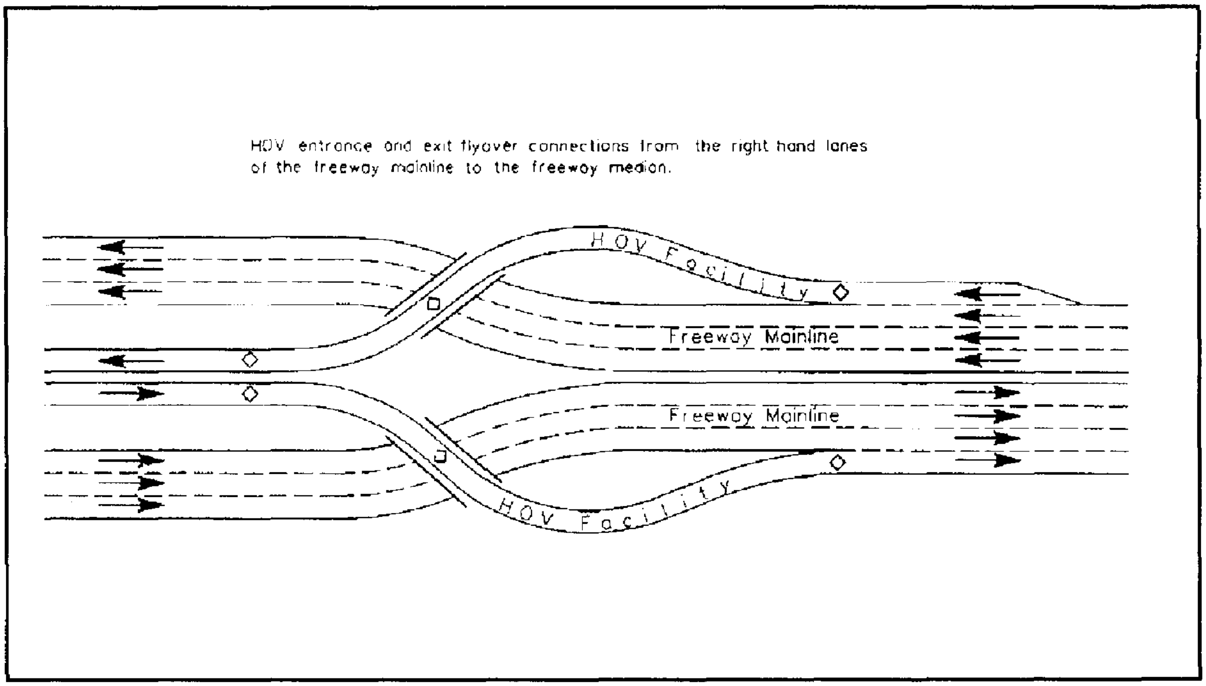


Figure 6-16. Terminal Flyover Connection to Freeway Mainline.(10)

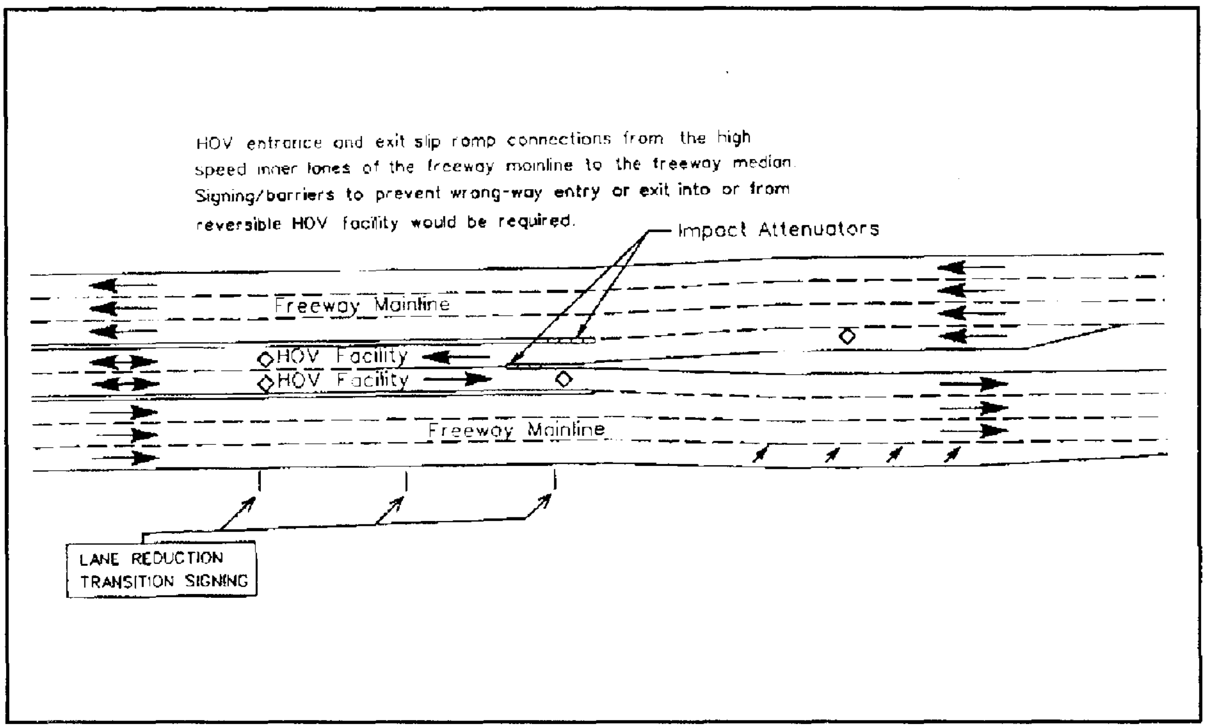


Figure 6-17. Terminal Slip Ramp Connection.(10)

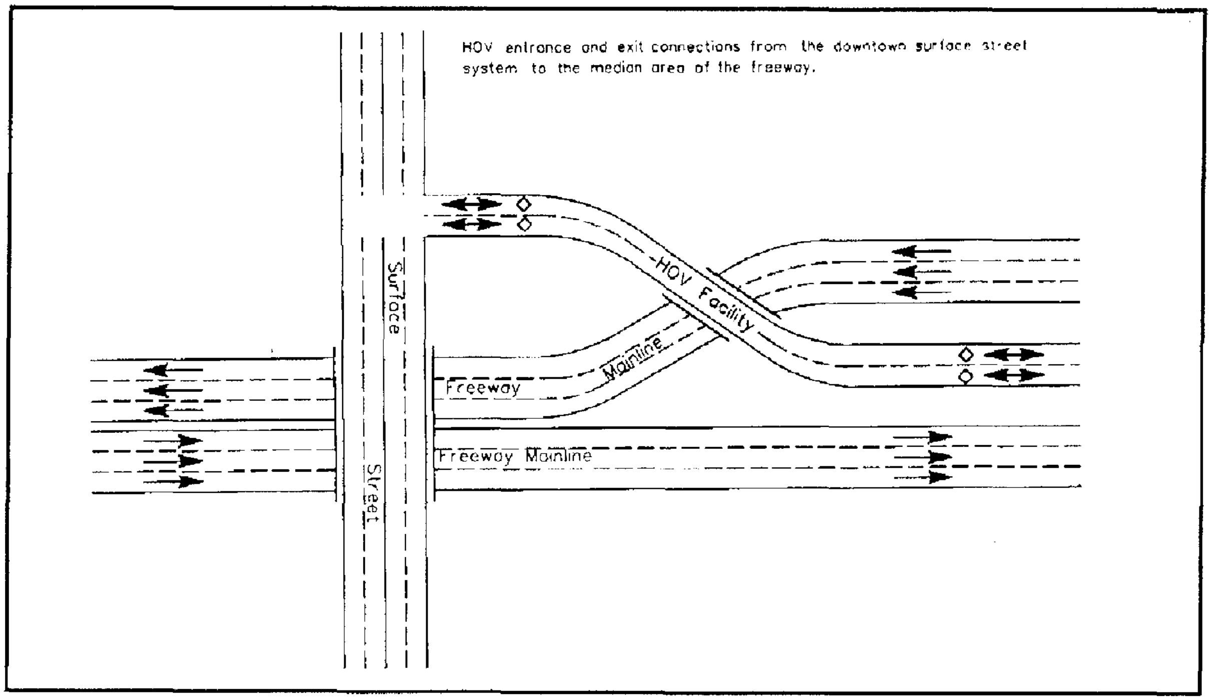


Figure 6-18. Terminal Flyover Connection to Surface Street System.[10]

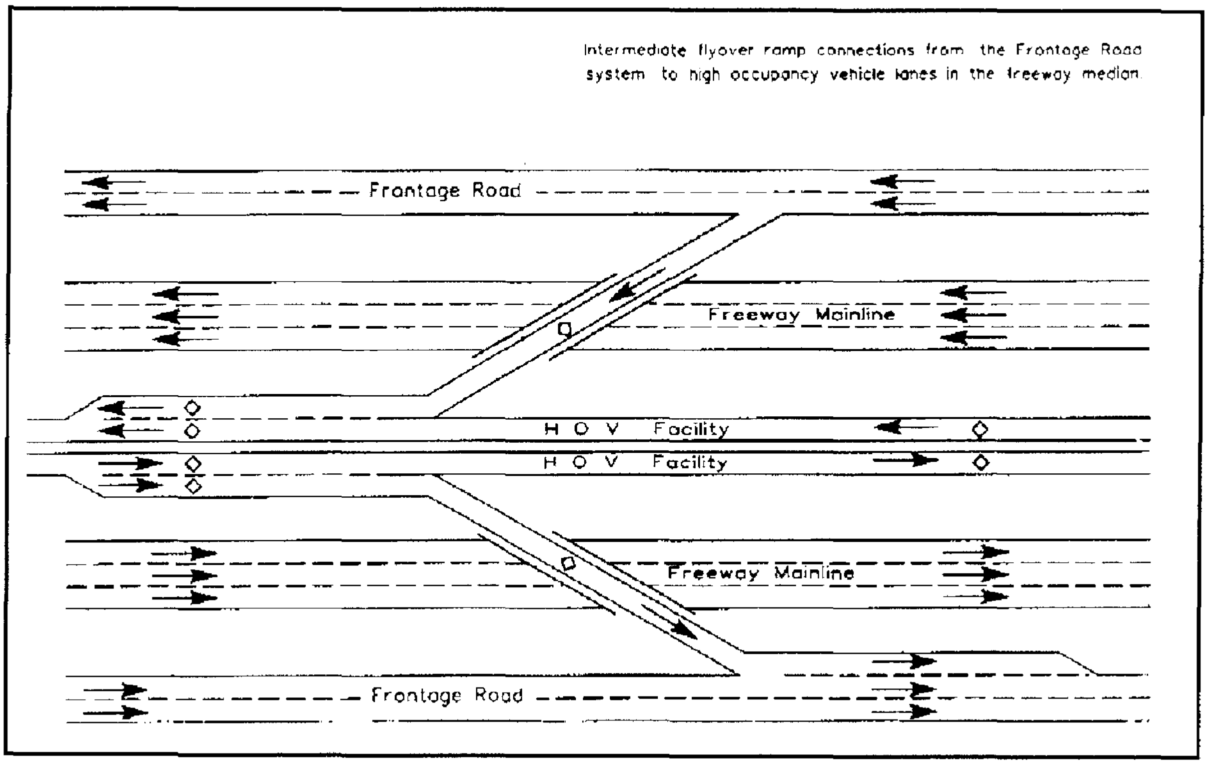


Figure 6-19. Intermediate Flyover to Frontage Road.[10]

Ramps are generally designed for speeds between 0 and 64 km/h (0 and 40 mi/h). Acceleration and deceleration lanes should be used for all types of HOV ramps. A minimum width of 4.0 m 13 ft) is recommended for HOV ramps. The minimum grade is the same as on the HOV lane, 0.35 percent; the maximum grade, however, is 8 percent.[11] Additional information is provided in the latest edition of the *Green Book.* [15]

PRIORITY ACCESS

Ramp Metering

Ramp meters are installed on freeway entrance ramps to do the following:

- Maintain uninterrupted, noncongested flow.
- Increase safety and efficiency by spreading out platoons of entering vehicles.
- Reduce congestion at the mainline ramp merge point.
- Limit amount of traffic entering the freeway so that demand for any section does not exceed capacity.

Ramp metering accomplishes these objectives by means of traffic signals on the entrance ramps that control the rate at which vehicles enter the freeway to maintain a balanced demand-capacity relationship. Usually, the rate of entry to the freeway is adjusted in response to the level of congestion or capacity available on the freeway. As freeway congestion increases, the rate at which vehicles are allowed to enter the freeway decreases. Also, excess freeway vehicular demand is encouraged to shift to alternative routes, to less congested time periods, or to HOV modes of transportation.

Ramp metering provides an opportunity to give priority treatment to, and encourage the use of, HOVs. This priority treatment can be in the form of a bypass of the meter or a preferential metering rate as compared with that of the general purpose ramp-metered lane. These treatments can be used in conjunction with mainline HOV lanes or where a freeway management system maintains an acceptable level of service and no HOV lanes are provided.

These bypass lanes can be restricted to buses only or can be made available to all HOVs. The decision on eligibility for use of the bypass should depend on the goals of the community, the number and types of vehicles that will use the bypass, and geometric conditions at the site affecting enforcement and operation of the ramp.

Bypass Lanes

The configuration of an HOV bypass lane can be that of a two-lane entrance ramp which tapers to a single-lane ramp prior to the merge with the freeway mainline, or a separate HOV bypass lane which merges with the entrance ramp downstream of the ramp meter. Figure 6-20 shows an example of the two-lane entrance ramp bypass.

The design of the ramp meter bypass should be determined by the conditions at each location. Bypasses should be 3.7 m (12 ft) wide with full ramp shoulders where possible, and should extend 91 m (300 ft) beyond the metering signal to permit HOVs to merge with normal ramp traffic. The ramp bypass traffic should merge first with regular ramp traffic, and then with freeway traffic.[10]

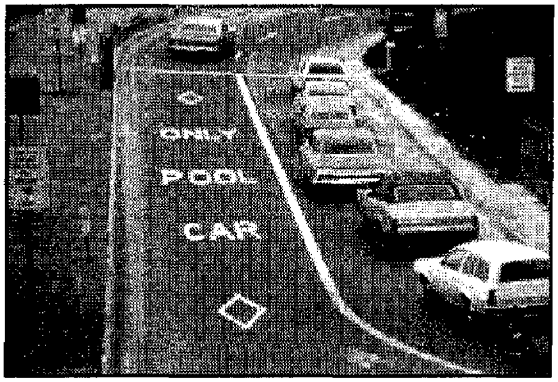


Figure 6-20. Two-Lane Entrance Ramp with HOV Bypass. [9]

Signs

For the two-lane entrance where one lane is designed as an HOV bypass lane, signs and pavement markings need to indicate the use of the right or left lane as the bypass lane. Such regulatory signs typically bear the legend "RIGHT/LEFT LANE BUSES AND CARPOOLS ONLY," and have the diamond symbol on the sign. The diamond symbol is also used as a pavement marking in the bypass lane. If a separate HOV bypass lane is constructed, the entrance to the bypass lane often has a sign installed reading "BUSES AND CARPOOLS ONLY," and the white-on-black diamond symbol.

Markings

Pavement markings have three major functions in a ramp metering HOV bypass installation:

- Indicate to drivers where to stop.
- Guide vehicles to form a single lane if the ramp begins as two lanes and tapers to one.
- Indicate the HOV bypass lane.

Ramp meter bypasses may be separated from the mixed-use lane by solid white pavement markings 20 cm (8 in) wide or wider. Diamond symbols should be used at 23 to 31 m (75 to 100 ft) intervals. Word pavement markings such as "CARPOOL ONLY", or "BUS ONLY" can also be used as appropriate and should be supplemented with signs.[10]

PARK-AND-RIDE FACILITIES

Park-and-ride facilities are an integral part of a multimodal transportation system. The purpose of these facilities is to provide a location for individuals to transfer from a low-occupancy mode of travel to a high-occupancy mode of travel. Park-and-ride facilities are typically provided in conjunction with transit services.

Most of the HOV facilities in operation around the country are connected either directly or indirectly to park-and-ride lots. For HOV lanes, transfers at park-and-ride lots are usually made from a vehicle to a bus; however, transfers may also occur from single-occupancy vehicles to carpools or vanpools. Examples of park-and-ride facilities used with HOV lanes are shown in figure 6-21.

There are many benefits associated with the proper use of park-and-ride facilities, including the following: [16]

- Encouragement of use of high-occupancy travel to maximize the efficiency of the transportation system.
- Improvement in efficiency of transit system by providing high-density areas for transfers and by increasing ridership.
- Assistance with congestion management, through a reduction in the number of single-occupancy vehicles on the freeway.

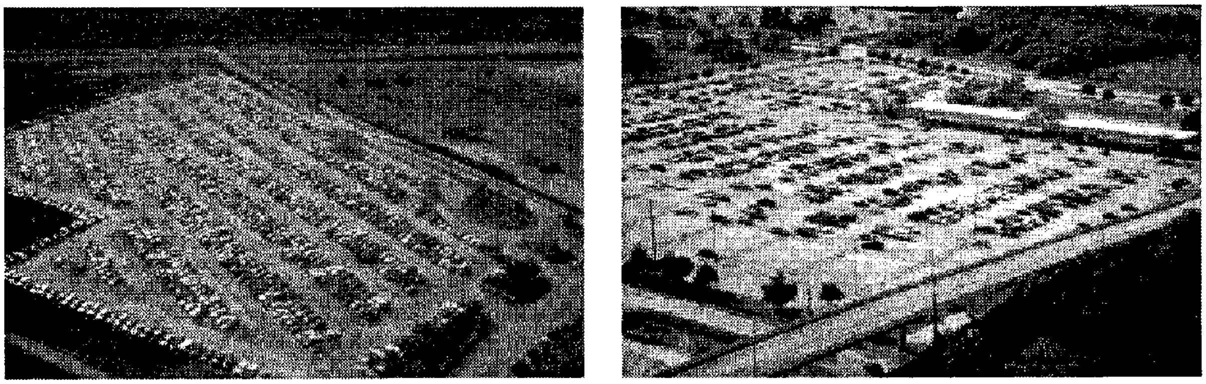


Figure 6-21. Park-and-Ride Lots with HOV Lane. [9]

- Reduction in energy consumption and air pollution.

The following sections provide discussions on locating and designing park-and-ride facilities. The information in these sections was gathered from several sources, and the reader is encouraged to refer to these sources for further information.[16,17,18]

Location of Facilities

Choosing the optimum location for a park-and-ride facility involves investigating several factors. Factors that should be considered when selecting an appropriate location for HOV-related park-and-ride facilities include the following: [16]

- Locate facilities in advance of areas experiencing major traffic congestion.
- Locate facilities so that drivers have a direct route to the lot.
- Orient facilities to ensure good accessibility and visibility.
- Locate facilities at appropriate distances apart.
- Locate at transit stations.

Encourage cooperation among agencies involved in developing and operating the facilities.

The four general steps in choosing an optimum location for a park-and-ride facility include:

- Establishing site selection criteria.
- Identifying alternative sites.
- Evaluating alternative sites.
- Determining size of park-and-ride facility.

Establishment of Site Selection Criteria

During the site selection process, site selection criteria must be established. The criteria should be used both in the initial screening of potential sites and in the evaluation process. The American Association of State Highways and Public Transportation Officials (AASHTO) publication, *Guide for the Design of Park-and-Ride Facilities*, provides the following descriptions for the criteria to be considered:[17]

- **Facility Development Policy.** The park-and-ride facility development program may make use of publicly owned property, excess right of way, or property used with the permission of private owners, that may be used for other parking purposes. The policy establishes the guidelines for the relative importance of each type of facility within the program.

- **Site Availability.** The first step in the site selection process is the development of an inventory of potential sites.

- **Site Accessibility.** A site must be easily accessible to commuters and transit vehicles when transit service is anticipated. Park-and-ride facilities that are inconvenient for potential users will not, in most cases, be well utilized and so should be avoided.

- **Site Visibility.** Potential sites should be visible from their access roads. Visibility of park-and-ride facilities contribute to the recognition by passing motorists of their availability. Visibility of a park-and-ride site is a deterrent to vandalism and an asset to the security of vehicles.

- **Projected Demand.** Demand for park-and-ride space is based on analysis of individual travel corridors. The indicated demand provides a guideline for the number of potential spaces and estimated lot size that must be identified within each corridor.

- **Transit Service Availability.** Potential sites for park-and-ride facilities should be located along existing or potential transit routes. The potential for transit service should be considered even at those lots which are intended for carpool and van-pool users. If transit service is to be provided by the local transit agency, coordination is a very important element.

- **Accessibility to HOV Facilities.** Sites located adjacent to HOV lanes, HOV priority ramps or other priority facilities provide benefits to park-and-ride users. Coordination of the location of park-and-ride facility sites with HOV facility development can increase the usefulness, demand, and efficiency of both facilities.

- **Development and Operating Costs.** Since most park-and-ride lots do not collect fees, sites that can be developed economically are desirable. Potential development costs include related non-site costs such as added traffic signalization or intersection improvement costs. Shared use of a private facility, church parking lot, mall, etc., can be a factor in development and operating costs.

- **Available User Benefits.** Sites that provide users with the benefits of both travel time and cost savings are preferable to those that provide only a transfer opportunity.

- **Staged Construction Potential.** In many cases, it may be desirable to test demand analysis accuracy before committing funds for larger lots or more permanent construction. In these cases, it is desirable to have a site that can be developed in stages to reduce resource commitments until space requirements are verified. Staged construction potential is also desirable when projected land use development is expected to generate additional park-and-ride demand.

- **Development of Sites in Environmentally Sensitive Areas.** Special attention must be given to consideration of the placement of park-and-rides in areas determined to be especially environmentally sensitive.

Identification of Alternative Sites

Alternative sites for park-and-ride facilities can be identified using any one or a combination of the following techniques:[17,18]

- **Office Survey.** The goal is to identify those properties which would most readily be developed for parking and which have suitable access.
- **Field Observations.** Field reconnaissance along travel corridors is the preferred method of potential site identification.
- **Aerial Photography.** Aerial photographic mapping provides an ideal means of locating vacant land and private parking areas that can be easily related to travel patterns and corridor routes.
- **Local Contacts.** District highway engineers, local government officials, law enforcement agencies, transit representatives and other local groups can be used as sources to identify sites that are suitable for park-and-ride use.
- **Inventory Records.** Potential park-and-ride sites should be documented on an inventory record form.

Evaluation of Alternatives

Once alternative sites have been selected for the location of a park-and-ride facility, the next step is to evaluate the alternatives and choose the most appropriate location. Many transit agencies use some type of form or check list to evaluate alternative locations. The AASHTO *Guide* presents an evaluation form that includes criteria for establishing a priority rating system.[17] The primary categories of factors are classified below:

- Location Criteria.
- Site Considerations.
- Economic Considerations.
- Potential User Costs and Time.

The criteria used in the AASHTO approach will vary depending upon an agency's preference and needs.

Agencies may establish their own evaluation technique based on local practice and available resources; however, the procedure used should provide a comparative analysis of each site's potential that results in the most economical and efficient use of park-and-ride facility resources. During the site selection process, local officials should be given an opportunity to comment on sites proposed in their areas.[17]

Determining Size of Facility

Once an ideal location for the park-and-ride facility has been identified, the next step is to estimate the parking area required to serve the estimated demand. Factors affecting the required size of the lot include the following:[16,17,18]

- **Traffic Demand.** The major factor affecting the required size of the parking facility is the estimated average daily demand. It is recommended that the lot be designed to accommodate at least 10 percent more vehicles than the estimated average daily demand in order to ensure that adequate parking spaces are available on a typical day.[16,18]

- **Maximum Walking Distance.** Recommended maximum walking distances range from 120 to 300 m (400 to 1000 ft); however, maximum walking distance should not exceed 195 m (650 ft) whenever possible. Walking distance can be minimized by moving the transit station to a central location. Walking distances longer than 300 m (1000 ft) may require consideration of additional transit stations. [18]

- **Bus Service.** The frequency of buses using the park-and-ride facility affects the demand that can be accommodated. For example, as the headways between buses decrease, the number of passengers that can be serviced increases. The increase in transit capacity may increase demand, which will directly affect the required number of parking spaces.[18]

- **Rideshare Use.** Park-and-ride facilities used strictly for rideshare use (e.g., carpool and vanpool) will not have the same restrictions as those facilities accommodating bus service. For example, maximum walking distance will not be as big a factor because drivers will typically have a prearranged meeting location, rather than walking to a central waiting area.[16]

- **Access.** Inadequate capacity on nearby roadways and intersections may severely restrict the volume of traffic that can enter or leave the lot during a given time.[18]

- **Land Availability.** The size and shape of a lot may be restricted by land availability and/or site development costs.

Typical Designs

After an appropriate location is selected for the park-and-ride facility, the next step is to design the facility. There are a number of existing design standards that can be used as guidelines during the design process. Some of the better known documents are the previously mentioned FHWA and AASHTO reports.[17, 18]

Internal Lot Layout

Park-and-ride facilities that accommodate bus services encompass design elements for both parking lots and transit stations. Elements that need to be addressed in the design process are discussed below:[16]

Functional Area Design. The functional design of a park-and-ride facility should meet the requirements of user groups with different access modes. Examples of access modes that may need to be accommodated include the following:

- Long-term parking.

- Drop-off (or kiss-and-ride) areas.

- Handicapped parking.

- Bicycle racks.

- Pedestrian walkways.

In addition, facilities that allow parking for carpooling or vanpooling will need to provide space accordingly. An example of a typical layout for a park-and-ride facility is shown in figure 6-22.

Figure 6-22. Example of Park-and-Ride Layout. [9]

Internal Circulation. Park-and-ride lots should be designed to provide internal circulation to meet all modes of transportation and to minimize pedestrian/vehicle conflicts. Internal circulation should provide for safe and efficient movement of vehicles, buses, motorcycles, bicycles, and pedestrians.

Amenities. Amenities are elements that are considered to enhance the comfort and convenience of using a park-and-ride facility. The number and type of amenities provided will depend on a number of factors, such as: type of facility, anticipated use, local policies, and available funding. Typical amenities that may be considered for use at various park-and-ride facilities include the following:

- Public telephones.
- Trash receptacles.
- Newspaper vending machines.
- Other vending services.
- Transit information displays.
- Transit shelters.
- Seating/benches.
- Bicycle storage facilities.

Pavement and Drainage. Providing adequate pavement design and ensuring proper drainage are other objectives that must be addressed in the design stage. The pavement design will depend on the functional area that it will serve. Typical sources of design guidelines include the following:

- AASHTO standards.
- Local and state pavement specifications.
- Agency guidelines.

Landscaping. Using landscaping for park-and-ride facilities will enhance the appearance of the facility, which will in turn improve public acceptance and enhance the feeling of security. Landscaping should be designed to be compatible with the type of facility and the surrounding area. It should not interfere with sight distance, safe operation, or access to the facility. Guidance for landscaping is available in several publications, including publications by AASHTO and Federal Transit Administration (formerly UMTA).[19,20]

Lighting. Adequate lighting should be provided at park-and-ride facilities to promote safety and security. Factors that must be considered when designing for lighting include:

- Type of lighting.
- Mounting height.
- Spacing of luminaries.
- Intensity of lighting.

Recommendations for designing lighting at park-and-ride facilities are provided in the AASHTO *Guidelines*.[17]

Security. An important factor in ensuring the success of a park-and-ride facility is providing adequate security. Both personal safety and automobile security are important to users of the facility. Measures that are used to enhance safety and security include:

- Lighting.
- Fencing and gates.
- Security monitoring booths.
- Cameras and surveillance equipment.
- Signing.
- Ensuring adequate visibility from all parts of the facility.
- Quick removal of graffiti.

Environmental Considerations. Any effects that a park-and-ride facility will have on the environment should be considered in the design process. For example, effects on air quality can be addressed by minimizing the number of idling buses and vehicles. Factors besides air quality that should be considered include the following:

- Groundwater runoff and water quality.
- Noise impacts.
- Visual and traffic impacts.

Roadway Interface

Providing adequate access between a roadway and a park-and-ride facility is important to ensure efficient operation of the facility and to minimize the effects on surrounding roadways. Both the FHWA *Guidelines* [18] and the AASHTO *Guidelines*[17] provide design recommendations for interfacing the park-and-ride facility with the surrounding roadway. Design issues that are associated with roadway interface are discussed below.

General Access and Egress Considerations. Providing adequate access and egress for all modes of transportation should be considered when designing a park-and-ride facility. The location of entrances and exits can be controlled by a number of factors, including the following:

- Topography.
- Position relative to adjacent roadways.
- Types of local roadways.
- Types of traffic control.
- Connecting service provided by transit.

Access Points. Another factor that should be considered when determining the location of access points for park-and-ride lots is the effect on the surrounding transportation system. To determine the optimum location of access points, a traffic impact study should be conducted. The study should involve determining the current operating conditions on surrounding roadways and estimating the effects of different access points on existing traffic operations. Factors that may be investigated in the analysis include the following:

- Existing roadway capacity.
- Current traffic volumes.
- Normal projected growth.
- Projected growth due to park-and-ride lot.
- Impact of commercial development that may occur due to location of lot.

Access Roadways. On the basis of results from the traffic impact study, the capacity of the existing roadways should be analyzed to determine if they can handle the additional demand due to the park-and-ride facility. The analysis should investigate both current operating conditions and future (projected) conditions. The outcome of the analysis can be used to identify any needed improvements to the surrounding roadways.

Traffic Control Devices and Traffic Signals. The purpose of traffic control devices is to improve the safety and efficiency of traffic operations by providing guidance to drivers through the use of signs, signals, and roadway markings. The need for new traffic control devices, or for modifications to existing traffic control devices, should be identified in the traffic impact study. Guidance on the use of traffic control devices is found in the *MUTCD*.[13]

Handicapped Considerations

For park-and-ride facilities, handicapped considerations must be addressed during the design process for both the parking and bus loading area.

Parking

The AASHTO *Guidelines* contain standards for providing handicapped parking at park-and-ride facilities.[17] Parking-related factors that must be considered for handicapped provisions include capacity, location, design, and signing and marking.

Capacity. Standards for the minimum number of handicapped parking spaces given in the *Uniform Federal Accessibility Standards* are shown in table 6-7.

Location. Handicapped facilities are to be designed in accordance with State or local codes and should be provided at the nearest possible location to the bus loading zone.

Table 6-7. Accessability Standards. [21]

Total Parking Spaces	Required Minimum Number of Handicapped Accessible Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 to 300	7
301 to 400	8
401 to 500	9
501 to 1000	2%
Over 1000	20 plus 1 for each 100 over 1000

The facilities should be in accordance with the following considerations:

- Preferably no access roads or bus lanes should be crossed by handicapped patrons en route to the bus loading zone.
- The handicapped patron must never be forced to travel behind parked cars (in their circulation path).
- To facilitate the movement of physically handicapped patrons, wheelchair ramps must be provided.

Design. The designer should consider grading the handicapped parking stall so that the head of the stall is at the same level as the sidewalk and the rear of the stall is at the appropriate aisle grade. This will reduce the need for depressed curbs, keep the handicapped patron from crossing any type of storm drainage, and simplify construction of the handicapped parking area.

Signing and Marking. Appropriate signing and/or pavement markings should indicate the restricted use of the space for handicapped persons. Curbs to and from the bus loading area should be depressed for wheelchairs, as dictated by local standards.

Bus Loading Area

The Americans with Disabilities Act (ADA) of 1990 establishes guidelines for providing reasonable access to and use of buildings, facilities, and transportation. All new or renovated transit facilities must comply with the accessibility regulations in the ADA guidelines. Rules applying to transportation and transportation facilities are contained in *Transportation for People with Disabilities.*[22] The *Americans with Disabilities Act: Accessibility Guidelines for Buildings and Facilities, Transportation Facilities, and Transportation Vehicles* publication, hereafter referred to as the *Guidelines*, contains guidelines for meeting

ADA requirements for transit facilities.[23] Section 10 is titled "Transportation Facilities" and contains guidelines related to transit facilities. It also references portions of section 4 in the *Guidelines* that relate to transportation. A TCRP (Transit Cooperative Research Program) report discusses information in the *Guidelines* relevant to the design of bus stops.[24] Another TCRP report presents guidelines on the design and location of bus stops, and includes a summary of ADA issues.[25]

PARKING INCENTIVES

Implementing special parking policies can provide incentives for commuters to use high-occupancy modes of travel. For instance, adopting preferential parking for carpools and vanpools can increase the attractiveness of ridesharing. Examples of parking programs to induce commuters to use high occupancy vehicles include the following:[26]

- Preferential parking.
- Free or low-cost parking.
- Differential parking rates.

Preferential Parking

Preferential parking involves providing special parking spaces at the final destination for high-occupancy vehicles. The advantage of this strategy is that the utilization of existing parking facilities is increased without having to add additional parking spaces. Preferential parking strategies include the following:[26]

- Guaranteeing spaces for carpools and vanpools where parking is limited.
- Assigning closest and most convenient spaces to carpools and vanpools.
- Assigning specific garage spaces to carpools and vanpools.

Preferential parking strategies should also be considered as a part of new development. Using these strategies can reduce the parking requirements by designating parking spaces for high-occupancy vehicles during the planning process. This approach allows developers flexibility in meeting minimum parking requirements, while increasing ridesharing. [26]

Free/Low-Cost Parking

Free or low-cost parking is another strategy that can be implemented to encourage ridesharing. Using this strategy, carpools are allowed to park in designated areas for no cost or for a small monthly fee. Some of the parking programs that have been established around the United States allow carpools to purchase a permit for a small monthly fee. The permit allows these vehicles to park in designated spaces or to park at metered parking spaces without paying the standard fee. [26]

Differential Parking Rates

Another parking program to increase ridesharing involves charging commuters a flexible parking rate based on the number of occupants in a vehicle. The cost of parking decreases as the vehicle occupancy increases. An alternative is to maintain a constant parking rate and provide employers subsidies that vary according to vehicle occupancy. An example of this strategy that has been used by some private firms is shown in table 6-8.[26]

Benefits of Parking Incentives

Parking incentives have been shown to have a positive impact on the number of commuters that choose ridesharing alternatives. A study conducted in Washington, DC showed a 20 to 40 percent increase in commuters who chose to carpool when parking incentive programs were adopted. [27] A company in Boston, Massachusetts implemented a parking program in which the daily parking fee was

Table 6-8. Example of Differential Parking Rates. [22]

Vehicle Occupancy	Percentage of Parking Paid for by Employer
Single Occupant	0 %
Two-Person Carpool	50 %
Three-Person Carpool	100 %
Vanpool	100 %

dropped for vehicles with three or more occupants. The company reported that at least 34 percent of their employees shifted to carpools when this strategy was adopted.[26]

Most parking incentive programs are partially or wholly subsidized by employers for a number of reasons, including the following:[26]

- A sense of responsibility to promote energy conservation.
- A desire to reduce the costs of maintaining current parking arrangements.
- The need to eliminate new parking construction.
- Improvement in employee morale when employers take an active role in reducing transportation costs for employees.
- Possible favorable media coverage for participating employers when they are identified as contributing to energy conservation, air pollution control, and reduced traffic congestion.

Barriers to Implementing Parking Incentives

A critical barrier that typically impedes implementation of preferential parking strategies is public and business opposition. Opposition from these groups occurs for the following reasons:[26]

- Merchants, employers, and employees traditionally resist changes in the status quo.
- Merchants are leery of any changes in municipal parking supplies that they feel would reduce their competitive position with other retailers who offer free customer parking.
- Employers and employees often resist changes because parking is part of an overall benefits package.
- Some executives may fear that they will lose their parking privileges by adopting this type of strategy.

There have been some factors, however, that have influenced officials in some cities to call for policies that would enhance the coordination between traffic demand management and parking incentives. Factors to be considered include the following:

- Auto ownership continues to increase. Ownership has increased at a rate of 2.5 times the population growth rate over the past few years.

- Structure parking is becoming prohibitively expensive.

- Metropolitan freeway construction is extremely expensive and is widely perceived to be environmentally disruptive.

EMERGING TECHNOLOGIES

Enforcement

The Texas Transportation Institute (TTI), in a research study sponsored by the Dallas Area Rapid Transit (DART), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and Texas Department of Transportation (TxDOT), is investigating the use of advanced technologies in HOV lane enforcement. The study is aimed at identifying technologies to improve the safety and cost-effectiveness of HOV lane enforcement. The study's objective is to identify the most promising technology and perform a 6-month operational test on the East R. L. Thornton (I-30) Contraflow HOV lane in Dallas, Texas. The results of the operational test will help DART improve enforcement procedures in HOV lanes in Dallas.

The enforcement system will perform the following basic functions: [28]

- Collect and transmit video images of vehicle license plates and vehicle compartments for all HOV lane users to a remote computer workstation.

- Perform automatic license plate character recognition on the license plate video image.

- Synchronize captured video images of vehicle occupants with license plate numbers.

- Search a license plate database containing vehicle occupancy histories and, based upon failure to meet set criteria, display the vehicle license plate number and vehicle compartment images on a computer monitor for review and enforcement purposes.

After the equipment is procured and installed, an operational test will follow to evaluate and refine the enforcement procedures. The operational test is expected to be concluded by August 1997.

Movable Barrier

The movable concrete barrier system consists of a barrier transfer vehicle and a movable concrete barrier (see figure 6-23). The main advantage of the barrier is its ability to provide a solid, physical separation between opposing flows of vehicles. The movable barrier consists of 0.9 m (3 ft) concrete segments jointed together by pins. A specially designed conveyor system on the self-propelled transport and transfer machine (TTM) is used to shift the barrier laterally across the roadway (see figure 6-24). The distance of the shift can vary from 1.2 to 6.7 m (4 to 22 ft). The T-shaped barrier top is engaged by conveyor wheels on the TTM. The barrier is then lifted several inches off the ground, moved sidewinder fashion through an elongated S-curve, and repositioned to form a new lane. Barriers can be moved at up to 8 km/h (5 mi/h), depending on the circumstances.[29]

The use of the movable barrier to create the HOV lane on the East R. L. Thornton (RLT) Freeway in Dallas began in September 1991. The movable barrier shifts the barrier approximately 6.7 m (22 ft) laterally to

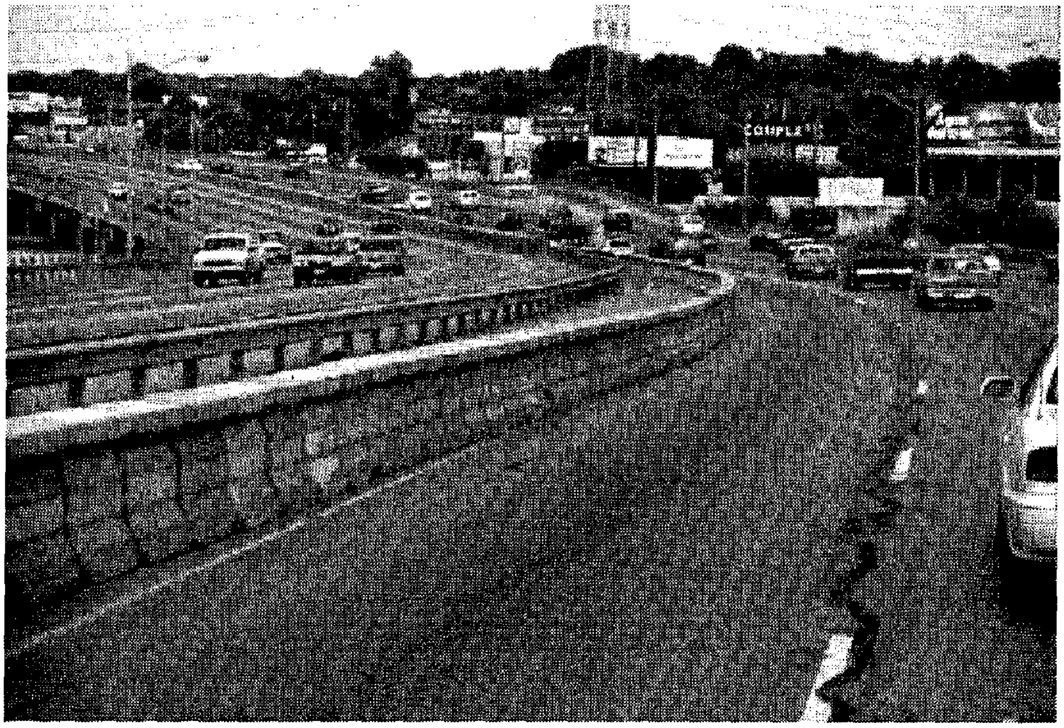


Figure 6-23. Movable Barrier. (9)

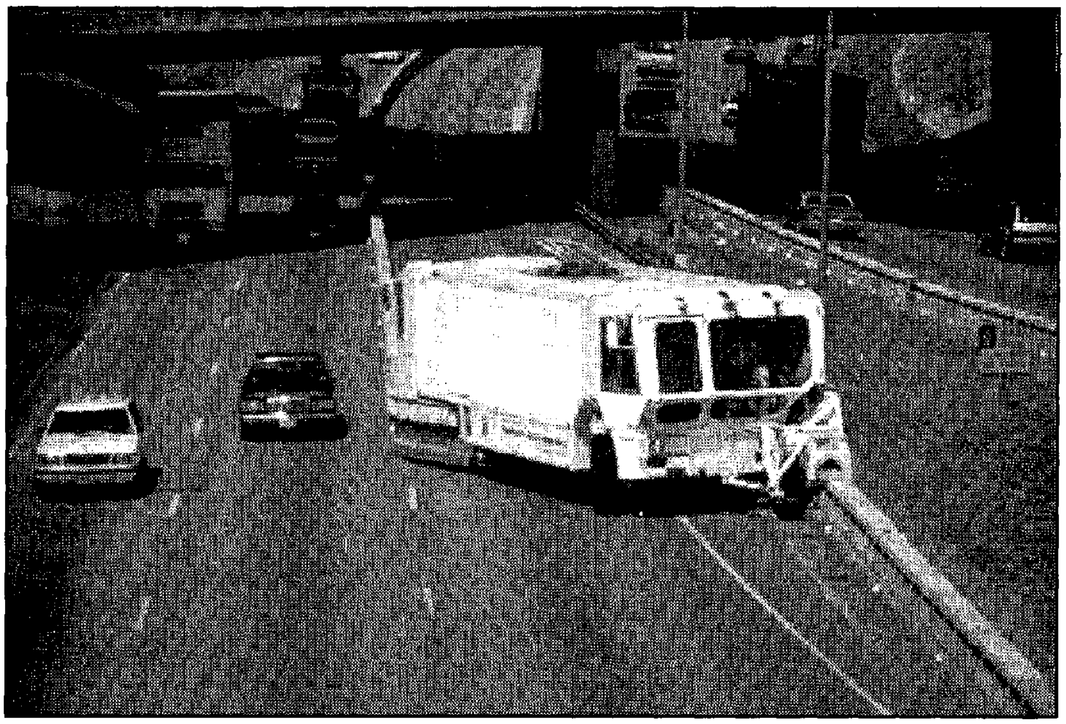


Figure 6-24. Movable Barrier Used in Dallas. (9)

create an extra travel lane for the peak direction of flow. The implementation of this HOV lane was accomplished by narrowing freeway lane widths to 3.4 m (11 ft) and reducing the inside shoulder of the freeway in some locations (see figure 6-25). The contraflow lane is 8.4 km (5.2 mi) long. The cost to construct this contraflow lane (in 1995 dollars) was $15.4 million. In December 1995, the East RLT HOV lane served 13,572 daily person trips.[26]

The second contraflow HOV lane to use a movable barrier opened in November 1995 on the I-93 Southeast Expressway in the Boston metropolitan area. Like the project in Dallas, the I-93 contraflow HOV lane is created by moving a concrete barrier from the median across one traffic lane to create an additional HOV lane in the peak direction of travel. After six months of operation, the HOV lane, or *zipper* lane as local commuters call it, has met the operational goals for the initial phase of the project. In 1996, the lane carried over 14,400 people each weekday. Concerns expressed about operation during winter weather were dispelled when the lane was opened 99 percent of scheduled times during the snowiest winter in Boston's history (250 plus cm (100 plus in).[29]

6.4 LESSONS LEARNED

PLANNING

A planning process that yields information on the best possible HOV candidates should be undertaken to ensure an efficient and effective HOV facility. This can aid in determining the type of HOV facility needed and the proper vehicle eligibility requirements. Operational considerations such as operating periods, eligibility, active traffic management, incident response, and enforcement should be addressed during the planning process. When operational issues are not considered, the end result can be an HOV facility that is mismanaged, vulnerable to long periods of nonuse when incidents occur, and difficult to enforce.[5]

Fuhs developed a generic process for evaluating HOV alternatives. [5] The four stages are as follows:

- **Stage 1: Conceptual Viability.** The first of the four stages of HOV development is an evaluation of HOV conceptual viability, accomplished by applying a list of criteria to the candidate corridor. If the corridor fails to meet these criteria, it should be excluded from further consideration, or efforts should be undertaken to better understand what may be needed for the criteria to be met.

- **Stage 2: Alternative Development.** The second stage involves a more qualitative and quantitative assessment of the merits of the candidate corridor and an identification of the specific types of HOV designs and operational elements that are applicable and feasible. There is less likelihood that a candidate corridor will be excluded at this stage; however, a number of design and operation alternatives may be created at this stage that warrant further study. If this is evident, follow-on studies may occur here to better assess the relative merits of each.

- **Stage 3: Development of Recommended Alternative(s).** The third stage involves development of one or more recommended alternative(s). This stage focuses on specific design and operation issues that deserve attention. Activities include the following:

  - Selected elements of preliminary engineering.

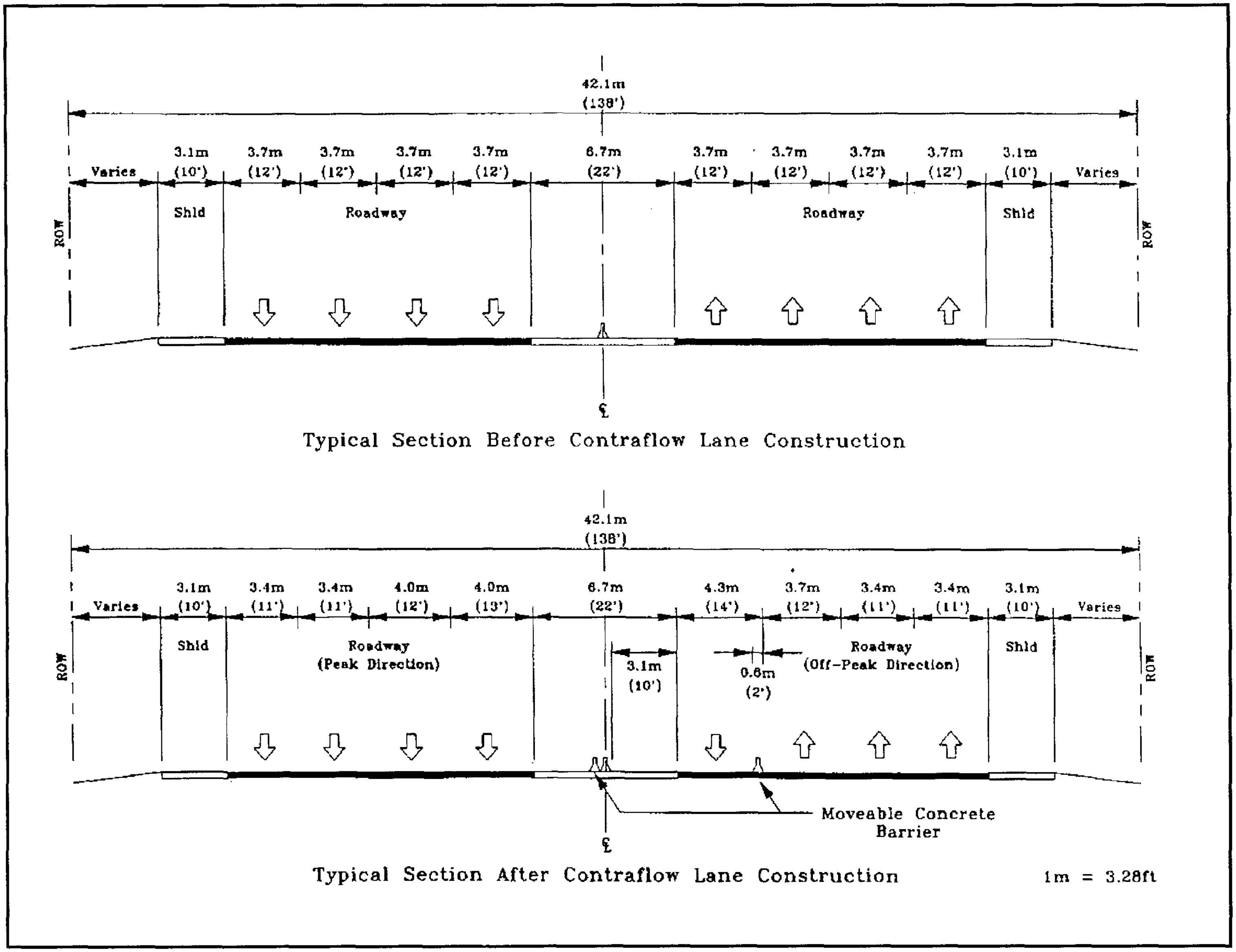


Figure 6-25. Typical Sections, Before and After East RLT Contraflow Lane Construction.[26]

- Checks for constructibility and implementation staging.
- Support facilities (park-and-ride and/or park-and-pool lots, and on- and off-line bus facilities, etc.).
- Identification of supporting programs like ridesharing.
- Implementation phasing.
- Cost estimating and cash flow analyses.
- Other corridor-specific issues.

Products from this third stage include an operation plan and a geometric design plan.

- **Stage 4: Plan Adoption.** The fourth and final stage is formal adoption of the local preferred HOV plan. The results of the HOV planning study are officially sanctioned by respective boards, commissions, or other official bodies, and an implementation process is defined. The adopted HOV plan may be a stand-alone approach or may be one of a number of other capacity alternatives (highway or transit) that are subjected to alternative and environmental analysis before being eligible for design and construction.

Public and Political Support and Consensus Building

HOV concepts are often not understood by the public, politicians, or media. Within the scope of the planning study, a multiagency review group (also called an advisory committee or steering committee) should be formed. Their role includes the following:

- Technical and policy guidance
- Concurrence powers at major decision points.
- Coordination and liaison with others in the respective agencies.
- Outreach to greater public participation efforts as needed.

HOV projects are particularly in need of this type of oversight, where an ongoing commitment is needed among a number of agencies to effectively plan, implement, operate, enforce, maintain, and modify the HOV project as necessary to ensure continued viability. The composition of the review group may vary during the planning and implementation process, but at a minimum, representatives from affected local agencies, police, the state DOT, and the FHWA should usually be involved. If a project is adopted for implementation, this group should continue to function through the design phase, and some semblance of the group should be named to provide operation and maintenance overview of the HOV facility once it is opened.(5)

Apart from the multiagency review group, focus groups composed of local civic associations, special interest groups, politicians, the media, and others may be necessary to bring public participation into the planning process. This process should be highly structured to keep issues focused. Appropriate in many areas will be the need for some public awareness outreach to market the HOV concept. There are four steps to an effective public education program:(5)

- Information should be disseminated three to four months prior to the opening of the project to prepare the public for the new facility and its regulations.

- During the first few weeks of project operation, there should be an intense public relations effort until users are familiar with the HOV facility and its operation.

- As soon as data on project use are available, they should be presented to the public to disseminate information about the positive impacts from the project.

- The public education program should be continued, as needed, to reinforce an understanding of concept objectives and the role of enforcement.

An important lesson that has been learned from project failures to date is that the public must be involved and must be able to understand and appreciate the role that HOV systems can serve. To this end, any HOV planning process will necessarily need to be an information, awareness, and education process as well.

Public Involvement

Traditional methods of public notification and community relations are important to gaining public acceptance of changes to transportation services. The public interest, however, has progressed to a desire to become directly involved in the initial and ongoing decisions about service and design. Public involvement is not public relations. Public relations strategies attempt to position an issue, project, or plan in the best possible light for decision-makers and the public. Frequently the objective is to gain public acceptance of a prior decision. Public involvement, on the other hand, involves the public in the shaping of policy and project decisions that affect a community. Public involvement is best initiated before project alternatives are developed or decisions made. Public involvement can be loosely divided into four components—data gathering, public and private communications, promotion, and evaluation.[2]

- Data Gathering.
  - Literature Search.
  - Surveys.
  - Focus Groups.
  - Focused Interviews.
- Public and Private Communications.
  - Kick-Off Briefing.
  - Community/Jurisdiction/Elected Official Briefings.
  - Public Meetings, Hearings, Open Houses, Workshops.
- Promotion (Heightening General and Targeted Awareness).
  - Media Relations.
  - Newsletters.
  - Speakers Bureau/Public Forums.
  - Advertising and Public Service Announcements.
  - Special Events and Ceremonies.
  - Customer Service Representatives and Other Staff.
- Evaluation.
  - Survey.
  - Focus Groups.

- Focused Interviews.
- Public/Private Partnerships.
- Sponsorships: Corporate & Media.

System Approach to HOV Planning

Most HOV projects have been implemented on a corridor basis. As such, *corridor planning* has been pursued with focused evaluation on the specific needs and travel characteristics of the corridor in mind. As additional corridors have been addressed in a region, there has been a recognition of the need for *regionwide system planning,* in which a broader perspective of HOV applications for a metropolitan area, is studied. There have been few cases where regional system planning occurred prior to the study of a particular corridor. Pursuing a regionwide approach assumes a much higher level of commitment to the HOV concept as a valid regionwide option.

Regionwide planning recognizes the relationships among system elements, particularly in staging system implementation to maximize early benefits. Regionwide issues may influence operation polices in which the same hours of operation or rules regarding eligibility are uniformly established for all projects in a given area. This policy of operation consistency has been adopted for Orange County, California, while the Seattle and Houston areas have policies allowing operation policies to be tailored to the unique attributes of each corridor. Both policy approaches can be locally popular and successful.[5]

Possible Pitfalls in Implementation

The following are typical issues to be aware of and to avoid in the implementation process:[5]

- **Policies and Procedures**: Involved agencies are often unaware of the strings attached to funding, review, and approval steps, and the procedures required for project implementation. Involved agencies should become familiar early on with the rules and policies associated with funding, programming, and implementing projects. This is particularly important when more than one agency is actively involved in the process. FTA and FHWA guidelines are not always in agreement. State policies and procedures may not be familiar to local agencies assisting the State in various activities.

- **Involvement**: In trying to accelerate the effort, some of the agencies that should be involved are overlooked.

  Keep all appropriate agencies involved in decisions being made. This will keep the project properly focused and on schedule.

- **Commitment**: One agency pursues the project without additional external, and sometimes internal, support.

  A dedicated commitment is needed from all the respective parties before proceeding with a project. This provides a broader base of support for sustaining the project.

- **Taking Unnecessary Risks**: In an attempt to achieve faster results, authorization is given to proceed on future activities before all reviews and approvals have been acquired from prior actions.

  Risk management is involved in any implementation process. If such risk is to be taken, it should be based on a general consensus from the project team with an understanding of the possible downside impacts.

- **Changing Course**: A prior approval or commitment is rescinded, for any of a number of reasons.

  Inevitably, as any project progresses into greater and greater detail of development, there can be justification to re-explore a prior matter that was thought resolved. In such instances, the project manager can be effective in bringing together the affected parties to reach a renewed understanding and, if necessary, to change the course or scope of the project. Recurring problems of this sort may require resolution at higher levels in the organization, providing another reason why a top-down commitment to a project is essential before undertaking implementation.

- **Scope, Budget, and Schedule**: An early effort should be undertaken to understand any change in scope, schedule, and budget and to obtain a resolution that rebalances these variables. Performance and delivery expectations should be based on a realistic understanding of the project requirements. The risks of fast-tracking a schedule, for example, should be defined and understood. Again, a single project manager can be the focal point for this understanding.

Tables 6-9 to 6-10 list characteristics of successful HOV facility implementations and potential pitfalls, respectively.

Development Concerns for Park-and-Ride Facilities

There are many factors that must be considered when implementing a park-and-ride program. These factors are discussed below.

Program Planning

Program planning involves developing the operating plan that defines specific program requirements. These planning requirements are discussed below:

- **Site Development Policies.** Once it has been determined that park-and-ride facilities will accompany specific HOV lanes, the first step is to establish site development policies. These policies will provide guidance in developing the facilities. Typical policies that need to be addressed include the following:

  - Stage construction guidelines.
  - Maximum or minimum size lots.
  - Extent of amenities (e.g., telephones, lighting, etc.) to be provided.
  - Transit service guidelines.
  - Joint accommodation of carpools and vanpools with transit users.

- **Inventory of Potential Sites.** The next step is to identify potential sites. This can be accomplished by a number of means, including the following:

Table 6-9. Successful Characteristics of HOV Facility Implementation. [(2)]

☞	Clear set of objectives and measures of success
☞	Development of the HOV lane as an additional lane
☞	Existing congestion in corridor (able to save 1/minute/mile & 5 to 8 minutes total)
☞	Projections for continued increase in demand
☞	Enforcement commitment/collaborative working relationships with enforcement agencies/courts along the corridor
☞	Reason to believe you can get support from both agencies and public
☞	Reason to believe you can provide a lane that can be safely operated and enforced
♥	Policies and programs supporting transit use
♥	Rideshare program in corridor
♥	Successful HOV facilities already in operation in same corridor or adjacent corridors
♥	High existing volume of 2+ HOV's (700 or more vehicles per hour)
♥	Traffic system management program already in place along the corridor
♥	High level of convenient transit service along the corridor (local/express/Park & Ride routes)
♥	Commute trip reduction legislation
♥	Existing communication network with employers along the corridor
♥	Collaborative working relationships with environmental agencies/groups along the corridor
♥	Collaborative working relationships with neighborhood/community groups along the corridor
♥	Collaborative working relationships with local jurisdictions/transit agencies/DOT along the corridor
♥	Commitment to evaluation to accurately show benefits/disbenefits
♥	Origin-destination pattern that can benefit from the HOV lane

Legend
☞= Essential Characteristic
♥= Desirable Characteristic

- Aerial photographs.
- Excess property lists.
- Field reconnaissance.

• **Facility Implementation Priority Rankings.** Once potential sites are identified, a list of the sites is prepared for use in defining the short-term and long-term programs. The next step is to establish a methodology to allocate available funding and to address the most critical needs on a priority basis.

• **Short-Term and Long-Term Site Development Programs.** Short-term and long-term site development programs are established to provide for planning, design, construction, funding, scheduling, and resource allocation.

• **Transit System Interface.** The location of park-and-ride lots should be coordinated with existing and proposed transit routes to maximize the benefit of these facilities.

Table 6-10. Potential Pitfalls to Successful HOV Facility Implementation. [2]

- Converting existing general purpose lane to HOV lane, may result in negative impacts (increased accidents, increased travel time, etc.) in general purpose lanes or protest by the public
- High accident rate along the corridor that will not be improved by HOV lane
- Little support from enforcement authorities (State Police/Patrol, municipal judges/magistrates)
- Low existing volume of HOV
- Poor working relationships with local media
- Poor working relationships with neighborhood/community groups along the corridor
- Poor working relationships with elected officials (especially critical during election years)

➢ Changing lane designation from general purpose to HOV during lane construction (example: begin construction as general purpose, change designation during construction phase to HOV)
➢ Low level of transit service
➢ Lack of transit funding
➢ No/low level of support facilities
➢ No incident management program in place
➢ No/inadequate ride matching services
➢ Poor pavement maintenance of existing facility that would not be helped by HOV lane construction

Legend
•= Potential Fatal Flaw
➢= Possible Problem

- **Roadway Interface.** The development of park-and-ride lots should also be coordinated with HOV lanes to provide for proper design of access routes and entrances. The objective should be to provide access to HOV lanes in a way that will maximize travel time savings for the users of the facility.

Design Requirements

Both transit planners and traffic engineers should be involved during the design process to ensure proper operating conditions for buses and cars. Standard design manuals for park-and-ride facilities are available and should be used to control design quality.[16,17,18] A following section titled *Typical Designs* provides a summary of some existing design guidelines.

Operation and Maintenance

It is very important that operation and maintenance issues be addressed during the development process. For example, it is important to ensure that adequate funding is available for the operation and maintenance of a facility. Also, the agencies and groups responsible for the operation and maintenance of the facility should be identified early in the development process:

- **Operation.** The successful operation of park-and-ride facilities will require close cooperation among local transit agencies, the community, and the State DOT. The operation of a park-and-ride facility involves a number of elements, including the following:[18]
  - Parking fee structures.
  - Frequency of transit service.
  - Fares for transit service.
  - Carpool use.
  - Providing security.
- **Maintenance.** Providing proper maintenance of a facility also has a significant impact on the success of a park-and-ride program. Ensuring that the facility is clean, attractive, and well maintained will have a positive impact onusers. In developing a comprehensive maintenance program, several factors must be considered:[16]
  - Periodic inspection.
  - Pavement repair.
  - Shelter or station repair.
  - Traffic control devices (e.g., signs and pavement markings).
  - Lighting.
  - Mowing.
  - Sweeping and cleaning.
  - Trash removal.
  - Landscaping.
  - Site furnishings.
  - Snow and ice maintenance.
  - Security/gates.

Program Marketing

The objective of a marketing program is to inform motorists about the park-and-ride facility and available transit services. It is important to develop a marketing program during the implementation of a new park-and-ride facility; however, ongoing marketing efforts are also important for the continued promotion of the facility. Two important needs that should be addressed when developing a marketing campaign are as follows:[16]

- Identify target audience.
- Determine effective mechanism for communicating desired information.

Examples of actual marketing techniques include the following:[16]

- Direct mail.
- Radio.
- Television.
- Newspaper.
- Billboards.
- Roadside signs.
- Lot location maps, transit maps, and transit schedules.
- Employer-focused efforts.

For further information on the marketing of HOV systems, the reader is referred to the

High Occupancy Vehicle (HOV) Lane Marketing Manual.[30]

DESIGN/CONSTRUCTION

The development of HOV facilities within freeway corridors is typically a retrofit process. Not all desirable design standards are likely to be obtainable. Some compromise in design requirements will probably be needed, and the elements of compromise will differ from one location to another. Tradeoffs need to be considered on a case-by-case basis, according to an agreed-upon understanding of what design treatments are acceptable to the appropriate reviewing agencies. Therefore, HOV practitioners recognize that the typical recommended designs provided in any of the currently available design resources must be considered as *guidelines* and not *standards.* The guidelines are of two types, *desirable* and *reduced.*

- *Desirable* design guidelines are those that should be considered in the concept development of any new or substantially reconstructed freeway corridor or HOV guideway in separate right-of-way. Desirable guidelines are generally recognized as reflecting a permanent facility treatment with the same commensurate design as that which would be applied to a new freeway with full design standards. HOV projects constructed with these dimensions have had significant costs and have been accompanied by substantial freeway reconstruction as well.

- *Reduced* design guidelines are those that may be considered for retrofit projects on a case-by-case basis, where space or cost considerations might otherwise make application of the HOV treatment environmentally infeasible or cost prohibitive. Reduced designs often reflect restriping or otherwise modifying the existing freeway to achieve an HOV operation that may be termed "interim," with a longer-range intent for meeting desirable guidelines. The reduced dimensions have also been used in short sections of projects otherwise meeting desirable standards, where significant cost would have been incurred to provide the desirable widths.

Tradeoffs in Retrofitting Cross Sections

The process of retrofitting HOV facilities onto existing freeways requires design compromises. Often, bridge columns, narrow structures, limited right-of-way, and other isolated constraints are encountered which make adherence to desirable or even reduced criteria difficult without some commensurate reduction in the overall cross section of the freeway. Design compromises should be thoroughly investigated before an HOV facility is implemented. The key concerns relevant to this issue appear to be cost effectiveness of the remedy and length of the design exception required. If reductions in typical guideway standards are necessitated, general practice indicates that the sequence of tradeoffs presented in table 6-11 should be considered when making these determinations.[5]

Impacts of Ingress/Egress on Adjacent Freeway and Arterial System

HOV ingress/egress designs have evolved through experience, and much has been learned from various applications. Following are a few general guidelines:[5]

- Where possible, the same geometric criteria should be applied as would be used for a freeway ramp, including locally recognized entrance and exit design standards.

Table 6-11. Tradeoffs in Reducing Cross Section Elements.[5]

Compromise Sequence	Cross Section Element		
	For Reversible-Flow HOV Facilities	For Two-Way Barrier-Separated HOV Facilities	For Buffer-Separated HOV Facilities
First	Reduce single-lane HOV envelope to no less than 6 m (20 ft), or two-lane envelope to no less than 8.5 m (28 ft).	Reduce left HOV lane lateral clearance to no less than 0.6 m (2 ft).	Reduce left HOV lane lateral clearance to no less than 0.6 m (2 ft).
Second	Reduce freeway left lateral clearance to no less than 0.6 m (2 ft).	Reduce right HOV lane lateral clearance to no less than 2.4 m (8 ft).	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).
Third	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).	Reduce freeway left lateral clearance to no less than 0.6 m (2 ft).	Reduce buffer separation to no less than 0.3 m (1 ft).
Fourth	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fourth and fifth steps when buses are projected to use the HOV facility).	Reduce freeway right lateral clearance (shoulder) from 3.1 m (10 ft) to no less than 2.4 m (8 ft).	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fourth and fifth steps when buses are projected to use the HOV facility).
Fifth	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft) (leave at least one 3.7-m [12-ft] outside lane for trucks).	Reduce HOV lane width to no less than 3.4 m (11 ft) (some agencies prefer reversing fifth and sixth steps when buses are projected to use the HOV facility).	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft) (leave at least one 3.7-m [12-ft] outside lane for trucks).
Sixth	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).	Reduce selected mixed-flow lane widths to no less than 3.4 m (11 ft). Leave at least one 3.7-m (12-ft) outside lane for trucks.	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).
Seventh	Convert barrier shape at columns to a vertical face.	Reduce freeway right lateral clearance shoulder from 2.4 m (8 ft) to no less than 1.2 m (4 ft).	Transition barrier shape at columns to a vertical face or remove buffer separation between HOV and mixed-flow lanes.
Eighth		Convert barrier shape at columns to a vertical face.	

Adapted from Caltrans *HOV Guidelines*, as reported in the reference.

- The typical volumes using HOV access ramps are less than for commensurate freeway ramps. HOV volumes accessing a local street seldom overwhelm a signalized intersection. Average peak-hour ramp demand at an intersecting street probably will not exceed 300 to 500 vehicles per hour.

- Sight distance is particularly critical due to the proximity of barriers to ramp lane alignments. Lateral clearances are often no further than 0.6 m (2 ft) from the edge of the travel lane to barrier. Where practical, removal of barrier-mounted glare screens or slight adjustments in striping alignment may be necessary within the ramp envelope to accommodate the proper design speed.

- The location of ingress/egress facilities is influenced by a number of factors. For example, direct access ramps to/from local streets should be made with candidate streets that currently do not have freeway access, so as to better distribute demand and prevent overloading existing intersections. For at-grade access to the adjacent freeway lanes, designated outlets should be strategically positioned so as to minimize erratic weaving to reach nearby freeway exits.

- Left- or right-hand exits from a one-lane HOV facility are equally valid and equally safe. The standard "right hand only" rule for entrance and exit ramps should not apply to HOV facilities.

- Where possible, entering and exiting movements should be shared on the same structure or space envelope between retaining walls to reduce cost.

- Adequate advance signing should be provided, and pavement markings should emphasize the mainline (possibly through use of skip stripe markings across the diverging exit ramp).

- Safety lighting should be applied for all ingress/egress locations, using the same warrants as are applied for metropolitan freeway entrance and exit ramps.

- Where possible, provision for entrance ramp metering and/or enforcement should be considered (these are project-specific considerations based on a number of local issues and input from enforcement agents).

Signing Guidelines

Signing guidelines for HOV facilities should be no different than for any other high-speed highway application. Regional consistency should be considered when arraying periodic information regarding rules, policies, and operating procedures. The pitfalls commonly evidenced on projects include the following: [5]

- Lack of adherence to MUTCD color standards.

- Lack of diamond symbol exhibited on signs.

- Confusing regulatory sign information.

- Sign lettering too small to be read at the posted speed.

- HOV guide signs that can be read and misconstrued by mixed-flow drivers.

- Signs that have not been adequately upgraded to reflect the most current operating rules.

The following are general recommendations for handling these shortcomings and applying the MUTCD chapters:[5]

- The standard sign for HOV regulatory and guide signing is black-on-white, with a white diamond symbol on black background in the upper left corner. The diamond symbol should appear on all signs related to HOV user and nonuser communication (regulations and guidance).
- The size of the sign should be commensurate with the design speed, using the same relationship in letter size as is required for any other highway signing.
- Signs should be considered on the approaches to all HOV ingress and egress locations and at the ingress/egress locations themselves. It may be necessary to mount such signs over the lane to provide proper sizing. Guide signing for HOV users is necessary on HOV facilities that have designated ingress/egress locations.
- Regulatory signs related to lane restrictions should be mounted over the lane at regular intervals.
- Regulatory signs located in advance of a preferential lane should be mounted on the appropriate side of the approach roadway.
- If dynamic signing is used, the diamond symbol should be applied on or above the variable sign in the upper left corner.
- Regulatory signing should periodically clarify user eligibility, hours of operation, directionality (if appropriate) and other restrictions on the operation along the length of the facility. Regulatory information should be repeated along nonbarrier-separated facilities at 0.8 to 1.6 km (0.5 to 1.0 mi) intervals. Regulatory information for barrier-separated facilities can be displayed at entrances and exits only.
- Carpools and vanpools should be defined in terms of "PERSON" numbers. (Sample message: Buses and 2+ *Person* HOVs only.)
- Where lateral clearance is limited, as for a ground-mounted sign affixed to the median barrier, the sign panel may have to be skewed as much as 30 degrees to allow for an increase in panel length.
- All signing should be reevaluated whenever operation policies change. Signs should be changed in accordance with the revised policies and not be cluttered with amended information that confuses or contradicts the primary message or information being communicated.
- Where guide signing for similar destinations can potentially be seen by both HOV users and nonusers, the HOV message should be reinforced with the diamond symbol. All guide signs in the area of confusion should be mounted over the appropriate roadways.

Pavement Marking Guidelines

There is generally more diversity in pavement markings, and this is due to wide variation in locally accepted standards and uncertainty over proper pavement marking treatments. Following are general recommendations for interpreting and applying guidelines in the MUTCD: [5]

- Reserve the use of the diamond symbol on signs and pavement markings for

HOV treatments. Although the MUTCD recommends this symbol for bicycle lanes, and for commercial or other purposes not related to HOV, practitioners now concur with restricting the diamond symbol to HOV applications. The placement of the diamond on the pavement should be frequent enough to communicate the restrictive nature of the lane. Along higher-speed freeway facilities, the interval should be from 153 to 305 m (500 to 1,000 ft).

- The colors of pavement markings should, as a general rule, be in compliance with the MUTCD. White is usually applied to communicate a concurrent-flow condition; yellow is applied to communicate a potential for adjacent oncoming vehicles. Solid lines denote that crossing of the marking is not permitted. There are local exceptions.

- For a barrier-separated two-way configuration, a solid white stripe should delineate a right shoulder and a solid white or yellow stripe delineate the left edge of the travel lane. For buffer-separated lanes, the buffer should always be delineated with solid stripes, preferably white, if continuous access is not allowed. Some buffer-separated projects use a combination of white and yellow. Nonseparated lanes that allow continuous ingress/egress and become mixed-flow lanes during at least part of the day should apply standard freeway lane delineation. Contraflow lanes should apply a separation stripe that is either a single or double yellow dashed stripe . Queue bypasses should apply the same pavement markings as are routinely applied along ramps. The stop bars for meters should be highly visible and quite large (typically 20 to 30 cm [8 to 12 in] wide).

- Use of dashed (skip-stripe) markings across an exit ramp should be applied where there is possible confusion over the orientation of the mainline HOV facility. This is more likely where HOV ramps enter and exit from the left.

- Cross hatching of buffers of gore areas helps direct traffic, but is difficult to maintain. Some projects include cross hatching initially; however, they are not maintained. Drivers' experience and knowledge of the HOV facility provide guidance after the markings fade.

- Avoid use of raised reflectorized delineators of buttons in conjunction with pavement markings wherever motorcycles are allowed as eligible users. Consult with local police if motorcycle enforcement patrols are being considered.

OPERATIONS

Surveillance, Communication, and Control

An HOV facility operating without a surveillance, communication, and control (SC&C) system must rely on area traffic bulletins, police reports, or bus operator communications to locate and remove incidents. This approach can be acceptable and has proven adequate in most HOV applications. With the SC&C system, loop detectors and CCTV provide operators with information on the real-time operating status. An incident can be located in seconds. It is this reduction of time in locating a disabled vehicle, and its subsequent prompt removal, that provide travel time savings to the HOV facility users in the event of an incident. And, like any freeway operation, the greater the traffic volumes, the greater the delay that is associated with the increasing number of incidents.(10)

For the HOV facility to maintain a higher quality of service at all times, electronic surveillance and communication tools can help operators respond to an incident that disrupts flow. Applying technology to both the HOV facility and the mixed-flow facility in a common corridor may bring incremental benefits and economies of scale. Either consideration or expanded use of surveillance and communication techniques is prudent in the design phase, even if the only steps taken are to allow for easier adoption of this technology at a later date. Typical treatments in the roadway design that complement future installation include the following: (5)

- Inclusion of conduits adjacent to or under the outside shoulders (normally two, 7.6-cm (3-in) conduits are adequate). Placement of conduits inside barrier alignments is not recommended due to the difficulty in accessing the conduits.

- Inclusion of conduit valve openings within any longitudinal box beam structures and abutments.

- Placement of additional induction loops in Portland cement concrete pavement at 0.4 to 0.8 km (¼ to ½ mi) intervals. Up to three loops in a series should be applied, even if all are not ultimately used.

Incident Response

Once an incident is detected, a key to minimizing delay to HOVs is the speed with which the incident is cleared. Effective incident response must include service equipment and facilities that, upon detection and location of an incident, allow for the rapid removal of that incident.(10)

One important consideration in incident management on HOV facilities is the cooperation of the agencies responsible for providing the needed response. Often more than one department of an agency, or more than one agency, is involved. Since the priorities within each agency may be different, it is sometimes difficult to achieve the full cooperation of all parties. Matters involving multiple jurisdictions can also complicate the management process. To overcome these differences, it may be necessary to create an incident management team composed of representatives of the major operating agencies and governmental entities. At a minimum, the incident management team should coordinate incident response with existing groups or freeway incident management personnel, if any.(10)

An additional resource in incident response is the media. The dissemination of real-time traffic information by a central control facility to radio and/or television stations allows all citizens, especially commuters, to receive up-to-the-minute traffic information.(10)

Enforcement Strategies

Enforcement strategies are influenced by the compliance goal for a facility, accepted local practices of the enforcement agencies, and available staffing and resources. An acceptable violation rate varies from one type of priority treatment to another. In general, violation rates should be capable of being managed to no more than 10 to 20 percent of the observed traffic stream in the HOV facility.(5) Four primary enforcement strategies are being used on HOV facilities:(31)

- **Routine enforcement** activities are those activities which are randomly conducted in concert with normal police monitoring duties. Routine enforcement could be appropriate if the violation rate experienced is considered acceptable by the project management.

- **Special enforcement** is characterized by continuing, systematic staff allocations and enforcement tactics specifically dedicated to enforce HOV violation rules. It is used when routine enforcement cannot effectively address HOV needs without sacrificing other enforcement duties.

- **Selective enforcement** combines both routine and special approaches. Although most enforcement is routine, special tactics are applied periodically to specific problem areas where violations have been observed.

- **Self enforcement** means having motorists and HOV users police themselves, identifying noncompliance with the HOV facility and taking voluntary actions to report violators.

Other Users

Other users that are eligible (or considered for eligibility) for some HOV facilities include the following:[5]

- **Motorcycles.** Inclusion of motorcycles has been promoted by some as an effective and safe way of segregating these vehicles from the mixed-flow traffic stream. The 1982 Surface Transportation Act passed by Congress leaves the decision, in effect, to local authorities. The act specifically includes motorcycles as eligible to use HOV facilities constructed with federal aid funds, unless the responsible operating agency(s) take measures to have motorcycles prohibited for safety reasons. There does not appear to be any nationwide evidence to substantiate reports of positive or negative impacts associated with motorcycles. Inclusion of motorcycles as eligible users seems to be a local issue that has been effectively addressed at the local/state level.

- **Commercial vehicles.** The role of commercial trucks in moving goods to market has expanded significantly. Reducing commercial vehicle transportation costs can mean a higher domestic standard of living and a more competitive position for the U.S. in the world marketplace. For these reasons it is becoming increasingly viable to think of trucks as priority vehicles. A policy that includes large commercial vehicles (e.g., any vehicle with more than two axles) in HOV facilities has been proposed over and over, particularly by the general commuting public and politicians, as a means of remedying conflicts in the mixed-flow traffic stream. With greater focus being given to restricting trucking operations on metropolitan freeways or during peak hours, the possibility of opening HOV facilities in the off-peak periods could have merit. However, the differing origins and destinations of commuters and commercial trucks cannot be easily accommodated. HOV facilities often contain design elements that are restricted within the geometric limitation of the surrounding freeway, making accommodation for trucking movements difficult. Weaving movements of trucks can adversely affect mixed-flow operation where median HOV ingress/egress is primarily via these adjacent lanes. There are also some questions about the safety of such a vehicle mix, particularly the effect on sight distances and operating speeds.

Even so, Environmental Protection Agency (EPA) regulations at 40 CFR 88.313-93, which are based on section 246(h) of the Clean Air Act, added by the 1990 Clean Air Act Amendments, allows fleet vehicles from centrally fueled fleets of 10 or more that have been certified and labeled as inherently low emission vehicles (ILEV) to use HOV lanes in certain ozone or carbon monoxide nonattainment areas, regardless of the number of occupants, unless they would "create a clear and direct safety hazard."[32] If ILEVs will be allowed to use HOV lanes, the lanes need to be designed to limit the negative aspects of mixing commercial vehicles and HOVs discussed above.

- **Deadheading Vehicles.** The term "deadheading" refers to transit operators' operating empty buses on HOV facilities for the return trip to their routes. By allowing transit operators to deadhead on HOV facilities, transit services are afforded greater operation efficiency and more visibility on HOV facilities. However, it is not desirable to issue blanket approval of transit operator deadheading, because there are instances where the appearance of empty vehicles on HOV facilities may create a public perception problem. Also, there could be numerous private transit operators in a metropolitan area who may wish to deadhead on HOV facilities, possibly causing unnecessary congestion on the facilities.

- **Emergency Vehicles.** Emergency vehicles are generally allowed on all HOV projects. In practice, however, few emergency vehicles partake of the HOV lanes, because the ingress and egress locations are not generally oriented to the nearest emergency facility (e.g., fire station or hospital). Inclusion of emergency vehicles does not affect the design envelope that is applied, especially if all classifications of buses are accommodated. Any emergency vehicle that uses an HOV facility should be properly identified and involved in a legitimate mission. Use of the lane by off-duty enforcement or unmarked vehicles deteriorates public respect for the operation and its policies and should be discouraged.

MAINTENANCE

Maintenance needs, like incident handling, tend to be the same as for any other metropolitan roadway. HOV lanes can be designed to reduce certain maintenance needs. Following are a few recommendations:[5]

- Drainage inlets should not be placed under barriers. Inlets may be cast into barriers, but slots should be wide enough to be maintained. No inlets should be located in a lane of travel.

- Access to overhead signs should be available. Closed-circuit television, variable message signs and lighting need special attention to ensure that they can be accessed for maintenance without blocking a travel lane.

- Snow removal may require special consideration. This need can dictate the width of shoulders for temporary storage of plowed snow, or intermediate openings in barriers for access by snow removal equipment. HOV lanes should be afforded a higher priority for snow removal than other portions of the roadway.

- Litter removal from the median carries a higher priority on most HOV treatments, particularly on treatments that do not provide adequate lateral clearances with barriers. Even small objects that are blown against a barrier can affect HOV operation. Barrier-separated facilities tend to collect debris blown in from mixed-flow lanes. Some projects have resorted to sweeping or driving the HOV facility in advance of operating periods to remove major obstacles.

- Transit support facilities, most notably bus transfer stations, can be subject to extensive vandalism, and require an inordinate amount of maintenance. Special attention to material selections that are in keeping with anticipated use (staffed versus unstaffed facilities) are recommended.

- The typical one-lane HOV roadway is subject to extensive wear along a specific wheel path. It is not uncommon for ruts in asphaltic concrete surfaces, or tears in the seams between differing pavement materials, to create ongoing maintenance problems. Every effort should be made during the design process to develop a consistent pavement section with sufficient quality for longevity.

- Barriers between parallel directions of travel (HOV and mixed-flow) should be only loosely fixed to the pavement, and barriers preferably precast. This design treatment allows sufficient flexibility in the future to move barriers when the inevitable need arises to handle traffic during pavement resurfacing and rehabilitation activities.

- Pavement markings and HOV signing should be designed with longevity in mind, and properly maintained to minimize confusion and ensure proper operation.

- The design of the HOV facility should not attempt to address every detail. To optimize operation, there will be a need for maintenance activities to address minor modifications to signing, pavement markings and other elements of the project that require some refinement as operating experience is acquired. Capital or maintenance funds should be budgeted for these inevitable needs.

CONCURRENT FLOW LANES

The following issues should be considered when planning and designing concurrent flow HOV lanes:

- Phased construction is sometimes used to build concurrent flow HOV lanes. Often, the finished portions are opened to regular traffic. Converting these lanes to HOV operation can cause opposition and resentment. System planners and operators should either keep the lane free of traffic until it is completely finished or impose HOV restrictions on any opened partial section. In both cases, marketing and public relations campaigns may be needed to explain how the HOV lanes will be used during construction.

- Careful consideration should be given to how vehicles merge into and out of concurrent flow HOV lanes. Designers should be careful not to create a design where unsafe driving conditions are generated because of the speed differential between HOV and regular traffic lanes.

- Concurrent flow HOV lanes can be used by aggressive drivers to pass slow moving vehicles, and to weave in and out of regular flow traffic. Regular enforcement activities may be needed to curb this activity.

6.5 EXAMPLES OF HOV TREATMENTS

Two case studies of HOV Systems are offered. These studies provide an overview of the HOV facilities in Houston, Texas, and Seattle, Washington.

HOUSTON

Houston, Texas hosts the most extensive network of barrier-separated HOV facilities in the United States.[33] Ultimately, the Houston HOV system will incorporate 166 km (103 mi) of HOV lanes.[34] The Houston HOV system has enjoyed a great deal of success largely due to the coordinated support offered by the Metropolitan Transit Authority of Harris County (METRO) and the Texas Department of Transportation (TxDOT).[33]

The HOV facilities in Houston were created in response to a surge in traffic congestion that began in the 1970s. The City of Houston and TxDOT sought to improve transit operations and reduce traffic demands by increasing vehicle occupancy from an average occupancy of 1.2 persons per vehicle through HOV priority treatments. Houston's HOV experience began with the development and operation of a 14.4 km (9 mi) contraflow lane on the North Freeway (I-45). The contraflow lane hosted only authorized buses and vans and, when opened for use in 1979, was extremely successful. The contraflow lane was operated only for 2.5 hours during each peak period, but was credited with moving over 8000 persons during those times. As a result of the success of the contraflow lane, Houston began development of a large-scale HOV system concept.[33]

Having committed to the development of HOV facilities in Houston, the City of Houston and TxDOT laid plans for the development of a 166 km (103 mi) HOV lane system as illustrated in figure 6-26. While two-direction HOV facilities are being developed, the typical HOV lane in Houston currently provides for reversible operations, and is separated from general-purpose freeway lanes by concrete median barriers (see figure 6-27). The HOV lanes are typically located in the freeway median and measure approximately 6 m (20 ft) in width. Due to geometric constraints, freeway mainlanes and inside shoulder widths were narrowed in some locations to accommodate HOV lane construction.[33]

Access to the Houston HOV facilities is provided by several means and is typically provided at 5 to 8 km (3 to 5 mi) intervals. Most access to the HOV lanes is provided by grade-separated interchanges. At these interchanges, the HOV lane is elevated in the freeway median, and grade-separated ramps are used to convey traffic over the freeway lanes to select local streets, transit facilities, and park-and-ride lots (see figure 6-28). The grade-separated ramps were chosen for their ability to eliminate interference with freeway mainlane operations, enhance safety, reduce travel time, and provide locations for enforcement personnel to operate. The construction costs of the grade-separated interchanges are estimated to range between 2 and 7 million dollars each. In addition to the grade-separated ramps, some access to the median HOV lanes is provided through the use of slip ramps, as shown in figure 6-29.[34]

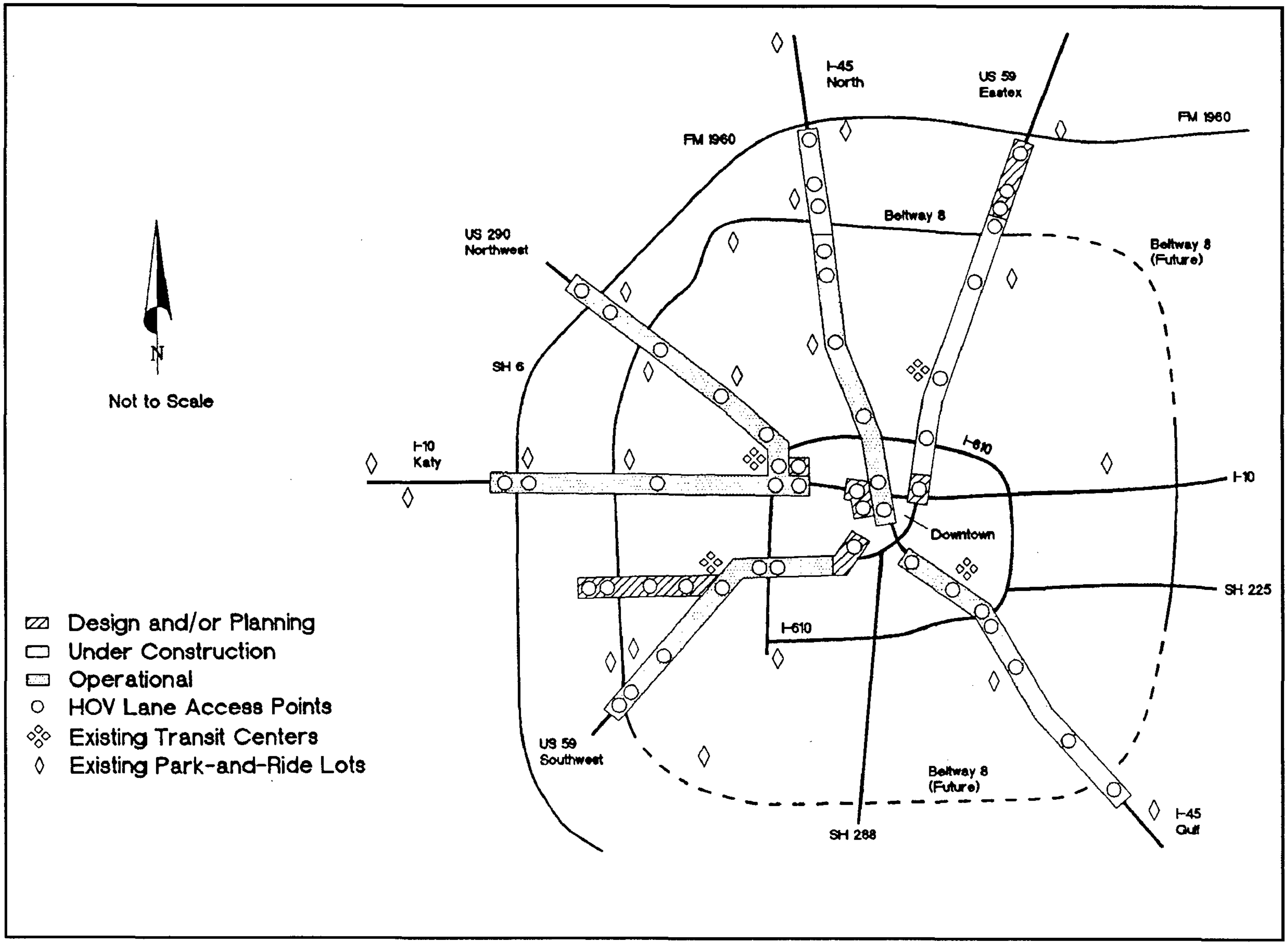


Figure 6-26. Houston HOV System.[34]

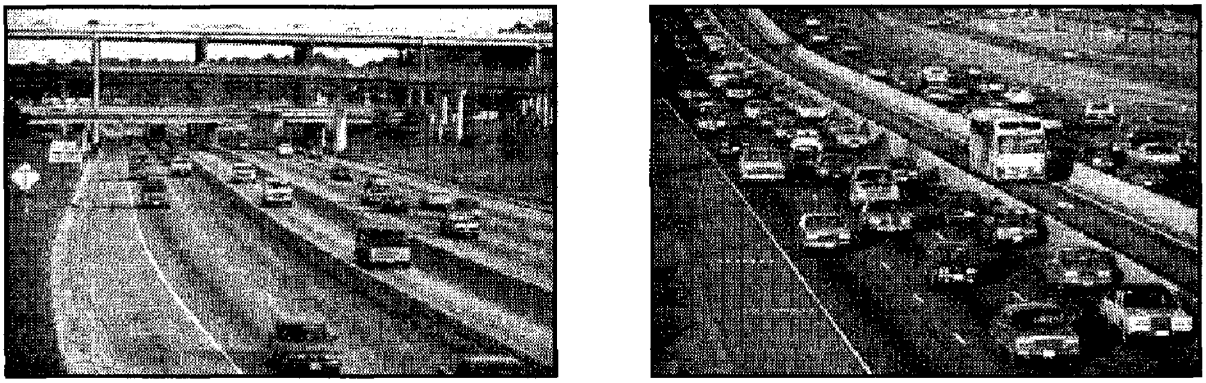


Figure 6-27. Typical Houston HOV Lane.[9]

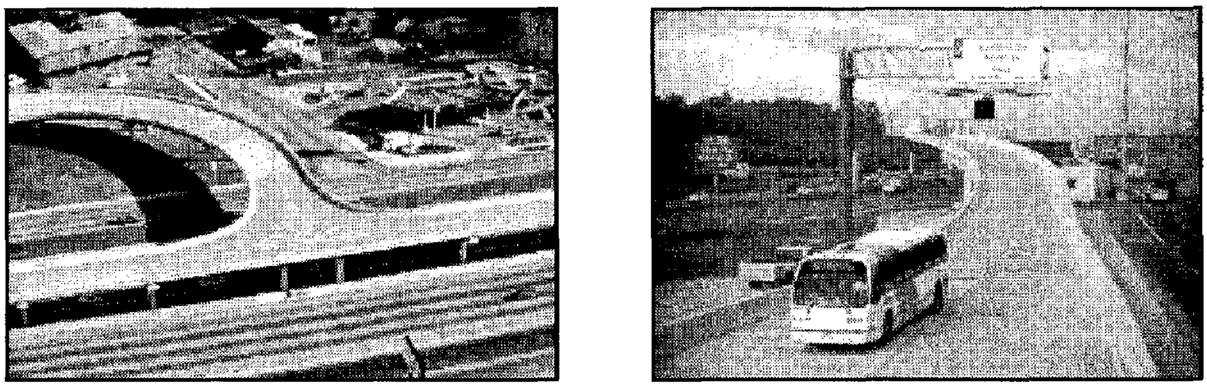


Figure 6-28. Houston Grade Separated HOV Lane Access Ramps.[9]

The occupancy requirements of the Houston HOV lanes, as well as the vehicles that are allowed on them, continue to evolve. Changes have been made to both the occupancy and vehicle requirements to manage traffic volumes on the HOV lanes (see figure 6-30). The changes were made to ensure the desired high speeds and reliable trip times that contribute to the success of HOV lanes.[33]

As of December 1995, the system was hosting in excess of 77,000 person-trips per day.[34] Peak-hour vehicle occupancy has increased by approximately 20 percent on freeways with HOV lanes as compared to their pre-HOV conditions. Freeways without HOV lanes witnessed a decrease in occupancy during the same periods. Given the quasi-independent status of the HOV lanes in relation to the freeway mainlanes, operations on the freeways and other parallel routes have not been significantly affected by the HOV lanes. No significant changes in freeway and parallel route congestion have occurred. This finding is attributed to the HOV's ability to reduce the growth rate in congestion, as opposed to reducing the existing levels of congestion.[33]

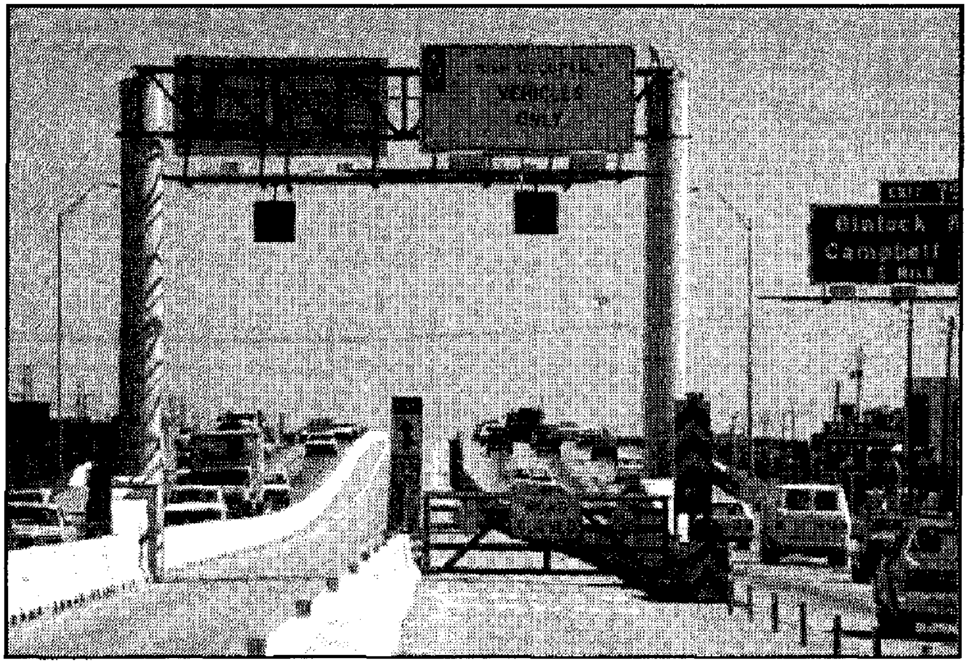


Figure 6-29. Houston HOV Slip Ramp.[9]

Figure 6-30. Example of Dynamic Message Sign Showing New Occupancy Requirement.[9]

Contributing to the success of the HOV lanes has been the development of several strategically located park-and-ride lots, transit centers, carpool lots, and downtown bus lanes (see figure 6-31). Park-and-ride lots themselves have experienced a tremendous growth in demand due to use of the HOV lanes. In two of Houston's HOV lane corridors, use of the park-and-ride facilities increased 200 percent or more from pre-HOV levels. Similar corridors not equipped with the HOV lanes experienced only small changes during the same time period.[34]

Travel time savings offered by the HOV lanes have also served as a lucrative means of attracting new users. Because the Houston system is still relatively new, it is not believed to have reached its full potential yet. Nevertheless, time savings range from five minutes on the Gulf Freeway HOV lane to 18 minutes on the Katy Freeway HOV lane. The current 102 km (63.6 mi) system is estimated to result in 41 minutes of time savings, or one minute per mile. Recent survey evidence indicates that the time savings perceived by users of the HOV lanes are much higher and it is expected that future benefits will be even greater as congestion on freeway mainlanes increases.[34]

On the basis of survey evidence, the typical users of the HOV lanes are characterized as young, educated, white-collar commuters. Furthermore, over 90 percent of the transit bus riders using HOV lanes have an automobile at their disposal, indicating a significant expansion of the transit market. Principal reasons cited for using the HOV lanes include the following:[28]

- Freeway too congested (22%).
- Saves time (18%).
- Time to relax (16%).
- Reliable trip time (15%)

Sixty-five percent of the total person trips on the HOV lanes are currently served by vans and carpools. The remaining 35 percent are served by buses.[34]

The latest regional plan for the HOV system estimated that the entire Houston HOV system will have cost approximately $900 million, or $5.5 million per km ($8.8 million per mi), when the system is complete. These costs, estimated in 1995 dollars, include the HOV lanes, HOV lane access and egress ramps, all park-and-ride lots, park-and-pool lots and bus transfer centers, and the HOV surveillance, communication, and control systems. The exact capital cost of the HOV lanes will be difficult to determine because the HOV lanes have usually been constructed in conjunction with freeway renovation projects.[34]

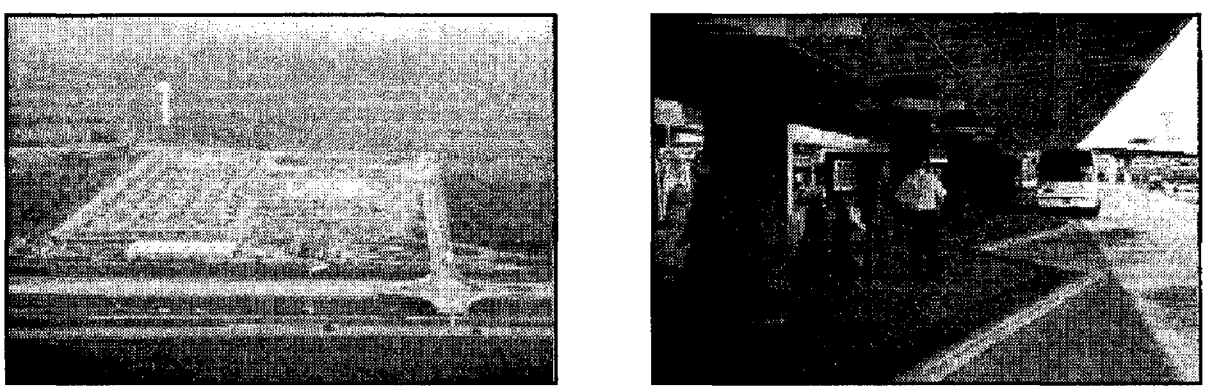


Figure 6-31. Examples of Park-and-Ride Lot and Bus Station.

SEATTLE

Seattle's HOV system is sponsored mainly by the Washington State Department of Transportation (WSDOT) and is eventually expected to include the HOV lanes depicted in figure 6-32. The Seattle HOV system traces its origins to several failed heavy rail and freeway expansion planning projects that were initiated during the 1960s. From those early defeats arose an HOV system that is now considered to represent a long-term component of Seattle's transportation system that doesn't compete with other transit guideway technologies under development. [3]

The first HOV project in Seattle arose as a result of an express bus service demonstration project sponsored by the Urban Mass Transit Association (UMTA) and known as the Blue Streak. The Blue Streak Project involved the operation of eight different transit routes using reversible express median lanes along I-5 in conjunction with downtown ramps. Owing to the success of the Blue Streak program, funding was allocated to further develop and evaluate the Blue Streak program and led to additional HOV operations. In 1972, the Puget Sound Governmental Conference and the regional transit agency published their first transit plan that addressed exclusive/preferential lanes. Further expansion of HOV use came with projects involving I-90 during the late 1970s. During the 1980s, an underground bus tunnel through the downtown area was completed, the I-5 north reversible lanes were extended, concurrent-flow HOV treatments were used on I-5, I-405, and SR 67, and the SR 520 HOV operation witnessed the expansion of its operational hours and eligibility requirements to meet increased demand. [3] Figures 6-33 to 6-35 show typical Seattle HOV facilities.

As each of the HOV projects progressed, the planning process that supported their development evolved. Interagency panel reviews and a task force representing all affected agencies was formed to provide guidance in HOV planning and operations. [3] Public information measures have been used, including telephone and mail-out surveys, newsletters, media events, and other means. In 1992, WSDOT initiated a major policy shift with one of its reports that stated, "When new capacity options are proposed, one of the alternatives to be considered shall be the conversion of a general purpose lane to an HOV lane." In the past, WSDOT had created HOV lanes through construction of new lanes. The first application of this new concept involved the creation of a HOV lane on a 7.5 mile segment of I-90 which had been experiencing lane balance problems. After receiving FHWA approval in the spring of 1993, a combination of lane conversion and new lane construction was undertaken to create new eastbound and westbound HOV lanes. Other sites were later placed under consideration for similar lane conversions.[36]

In most cases, WSDOT serves as the sponsoring agency for HOV lane projects. Funding has been secured from a variety of sources, including a special high-capacity funding package based on regional sales tax revenue.

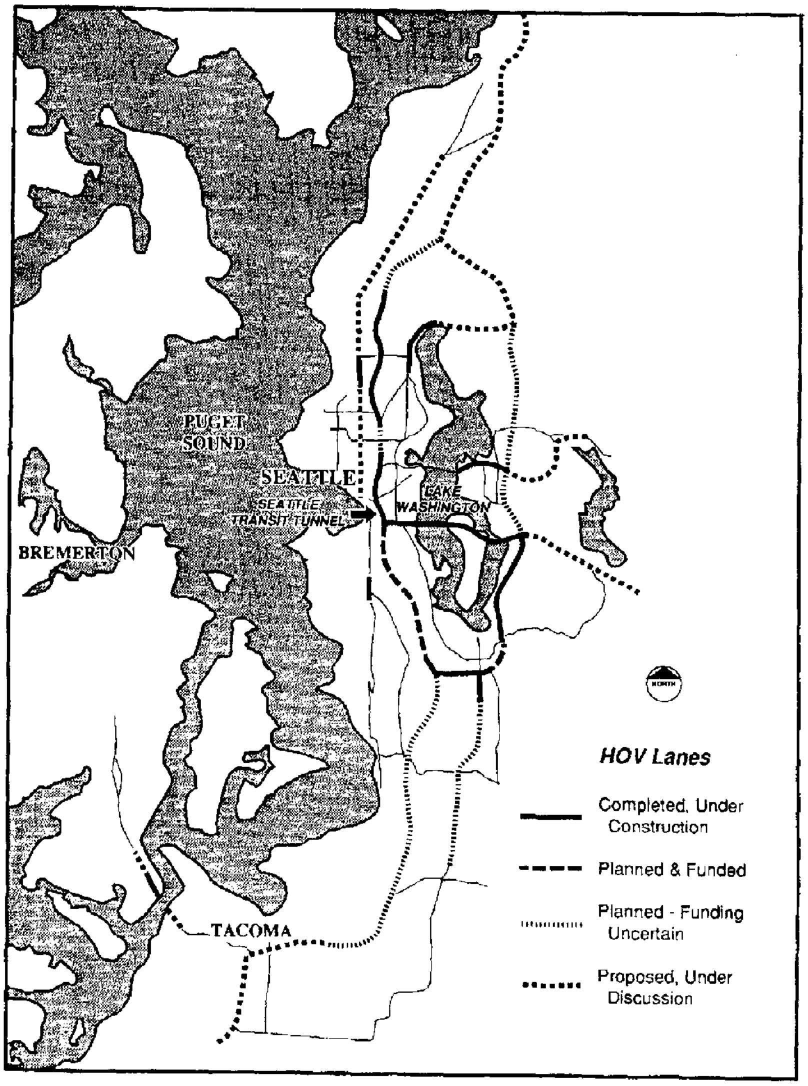


Figure 6-32. Seattle Area HOV System. (35)

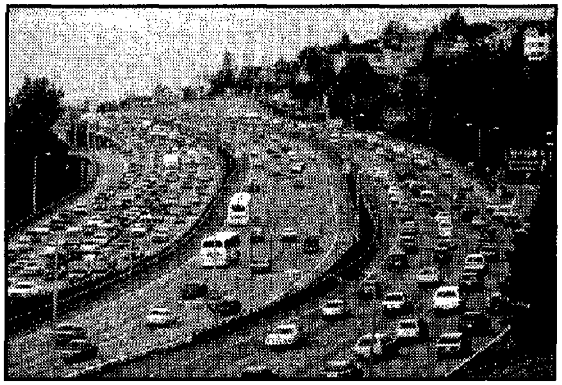


Figure 6-33. I-5 Reversible-Flow HOV Lanes. (9)

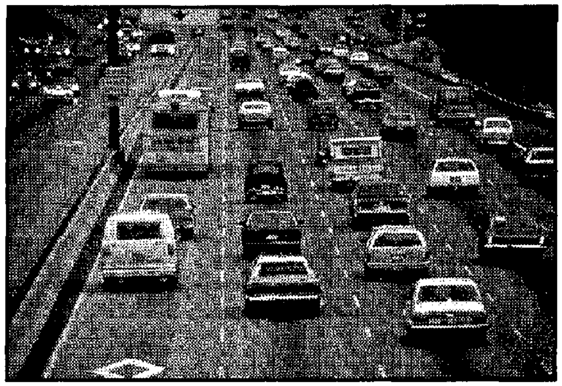


Figure 6-34. I-5, Seattle Concurrent Flow HOV Lanes (Median Location). (9)

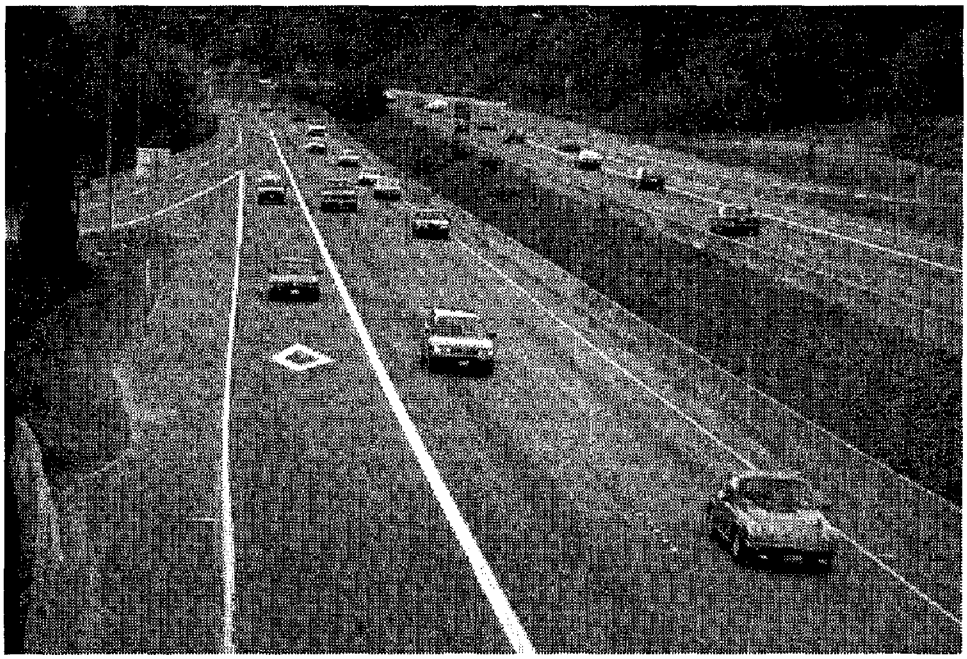


Figure 6-35. I-405, Seattle Concurrent Flow HOV Lanes (Shoulder Location).(10)

6.6 REFERENCES AND SUGGESTED READINGS

REFERENCES

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MODULE 7. INFORMATION DISSEMINATION

TABLE OF CONTENTS

MODULE 7. INFORMATION DISSEMINATION

Figure 7-1. Dynamic Message Signing on New Jersey Turnpike.

7.1 INTRODUCTION

It is well known that the key to successful driving task performance is efficient information gathering and processing.[1] Likewise, properly communicating with motorists is critical to successful freeway traffic management and operations. Motorists rely on a wide variety of information to properly accomplish the control, guidance, and navigational aspects of the driving task. The roadway alignment and general terrain itself provides a great deal of this information through visual "cues;" sources such as pavement markings and regulatory, warning, and guide signs also contribute greatly to the overall information system. However, in an effective freeway management system, dynamic methods of conveying information to motorists or travelers are often needed to better operate and control the system.

Freeway management systems rely on various information dissemination components to apprise all types of travelers (motorists, transit users, commercial vehicle operators, etc.) of current and anticipated travel conditions so that informed mode, departure time, and route choice decisions can be made.

Information dissemination is also managed in order to improve travel conditions in the corridor by influencing traveler behavior (by recommending diversion routes around an incident, for example). This information can be disseminated from a variety of sources (State departments of transportation, transit agencies, private-sector information service providers, etc.) using a variety of methods (dynamic message signs, commercial radio traffic reports, traffic information kiosks, etc.).

MODULE OBJECTIVES

The objectives of this module are threefold:

- To describe how to define, establish, and coordinate effective traveler information components in a freeway management system.

- To identify existing and emerging technologies available to facilitate information dissemination to travelers.

- To illustrate how information dissemination components can integrate with each other and with other components of a freeway management system.

MODULE SCOPE

This module addresses both traditional and emerging information dissemination processes and technologies for freeway management systems. Whereas a number of technologies (i.e., dynamic message signs, highway advisory radio) have been around for a number of years, there are new opportunities today. In the past, information was distributed in response to an incident. Today, the focus is to provide a continuous flow of information to travelers, businesses, and commercial carriers in order to make their trip travel time more predictable. The focus of this module is to emphasize the need for integration among all components and technologies being utilized for information dissemination within the integrated regional transportation management system.

7.2 DESIGN PROCESS

Decisions about when, where, and how to disseminate travel-related information to the public have become much more complex in recent years, due to improved traffic/weather/transit surveillance capabilities and expanded information dissemination options. As with the other components that can be included in a freeway management system, the decisions necessary to develop and integrate information dissemination into the system can be best accomplished by following the basic decision process described in Module 2. Specific application of this process to the task of incorporating information dissemination into a freeway management system is discussed in the following sections.

IDENTIFY NEEDS

The first step in the decision process is to identify the need to be addressed through information dissemination, or stated another way, the information needs that exist in the freeway corridor. Two basic categories of information dissemination exist:

- Pre-trip planning.

- En route guidance and information.

Table 7-1 presents examples of some of the specific types of need and/or information needs in these categories. Certain information may be needed both pre-trip and en route, whereas other information may be needed for either one or the other. To the extent possible, these information needs should be further defined by the following:

Table 7-1. Information Need Categories.

Category	Examples of Information Need
pre-trip planning	• current/anticipated traffic conditions - speeds - incident locations - other congestion locations - upcoming road closures • weather effects - pavement conditions - road closures • route guidance - around incidents - to special events • transit information - bus schedules and status - transfer locations - rideshare matching (preplanning and real-time matching)
en route guidance and information	• current traffic conditions - speeds - incident locations - other congestion locations • weather effects - pavement conditions - road closures • route guidance - around incidents - to special events • lane/shoulder/ramp use status

- Audience.
- Location.
- Time-of-day.

These characteristics affect how well information can be received by the users, and what types of responses can be expected from the users who have that information available.

In addition to the needs to be addressed through information dissemination efforts, it is also important early on to identify those factors or issues that will influence the ability of agencies and/or the private sector to provide that information. Tort liability concerns can be one such factor. Some agencies may avoid providing current pavement condition information, for example, for fear of establishing a precedent that may be used against them if they fail to warn of that pavement condition (or a similar one) in the future. Preestablished agreements between public agencies and private sector companies regarding access to agency data may also influence the direction of future dissemination efforts.

The problem identification step of the decision process also includes an inventory of existing information sources, including media reports and private sector initiatives. The inventory can include such data items as target audiences, accessibility, frequency of reports, and information accuracy. If possible, assessments of user satisfaction with the information should also be obtained.

IDENTIFY INFORMATION DISSEMINATION PARTNERS

The key partners in the development of the information dissemination component of a freeway management system include the following:

- Traditional State and local public sector agencies (transportation and public works, transit, toll authorities, law enforcement).
- Commercial media.
- Private sector traffic reporting services (distributing through commercial media venues or through direct subscription to motorists).
- Local fleet operators (delivery services, taxis, etc.).

In some cases, the owners/operators of major traffic generators (malls, tourist attractions, annual special event promotions, etc.) could also be important partners to include in the decision-making process.

BUILD CONSENSUS AMONG PARTNERS

Identify Differences in Operating Philosophies Among Partners

Developing a consensus regarding the importance of information dissemination and its role as part of an overall freeway management system is the next step in the decision process. It is important that project partners take ownership of the effort up front, or it may never work. To make this happen, it is important to identify and understand the differences in operational philosophies of the different partners involved.

For example, highway and transit agencies may view the presence of some degree of recurrent congestion on the freeway in very different ways if an HOV lane is included within the freeway right-of-way. Whereas diverting freeway traffic to arterial streets might be a primary goal of the highway agency, the transit agency may desire to promote bus utilization and the HOV lane as a means of reducing that congestion. Partners need to communicate these concerns to each other so that a consensus about goals can be reached.

The partners must also be aware of the differences in operational philosophies between public agencies and private sector entities. Whereas equity concerns typically drive public agency decisions regarding the dissemination of travel-related information, marketing opportunities and profit motives will generally dictate private sector interests, perceptions, and decisions. A clear understanding of the differences among these philosophies is required.

Establish Common Ground Between Partners

Once operational and philosophical differences among the various partners have been identified, the next step is to establish areas of common concern or priorities between the partners with respect to travel-related information dissemination. Common ground must be established both at the upper management and political level, and at the day-to-day operations level. Information dissemination requires upper management and political support of a common vision of information availability in order to ensure continued funding support. Meanwhile, consensus among partners at the operations level is needed to promote true operations integration among the various information dissemination components utilized within the corridor.

ESTABLISH GOALS AND OBJECTIVES

Once a consensus has been established among the partners involved with information dissemination efforts, it is necessary to define the goals and specific objectives that are going to be addressed through this component of the freeway management system. As discussed in Module 2, goals are broad statements of the intent of the system or one of its components, whereas objectives are specific statements about what the system or component of that system will attempt to accomplish. A given goal may have more than one objective specified to reach that goal. Table 7-2 presents examples of goals and objectives an agency might have for the information dissemination component of its freeway management system.

Table 7-2. Examples of Goals and Objectives for Information Dissemination.

Category	Examples
Goals	• Reduce motorist demands upstream of a freeway incident • Reduce motorist errors in locating unfamiliar destinations • Reduce transit user uncertainty about bus arrivals
Objectives	• Warn motorists of adverse weather conditions • Notify motorists of downstream incidents • Advise motorists when to seek alternative routes • Provide motorists with origin-to-destination route guidance assistance • Inform motorists at park-and-ride lots when the next bus will arrive

In general terms, each of the objectives developed for information dissemination should be specific enough to answer the following questions: [1]

- Who is being communicated with?
- What responses are desired or anticipated?
- Where will the responses take place?

ESTABLISH PERFORMANCE CRITERIA AND MEASURES

In order to assess the extent to which information dissemination efforts within a freeway management system are meeting goals and objectives, a set of performance criteria and measures-of-effectiveness pertaining to these efforts must be identified. Relative to information dissemination, performance criteria have three different dimensions that are of interest:

- Information credibility.
- Market penetration.
- Traveler response.

These three dimensions are interrelated. The following sections provide additional details and examples of criteria for each of the above dimensions.

Information Credibility

An information dissemination tool must be credible to travelers if it is to be utilized and have an impact upon traffic operations. The following criteria define how credibility is established: [2]

- The information must be accurate.
- The information must be timely.
- The information must be relevant to its intended audience.

While these are generally accepted concepts, it is sometimes difficult to identify and obtain objective and quantifiable measures with which to judge them. This task is further complicated by the fact that the measures themselves may depend on the specific message or unit of information that a partner is trying to convey. Examples of performance measures that could be used to evaluate the credibility of information being disseminated to motorists are provided in Table 7-3. Local concerns and capabilities will dictate which performance measures are most appropriate for evaluating information credibility in a given locale.

Market Penetration

Market penetration refers to the percentage of the potential audience reached by the information dissemination efforts. Performance criteria regarding market penetration may be appropriate for evaluating certain system goals and technologies, particularly those emerging as part of Advanced Traveler Information Systems (ATIS). It is expected that some technologies, such as in-vehicle dynamic route guidance, will require only limited market penetration in order to achieve operational benefits. Other technologies, such as information kiosks in major traffic generators, may require agencies to strive for as great a market penetration as possible in order to distribute the information to a wider audience and possibly attract private sector advertising and sponsorship.

Table 7-3. Examples of Performance Measures for Information Dissemination.

Category	Examples
Information accuracy	• Difference in the number of incidents in the system and number of incidents reported • Difference between reported expected arrival times of buses and the times the buses actually arrive at a transit station • Number of complaints received from the public about inaccurate information (by device and type of information)
Information timeliness	• Average delay time between when an incident is verified and when information about the incident is disseminated to travelers
Information relevance	• Number of travelers who access a given information component or unit

Traveler Response

Ultimately, the purpose of providing information to travelers is to effect some-change in traveler behavior that will cause an improvement in safety or operations. Thus, performance measures are also needed to determine the extent to which information dissemination accomplishes this purpose. Changes in traveler mode, departure time, and route (if appropriate) are appropriate for evaluating the effectiveness of real-time travel-related information. However, it may be very difficult and expensive to obtain actual data for these measures. Traveler opinions about the effectiveness of the information being provided can be another important eval-uation measure. Reductions in travel time, turning and route choice errors, or similar measures may also be useful to evaluate certain types of information. [3]

It is important to recognize that because of the complex travel patterns of travelers at any point in the roadway, it may not be possible to adequately measure the overall effects of many types of information or dissemination modes upon traffic volumes, speeds, or delays. The day-to-day variances in travel patterns themselves may mask the effects of any information disseminated during a specific event such as an incident, particularly if the information is intended for a very specific audience (such as vehicles within a freeway traffic stream destined for a specific downstream exit).

Consequently, it may sometimes be necessary to include performance measures that evaluate the effect of information dissemination at an individual traveler's level. For example, trip diaries that identify a specific driver's travels on any given day may need to be compared to determine whether the presence of information had any influence on driving behavior for that select group with drivers on that particular day. This approach can be very costly and manpower intensive, however.

FUNCTIONAL REQUIREMENTS

The functional requirements of information dissemination components in a freeway management system define specific actions or activities that are to be performed in order to achieve one or more of the objectives. Initially, the functions should be defined without considering the dissemination technology or system architecture that will be employed. Functions simply specify what information will be disseminated and possibly when and where it is to be presented, not how this will be done. Table 7-4 presents some examples of functional requirements for various information dissemination objectives.

The ITS National Architecture should serve as the basic building block of the functional requirements definition process for information dissemination.[4] The functions described in the National Architecture must then be detailed to match the needs and desires of the local agencies.

Details regarding who should receive information, as well as when and where that should occur, all become a part of the functional definitions. The intent of this step in the design process is not only to specify functions independent of the technology that could be used to achieve those functions, but also to highlight what and why other components of the freeway management system must link with the information dissemination components.

Table 7-4. Examples of Functional Requirements for Information Dissemination Objectives.

Examples of Objectives	Examples of Possible Functions
• Warn motorists of adverse weather conditions	• Notify freeway motorists of downstream roadway flooding whenever more than 100 mm of water collects in an underpass section • Notify motorists approaching an entrance ramp whenever the freeway is closed because of adverse weather conditions such as high winds or ice
• Notify motorists of downstream incidents	• Within "X" minutes of its occurrence, notify freeway motorists of any incident that occurs in the travel lanes within the next exit or decision point
• Advise motorists when to seek alternative routes	• If the road is closed due to an accident, recommend that freeway motorists traveling to the CBD exit at an upstream connector to a parallel toll road whenever travel times to the CBD on the freeway are more than "X" minutes longer than on the toll road

For example, an information dissemination function that gives route specific travel times requires that travel time monitoring be a function in the freeway management system. Likewise, a function of notifying motorists about downstream lane-blocking incidents within a set time also affects the design of the freeway surveillance component of the freeway management system (what type of vehicle detection technology can be used, how close together detectors must be placed, etc.). As a final example, notifying motorists that lanes are closed downstream for maintenance work implies that a mechanism for determining when and where such closures occur is available via direct communication between the maintenance and operations divisions of the transportation agency, observation of the closure via closed-circuit television, or other methods.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The purpose of defining functional relationships, data requirements, and information flows is to establish an understanding of how the various information dissemination functions that are to be accomplished will be integrated with each other and with the other components in the freeway management system. In this step, the relationships between information dissemination functions are further refined to incorporate local issues, concerns, and capabilities.

The relationships between the desired information dissemination functions and necessary data flows to those functions can be particularly important when designing a freeway management system, especially if several partners are involved in the information dissemination process. Locations of potential information dissemination conflicts can be identified beforehand (a highway and a transit agency may want to display information at the same roadway location, for example). Perhaps more commonly, locations and situations where information sharing between partners can occur may be identified, and result in a more efficient system design.

IDENTIFY AND SCREEN TECHNOLOGIES

Once the system requirements for information dissemination have been developed, it is then appropriate to assess the actual technologies available to meet the functional and system architectural requirements that have been developed for meeting the goals and objectives of information dissemination. Technologies that are available for information dissemination can be grouped into one of three categories:

- Those located on the roadway where the information transfer to the traveler occurs at a specific point or within a very small segment of roadway (i.e., using dynamic message signs or highway advisory radios.)
- Those located within the vehicle where the information transfer is not constrained to a point or a small segment of roadway (e.g., using radio, cellular telephone, or in-vehicle navigation devices).
- Those located off of or away from the roadway altogether (e.g., using television, computer linkages, or kiosks in major traffic generators).

A review of the technologies in each of these three categories is provided later in this module. This review can serve as the starting point for the technology screening process. However, technology in the information dissemination realm continues to change rapidly and should be reassessed each time this point is reached in the decision process.

Initial screening can be used to determine which of the three basic categories can be used to effectively accomplish each of the specified information dissemination functions. More than one of the categories may be useable. Then, within each category, a more detailed screening and evaluation process can help select among the various alternatives of that technology. Screening should include such considerations as the following:[5]

- Legibility (for visual information components).
- Reliability.
- Costs to the user and public agency (these should be life-cycle costs, discussed in greater detail in Module 11).
- Potential market size.

If, for some reason, the screening process does not identify technologies that can adequately perform the functions that were established, then the analyst must step backwards and reassess the objectives and/or functions of the information dissemination component of the freeway management system. Objectives and associated functions may have to be scaled back or otherwise modified.

DEVELOP IMPLEMENTATION PLAN

The next step in the process is the development of an implementation plan. Implementation plan development is governed by federal guidelines, and is required for all new or expanded traffic control system projects that utilize federal funds.[6] Actually, an implementation plan is a good idea for all traffic control system projects, regardless of whether or not they utilize federal funds.

Module 2 described the general guidelines regarding overall plan development for a freeway management system. In this section, special issues of plan development are discussed that relate specifically to the information dissemination components of a freeway management system.

Because information dissemination must be coordinated among the various partners, a portion of the plan should be devoted to a discussion of the management structure and the agreements that will be utilized to achieve this coordination. Items to be included in this portion of the plan are as follows:

- Names of contact person(s) for each partner.
- Protocols and methods to be utilized to coordinate.
- Definition of each partner's responsibilities regarding information exchange.
- Estimates of each partner's financial contribution to the effort (cash, in-kind exchange of equipment or services, etc.).
- Letters or memoranda of agreement regarding the desire to coordinate among partners.

Additional details may need to be included in the letter of agreement if some of the partners will jointly operate some of the information dissemination technologies to be implemented. For example, a transportation agency may wish to allow law enforcement personnel to access and utilize their dynamic message signs or highway advisory radio equipment for managing major incidents during late-night hours when the transportation agency does not have someone on duty.

A detailed implementation plan is also needed in order to properly coordinate information dissemination within the freeway management system. Whereas the letters of agreement and discussion of the management structure lay out broad administrative boundaries and consensus to coordinate, the implementation plan spells out in detail how this will occur.

An implementation plan may include specific preplanned actions that will be taken in response to certain common or expected situations (i.e., which dynamic message signs will be activated and what will be displayed on them in response to an incident that occurs on a specific section of freeway), as well as more general rules that will be used to decide what information to present for unusual, unexpected situations. For example, the TransGuide Traffic Management System in San Antonio, Texas has over 60,000 preplanned "scenarios" coded into a computerized database. Depending on the time of day, location of an incident, and the number of lanes that are blocked, a specific scenario is selected that defines which dynamic message signs and lane control signals are to be activated and the messages that are to be displayed on each (i.e., "LEFT LANE CLOSED AHEAD"). Most of the time, system operators simply activate one of these preplanned actions. Occasionally, a freeway problem develops for which preplanned actions have not been developed. In these cases, system operators use basic information dissemination rules for the system they have learned to decide what messages need to be displayed, on which signs they should be displayed, etc.

IDENTIFY FUNDING SOURCES

Identification of funding source alternatives actually occurs as part of the plan development process. As with the other components of freeway management systems, the partners involved in information dissemination can share costs through some combination of the following:

- Individual agency hardware purchases and operation/maintenance which is coordinated with another agency's efforts in the region.
- In-kind contribution of equipment and services to a pooled service.
- Establishment of user fee schedules (direct or indirect).

Several different cooperative institutional arrangements have been successfully utilized to distribute information dissemination costs in a rational and equitable manner to public and private partners. For the TRANSCOM organization in New York/New Jersey, cash and in-kind contributions from each member agency fund the operations of the organization.[9] Each partner has an official assigned to the TRANSCOM executive committee, which works together to establish the actual fee structure, management policies, and other matters of concern to the agencies as a group.

In Boston, the SmarTraveler cellular call-in system is sponsored in large part by FHWA and the Massachusetts Highway Department, but is managed by a private-sector limited partnership, SmartRoute.[10] Several other private-sector companies (cellular telephone companies, a paging company, and broadcast media) purchase some of the information being managed and disseminated, which has helped offset some of the costs to the public agencies. [11]

In San Antonio, Texas, both public and private-sector partners have entered into a Cooperative Industry Product Agreement to facilitate the development and implementation of the software that will decode the video and data transmissions from a low-power television station that the Texas Department of Transportation has purchased and will operate. [12] This has allowed the various potential beneficiaries of the system (i.e., media stations, fleet operators, etc.) to contribute to software development for a relatively small price (and risk). Furthermore, it provides a mechanism to allow future partners to enter into the agreement in a fair and equitable manner. [12]

IMPLEMENT

Implementation of information dissemination components in the freeway management system occurs as a natural result of following the systems engineering process. Module 2 described, in general terms, the implementation activities that should occur at this point in the process. In addition to the issues brought out in that module, other concerns that pertain directly to information dissemination include:

- Implementation schedule.
- User training.

Information dissemination is the main link between the freeway management system and the motoring public. Experience indicates that the implementation of information dissemination devices should occur only after the surveillance and control infrastructure has been installed. Otherwise, the credibility of the overall system with the traveler can be severely degraded by having the devices in place and not using them or by having the devices display wrong information. One of the problems reported by officials of the INFORM project in New York was that the DMSs for the project were installed early on in the contract and then sat there unused for several years as the agencies built the rest of the infrastructure. Since it was not immediately apparent to motorists why the devices could not be used to communicate about downstream roadway and traffic conditions, public opinion about the project suffered.

Another important facet of information dissemination implementation is the development of training necessary to assist travelers in correctly interpreting and responding to some of the information dissemination technologies. For example, the Texas Department of Transportation in Fort Worth displays the meaning of lane control signals mounted over each travel lane periodically throughout the freeway network. As a result, motorist comprehension of the available symbols for the signals are somewhat higher in Fort Worth than in other locations in Texas. [13] Other possible training alternatives include public service announcements or mailing inserts in local utility bills.

EVALUATE

The final step in the design process is to evaluate the effectiveness of the information dissemination component of the freeway management system. However, this evaluation should not be considered a one-time activity, but should be part of a periodic review of the effectiveness of the information dissemination components and of the overall system. As discussed previously, it is rather difficult to measure the impact of information dissemination upon overall traffic measures, because of the stochastic nature of travel demands and behavior in a given freeway corridor, as well as the events which cause disruptions to these demands (incidents, special events, etc.).

Care should be taken not to overestimate the benefits achieved by the implementation of information dissemination components in a freeway management system. Specifically, it is important to recognize that travel patterns in a freeway corridor are quite dynamic, and that some drivers will divert naturally when they encounter freeway congestion regardless of whether or not they receive information beforehand about that congestion. Therefore, information dissemination should be considered as having an *incremental* effect upon traffic conditions by modifying where and how some travelers respond to congestion (where travel routes are changed, how many motorists change departure times, how many changed modes, etc.).

7.3 TECHNIQUES AND TECHNOLOGIES

Information dissemination components of a freeway management system can range from a single device owned and operated by one agency, to an integrated collection of devices and mechanisms under the control of several agencies and several private sector entities. In this handbook, a basic distinction is made between kinds of information depending on which of three main locations it comes from:

- On-roadway information.
- In-vehicle information.
- Off-roadway information (typically at origin of a trip).

Specific technologies available in each of these categories are discussed below.

ON-ROADWAY INFORMATION TECHNOLOGIES

One of the most fundamental technologies available for disseminating traffic-related information from the roadside is that of dynamic message signs (DMS). DMSs are sometimes referred to as changeable message signs (CMS) or variable message signs (VMS). DMSs allow operating agencies to visually disseminate travel information to motorists on a near real-time basis. DMSs use words, numbers, or symbols to convey information. They are extremely flexible and powerful traffic management tools in freeway operations.

DMSs can be either portable or fixed, and can be operated either on a fixed-time basis with on-site control or interconnected with a traffic control center to provide remote control.[14] DMSs can be used to perform the following functions:

- Inform motorists of varying traffic, roadway, and environmental conditions.
- Provide specific information relative to the location and delays associated with incidents.
- Advise motorists on detour routes because of construction or roadway closure.
- Suggest alternate routes to avoid freeway congestion.
- Reassure drivers on unfamiliar alternate routes.
- Redirect diverted drivers back to freeways.

Table 7-5 lists the applications for which DMSs can be used.[14]

Types of DMS

DMSs can be conveniently classified into three categories, namely:

- Light-reflecting.
- Light-emitting.
- Hybrid.

Light-reflecting signs reflect light from some external source such as the sun, headlights, or overhead lighting. Figure 7-2 shows examples of different types of light-reflecting DMSs. In comparison, light-emitting DMSs generate their own light on or behind the viewing surface. Examples of different types of light-emitting DMSs are shown in figure 7-3.

Some manufacturers have combined two DMS technologies (e.g., reflective disk and fiber-optic) to produce hybrid displays that

Table 7-5. Applications of DMSs. [14]

Category	Applications
Traffic management and diversion	• Freeway traffic advisory and incident • Freeway-to-freeway diversion • Special events • Adverse road and weather conditions • Speed advisory
Warning of adverse conditions	• Adverse weather and environmental conditions (fog, smog, snow, rain, dust, wind, etc.) • Adverse road conditions (ice, snow, slippery pavement, high water, etc.) • Low bridge clearance
Control at crossings	• Bridge control • Tunnel control • Mountain pass control • Weigh station control • Toll station control
Control during construction and maintenance operations	• Advisory of upcoming construction/maintenance • Speed advisory • Path control
Special-use lane and roadway control	• Reversible lanes • Exclusive lanes • Contraflow lanes • Restricted roadways • Temporary freeway shoulder use control

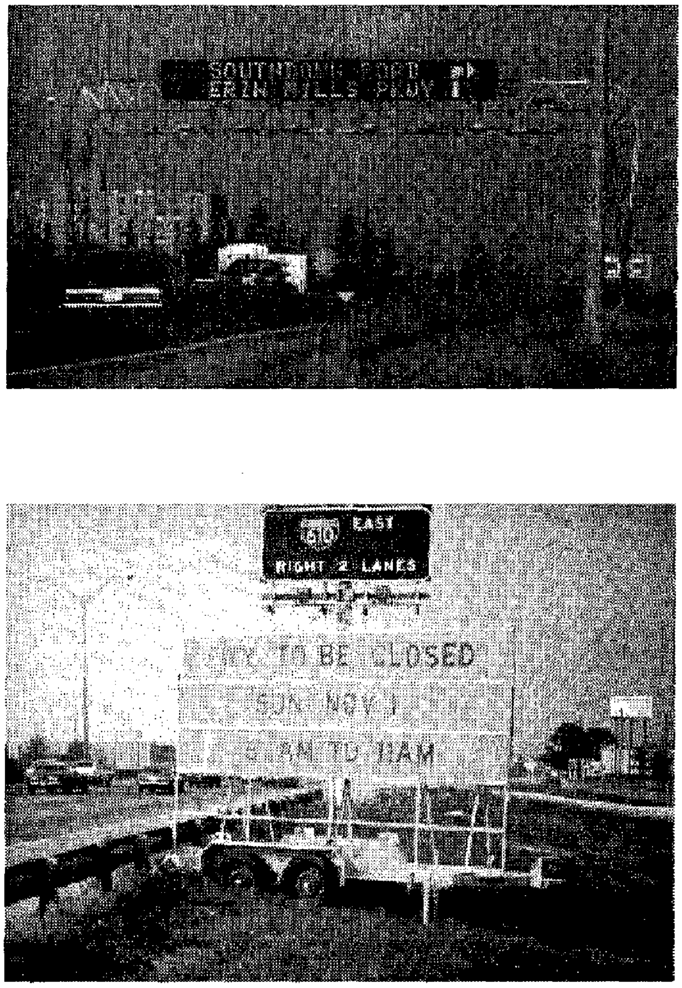

Figure 7-2. Examples of Light-Reflecting DMS Technologies.

exhibit the qualities of both. Some agencies have also combined DMSs with static displays to form what can also be considered to be hybrid displays.

Several references are available that describe the operational and performance characteristics of various DMSs (see references 1, 14, 15, 16) The following paragraphs, taken from those references, briefly describe the different types of DMSs in each category.

Light-Reflecting DMSs

The basic categories of light-reflecting DMSs are as follows:

- Fold-out.
- Scroll.
- Rotating drum.
- Reflective disk matrix.

Basic operations and characteristics of each are described below.

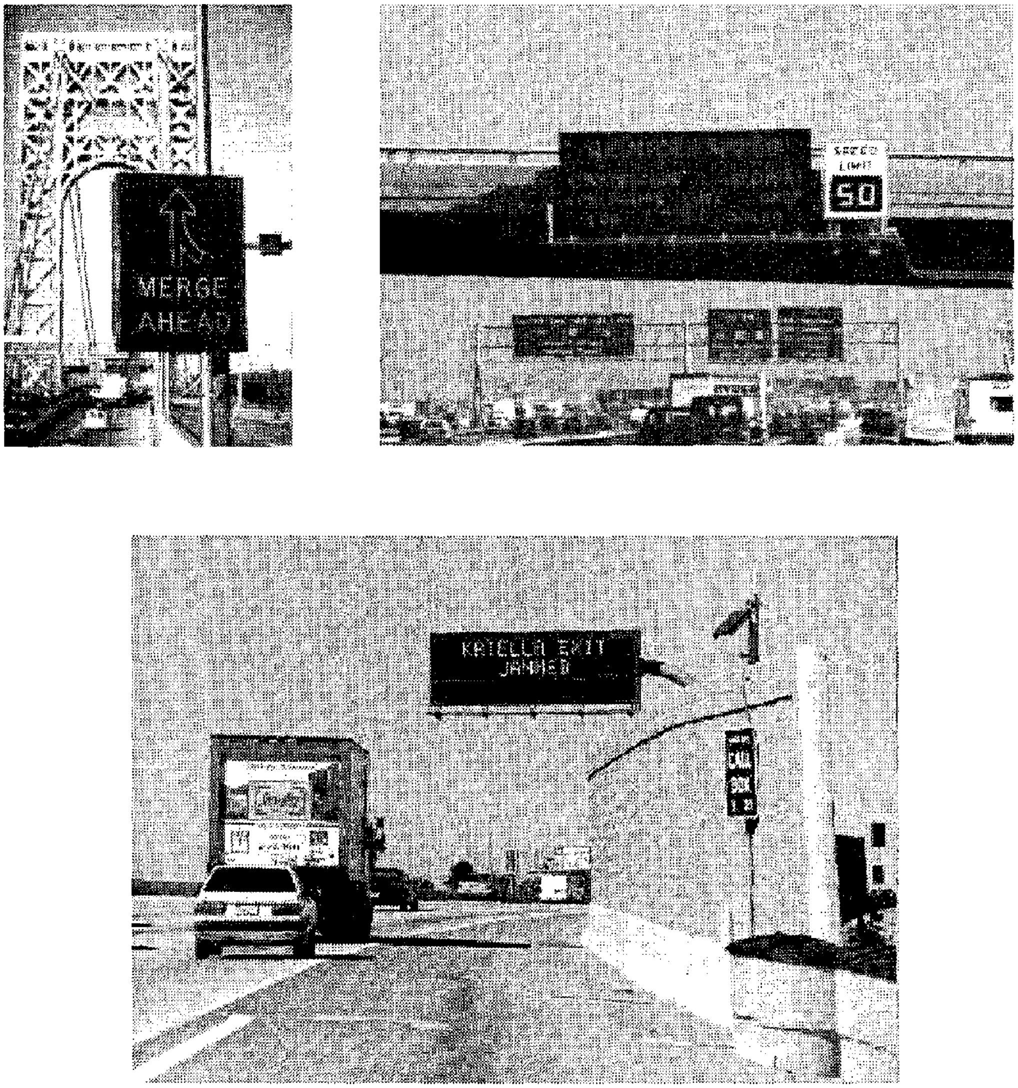

Figure 7-3. Examples of Light-Emitting DMS Technologies.

Fold-out. A fold-out sign is a conventional highway sign with a hinged viewing face. This type of sign can either display two messages (one with the hinged face closed, one with it open) or show a message only when the hinged face is open (no message is displayed when the hinged face is closed). Typically, signing materials that conform directly to the *Manual on Uniform Traffic Control Devices* (MUTCD) are used to make each message. For freeway applications, they are most often used to indicate icy bridge or other hazardous roadway conditions, or to indicate whether truck weigh stations are open or closed.

Scroll (or Tape). A scroll sign uses a tape or film upon which desired messages are imprinted. The tape is then rolled one way or the other (or up or down) to place a desired message within a display window. As with fold-out signs, scroll signs can use colors and other message characteristics that conform with the MUTCD. Typically, up to 8 to 12 messages can be stored on the tape. The inclusion of more than 12 messages can create long change-times if one or more of the messages is at the opposite end of the tape.

Rotating Drum. Rotating drum signs are made up of one to four multifaced drums, each containing two to six messages. Each face of each drum portrays one line of a fixed message, and pivots about its axis in order to display the appropriate face for a given message. Colors and lettering characteristics that conform to the MUTCD can also be used on rotating drum signs.

Reflective Disk Matrix. These types of DMSs were very popular for freeway management purposes in the 1970s due to their low energy requirements relative to light-emitting DMS technologies. The viewing face of a reflective disk matrix DMS is comprised of an array of permanently magnetized, pivoted indicators that are flat matte black on one side and reflective yellow or a similar color on the other. The indicators may be square, rectangular, or circular in shape. An electrical current activated when a given pixel is to be turned flips the indicator from a black matte finish to the reflective side. The sign itself can exist of a series of arrays of these indicators (e.g., 5 pixels by 7 pixels, or similar grid for each letter position), or a continuous grid or matrix over the entire sign face. The latter provides more flexibility to operators, but at a higher purchase price.

Light-Emitting DMSs

The following types of light-emitting DMS technologies are described in this section:

- Neon or blank-out.
- Lamp (incandescent mulb) matrix.
- Fixed-grid or shuttered matrix fiber-optic.
- Fixed-grid or matrix light-emitting diode (LED).

Neon or Blank-Out Signs. Neon signs use neon tubing to form characters and messages that are to be displayed. Two basic sign designs are possible:

- Separate each message on the sign face.
- Stack the neon tubing for each message one over another.

The stacked design has reported drawbacks, in that emitted light will be diffused as it passes through the overlayed neon tubing, reducing its legibility. Conversely, the separate message design will require a fairly large sign face in order to display even a moderate number of messages.

Lamp (Incandescent Bulb) Matrix Signs. A lamp matrix DMS relies on an array of incandescent bulbs affixed to a dark background to create the characters needed for a given message. The DMS can be a continuous array of bulbs, or a series of array modules, each of which can display a single character in the overall message. This design provides considerable message flexibility, limited only by the size of the sign (typically 4 lines of text, each comprised of 12 to 20 characters).

Fixed-Grid or Shuttered Matrix Fiber-optic Signs. Fiberoptic DMSs funnel light energy from a light source through fiber bundles to the sign face. For a fixed-grid fiberoptic sign, the ends of these bundles (pixels) are positioned on the sign face to create a given message. Sets of bundles and a separate light source are then used for each message portrayed on the sign. Conversely, the shuttered matrix fiberoptic DMS positions the ends of the fiber bundles on the sign face in an array similar to that used for other matrix signs. The light sources for all of the fiber bundles remain on constantly, and shutters at the ends of the bundles open and close to create the characters needed to display each message. As with the lamp matrix DMS, the shuttered fiberoptic signs can be either a continuous array of pixels or a series of array modules, each of which portrays a single character. Because of its flexibility, this tends to be the more common type of fiberoptic DMS utilized for freeway traffic management purposes.

Fixed-Grid or Matrix Light-Emitting Diode (LED) Signs. Light-emitting diodes (LEDs) are semiconductors that glow when voltage is applied. Recent advances in LED technology have allowed DMS manufacturers to utilize this technology to construct both fixed-grid and matrix style DMSs. Typically, several individual LEDs are "clustered" together in order to create each pixel. Early versions of the LED DMSs experienced difficulties in maintaining acceptable performance levels over time. However, LED manufacturers have strived to alleviate many of these types of problems in the next generation of DMSs that have been developed. [16]

Hybrid DMSs

Two of the most common types of hybrid DMSs are the following:

- Reflective disk with fiberoptics/LEDs.
- Static sign/DMS combination.

Reflective Disks with Fiberoptics/LEDs. To combat the times of the day and environmental conditions when reflective disk DMSs are not very visible, some manufacturers have combined fiberoptic or LED technologies into these types of signs to give them the visual boost they need. During the times of the day that the sun shines upon the sign and provides adequate visibility, the light sources are turned off by the sign. In addition to providing the additional visual boost during nighttime conditions, this technology also eliminates the need for external lighting on the sign. This eliminates the potential for glare off of the sign face as well. Some agencies are retrofitting reflective disk DMSs with hybrid reflective disk/fiberoptic technology.[15]

Static/DMS. The other major type of hybrid DMS currently in use employs components of both static signing and one of the DMS technologies into a single sign. This can reduce costs in situations when part of a message will be constant and another part of the message will be changed.[1] Also, the static components can be constructed to conform to MUTCD principles. However, this approach does limit the use of the sign to the specific situations addressed by the static component of the message.

Advantages and Disadvantages of the DMS Technologies

The selection of appropriate DMS technology is a complex task requiring analysis of trade-offs between display capability to fulfill a specific need and display cost (including operating and maintenance considerations). Further complicating the selection process is the large number of signing techniques available, each possessing quite different design and operating features. Tables 7-6 through 7-8 present a summary of the advantages and disadvantages that have been reported for each type of DMS technology (see references 1, 14, 15, 16).

Table 7-6. Advantages and Disadvantages of Light-Reflecting DMSs.(Adapted from 1,2,14-16)

Type	Advantages	Disadvantages
Foldout	Simple operation Can conform to MUTCD regulatory and warning signing principles	Limited capacity (1 or 2 messages) Higher potential for environmental and mechanical failures (i.e., panels jamming)
Scroll	Simple operation Can conform to MUTCD regulatory and warning signing principles	Limited capacity (8 to 12 messages) Time to change messages may be significant
Rotating Drum	Simple operation Can conform to MUTCD regulatory and warning signing principles	Limited character size Limited message capabilities (but more than fold-out or scroll)
Disk Matrix	Total message display flexibility Wider angle of legibility than fiberoptic or LED DMSs (see Table 7-7) Low power consumption relative to light-emitting DMSs	Visibility typically lower than similar size light-emitting matrix DMSs Disks sometimes stick or fail prematurely due to excessive dirt or moisture Illumination is required at night, sometimes causing glare or blurring problems

Too often agencies will purchase DMSs before signing objectives and messages are determined. Often, this causes disappointment in the DMSs when these agencies cannot display the desired messages, or when the signs provide lower than expected target value and legibility for the environmental conditions present at the site.[2] Conversely, agencies may end up purchasing a more expensive DMS with capabilities that exceed their actual needs.

IN-VEHICLE INFORMATION

Another realm of information system technologies available are those located within the vehicle itself. In-vehicle information can be disseminated to the motorist by audio or visual means. The following sections describe the basic types of in-vehicle information technologies.

Auditory In-Vehicle Information Technologies

Highway Advisory Radio

Although not as widely used as dynamic message signs, Highway Advisory Radio (HAR) is another means of providing highway users with information in their vehicles. Traditionally, information is relayed to highway users through the AM radio receiver in their vehicles. Upstream of the

Table 7-7. Advantages and Disadvantages of Light-Emitting DMSs. (Adapted from 1,2,14-16)

Type	Advantages	Disadvantages
Neon (blank out)	Simple operation	Limited message capacity Requires a fairly large sign for even moderate number of messages Current designs to not allow for nighttime dimming
Lamp (Incandescent) Matrix	Simple, proven operation High target value Message flexibility	Continuous energy supply required to display message High operation and maintenance costs (energy, bulb replacement)
Fixed Grid Fiberoptic	Low power usage Can display symbols and messages	Narrow cone of vision Limited message capacity
Shuttered Matrix Fiberoptic	Simple operation Message flexibility Low failure rates reported	Narrow cone of vision Mechanical component (shutters) increases potential maintenance costs
Fixed Grid LED	Low power usage Solid state devices (no bulbs) Reported reliability of LED lamps is very high	Narrow cone of vision Limited message capability Intensity adversely affected by high temperatures Long-term performance not known Super-bright LED lamps must be used for adequate daytime visibility
Matrix LED	Low power usage Solid state devices (no bulbs) Reported reliability of LED lamps is very high	Narrow cone of vision Intensity adversely affected by high temperatures Long-term performance not known Super-bright LED lamps must be used for adequate daytime visibility

Table 7-8. Advantages and Disadvantages of Hybrid DMSs. (Adapted from 1,2 14-16)

Type	Advantages	Disadvantages
Disk Matrix with Fiberoptics or LEDs	Some energy conservation (light-emitting technology is turned off in daytime conditions) Eliminates need for nighttime illumination of sign	Use of LED technology limited to date (long-term performance not known) More complex operation (maintenance may be more costly)
Combined Static/DMS	Portions of sign can conform to MUTCD regulatory and warning signing principles Some cost savings is possible relative to full-matrix DMSs	Static portions of sign limits message flexibility Light-emitting DMS technology may wash out static portions of sign if too bright

HAR signal, users are instructed to tune their vehicle radios to a specific frequency via roadside or overhead signs. Usually, the information is relayed to the users by a pre-recorded message, although live messages can also be broadcast.

Message transmissions can be controlled either on-site or from a remote location through telephone or radio interconnects. Most HAR systems operate at the 530 or 1610 kHz frequency level; however, any available frequency can be used as long as a low enough power level is used. A license from the Federal Communication Commission is required to operate a HAR system at high power levels (10 watts or greater).

HAR is used in many different applications. With respect to freeway management, uses of HAR are similar to those of DMSs, and include the following:

- Warning of roadway incidents or congestion.
- Warning of adverse environmental conditions (fog, ice, etc.).
- Notification of highway construction or maintenance.
- Alternate route information.
- Advisories within and regarding transportation terminals (airports, special events, and other major traffic generators, etc.).

One of the major advantages of using HAR is that information is received through a different sensory channel (audio), which reduces information overload received visually while driving.(17) Also, longer and more complex messages can be provided to motorists than can be accomplished using DMSs. However, traditional HAR systems have their drawbacks. They require motorist action (i.e., tuning radio to appropriate frequency) in order to receive information. Also, if a motorist misses one part of an HAR message, he or she must listen to the entire message again in order to obtain the missed part.

There are two types of HAR systems: vertical "whip" antenna systems and induction cable antenna systems. Vertical "whip" antenna systems use individual antennas or a series of antennas electronically connected together to transmit information. The signal radiates from the antenna in all directions providing a circular area of transmission. Vertical antenna systems have the following advantages:

- They are small.
- They are easy to install.
- They can be placed within several hundred feet of the roadway.
- They are less costly to purchase and install than induction cable systems.

Vertical antenna systems also have the following disadvantages:

- They are subject to damage by weather, accidents, and vandalism.
- They often require special equipment to ensure that the signal is stable, reliable, and easily tuneable.
- Motorists can lose the HAR signal when traveling through tunnels, canyons, etc.

Induction cable antenna systems use a cable installed either under the pavement or adjacent to the roadway. This type of antenna design produces a strong but highly localized signal within a short lateral distance 30 to 45 m (100 to 150 ft) from the cable. Induction cable systems have the following advantages:

- The signal is strong enough to provide full coverage of a multilane facility without causing interference to other HAR systems.
- Messages can be individualized by direction of travel.
- Interference with other radio systems in the area is minimized.

Disadvantages of induction cable HAR systems include the following:

- Induction cable systems are more expensive to purchase and maintain since the cable must extend the full length of the desired coverage area.
- Once installed, induction cable HAR systems cannot be transported from one location to another.

Automated HAR (AHAR)

One of the disadvantages of HAR systems is that they require advance signing to notify motorists of the availability of information, and an action by the motorist to activate and receive that information. Automated highway advisory radio (AHAR) systems have been proposed that require no actions by the motorist to obtain radio information. These systems emit a special electronic notification signal upstream of an HAR message, which interrupts the specially-designed radio/cassette/compact disc player to broadcast the message to the motorist.

FHWA sponsored the prototype development and pilot testing of an AHAR system in the early 1980s. [18,19] However, the difficulties associated with producing and marketing a receiver within a price range acceptable to motorists hindered further AHAR implementation. However, recent emphasis on ITS has sparked renewed interest in AHAR systems. Michigan is experimenting with alternative AHAR designs at this time. [20] Meanwhile, Europe has been experimenting with a version of these types of systems (termed the Radio Data System [RDS] Traffic Management Channel [TMC]) for the past few years. This system relies on a silent data channel broadcast via FM from existing radio stations. With an appropriate radio receiver, a motorist is then able to receive information from the closest or strongest FM radio signal at that location. [15]

Cellular Telephone "Hotlines"

An in-vehicle communication technology that has seen dramatic growth in the past few years is cellular telephones, which gives the motorist the ability to call special "hotline" systems for traffic information from within their vehicle. Originally, these systems allowed motorists and transit users to call for information to assist in pre-trip decisions from their homes. Information can now be accessed en route via cellular telephone, and decisions can be made whether to alter travel routes. The creation of call-in systems has been a popular traffic impact mitigation strategy for many major urban freeway reconstruction projects in recent years. [21]

One of the more successful examples of this technology is the two SmarTraveler systems now in place in Boston and Cincinnati. [10] Both systems employ special telephone numbers to keep the service free to cellular telephone users. Touch-tone menus allow callers to receive route-specific traffic information (delays, construction activity, recommended alternative routes), bus and train scheduling, and special event transportation information.

This type of in-vehicle communication has the advantage over HAR of giving the motorist some control over the type and amount of information he/she wants to obtain through the touch-tone menus. In addition, it is also possible to generate two-way communication between the motorist and the information source.

Many metropolitan areas have established cellular "hotlines" for motorists to call in and report accident information to the highway agency. Examples include #77 and *SP. The public agency must negotiate with the cellular companies to provide the toll free calls.

Recommendations for establishing cellular telephone "hot-line" systems include the following:

- The call must be toll-free to users.
- The telephone number must be easy to remember and dial.
- The information must be concise.
- If a menu system is used, a long and tedious menu selection process should be avoided.
- A sufficient number of telephone lines should be provided to prevent the majority of users from receiving a busy signal.
- If a system is going to be used to gather information from users, there must be a method of ensuring the accuracy of the incoming information.
- "Official" use of tipster information should include procedures for verifying that information.
- If incident information is to be received, a human operator is recommended so that secondary questions can be asked to clarify confusing or unclear reports.

As with HAR systems, this technology also requires action by the motorist to access information. There are also significant operating costs associated with this technology, as any calls made using cellular telephones must be paid for by either the motorist, or a public agency, or else absorbed by the corporation providing cellular telephone communication capabilities in the region. Finally, there is some concern that cellular telephone usage while driving may degrade motorist attention and operating capabilities. Manufacturers have developed "hands-free" telephones that allow motorists to listen and talk without holding the telephone receiver.

Commercial Radio

The public has learned to depend upon the media to provide them with "almost" real-time traffic information. Commercial radio has proven to be a good means of providing travelers with traffic information both in and out of their vehicles. Traffic and roadway condition reports have become standard programming items on many commercial radio stations. Commercial radio has the best potential of reaching the greatest number of commuters, since most of them have radios in the vehicles they drive to and from work.

The primary disadvantage of using commercial radio relates to the accuracy of the information. Traffic reports often are transmitted only when normal scheduling permits. This may cause considerable time delays between when an incident occurs and when it is reported by the media. Often, many incidents go unreported or are cleared by the time they are reported on the radio and television. The accuracy of the information provided by commercial radio is a function of the time between the broadcaster's last communication with the incident reporting source and the number of incidents that have occurred and/or have been cleared during that time.

Some transportation agencies have made substantial efforts to improve coordination and cooperation between themselves and the media traffic reporters. For example, some agencies allow private traffic reporting agencies to place personnel in the traffic management center to obtain information on traffic conditions and expected agency responses in an accurate and timely manner.

Citizen-Band Radio

Even though it was once considered an excellent means of providing motorists with two-way communications from their vehicle, Citizen-Band (CB) radio has declined in popularity in recent years. However, there are still a significant number of vehicles, particularly commercial vehicles and trucks, equipped with CB radios. In the past, CB radios have been used primarily in motorist-aid systems. A disabled or passing traveler broadcasts a request for assistance on channel 9. The channel is monitored 24 hours a day, 7 days a week by a police or volunteer organization, which dispatches aid to the stranded traveler. The primary advantage of a CB radio system is that it permits two-way communication between the traveler and the response agency. The effective range of many CB radios is approximately 32 kms (20 mi), depending upon geographic conditions.

Visual In-vehicle Information Technologies

Video Display Terminals

One of the newer technologies for communicating with motorists in their vehicles is through a video display terminal (VDT) mounted in the dashboard. This is primarily a private sector industry, which has not been used widely for information distribution. These systems can be used to provide motorists with route guidance and navigational information in one of two different formats. One approach is to present the driver navigation and route guidance information in the form of maps or equivalent displays. With these systems, a global picture of the traffic network can be provided. Recommended routes can be highlighted on the video map display as well. In another approach, simple symbolic signals (e.g., arrows, text instructions, or a combination of both) guide the driver along a recommended route. Some prototype systems use a variety of displays depending upon whether or not the vehicle is in motion, the functions selected, and level of informational and navigational displays available.

In-vehicle VDTs offer a number of advantages over available technologies in providing information to motorists while driving. These include the following:

- Travel information is more readily accessible to the driver (providing continuous access to current position, routing, and navigational information).

- Computer-generated navigational maps and displays are logical extensions of traditional forms of providing drivers with route guidance and navigation information.

Information can be displayed in text, graphics, or both and tailored to the needs and desires of each motorist.

There are also limitations to in-vehicle VDTs. These include the following:

- Drivers have to take their eyes off the roadway in order to receive the information.

- In-vehicle VDTs present the driver with complex maps and diagrams that may create a potential to overload the driver with too much information.

- VDTs may also add to the visual clutter already inside the vehicle.

Head-Up Displays

As technology continues to improve, the Head-Up Display (HUD) has become another alternative to in-vehicle VDTs for presenting visual navigational and route guidance information to motorists. Although originally developed for the aviation industry, several automobile manufacturers are beginning to develop HUDs for presenting vehicle status and navigational information to drivers.

A wide variety of options for displaying information may be available using HUDs. Through both icons and alpha-numeric text, navigation and route guidance information may be projected directly into the driver's field of view. This is expected to reduce the need for visual scanning between two information sources (the inside instrument panel and the outside environment), and the associated visual accommodation time.

However, as might be expected, numerous concerns exist regarding the safety and applicability of using HUDs in the driving environment.[23] Currently, most HUDs under development and implementation provide drivers with only relatively simple information, such as speed indications.

OFF-ROADWAY INFORMATION

The final type of information systems discussed in this module are those that drivers access off-roadway, at their homes, offices, shopping malls, etc. A major thrust of ITS development and implementation focuses on putting more information into the hands of motorists and passengers so as to improve departure time, mode choice, and route choice decisions. This emphasis has resulted in increased utilization of a number of traditional information technologies, and has yielded a number of new off-roadway information sources and several new dissemination technologies. Off-roadway information dissemination technologies include the following:

- Television.
- Telephones.
- Pagers.
- Personal Data Assistants (PDAs).
- Computers.
- Kiosks.

Television

Television (together with radio) was one of the first off-roadway motorist information technologies available to motorists. Even today, commercial television stations in most major cities provide traffic reports to viewers as part of their morning programs to indicate incident locations, traffic signal malfunctions, and other traffic "hotspots." These locations are usually shown on some type of wall-mounted or computer-generated map display.

Public access television is a means of overcoming many of the disadvantages associated with privately owned media stations. Many city governments are responsible for franchising cable television service within the corporate limits of the city. As part of awarding the franchise to a company, many city governments offer their own programming on one or more of these dedicated channels. Public access channels can be used by traffic management agencies to broadcast continuous traffic information during peak hours. Either "crawl" messages across the bottom of the screen or map displays accompanied by voice messages can be used to provide users with information. Traffic reports can also be provided by interrupting normal programming. The primary disad-vantage of using public access television is that the information is available only to cable subscribers. Travelers living outside the service area or not subscribing to the particular cable company do not have access to the information.

One freeway traffic management center in the U.S. has developed the capabilities to provide video and digital data directly to television signals. [12] They broadcast live video, a computerized map display, and current control and management actions being implemented (which DMSs have been activated). These signals are scrambled so that only those with the appropriate software and hardware can properly receive the signal. This is believed to reduce the need for censoring the images that are being presented, since they are not available to the public at large.

Telephones

As discussed earlier, telephone "hotlines" can allow both freeway and transit users to obtain pre-trip information via their telephones at home or work, or in their car if they are willing to pay for cellular airtime charges to call the hotline. Information can be provided using recorded messages, synthesized voice messages, or human operators. A touch-tone menu system can be used to tailor information to a specific route or travel corridor. Telephone calls are also a means of developing real-time rideshare matching systems that are being explored in several U.S. locations.

Pagers

A more recent technology now used to help disseminate travel information to users away from the vehicle are personal pagers. In Bellevue, Washington (east of Seattle), alphanumeric pagers provide their owners with hourly information regarding available carpools looking for riders as well as current traffic conditions on the Puget Sound-area freeway system.[24] The Genesis project of the ITS Guidestar program in Minneapolis, Minnesota and TRANSCOM in New Jersey also utilize alphanumeric pager technology to disseminate travel conditions in real-time to its owners. A key constraint of pager technology is that broadcast messages are limited to a small number of characters. Consequently, efforts are underway to determine which information is most relevant to pager owners and how to format that information succinctly, but accurately.[25]

Personal Data Assistants (PDAs)

Personal Data Assistants (PDAs) are the next higher level of sophistication in off-roadway information dissemination technology. PDAs are computer products that have enough power to support applications such as time management and handwriting recognition. By adding radio frequency (RF) communications technology, PDAs allow users to interact directly with travel information systems. This interaction allows users to obtain route planning assistance, traffic information broadcasts, and other pertinent information. Through keypad entry, the user can log on to the information system, request pertinent information, and then log off. PDAs offer the user increased communication and information transmission/receiving power over alphanumeric pagers. However, they are more complex to use and expensive to purchase.[25]

Computers (Internet)

Personal computers, both desktop and laptop/notebook, can also be used to disseminate information to travelers. As with PDAs, two-way communications between the computer user and the travel information center can be established by telephone modem or an RF communication link. This two-way flow of information allows the user to request information specifically tailored to his or her needs (route planning, traffic information on specific roadway links, transit bus schedule and status, etc.).

Kiosks

The last off-roadway information dissemination device to be discussed is the information kiosk. Kiosks are video monitors mounted on a stand-alone cabinet, in a wall, or on a counter-top. They may have input devices such as keypads, trackballs, or touch-screen displays. Kiosks can serve as an important point of access to travel information networks in a variety of public locations, including the following:

- Hotels.
- Restaurants.
- Airports.
- Gas stations (truck stops).
- Retail establishments (shopping malls).

Kiosks are one type of information dissemination technology where private/public partnerships are particularly relevant. For instance, some agencies are looking to the private sector (through advertising revenue) to help defray the operating and maintenance costs of these systems.[26, 27] Proper kiosk placement is also a critical issue. Many kiosks are not well utilized because they are not located where they can draw attention and reach their intended market.[27]

7.4 LESSONS LEARNED

NTCIP STANDARDS

Equipment compatibility, especially with respect to communications, has long been a problem for many transportation agencies operating various components of freeway management systems. Incompatibilities between DMS and HAR hardware from different vendors have required the agency to have separate systems to communicate with each type of DMS or HAR. This has made it difficult to operate the equipment efficiently and in an integrated manner.

In response to these and other problems, a National Transportation Communications Interface Protocol (NTCIP) is under development to reduce the difficulties associated with developing an integrated freeway management system. These protocols establish standard communications linkages between various types of hardware and software used for traffic management purposes. This ultimately reduces the need for an agency to select and stay with a particular vendor or model of equipment.

In the information dissemination arena, standards have been proposed, or are under development, for DMS and for HAR. Standards for other equipment are likely to emerge as the need arises. Partners are strongly encouraged to utilize NTCIP standards where possible.

INFORMATION MESSAGE DESIGN

Although traditionally a concern associated with public agency information dissemination mechanisms such as DMS and HAR, the proper design and packaging of the information being disseminated is critical to successfully meeting the goals and objectives for all components of an information dissemination subsystem. Evidence already exists on some of the newer ATIS technologies that improper message designs have an adverse impact upon customer (i.e., motorist) interpretation of the worth and usefulness of these technologies.[29] Without proper attention to packaging, the intended audience may not be able to adequately perceive, interpret, and respond to the information. The following factors are critical to proper message design:

- Message load.
- Message length.
- Message format.

Message load refers to the quantity of information that is included in a given message. Message load is an important consideration for DMS operations, because the driver must attend to many different tasks at the same time, while trying to read and comprehend a message. If the message presents too much information, message overload may occur. Some transportation agencies have reported traffic slowing down and other adverse operational problems in the vicinity of DMSs when messages are too long.[1]

Message length refers to the number of words or characters that are displayed on one or more lines of a sign or sequence. Obviously, message length and load are related. However, message length and how the message is formatted, or "chunked," both affect message load.

Message formatting is a term that refers to the arrangement of message elements (words or lines) on an information dissemination device (e.g., a sign) to form a message. Use of abbreviations also relates to message formatting. Placement of message elements on the wrong line or in the wrong sequence will result in confusion and increased message reading and comprehension times.

The completed and detailed set of guidelines regarding message design from which these paragraphs were drawn are available elsewhere. [2]

ENVIRONMENTAL ISSUES CONCERNING DMSs

Because they are located outdoors next to the freeway, the effectiveness of DMSs as an information source is also affected by environmental factors. Two factors that can be significant are sun position and weathering effects.

Sun Position

Both sunlight falling directly upon the face of a DMS and sunlight located directly behind the DMS adversely affect a driver's ability to see the message. Sign positions with the rear surfaces oriented west-southwest and east-northeast should therefore be avoided if possible. The west-southwest orientation is more problematic, however, because the setting sun tends to be more intense than the rising sun.[1]

Weathering

Because of their proximity to freeway travel lanes, road grime can be a problem for certain DMSs, and significantly reduce the distances at which they are legible. Consequently, DMS manufacturers often place clear Lexan covers over the DMS face to protect the sign from road grime and other environmental effects. One study suggests that legibility distances of a fixed-grid fiberoptic DMS (a freeway lane control signal without a Lexan cover) may be reduced by as much as 25 percent after 18 months in the field. [29] It appears that these losses in legibility can be minimized to a large extent by a regular sign maintenance (pixel lens cleaning, light bulb replacement) program.

"AT-REST" DISPLAY CONDITIONS

Another DMS-specific issue is what to do with the signs when there is nothing special to report to travelers. There are generally two schools of thought regarding when information should be provided in dissemination devices.[2] One perspective is that some type of information such as current time and temperature, an agency slogan, etc., should be provided at all times. Proponents argue that this indicates to motorists that the devices are working. The other perspective is to display information only when there is something new to tell travelers. Proponents of this school of thought argue that, according to human factors principles, trivial or non-traffic specific information should be avoided so that the devices do not lose credibility with the travelers.

7.5 EXAMPLE OF AN INFORMATION DISSEMINATION SYSTEM: TRANSCOM

ORGANIZATION

TRANSCOM (Transportation Operations Coordinating Committee) is a consortium of 14 transportation and public safety agencies in the New York, New Jersey, and Connecticut area whose goal is to provide a cooperative, coordinated approach to regional traffic management. TRANSCOM is funded, staffed, and governed by its member agencies. It has an Operations Information Center (OIC) that is staffed 24 hours per day, 7 days per week. TRANSCOM shares incident information via alphanumeric pager, phone, and fax to more than 200 highway and transit facilities, police agencies, and radio traffic services. It also serves as a forum for incident and special event management planning, construction coordination, and for shared testing and implementation of regional traffic and transportation management technologies.

The planning process for TRANSCOM began at the end of 1984. TRANSCOM began operations in 1986. Originally, the Port Authority of New York envisioned TRANSCOM as a coordinating mechanism to facilitate traffic flow and operations at the Hudson River crossings. However, TRANSCOM's focus quickly expanded to all traffic facilities in the region.

TRANSCOM is managed by a steering committee made up of senior and mid-level managers from each agency. This committee directs the technical and operational focus of TRANSCOM. Meanwhile, an executive committee consisting of the chief executive officer from each agency decides major policies pertaining to TRANSCOM.

Although TRANSCOM is a public sector information dissemination example, it is considering moving towards a public/private partnership. Public/private partnerships are a much more appropriate example of what is likely to occur in the future.

OPERATIONS

The TRANSCOM OIC receives information regarding incidents and transit facilities from all over the metropolitan area. The operations personnel in the OIC are employees of one of the member agencies and generally have some background in dispatch, operations, or media reporting. The TRANSCOM partnership has allowed several projects to be developed and implemented to facilitate information dissemination and incident response in the region. These include the following:

- Regionwide initiatives for coordinated deployment and operation of VMSs, HAR, and enhanced traffic monitoring via CCTV.

- An enhanced traffic advisory/diversion system at the intersection of the New Jersey Turnpike and Garden State Parkway, which will focus on alternative routing for New Jersey transit buses.

- Expansion of traffic monitoring along the I-287 Tappan Zee Bridge corridor.
- Initiation of the TRANSMIT (TRANSCOM's System for Monitoring Incidents and Traffic) Operational Test. This project uses vehicles with transponders on a highway system equipped with readers/antennas.

TRANSCOM receives information regarding incidents and transit facility conditions from all over the area. The OIC is normally staffed with two operators who receive, collate, and disseminate transportation-related information. The information is relayed to the agencies affected by the incident via alphanumeric pagers, facsimile machines, and voice communications. This information is then disseminated by the various agencies according to their capabilities. In some instances, TRANSCOM has been granted authority to operate the information dissemination technologies for certain agencies.[9]

TRANSCOM operations are fully funded by its member agencies. This funding consists of both monetary contributions and in-kind services such as providing operators to staff the OIC.

FUTURE ACTIVITIES

The executive and steering committees are looking at a number of issues relating to future TRANSCOM operations. TRANSCOM will continue to pursue research and testing of advanced technologies to help the region more effectively manage travel in the congested northeast corridor. The TRANSMIT system is an example of this commitment to future operations. [30] TRANSCOM is participating with other agencies in the development of a computerized Information Exchange Network (IEN) to automate the information retrieval and dissemination process.

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MODULE 8. INCIDENT MANAGEMENT

TABLE OF CONTENTS

MODULE 8. INCIDENT MANAGEMENT

Figure 8-1. Example of an Incident Response Site.

8.1 INTRODUCTION

BACKGROUND

Congestion occurs when the amount of traffic wishing to use a facility (demand) exceeds the traffic-carrying capabilities of the facility (capacity). There are two types of congestion: recurring and nonrecurring. Recurring congestion occurs when normal demand exceeds the physical capacity of the freeway. This type of congestion typically occurs during high volume periods (such as the a.m. and p.m. peak periods) and is predictable in terms of its location, duration, time, and effect. Through experience, most motorists have learned to deal with the effects of recurring congestion by planning for it in their daily routines.

Nonrecurring congestion, on the other hand, is a result of either 1) a temporary reduction in capacity of the freeway (such as an accident or a work zone lane closure) or 2) a temporary excess of demand (caused by a special event or other similar activity). Generally, the activities that cause nonrecurring congestion can be either unpredictable (as in a stalled vehicle) or planned (such as a construction activity). The primary factor distinguishing nonrecurring and recurring congestion is that nonrecurring congestion is unexpected by motorists. As a result, nonrecurring congestion can be a considerable safety hazard and cause excessive delays to uninformed motorists.

Most of the activities that cause nonrecurring congestion can be classified as incidents. Incidents are responsible for a significant proportion of the delays and costs to the motoring public. For example, Caltrans estimates that over 50 percent of all delays experienced by motorists on their freeway system are caused by incidents. [1] In Texas, freeway incidents in 1990 were the source of over 440,000 hours of delay, costing the motoring public approximately $2.2 billion. [2] By 2005, the impacts of incidents in terms of hours of delay, wasted fuel consumption, and excess road user costs are expected to increase 5 fold over levels experienced just 10 years ago. [3]

One method for combating nonrecurrent congestion problems is to implement an incident management program or component of a freeway management system. Incident management refers to a coordinated and planned approach for restoring traffic to its normal operations as quickly as possible after an incident has occurred. It involves a *systematic* use of human and mechanical processes for the following purposes:

- Detecting and verifying the incident.
- Assessing its magnitude and identifying what is needed to restore the facility to normal operation.
- Providing the appropriate response in the form of control, information, and aid.

MODULE OBJECTIVES

The goal of this module is to provide guidance on how to develop or enhance incident management as part of a freeway management system. The specific objectives are as follows:

- To illustrate the decision-making process associated with developing improved incident management capabilities as part of a freeway management system.
- To describe and provide current summary data on the various techniques and devices available to facilitate freeway incident detection, verification, response, clearance, and traffic management.
- To identify and discuss unique issues and lessons learned pertaining to the planning, design, operation, and maintenance of an incident management component of a freeway management system.

MODULE SCOPE

This module is intended to be an overview of the incident management development process. The reader should note that a number of other documents dealing with incident management are available, and should be reviewed for additional information (See references 4,5,6,7.) The focus of this module is to present the decision-making process to assist in identifying, selecting, and implementing an integrated package of incident management actions that are most appropriate for the region of interest.

8.2 DECISION PROCESS

Incident management is a coordinated and planned approach for responding to incidents when they occur on the freeway systems. It involves the systematic use of human and mechanical processes for detecting, responding to, and clearing incidents. In this section, the systems engineering process that serves as the common thread throughout this handbook is applied to the development of this incident management module. It is important to note that incident management is a separate metropolitan component of an integrated regional transportation system. It is very often implemented with freeway management systems.

IDENTIFY NEEDS

Before an incident management component can be properly designed, it is important to have an understanding of the characteristics and impacts of incidents on freeway traffic in the region. Non-recurrent congestion is caused by one of three events:

- Roadway incidents (crashes, stalls, spilled truck loads, work zones, etc.).
- Special events.
- Regional transportation emergencies (flooding, hurricanes, chemical plant emergencies, etc.).

All of these events can reduce the amount of roadway space available to carry traffic. Furthermore, the last two categories can also increase traffic demands on a roadway segment, causing additional congestion.

To date, data regarding the frequency of incidents remains somewhat limited. Table 8-1 presents a summary of some of the different freeway incident frequencies that have been reported, and the units of measure utilized to describe these frequencies.

Rates of between 12 and 125 incidents per million-vehicle-kilometers (MVK) have been reported in the literature over several years.(1,7) Other studies have reported freeway incident frequencies as a daily or hourly rate per lane-kilometer.(8) Generally, these rates represent all reported incidents, from very minor vehicle stalls lasting only a few moments to major incidents involving hazardous materials or fatalities that take several hours to clear. Rates of more severe incidents that typically involve multiple agency response are significantly lower. For example, data from Houston indicated that a major lane-blocking freeway incident lasting more than 45 minutes occurred once every 137 MVK, or a rate of 0.73 per 100 MVK.(9) Undoubtedly, use of local data is the preferable method of assessing the severity of the incident problem at a location or in a given region.

Table 8-1. Summary of Reported Freeway Incident Rates.

Unit of Measure	Value
Incidents per million-vehicle-kilometers (1)	12-125
Incidents per million-vehicle-kilometers(7)	65
Lane-blocking incidents per hour per lane-kilometer(8)	0.006-0.023
Lane-blocking incidents lasting more than 45 minutes per 100 million-vehicle-kilometers(9)	0.68

Incident severity is also described in terms of its capacity-reducing effect on the roadway. Generally speaking, an unplanned incident or work zone activity will reduce freeway capacity by an amount greater than the reduction in roadway space due to that incident. For example, an incident that blocks one lane of a three-lane freeway section reduces available roadway space by 33 percent, yet reduces the capacity of the freeway by about 50 percent.[1] This additional capacity loss is due to the turbulence caused in the traffic stream as drivers attempt to move from the closed lanes into open lanes, and from driver "rubbernecking."

Table 8-2 summarizes the effect of stalls and accidents on freeway capacity.[1] Data regarding roadway capacities for work zone lane closures are shown in table 8-3.[11] Note the similarity in the estimated percentage reductions in capacity for one and two-lane blockages on freeway sections with three travel lanes per direction.

Generally speaking, frequencies of special events and major transportation emergencies are much smaller than those referred to above. However, when they occur, they can have a severe impact upon mobility and traffic conditions in an entire region. Fortunately, they are usually confined to a specific location and future time period, so that more preparation time can be spent analyzing and implementing various alternatives to help combat any adverse impacts expected.

It is important not only to attempt to quantify the overall magnitude of the incident problem that must be addressed, but also to identify in as much detail as possible the types of incidents that are a problem and the magnitude of their impacts. The degree to which specific problem areas can be identified in this step of the process determines how effectively possible mitigation alternatives are identified and implemented.

Table 8-2. Typical Capacity Reductions During Incident Conditions.[1]

Type of Incident	Normal Number of Lanes	Number Lanes Blocked	Capacity Reduction (%)
Accident on shoulder	3	0	26
Vehicle stall	3	1	48
Non-injury accident	3	1	50
Accident	3	2	79

Table 8-3. Typical Capacities During Work Zone Activities.(Adapted from 11)

Normal Number of Lanes	Number of Lanes Closed	Average Capacity (vph)	Reduction in Roadway Space (%)	Capacity Reduction (%)[a]
2	1	1340	50	63
3	1	2980	33	45
3	2	1170	67	81
4	1	4560	25	37
4	2	2960	50	59
5	3	2740	60	70

[a] Percent reduction based on an assumed normal vehicle capacity of 1800 vehicles/hour/lane
vph = vehicles per hour

As a final note, it is important to limit problem identification at this point in the process to the symptoms that need to be addressed, and not try to attach responsibility (or blame) for that symptom to an individual or organization. Part of the difficulty in establishing effective incident management programs is developing the lines of communication, cooperation, and trust within and between the various agencies that need to be involved. These cannot be established effectively in an environment where affected parties are pointing fingers at each other.

IDENTIFY INCIDENT MANAGEMENT PARTNERS

A key to effective freeway incident management lies in the ability of multiple agency partners to coordinate and cooperate before, during, and after an incident. Generally speaking, some or all of the following agencies will have a vested interest in improving freeway incident management capabilities and procedures within a region:[12]

- Elected officials.
- State and city/county DOTs.
  - traffic operations.
  - traffic management.
  - maintenance.
  - public relations.
- Transit operators.
- State, city/county, and transit law enforcement agencies.
- Fire and emergency medical services.
- Hazardous materials (Hazmat) contractors.
- Other emergency agencies (office of emergency management, etc.).
- Environmental protection agencies.

- Towing services.
- Corporate service patrol providers.
- Regional authorities (metropolitan planning organizations, council of governments, etc.).
- Media representatives.
- Special event promoters.

Depending on the number of agencies potentially involved in the incident management process, it may be advantageous and necessary to establish smaller subgroups of partners who must interact and cooperate for specific types of incidents.[13] For example, fire and emergency medical services, environmental protection agencies, and offices of emergency management typically have little involvement in the minor accidents and stalls that are of concern to police, DOTs, transit agencies, towing services, etc. Of course, partners such as police and State DOTs will be involved in nearly all subgroups.

BUILD CONSENSUS AMONG PARTNERS

One of the most critical activities that must occur early on in the incident management development process is consensus building among the partners. A consensus is needed on both the importance of optimizing the incident management process and the importance of adopting a "team" approach to addressing the need for coordinated incident management in a region.

Consensus-building does not just "happen." It must be fostered and developed over time. One way to facilitate consensus-building is for each partner to develop a true understanding of the goals, responsibilities, and capabilities that the other partners have within the incident management process.[9] Also, a critical review should be made not only of what the roles and responsibilities of each partner currently are, but also of what they could be (or what the partner wants them to be).[5] Finally, legal ramifications pertaining to each partner's involvement in incident management must be assessed. Formal agreements of understanding and cooperation may need to be written and signed by upper management of each partner to further promote a unified team approach.

Traffic management teams (TMTs), established in numerous regions nationwide, serve as an excellent beginning of a cooperative environment in which to improve incident management. Basic guidelines for successful TMTs are shown below:[1]

- Regular meetings (monthly or bimonthly).
- Attendance by the same personnel at each meeting.
- Attendance by personnel with authority to commit the partner's resources.
- Informal interaction.
- Preparation of agenda for each meeting.
- Focus on reaching verbal consensus on issues being discussed.

It is important that the organization responsible for organizing and running the TMT meeting make an active, consistent effort to identify agenda items and tasks to be undertaken by the team. This is essential to keeping other partners interested and involved. The Palm Beach and Broward TMTs in Florida have hired a consultant to run their meetings. The consultant is seen as having a more organizationally neutral viewpoint on agenda items, and has more time to keep the various partners interested and involved.

ESTABLISH INCIDENT MANAGEMENT GOALS AND OBJECTIVES

Once a consensus to cooperate and coordinate incident management activities has been reached among the various partners, the goals and objectives that the partners wish to accomplish relative to improved incident management must be defined. As stated in **Module 2**, goals are broad statements about the intent of the system or one of its components, whereas objectives are specific statements about what the system or component of that system will attempt to accomplish. A given goal may have more than one specified objective. Furthermore, the emphasis at this point in the process is on identifying what the subsystem or component will accomplish, not what technology will be employed. Table 8-4 presents examples of some possible goals and objectives relative to incident management.

ESTABLISH PERFORMANCE CRITERIA

Performance criteria are used to determine whether the objectives established in the previous step are being achieved. For incident management, these criteria can be both quantitative and/or qualitative. Examples of some types of performance criteria for incident management are shown in table 8-5.

Table 8-4. Examples of Goals and Objectives of Incident Management.

Category	Examples
Incident management goals	• Reduce the impact of incidents upon peak-period traffic • Reduce the potential for injury to motorists stranded by disabled vehicles • Reduce the freeway congestion that develops at exits to a regular special event
Incident management objectives	• Detect all lane-blocking peak-period incidents within 2 minutes of occurrence • Provide first response to an incident within 5 minutes of occurrence • Reduce the time to clear an incident by 15 minutes • Reduce freeway traffic volume approaching a peak period lane-blocking incident by 10 percent • Detect 75 percent of all disabled vehicles within 20 minutes after they have stopped on the shoulder • Divert 25 percent of traffic that normally uses a given ramp to access a special event facility to other exits

Table 8-5. Examples of Incident Management Performance Criteria.

Objective	Examples of Performance Criteria
Detect all major incidents within 2 minutes of occurrence	• Average detection time • Percent of incidents detected within 2 minutes of occurrence
Provide first response to an incident within 5 minutes of verification	• Average response time • Percent of incidents responded to within 5 minutes of verification
Reduce the time to clear an incident from the freeway by 15 minutes	• Change in average clearance time due to improvements in incident management procedures

DEFINE FUNCTIONAL REQUIREMENTS

Once the goals and objectives for incident management have been identified, the functions (specific features or activities) that are required to achieve the objectives need to be defined. As with the objectives, the functions should be described independent of the technologies that could be used to accomplish the objectives (focusing on what should be done, not how it should be done).[14] Often, these functional requirements can be outlined in a hierarchial order. Figure 8-2 provides an example of possible functional requirements for the incident management component of a freeway management system. Note that each of the functional elements defines an action that is to be performed, and is independent of the technology that could be used to accomplish that action.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

The purpose of defining the functional relationships, information flows, and data requirements is to establish an understanding of how the various incident management functions that are to be accomplished will be integrated with each other and among the other components in the freeway management system. Much of these relationships, flows, and requirements have been prepared through the National Architecture development effort for ITS. The National ITS Architecture for incident management can be adapted to incorporate local issues, concerns, and capabilities.

Within this step in the decision process, local and regional details that further define when and how incident management functions will be accomplished are established. For example, it may be necessary to subdivide the freeway or corridor into smaller segments because of jurisdictional differences, and adjust the design of the system slightly for each segment, depending on the partners involved, chain-of-command for contacting each partner, etc. Special legislation may need to be established to allow certain incident management tasks (such as service patrol operations) to be privatized.[5] These and other institutional issues identified during problem

Identify incident
- Identify incident location
- Identify incident characteristics (vehicle types, injuries, etc.)
- Identify incident impacts upon traffic flow

Formulate response actions
- Identify necessary emergency vehicle response
- Select incident information for dissemination to travelers
  - Notify transit riders at a park-and-ride lot that their bus may be delayed
  - Notify traffic information services of incident location
- Identify traffic control strategies
  - Increase green time on parallel arterial nearest to the freeway
  - Initiate ramp metering upstream of the incident

Initiate and monitor response
- Initiate coordinated response by the appropriate agencies
  - Implement emergency vehicle response
  - Provide incident information to travelers
  - Implement traffic control strategies
- Monitor response
  - Arrival of emergency vehicles
  - Implementation of traffic control
  - Clearance of incident
  - Clearance of congestion

Figure 8-2. Examples of Incident Management Functions.

identification and goal/objective definition are resolved during this step of the process.

IDENTIFY AND SCREEN TECHNOLOGY

After the various institutional issues relative to incident management have been addressed, the decision process then reaches the point where it is necessary to identify and screen technologies available to achieve the functional requirements and incident management architecture defined for the freeway management system. A review of the various techniques available to facilitate incident management is provided later in this module. This section provides a review of the major issues pertaining to each of the basic phases of incident management (detection and verification, response, and clearance) as they relate to freeway management systems.

Incident Detection and Verification

Incident detection and verification requires the following:[1]

- A means of sensing that an incident has occurred.
- A means of verifying the incident's existence and location.
- A focal point for the fusion of data from multiple detection sources.
- Communications links between detectors and receivers of incident data.

- A means of displaying and recording incident information.

Many different technologies exist which can be used for incident detection and verification. Incident detection in many locations involves a combination of several different detection technologies, and appears to work quite well. Overall, detection and verification technology screening requires a consideration of the following issues:

- Detection speed.
- Accuracy.
- Costs.
- Maintainability.
- Personnel requirements.
- Usefulness of data for other freeway management purposes.
- Speed with which the technology can be implemented and benefits begin accruing.

It is the responsibility of the various partners involved in incident management to decide upon the relative importance of each of these items. The last bulleted item is particularly relevant to all phases (detection, verification, response, and clearance) of incident management. Several agencies have strongly recommended initially implementing low-cost technologies that can provide immediate and demonstrable benefits to the general public, and then building upon those successes to further enhance and improve incident management capabilities in an incremental fashion.[5,12] For instance, cellular phone calls from motorists and CB radio reports from truck drivers have become very important components of incident management efforts in many metropolitan areas, and are often the fastest means available for detecting incidents.[15] Methods of incorporating these detection sources into incident management efforts early on can yield significant benefits almost immediately.

Details of various incident detection and verification technologies are addressed in the Techniques section later in this module, and also in **Module 3**.

Incident Response and Clearance

Technology screening relative to incident response and clearance will depend on the specific types of problems identified initially in the process. Certain types of problems, such as lengthy clearance delays for large truck incidents, can be reduced by making sure that specialized response equipment (heavy-duty wreckers, inflatable air bag systems to upright overturned trucks, etc.) are available from private-sector services. However, specialized hardware or software to assist in incident response and clearance is only one part of the overall technology screening process. Other focus areas to be screened include:

- Minor geometric modifications to enhance response and clearance capabilities (i.e., installing or moving median barrier gates, constructing staging areas for incident management, etc.).
- Institutional arrangements to facilitate cooperation and coordination of incident response and clearance activities among the partners.
- Legislation supporting vehicle removal policies or other clearance activities.

As with incident detection and verification, the screening process for incident response and clearance should include consideration of the following issues:

- Costs.
- Maintainability.
- Personnel requirements.
- How quickly the technology can be implemented and benefits begin accruing.

Also, it is important to recognize that the technology screening process for incident management cannot occur in isolation from other ongoing or planned freeway management system activities. Implementation actions related to ramp control, information dissemination, HOV treatments, and lane use control all affect and tie into incident management efforts and initiatives as well.

Additional details regarding incident response and clearance are discussed later in the Techniques section of this module.

DEVELOP PLANS

This step in the decision process involves the development of a plan to implement the technologies that have been determined to best meet the goals and objectives of incident management and that are the most feasible for the unique geographic, environmental, and institutional characteristics of the region. As discussed in detail in **Module 2**, this plan documents the following features of the incident management system:[16]

- Needed legislation.
- System design (architecture, technologies utilized, etc.).
- Procurement methods.
- Construction management procedures (if construction is involved).
- Start-up plan.
- Operations and maintenance plan.
- Institutional arrangements.
- Required personnel and budget resources.

In conjunction with the implementation plan (or possibly as a separate development effort), an incident response plan can also be an important activity to facilitate improved incident management within the region. This plan is a detailed document which specifies the following:

- Key partner roles.
- Communication links.
- Detailed traffic management procedures.
- Resources (and their locations).
- Logistics.

Table 8-6 summarizes the information provided for each of the items listed above. Commonly, a detailed response plan recognizes that traffic demands vary over time and location within the region, and so the management procedures required to effectively accommodate an incident will depend upon where and when it occurs as well as its severity. Consequently, some agencies have found it convenient to develop varying levels of incident management implementation. These levels may range from minor on-site management activities during low-volume conditions to a full-scale integrated major response effort involving

Table 8-6. Information in an Incident Response Plan. [1]

Section	Function
Participating Agencies	• Lists all participating partners and telephone numbers of the incident management coordinator for each • Lists other agencies that may participate (i.e., resource locations)
Summary	• Describes major plan elements
Levels of Implementation	• Describes the series or levels of incident management intensity and conditions under which each level is to be invoked
Traffic Management	• Describes communications procedures for each roadway section, agencies to be informed, diversionary routes, traffic control locations, local and regional signing
Resources and Responsibilities	• Lists each partner, contact numbers, key personnel, responsibilities, and other pertinent information
Media Contacts	• Lists each media contact, contact numbers, key personnel, responsibilities, and other pertinent information
Team Coordinators	• Lists all involved partner coordinators and telephone numbers

diversion strategies, information dissemination efforts, and other techniques.[1]

IDENTIFY FUNDING SOURCES

Because incident management is the coordination of multiple entities and techniques to achieve an overall goal (reduced disruptions to travel due to incidents), many different funding sources can play a part in the development and operation of an incident management subsystem. Typically, infrastructure-based investments (automated surveillance, roadway information dissemination tools, traffic signal timing improvements, accident investigation sites) have typically come from the public agencies (State, local) that have direct jurisdiction over the facilities on which they are located.

Initially, courtesy service patrols were funded primarily by DOTs, with the agency benefiting both from positive public relations and from the improvements in traffic operations.[12] In recent years, though, several regions have successfully implemented patrols in which different funding mechanisms have been used.[17] These mechanisms include the following:

- Additional gasoline taxes.
- Additional sales taxes.
- Department of motor vehicle fees.
- Federal construction funds.
- Bridge or highway tolls.
- Congestion Management and Air Quality (CMAQ) funds (for start-up and initial operating costs).
- National Highway System funds.

- Surface Transportation Program funds.
- Private funds.

IMPLEMENT

Experiences from several past incident management implementation efforts indicate that partners should utilize a building-block approach, initiating low-cost components first to demonstrate to the public and to elected officials the benefits of incident management activities.[12] It is then easier to "sell" other components (such as electronic surveillance) that are more capital intensive.

In general, the initiation of service patrols should be one of the first incident management activities that partners consider for their region. Benefit-cost ratios between 2.3:1 and 36:1 have been reported.[17] Again, partners should start small, and gradually build upon this service as they learn more about its operation and develop public and elected official support for it over time.[12]

EVALUATE

Evaluation is a critical component of the incident management decision process. Evaluation helps to define the benefits of incident management in order to maintain and improve funding levels. Also, evaluation is necessary to assess the extent to which the goals and objectives established for incident management are being met. Finally, evaluation is important in identifying new, unforseen difficulties that arise in the incident management process, as well as in identifying possible solutions for dealing with those difficulties.

Methods of evaluation of an incident management program include the following:[18, 19]

- Quantifying the impact upon traffic flow (delays, fuel consumption, emissions, secondary accidents, etc.).
- Critiquing the program through periodic traffic management team reviews or special debriefings held after major incidents.
- Staging mock drills or exercises of a major incident as a training activity and process review.
- Holding post-incident debriefings to review effectiveness of incident management activities and identify areas of improvement.

8.3 TECHNIQUES AND TECHNOLOGIES

INCIDENT DETECTION AND VERIFICATION

Rapid detection is a critical element in the incident management process. The sooner an incident can be detected, the quicker a response to clear the incident can be initiated. Technologies available for detecting incidents range from low-cost non-automated methods to sophisticated automated surveillance techniques requiring extensive public agency investments. It should be noted that emerging Intelligent Transportation Systems (ITS) technologies offer promise for dramatically improving detection capabilities and reliability. The various technologies used by transportation agencies to detect incidents are discussed in the following sections.

Non-Automated Detection Techniques

Whereas most thoughts of incident detection for a freeway management system focus on the various automated technologies that are available, experience suggests that non-automated detection methods serve a valuable and often primary role in incident detection efforts in many instances. These methods typically utilize motorist call-in technology or manual surveillance methods to achieve incident detection. Non-automated detection methods include the following:

- Cellular telephone calls to 911 or incident reporting hotline.
- Dedicated freeway service patrols.
- Peak-period motorcycle patrols.
- Citizen-band radio monitoring.
- Motorist call boxes.
- Aircraft patrols.
- Fixed observers/volunteers.
- Closed-circuit television.
- Fleet operators (taxis, transit, delivery drivers).

Table 8-7 summarizes the advantages and disadvantages of each of these non-automated detection technologies. It should be noted that the growth of cellular telephone popularity has resulted in that becoming the most important detection technology in most metropolitan areas.[15]

Freeway service patrols are able to begin incident response and clearance activities immediately, which increases their attractiveness from an overall incident management perspective. They are also a valuable public relations tool for the sponsoring agency. [12] Conversely, the use of fixed observers is most applicable to short-term needs (during special events, major freeway construction activities, etc.).

Closed-circuit television can serve as a manual means of incident detection by having system operators continually watch the monitors. However, this technology is more commonly used as a verification tool for incidents detected via cellular telephone reports or automated detection algorithms (discussed in the next section).

Automated Surveillance Techniques

Technologies

Most freeway management systems include some form of automated surveillance which can be used to detect freeway incidents. Types of automated surveillance are listed below:

- Inductive loop.
- Magnetometer.
- Microwave/radar.
- Laser.
- Infrared.
- Ultrasonic.
- Acoustic.
- Machine vision.
- Vehicle probes (automatic vehicle identification, automatic vehicle location).

Module 3 presents additional details about these detectors. The first two technologies, inductive loops and magnetometers, are placed within the pavement. The others are non-intrusive surveillance technologies,

Table 8-7. Comparison of Non-Automated Incident Detection Technologies.[1, 5]

Technology	Definition	Advantages	Disadvantages
Cellular telephone calls to 911 or incident reporting hotline	Motorists use their cellular phones or call from a roadside telephone to report incident.	Often fastest detection method available.	Dependent upon motorist input. Verification needed. May need additional staff to handle calls.
Freeway service patrols	Special vehicles circulate to provide breakdown assistance.	Serves detection, verification, and response functions.	Congestion reduces circulation frequency. Labor-intensive.
Peak-period motorcycle patrols	Motorcycle police officers patrol freeway segments.	Serves detection and verification functions. Already in place as part of regular police functions. Can travel through stopped traffic to get to incident.	Congestion reduces circulation frequency. Labor-intensive.
Citizen-band radio monitoring	Can establish a special frequency for incident reporting.	Inexpensive. Generally can be monitored by existing staff.	Detection dependent upon number of trucks/CB owners on facility. CB owners may need to be trained to use.
Motorist call boxes	Devices located on side of road which motorists can use to notify authorities.	Incident reporting can occur 24 hours/day. Citizen acceptance is high.	Start up costs are high. Requires motorists to walk to activate. Potential for vandalism. May require additional staff to handle calls.

Table 8-7. Comparison of Non-Automated Incident Detection Technologies.[1,5] (Cont'd.).

Technology	Definition	Advantages	Disadvantages
Aircraft patrols	Use of airplanes or helicopters to locate incidents.	Can be used to detect and verify incidents. Can cover a wide region, and see things from a larger perspective (easier to assess impacts of incident).	Costly, significant delays may occur between passes over a given segment. May not be useable during severe weather, fog, etc. Some areas may have airspace restrictions.
Fixed observers/volunteers	Observers are positioned on towers or buildings to watch traffic and report incidents.	Flexible. Useful as an interim measure such as for special events or during roadway construction.	Labor-intensive. Not practical during severe weather conditions.
Fleet operators (taxis, transit, delivery drivers)	Drivers call in incidents they encounter during their normal travels.	Large number of observers can be recruited. Little or no cost to public agency.	Accuracy, reliability cannot be controlled. Limited by fleet size.
Closed-circuit television (CCTV)	Cameras located in traffic management center are continuously monitored by system operators.	Provides detection and verification functions together.	Can cause operator boredom problems. Effectiveness dependent upon camera placement.

located above the travel lanes or off to the side. The first eight technologies typically measure speed, volume, and/or occupancy. Conversely, vehicle probe detection systems monitor vehicle position and elapsed travel time.

Although not listed as an automated detection technology, closed-circuit television is commonly used with automated detection systems to verify that an incident is truly present at a location and to begin evaluating and anticipating appropriate response measures.

Detection Algorithms

The effectiveness of automatic detection technologies depends in part on the type of algorithm used to analyze the detector data. Three parameters are generally used to monitor the performance of an incident detection algorithm: detection rate, detection time, and false alarm rate.[20] Detection rate is defined as the percentage of the total number of capacity-reducing incidents that are detected by the computer algorithm. Detection time is defined as the time between when an incident occurs and when it is detected by the algorithm. The false alarm rate is generally used to provide an indication of how many times the algorithm incorrectly indicates that an incident condition exists when, in fact, no incident is present.

As shown in figure 8-3, there is a general relationship that exists between detection rate, false alarm rate, and detection time. With most incident detection algorithms, the false alarm rate increases as the detection rate increases. Also, the false alarm rate increases as the detection time decreases. This is because as the sensitivity of the algorithm is adjusted to detect less severe incidents more quickly, minor fluctuations in traffic can trigger the algorithm to signal that an incident is present, when in fact no incident exists on the freeway.

Agencies must decide for themselves what is an acceptable balance between detection sensitivity and false alarm rate for their detection system. False alarms can be tolerated in order to achieve a higher detection sensitivity, so long as they are not too frequent and liable to be ignored by the system operator. Evaluation of false alarm rates should generally be based on the their frequency over a given time period (i.e., hourly or peak period). An algorithm may be reported as having a very small false alarm rate percentagewise (based on the total number of detection "checks" it performs), but yield a fairly high number of false alarms because the total number of such "checks" made during a given time period is so high.

The four general categories of incident detection algorithms that rely on volume, speed, and or occupancy data include the following:[21]

- Comparative.
- Statistical.
- Time-series/smoothing.
- Modeling.

Comparative (or pattern recognition) algorithms compare traffic parameters at a single detector station or between two detector stations against thresholds that define when incident conditions are likely. Statistical algorithms use statistical techniques to determine whether observed detector data differ statistically from historical or defined conditions. Time series and smoothing algorithms compare short-term predictions of traffic conditions to measured traffic conditions. Modeling algorithms use standard traffic flow theory

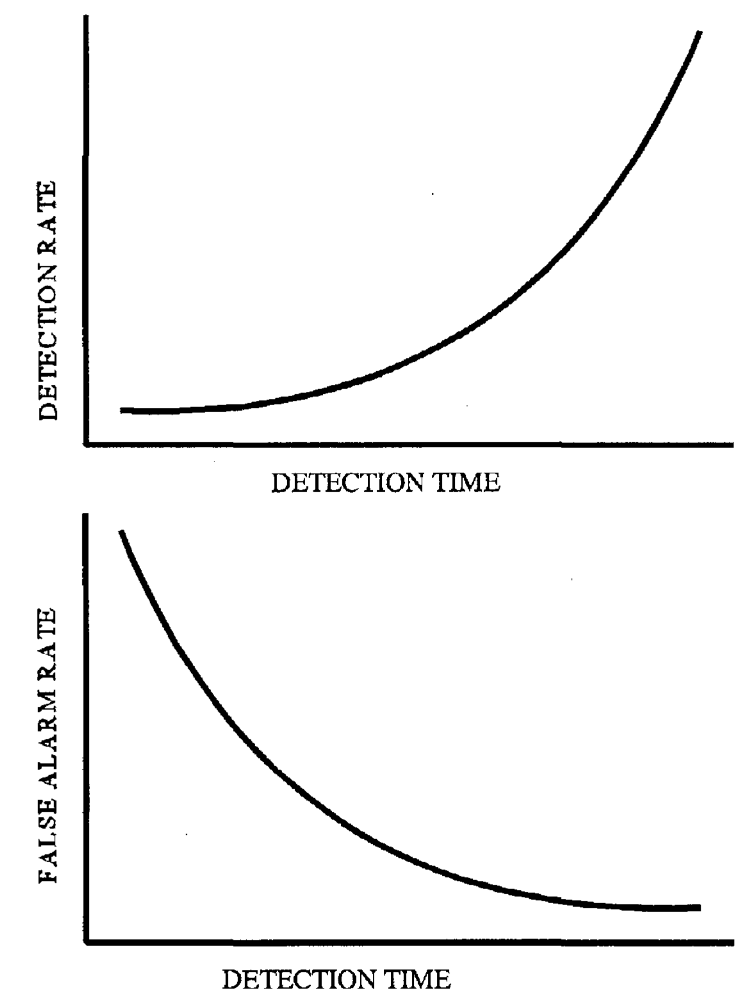


Figure 8-3. Relationship between Detection Rate, False Alarm Rate and Detection Time.[20]

to model expected traffic conditions on the basis of current traffic measurements. Table 8-8 lists the algorithms available in each category.

A recent review of the algorithms indicated that two of the Modified California Algorithms (#7 and #8) and the McMaster Algorithm rated the highest on the basis of reported performance, operational experiences, and model complexity. When calibrated properly, these algorithms can be expected to achieve detect 70 to 85 percent of all incidents, while incorrectly triggering a false detection alarm about 1 percent of the time or less.[22] Conceptually, these algorithms were also judged to be easy to understand and implement from an operator's perspective.

Detectors that monitor traffic parameters other than volume, speed, and occupancy (i.e., travel times, individual vehicle movements, queue lengths, etc.) have only recently been introduced. Consequently, only limited experimental data is available on the feasibility of these technologies for detecting incidents.[23, 24] More work in this area will be needed before AVI/AVL or

Table 8-8. List of Available Incident Detection Algorithms.[22]

Algorithm Type	Algorithms	
Comparative	California All Purpose Algorithm Pattern Recognition (PATREG)	Modified California (10 different algorithms)
Statistical	Standard Normal Deviate (SND)	Bayesian
Smoothing/Filtering	Exponential Smoothing	Low-Pass Filtering
Traffic Model	Dynamic Model	McMaster

other non-traditional technologies will be viable for incident detection purposes.

INCIDENT RESPONSE AND CLEARANCE

Response is defined as the activation, coordination, and management of appropriate personnel, equipment, communication links, and information media as soon as there is reasonable certainty that an incident is present. Steps in the response process include:

- Verifying the existence and location of the incident.
- Assessing the incident to determine the type of response needed to clear it.
- Initiating the appropriate response.
- Removing the incident.

A quick and timely response by the necessary resources to clear the incident can significantly reduce its duration. The following sections provide a summary of the technologies available to facilitate incident response and clearance, and thereby reduce its total duration and impact upon travel in the region. Each category is discussed in terms of equipment, management strategies, and operations involved.

On-Site Response Techniques

One of the most critical facets of incident response is the utilization of equipment and management strategies on-site. The effectiveness of incident response is a function of both the use of appropriate techniques for the situation and how well these techniques are managed by the personnel present. A well managed response that utilizes minimal available resources can still operate more effectively than a poorly managed response that has all of the latest and greatest equipment. In the following sections, equipment and management strategies/operations relative to on-site incident response are summarized.

Equipment

Several types of equipment are available to help with on-site response. These range from items that improve the management of resources, to special-use equipment items that help reduce the response and clearance times of certain types of incidents. Some of the more effective items are discussed below.

Identification Arm Bands and Vests. These can be used to quickly differentiate respondents from members of the public or media who may also be at the incident site. Specially-designated colors and/or patterns can be provided for each of the agencies. This can reduce confusion, and help in controlling who is allowed within the incident site.[5]

Incident Response and Hazardous Materials Manuals. Having adequate documentation detailing how to handle an incident situation can significantly reduce response times. Generally, a transportation agency needs to develop two types of manuals: a response manual and a hazardous materials manual.

- *Response Manual* - The response manual outlines how to respond to specific incident situations and who should be contacted.[6] It should list all of the resources available for responding to an incident regionwide, including both public agency and private sector sources. This list should include the locations and possible operators of large tow trucks, special incident handling equipment, and equipment suitable for handling hazardous materials.

  A key to the effectiveness of these lists is a commitment to keeping them current, updating them as personnel and other resources change within the region. Agencies may wish to consider keeping the manual on-line in a computer database to help keep it current. The manual may also include other important information such as maps, diagrams of selected interchanges, milepost identifiers, utility locations, and sensitive or hazardous off-freeway facilities. It should be organized to facilitate immediate access to specific information or telephone numbers. The type of information generally included in a response manual is shown in table 8-9.

- *Hazardous Material Manual* - Although the primary rule for responding to hazardous materials spills is "leave it to the expert," it is necessary to provide those agencies who are likely to respond first to an incident scene with some basic guidelines for when they suspect that hazardous materials may be involved.[6] These guidelines should be provided in the form of a reference manual. Two hazardous materials manuals are generally developed: one for use by field personnel (e.g., police and DOT personnel) on the scene, and one for use by response dispatchers. The field manual should include guidelines on identifying types of hazardous materials and how to stabilize them at the incident scene. In addition to describing who should be contacted in case of a hazardous materials spill, the dispatcher's manual should also include more detailed information that can be used to consult and advise the field personnel as to any situation that may occur before a hazardous materials response team arrives on the scene. Table 8-10 shows potential subject matter to be included in a hazardous materials manual.

Total Stations Surveying Equipment. This equipment utilizes infrared surveying technology to measure distances critical to an accident investigation. This technique is currently being used by law enforcement personnel in several States as an aid in investigating major accidents.[25, 26]

Table 8-9. Example of Resource Material Included in Response Manual. [6]

Police State City Park Tollway County (including sheriffs) Military	**Fire/Rescue** State City Airport County Industrial Military
News Media Radio stations Newspapers Television stations Traffic reporting services (Metro, Shadow, Smartroutes, etc.)	**Local and State Agencies** Health Pollution control Agriculture Air control
Highway Department Engineering Maintenance Cleanup Traffic Management Center Tollway or turnpike authority Traffic Management Team	**Emergency Medical Services** Coroner Red Cross Funeral homes Helicopters Special medical vehicles Ambulance Hospital emergency rooms Rescue squads-extrication
Special Vehicle and Equipment Cranes Oversize wreckers Tanker trucks Trucking companies Local transit service Livestock trailers Earthmoving equipment	**Towing and Road Service** Auto clubs Franchised tow truck operators Private-gas stations, garages, junkyards Public-police, hwy authority, service patrol
Special Hazard Teams Chemical Electrical Mechanical Biological Radioactive Ordinance disposal	**Utilities** Telephone Electric Gas Water Sewer Cable
Federal Agencies Department of Energy Energy Resources Development Administration Federal Aviation Administration Department of Defense U.S. Public Health Service Defense Civil Preparedness Agency Office of Emergency Transportation Environment Protection Agency Department of Agriculture Postal Service Federal Emergency Management Agency	**Other** National Guard and Reserve Accident investigation teams Vehicle rental companies Institutions Humane society Game warden Military personnel Railroads Weather bureau Pipeline companies Water authorities Scuba divers Transportation services

Table 8-10. Example of Material to Be Included in a Hazardous Materials Manual.[6]

• INTRODUCTION
• RESPONSE AT SITE
  ○ **Information to be gathered**
  ○ **Specifics of spill**
    - Liquid/gaseous
    - Description of leak
      ■ Rate of flow/quantity spilled
      ■ Odor
      ■ Color
      ■ Density
    - Type of container
      ■ Box, box trailer
      ■ Tanker type
    - Precise labels from truck
      ■ UN numbers
      ■ Company name
  ○ **Drainage systems in area**
    - Ditches
    - Bodies of water
  ○ **Weather conditions**
  ○ **Traffic flow**
    - Number of lanes open/blocked
  ○ **Communications**
    - Communications with central command post
      ■ Fire
      ■ Other police
      ■ Ambulance
      ■ Environmental protection
      ■ Other
  ○ **Securing the scene**
    - Establish field command post
    - Cordon off area
      ■ Green zone
      ■ Yellow zone
      ■ Hot zone
    - Types of vehicles to position in each zone
    - Implement traffic diversion plans
	• RESPONSE AT CENTRAL COMMAND POST
	  ○ **Query field personnel to obtain all relevant information on spill**
	  ○ **Notify other agencies**
	    - Environmental Protection Agency
	    - Local Boards of Health
	  ○ **Notify local contractors if required for clean-up**
	  ○ **Notify personnel on scene as to protection required**
	  ○ **Notify media**
	  ○ **Utilize available literature and guides**
	    - US DOT Guidebook Chemtrec Center, Washington, D.C.
	  ○ **Notify shippers**
	
	• APPENDICES
	  ○ Drills and Training
	  ○ State Regional Coordinators
	  ○ County Offices - Boards of Health
	  ○ Traffic Control Guidelines
	  ○ Blank Forms for Environmental Protection Agencies
	  ○ Radiation Accidents
	  ○ References to Laws and Regulations
	  ○ List of References

The equipment is used to quickly obtain measurements needed to reconstruct the accident, and can significantly reduce the time required to collect the necessary data to reconstruct the accident. It also allows more accident-related information to be collected with greater accuracy. A supporting computer system is required to achieve the maximum benefits. In addition, training and continued use is required to ensure that the officers are using the equipment properly. For example, the Maryland State Police have three "crash" teams which operate total stations equipment and are proficient in its use. They are on call 24 hours a day and report to an incident within 30 minutes.

Inflatable Air Bag Systems. These can be used to right overturned heavy vehicles.[5] The system consists of several heavy rubber inflatable cylinders of various heights. These bags are placed under the overturned vehicle at strategic locations, and inflated to right the vehicle. This system can be used in almost any location to right an overturned vehicle. Wreckers are still required to assist in the process, and, depending upon the size and shape of the vehicle, some vehicles can puncture the bags. Most large-scale towing and recovery specialists in large metropolitan areas have this type of equipment available. Appropriate contracts may need to be established between public agencies and these specialists to ensure that the equipment is available for use in an incident.

This type of system is ideal for righting vehicles with fragile loads or tankers where other means of righting the vehicle may rupture or damage the cargo. It is also ideal for working in constrained areas, such as tunnels, bridges, and overpasses, where larger towing or response vehicles may have difficulty maneuvering. Figure 8-4 illustrates the use of an air bag system.

Equipment Storage Sites. These sites are key locations, normally suffering from high incident rates, where incident response equipment is stored (particularly traffic control devices). To be effective, they need to be easily accessible and used by all response agencies. Also, agreements must be established as to who will stock and maintain the equipment and materials contained at the storage sites.[5]

Tow Truck/Removal Crane Contracts. These contracts can achieve minimum response times in specific sections of freeway. Tow trucks can be summoned to an incident location either by using a rotation list (in which each wrecker service in a specific section of freeway is called in order) or by securing a bid contract for service for a specific section of freeway. The use of tow truck contracts or agreements may require local agencies to adopt ordinances that ensure that existing wrecker services are not adversely affected. It is also essential to have a local ordinance providing the police with the authority to establish wrecker contracts, to lay the ground rules for using such contracts, and to determine penalties for non-compliance by wreckers with the ordinance. Some requirements that are commonly used in wrecker contracts include the following:[1]

- Minimums on equipment, storage space, insurance, and licensing.
- Specifications calling for the availability of heavy duty towing and recovery equipment.
- Twenty-four hour availability of wrecker service.
- Specified minimum response times (30 minutes is commonly used).

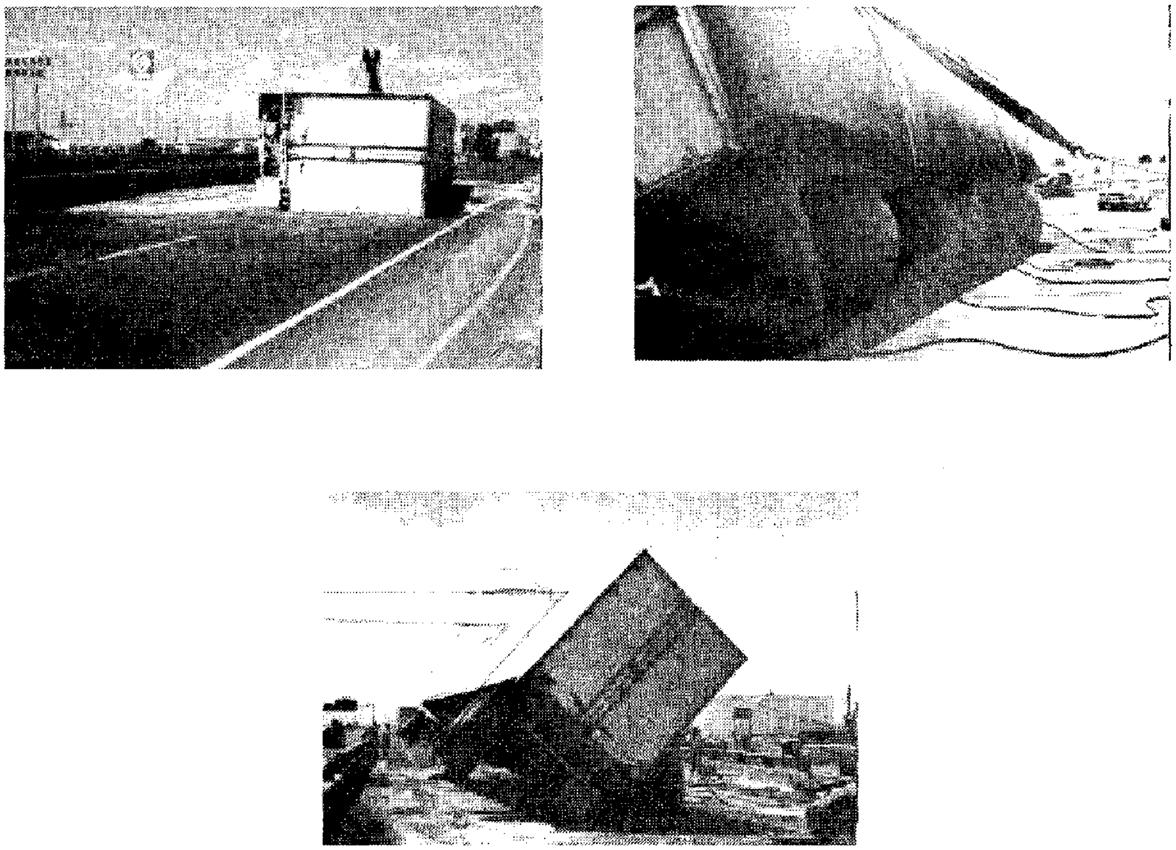


Figure 8-4. Air Bag Use to Overturn Tractor Trailer.

Management Strategies/Operations

In addition to special equipment to facilitate on-site response, a number of management strategies can be developed and invoked, as necessary, to assist in the response process, as summarized in the following sections.

Emergency Response Vehicle Parking Coordination. This coordination may be enacted to help facilitate an "order" as to the number of response vehicles parked in travel lanes at an incident site and how other response vehicles will be parked on the shoulder or similar off-roadway location in the most efficient manner possible. This "order" may differ depending on the type of incident.[5] However, the overall goal is to minimize the amount of maneuvering required by the different response vehicles, to ensure that no more space is taken up by the incident scene than is necessary, and that lanes can be reopened with minimal movement of response vehicles or disruption of incident clearance activities.

On-Site Traffic Control. This control is required to facilitate the orderly movement of traffic past the incident site or off of the freeway (in the case of a total freeway closure).[27] Channelization of traffic can be accomplished with flares or cones, depending on the anticipated duration of the incident. If the incident is anticipated to last several hours or days, a more elaborate traffic control plan, similar in content to a work zone lane closure set-up, should be employed. Figures 8-5 and 8-6 illustrate typical set-ups for traffic flow past an incident site and diverted completely from the freeway, respectively.

Incident Response Teams. These teams are often needed to clear major incidents. By assembling a major incident response team prior to an actual incident, a faster and more coordinated response can be provided.[1] Most major incident response teams are composed of individuals from law enforcement, traffic engineering, maintenance, and fire and emergency services. These individuals should be of sufficient rank to make decisions about committing the resources of their agencies without further approval from their superiors.

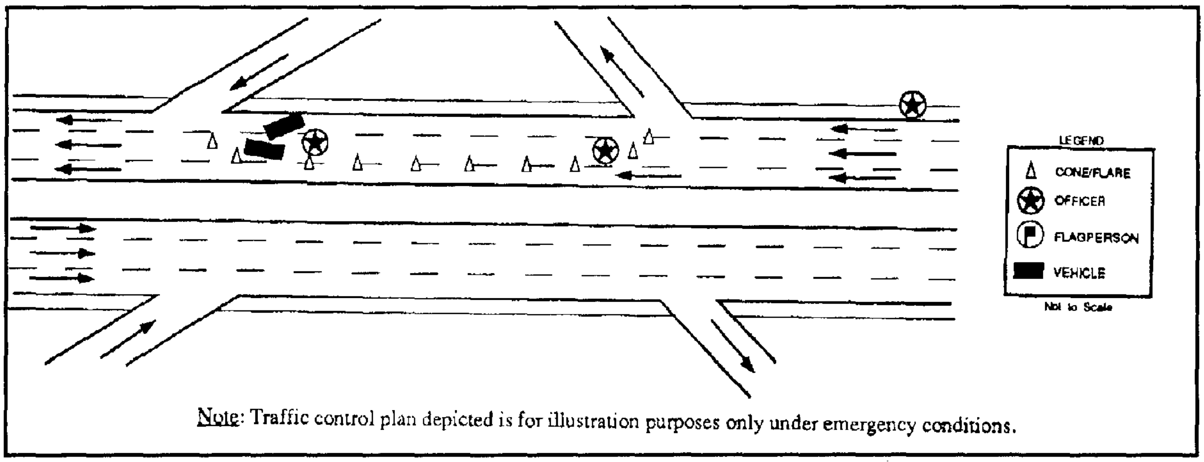


Figure 8-5. Typical Set-up for Traffic Flow Past a Freeway Incident. [27]

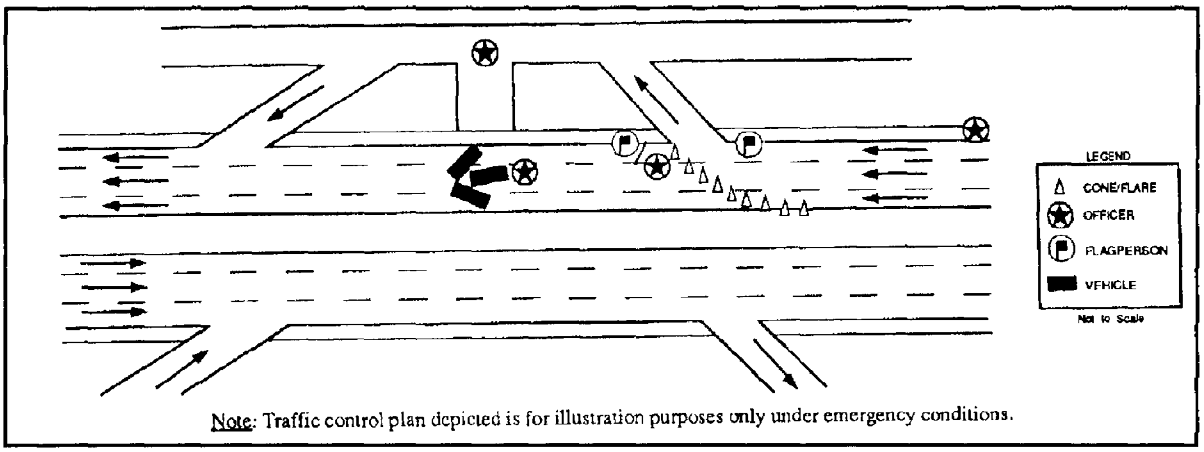


Figure 8-6. Example of a Typical Total Freeway Closure at an Incident. [27]

At a major incident, the team is responsible for assessing the situation and coordinating the implementation of a prepared response within each member's own agency. The team can also make on-site adjustments to the plan to conform to the specifics of the situation. Examples of the types of decisions that will be required by team members include:[1]

- Where traffic will be diverted.
- How and when the wreckage will be cleared.
- How and when repairs to the roadway will be made.
- When the roadway can be partially reopened.

The most important aspect of a major incident response team is that the same individuals report to the incident scene each time, and are familiar with the personnel, authority, and resources of each of the responding agencies. The major function of the team is to handle all logistical problems in support of the incident commander, and to smoothly transfer control of the scene from one agency to another as the incident progresses. Also, the team can be the single source for information to the media, so that consistent information is given out. One means of effecting ongoing improvement in incident response team operations is to hold post-incident debriefings to evaluate procedures and identify areas of improvement.

Vehicle Removal Laws. These laws are legislative or administrative policies that promote the fast removal of disabled, abandoned, or damaged vehicles that constitute a hazard to other motorists. Local laws or ordinances can be enacted that require motorists to move their vehicles (if driveable) off the freeway immediately after an incident. These laws can also define the maximum time limit for leaving a vehicle unattended in the right-of-way, and can establish procedures for removing vehicles by local authorities with push bumpers or tow trucks. To be effective, the enactment of these laws must be followed up with an extensive publicity campaign informing motorists of what to do in case of an incident. Local agencies must also translate the new laws or policies into effective operating procedures and must provide a mechanism for enforcing the new law.

Techniques to Improve Emergency Vehicle Access and Traffic Flow

The next category of techniques to be discussed are those related to improving vehicle access to, from, and around an incident. Whereas the controlled-access and barrier-protected designs of freeways promote the highest degree of safety possible, they are problematic when it comes to trying to get emergency vehicles to an incident site when traffic has queued behind the incident. Equipment and management strategies relative to vehicle access are discussed below.

Equipment

Barrier Openings. These openings can be designed into freeway sections with inadequate access for emergency vehicles, thereby reducing the time it takes for those vehicles to reach an incident location. However, adequate crash cushion protection must be provided for the exposed end of the barriers. Also, an improperly designed opening can be a temptation to freeway motorists to use as a turn-around if they miss an intended exit.

Barrier Gates. These gates have been used in some jurisdictions to combat unauthorized vehicle use. The gates are kept closed and locked until access is needed by an authorized vehicle. One of the major concerns with previous gate assemblies, however, has been with their crash worthiness. Houston has recently installed new remote-controlled barrier gate systems that the developers claim will meet NCHRP Report 350 standards for longitudinal barrier crash worthiness.[28] Figure 8-7 shows this barrier gate.

Emergency Ramps. As agencies reconstruct their aging freeways, entrance and exit ramps are often removed or relocated to improve freeway operations. Unfortunately, this can also reduce the ability of emergency vehicles to reach an incident scene. In some instances, emergency ramps are employed to maintain emergency freeway access. These ramps are closed to regular traffic, but can be utilized by authorized vehicles through a manual or electronic gate system.

Management Strategies/Operations

Police Escorts and Wrong-Way Entrance of Non-Emergency Response Vehicles. This strategy can yield significant incident response benefits. Since both towing services and most DOT equipment utilize yellow flashing lights, it is difficult for them to reach an incident scene. Providing for police escorts of these vehicles, or allowing them to enter the freeway in the wrong direction (i.e., from downstream of the incident) can reduce access times of these

Figure 8-7. Example of Crash Worthy Barrier Gate.

vehicles. Of course, this strategy must be planned beforehand and implemented through ongoing training efforts.

Shoulder Utilization. This management technique has been successfully used to increase traffic flow capacity around an incident site. This is normally implemented best by uniformed officers positioned upstream of the incident site.. For this technique to be effective, a minimum of 3 m of clearance is needed from the outer edge of the paved shoulder to the incident or any emergency vehicles that are needed at the response scene. Figure 8-8 illustrates the set-up of a shoulder utilization technique at an incident site.[28]

Contraflow Diversion. This technique can sometimes be used at an incident site that will close the entire freeway for several hours. This involves getting traffic across the roadway median (or across the concrete barrier via a barrier opening or gate as described earlier), utilizing a travel lane from the opposing traffic direction to bypass the incident, and returning the traffic back to its original side of the freeway. It also requires close coordination between law enforcement and transportation personnel, and is generally warranted for only the most severe, special cases. Figure 8-9 illustrates a contraflow diversion set-up at a freeway incident site.

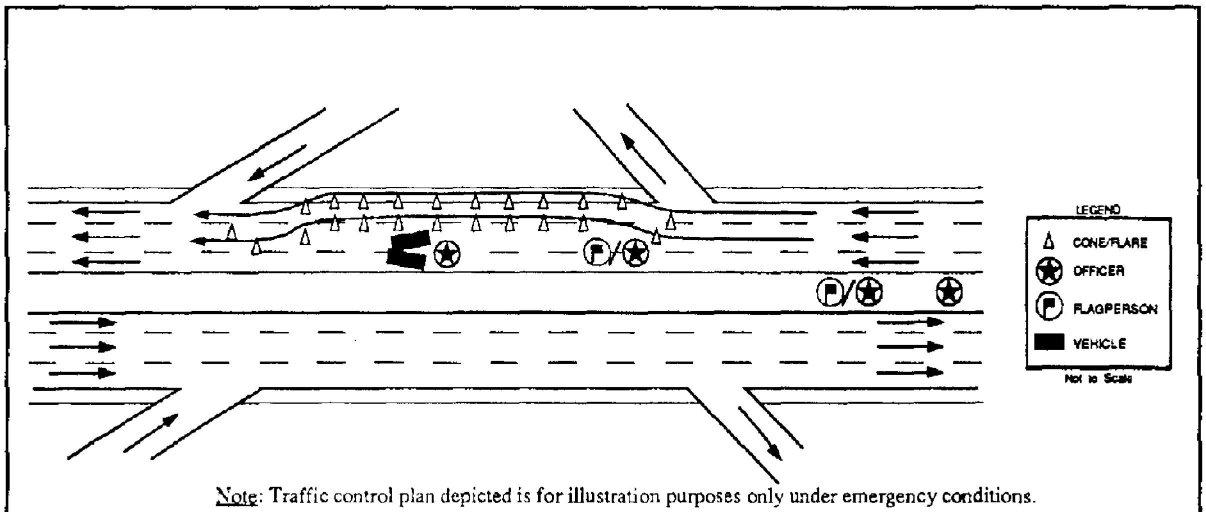
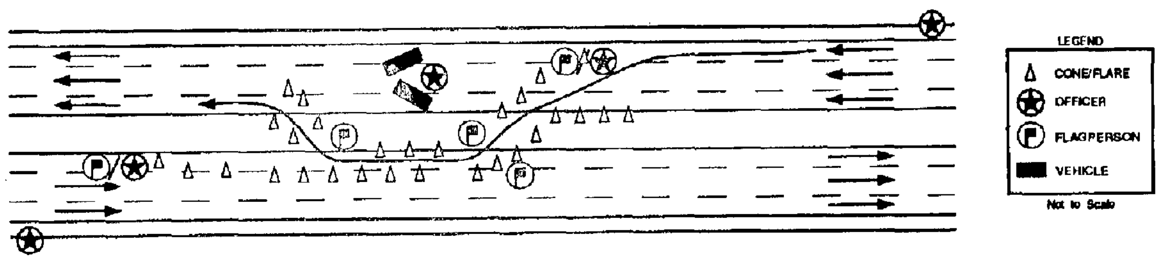


Figure 8-8. Example Set-Up for Shoulder Utilization at a Freeway Incident Site. [27]



Note: Traffic control plan depicted is for illustration purposes only under emergency conditions.

Figure 8-9. Example of a Contraflow Diversion Set-Up at a Freeway Incident. [27]

Accident Investigation Sites

Accident investigation sites are special designated and signed areas off the freeway or roadway where drivers of damaged vehicles can exchange information, and police and motorists can complete necessary accident report forms. These sites can also serve as an incident relocation point by agency-operated clearance equipment and as a media assembly location. In order to reduce rubbernecking, accident investigation sites are generally located so that motorists involved in an accident, the investigating police officer, and the tow truck operators are out of view from the freeway. The benefits of an accident investigation site include reduced motorist delays, reduced vehicle operating costs, reduced secondary accidents, reduced pedestrian exposure, and more efficient use of a public agency's personnel. Unfortunately, such sites have not been well received by the public or law enforcement in some instances, due to security concerns, poor access, or a general lack of awareness about their existence and location.

Equipment

Typical locations of accident investigation sites include under a freeway overpass, on a side street or parallel frontage road, or in a shopping center parking lot out of view of the freeway. An accident investigation site should have space for parking a minimum of five vehicles. This equates to a minimum size of 92 square m. Also, there should be a minimum of 31 m, longitudinally, to pull into and out of curb parking accident investigation sites.[29] Figure 8-10 illustrates examples of accident investigation site design.

Management Strategies/Operations

The criteria for locating an accident investigation site includes the following: [29]

- Easy access to and from the freeway.
- Sufficient overhead lighting and other provisions to ensure personal safety.

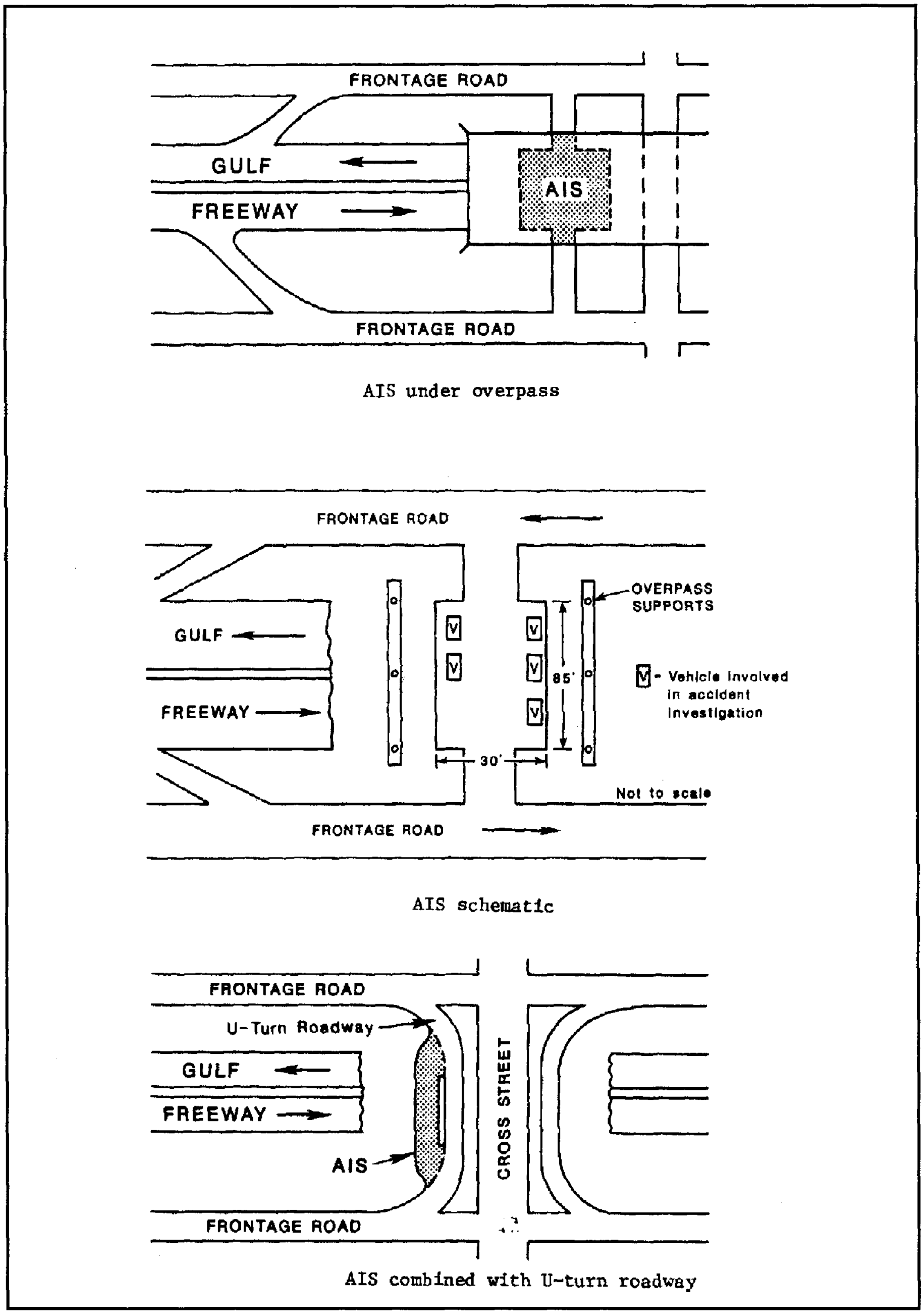


Figure 8-10. Examples of Accident Investigation Site Locations.[29]

- Concealed from the freeway.
- Well delineated and signed.
- Located near a high accident location.
- Little or no construction required.
- Access to a public telephone.

Also, the provision of accident investigation sites must be supported by proper vehicle removal legislation and by law enforcement personnel in order to be effective.

Freeway Service Patrols

Freeway service patrols are a major tool for combating the effects of incidents in metropolitan areas. The primary objectives of service patrols are to locate incidents, reduce the risks to motorists and patrol personnel around the incident, and reduce incident duration so that full capacity can be restored to the freeway as quickly as possible.

Equipment

Typical service patrols rely on light-duty trucks or vans, equipped with a wide assortment of supplies that could be needed to assist a stranded motorist. Some agencies, such as the Illinois DOT in Chicago, use medium-duty wreckers in their service patrol fleet to allow them to quickly relocate automobiles ans small trucks from the freeway lanes. Some of the more common supplies include the following:

- Gasoline.
- Water.
- Tools for minor automotive repair.
- Jumper cables.
- Flares.
- First-aid kit.
- Warning lights.
- Push bumpers.

Access to more extensive and specialized equipment may need to be worked out through private-sector agreements or by other methods. This equipment includes such things as heavy-duty tow trucks, removal cranes, sand spreaders, and rescue and extricator trucks. For large incident management operation in a major metropolitan area, this equipment will need to be accessible 24 hours per day, 7 days per week. [30]

Management Strategies/Operations

Freeway service patrols can be operated from stationary points to deal with spot locations (i.e., bridges, tunnels, construction zones, etc.), dispatched on a call-in basis, or circulated throughout a coverage area (the preferred method for dealing with larger freeway sections).[12] They can be organized and funded by several different organizations:[17]

- Enforcement agencies.
- Transportation agencies.
- Private organizations.
- Multijurisdictional cooperative arrangements.
- Private sector contracts with public agencies.

Electronic Traffic Management and Control Techniques

Equipment

The various traffic management and control components of a freeway management system are intended to assist in incident management activities. These components help to warn motorists approaching the incident about downstream traffic conditions, advise about reduced advisory speeds, reduce approaching traffic demands, and adjust control settings on other roadways that are accommodating increased traffic volumes due to diversion from the freeway. The management and control components that can be used for this purpose include ramp metering and information dissemination.

Ramp Metering. Ramp metering can be implemented upstream of incidents to reduce traffic demands entering the freeway. This technique requires metering of all entrance ramps along a section of freeway (since incident locations vary) and real-time control of these ramp meters.[31] Ramp metering typically operates during peak traffic periods, and may be adjusted slightly if an incident occurs during these periods. However, implementation of ramp metering explicitly for incident management during off-peak periods (when ramp metering is not normally operating) is less common. Additional information regarding ramp metering can be found in **Module 5**.

Information Dissemination Components. These components are typically activated to warn motorists upstream of an incident which travel lanes are closed and to encourage motorists to leave the freeway early or not enter the freeway at all. Notification can occur via any of the different information dissemination technologies (discussed in **Module 7**) present within the region, but must be coordinated and managed so that the information remains current (particularly with respect to location, expected duration, and its impact upon traffic conditions).

Management Strategies/Operations

Although the exact location, severity, and other characteristics of any given incident cannot be predicted in advance, some level of planning is appropriate for the management and operation of both ramp metering and motorist information subsystems for incident response. Table 8-11 summarizes some advance planning steps to facilitate the use of certain information dissemination technologies for incident response.

Alternative Route Diversion Techniques

Alternative route planning is a systematic process that involves examining where and how much traffic should be diverted whenever an incident or other blockage occurs on any section of freeway at any time of the day. In effect, alternative route contingency plans are developed for various levels of freeway incidents anywhere in the system.[12] Coordination and cooperation with local agencies during alternative route plan development is essential for these routes to be safely and effectively implemented when needed.

Alternative route planning involves determining not only where and how much traffic should be diverted, but also when diverting traffic would produce positive benefits. Since diverting traffic to alternate routes is often politically sensitive, how long a freeway is to remain closed before an official detour route is established is often a policy decision. For example, some areas

Table 8-11. Advance Information Dissemination Planning for Incident Response.[Adapted from 1]

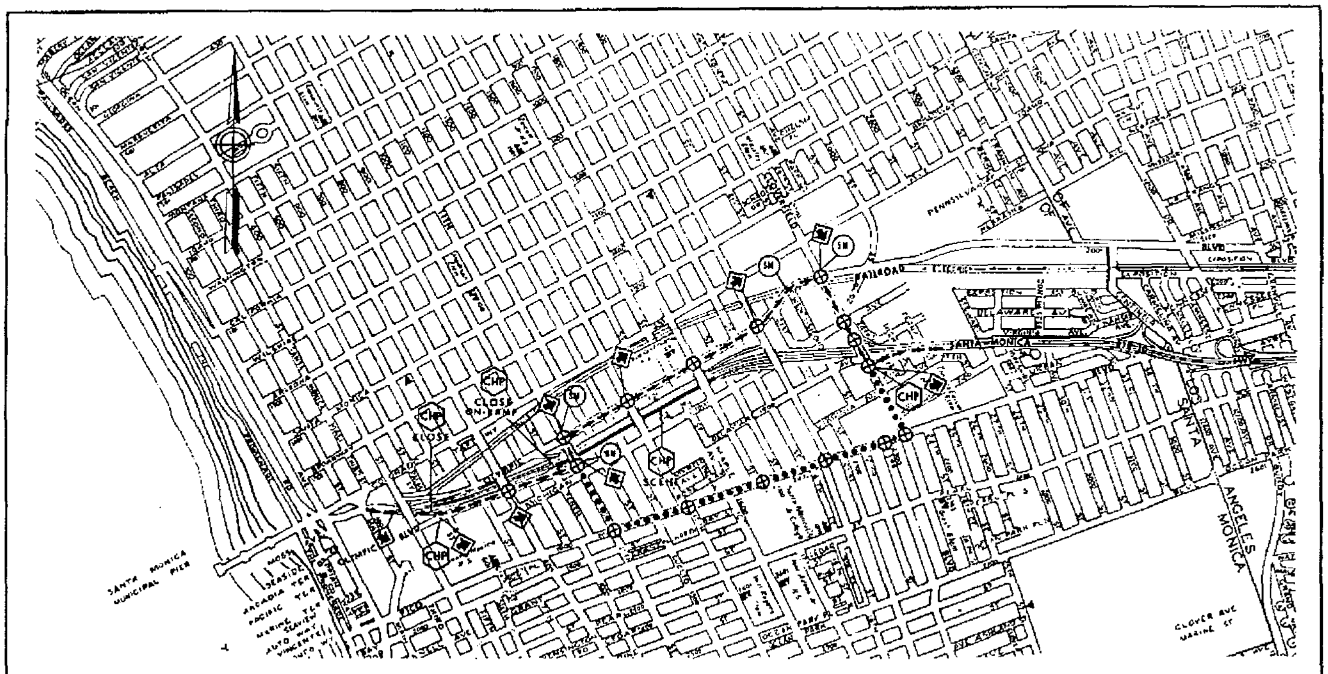
Technique	Planning Required
Variable Message Signs	• If messages are not computer selected, establish responsibilities for message selection and display. • Establish criteria for message selection/display. • If portable, establish dispatch procedures.
Highway Advisory Radio	• If messages are not computer selected, establish responsibilities for message composition and recording. • Establish criteria for message selection/activation. • If portable, establish dispatch procedures.
Private-Sector Information Service Providers (ISPs)	• Information transfer protocols and agreements need to be established between ISPs and agencies providing data.
Commercial Radio/Television	• Set up means for transfers of information to radio/television stations. • Meet with station managers to establish guidelines for reporting frequency. • If information not transmitted by computer, set up procedures and responsibilities for message transmissions.
Print Media	• Define formats for press releases. • Set up procedures and responsibilities for issuing press releases.
Telephone Hotlines	• Set up procedures and responsibilities for message updating and recording.

divert traffic only when an incident is likely to last more than one hour.

Equipment

The information needed on any alternative route plan may differ from jurisdiction to jurisdiction. Most commonly included are specifications about the equipment and manpower that will be needed to implement the specific plan, such as police officer control locations, barricades, signing, etc.[12]

Initially, alternative route plans were prepared on hardcopy printouts that were distributed to law enforcement personnel and to the incident response team. An example of an alternative route plan is provided in figure 8-11. Recently, however, these plans have began to be converted to computerized format on Geographic Information System (GIS) or other platforms to assist in organization and retrieval. Methodologies are also being developed to computerize



STAGES OF IMPLEMENTATION

NO. OF LANES CLOSED

	ESTIMATED DURATION	1	2	3			
MID	1 HOUR	—	I	IV			
TO	2 HOURS	I	II	IV			
0500	2-6 HOURS	III	III	IV			

	ESTIMATED DURATION	1	2	3			
0500	1 HOUR	II	III	IV			
TO	2 HOURS	III	III	IV			
1900	2-6 HOURS	III	III	IV			

	ESTIMATED DURATION	1	2	3			
1900	1 HOUR	II	III	IV			
TO	2 HOURS	II	III	IV			
MID	2-6 HOURS	II	III	IV			

I FIELD CHECK ALTERNATE ROUTES
II ALTERNATE ROUTE TRAFFIC ADVISORIES
III OFFICER & SIGN DEPLOYMENT (VOLUNTARY DIVERSION)
IV EMPLOY ALTERNATE ROUTE (MANDATORY DIVERSION)
V CLOSE FREEWAY CONNECTORS
VI BARRICADE ON-RAMP & CONNECTOR CLOSURES
NOTE ROMAN NUMERALS ARE STAGES OF IMPLEMENTATION UP TO AND INCLUDING THE STAGE SHOWN

PERSONS TO NOTIFY

AGENCY	TEL. NO.
CALIFORNIA HIGHWAY PATROL	213 620-3456
DEPT. OF TRANS. MAINT. COMM	213 620-2370
SANTA MONICA POLICE DEPT	213 391-9931

LEGEND

- LIMITS OF CLOSURE
- PRIMARY ALTERNATE ROUTE
- SECONDARY ALTERNATE ROUTE
- SIGNALIZED INTERSECTION
- STOP SIGN INTERSECTION
- SIGNING
- CHP CALIFORNIA HIGHWAY PATROL
- SM SANTA MONICA POLICE DEPT
- FIRE STATION

LIMITS OF CLOSURE

BETWEEN LINCOLN BLVD ON-RAMP AND 20TH ST OFF-RAMP

ALTERNATE ROUTES

PRIMARY:
LINCOLN BLVD OFF-RAMP TO E/B OLYMPIC BLVD TO N/B 11TH ST TO E/B OLYMPIC BLVD TO S/B CLOVERFIELD BLVD TO ON-RAMP

SECONDARY:
LINCOLN BLVD OFF-RAMP TO E/B OLYMPIC BLVD TO S/B 11TH ST TO E/B PICO BLVD TO N/B CLOVERFIELD BLVD TO ON-RAMP

SPECIAL NOTES:

OTHER - CLOVERFIELD BLVD ONE LANE

YES NO
☐ ☐ MEDIAN SHOULDER OK FOR TRAFFIC
☐ ☐ OUTSIDE " " " "
(MAJOR PORTION OF CLOSURE AREA, FIELD CHECK AT INCIDENT AREA)

ALTERNATE ROUTES

SANTA MONICA FREEWAY
ROUTE 10
EASTBOUND

DATE REVISED 10/75

LA-10-E24

Figure 8-11. Alternative Route Plan.[12]

some of the decision-making processes involved in alternative route selection. [32]

Management Strategies/Operations

Planning of alternative routes must be done by a team consisting of State and local transportation and enforcement agencies, as a minimum.[12] Not all arterials near a freeway may be desirable alternative routes. Features that make an arterial undesirable as an alternative route include the following:

- Schools.
- Hospitals.
- "Sensitive" neighborhoods.

Work Zone and Special Event Traffic Management

Work zones and special events constitute a special type of incident in that the location and duration are usually known in advance. This allows agencies to analyze beforehand the potential impacts of a work zone or special event, and if necessary, to develop a customized package of transportation system improvements to mitigate those impacts.

Equipment

General guidelines for traffic control are provided in the *Manual on Uniform Traffic Control Devices.*[33] In addition, various state and local agencies adopt their own version of these guidelines. These guidelines cover appropriate advance signing, barricades, channelizing devices (where lanes are to be closed) and other approved devices. Many of these devices are appropriate for site control at and near special events as well.

Management Strategies/Operations

The *MUTCD* also provides guidance on appropriate management strategies for various types of work zone lane closures, indicating such things as minimum cone taper lengths, locations of advance signing, and proper layout of channelization devices. These guidelines are dependent upon the duration of the scheduled work activity, the time of day, the roadway type, and the operating conditions.[32]

Major freeway reconstruction activities and special events place tremendous demands upon the freeway and surrounding surface street system to accommodate unusual traffic patterns. The planning horizon available for these types of activities allows for a number of demand management strategies to be implemented within the freeway corridor, if appropriate. Table 8-12 summarizes some of the impact mitigation strategies that have been implemented at a sample of major reconstruction projects and special events nationwide.[12]

8.4 LESSONS LEARNED

WATER ACCESS

Not all incident response and management activities must involve a high degree of technical complexity in order to provide a significant benefit to the public and to incident response agencies. Often, simple low-tech solutions can offer substantial benefits to a response agency or to the public.

In San Antonio, for example, officials have commented about problems encountered when trying to combat vehicle fires on elevated freeway sections. Simple standpipe assemblies that provide a fire department with access to a fire hydrant from an

Table 8-12. Traffic Management Actions During Major Freeway Construction and Special Events. [12]

Types of Actions	Actions Implemented
Actions to Improve Alternative Routes	Traffic signal timing adjustments Traffic signal equipment improvements Left-turn restrictions at critical locations Parking restrictions Police control of critical intersections Reversible lanes Implementation of alternating, one-way pairs Intersection widening and channelization Resurfacing and other pavement repairs Signing and lighting improvements Use of real-time information systems to encourage diversion Constructing temporary pedestrian overpasses at vehicle/pedestrian conflict points
Actions to Improve HOV and Transit Utilization	New or expanded commuter rail service Expanded rapid transit service New or expanded bus service Implementation of HOV only ramps and lanes New or expanded park-and-ride lots New or expanded ridesharing programs Eliminating or moving single occupant vehicle parking locations Increasing parking fees for single occupant vehicles
Actions to Improve Public Understanding, Cooperation, and Acceptance	Traditional P-R tools (press conferences, new releases) Special publications Toll-free hotlines Highway advisory radio systems Special freeway signing Employment of an ombudsman Rescheduling event start and end times to avoid peak periods Developing agreements with trucking agencies to avoid peak period deliveries

elevated freeway section can greatly facilitate their response capabilities. In other jurisdictions nationwide, the DOTs and fire departments have worked together to mark the location of hydrants, and to provide access doors through noise barrier walls to connect to hydrants on the other side.

SERVICE PATROL CHARGES FOR ASSISTANCE

A question often arises relative to courtesy patrol operations about whether or not to charge motorists for "service supplies" (typically gasoline) that are provided. For years, Chicago requested that motorists pay for gasoline provided by its Emergency Traffic Patrol; however, auditors recently found it more cost effective for them to give the fuel away than to try and recoup these expenses.[30] Likewise, a recent analysis of the Los Angeles service patrol system concluded that charging motorists for gasoline by that agency would cost more to administrate than would be recouped through revenues.[17] The differences in these two operational philosophies could be due to the different administrative structures utilized by each for managing service patrol operations (see the Examples section at the end of this module for a description of various service patrol operations).

TRAINING

A component of incident management that is sometimes overlooked is the need for proper training and retraining. This is particularly important for dealing with larger-scale incidents that involve multiple agencies. Because these types of incidents may occur very infrequently (hopefully), it is difficult to test out the processes and procedures that have been developed for these situations beforehand. In addition to working out the "kinks" of coordination, training also helps to demonstrate to incident response personnel the need for, and benefits of, some of the procedures and protocols that have been established. Methods of training for such large events include the following: [19]

- Workshops.
- Conferences.
- Instructional videos.
- Mock disaster exercises.
- Post-incident debriefings.

It appears that the liability an agency bears for failing to properly train its personnel to react to normal day-to-day situations is slowly being extended in the courts to cases involving more dynamic emergency situations.[34] In the future, if it can be proven that adequate training to handle emergency situations could have prevented injuries or damages, an agency may be forced to assume at least some liability for failing to provide that training.

Interagency training is also important. Fire departments, for instance, can provide training for police and DOT personnel in hazardous materials identification and response.

8.5 EXAMPLES OF FREEWAY SERVICE PATROLS

CHICAGO EMERGENCY TRAFFIC PATROL

The Chicago Emergency Traffic Patrol (ETP), also known as the "Minutemen" patrol, began operations in 1961 as an Illinois DOT effort. This program is an example of a completely State-DOT-operated project. The ETP consists of 58 drivers, 35 patrol vehicles, 11 light-duty four-wheel drive vehicles, three heavy-duty tow rigs, a crash crane, a tractor-retriever, a sand spreader, heavy rescue and extricator truck, and a hazmat response trailer.[17]

The ETP patrols 125 centerline kilometers of freeway 24 hours per day, 365 days per year.

Annually, the patrol assists at over 100,000 incidents.[30] The patrol drivers are trained to handle most incidents. They also provide fuel, water, and minor repairs, and can tow or push vehicles to the shoulder or frontage road.

Overall, the Chicago freeway management system (including the ETP and other incident management activities) have been estimated to provide a benefit-cost ratio of 17:1.[30] The ETP alone is estimated to provide an annual 9.5 million hour reduction in delay, for a $95 million delay savings per year.[35] The ETP costs approximately $5.5 million to operate annually, equivalent to about $55 per assist. Funding for the ETP comes from State taxes on motor fuel. Additional funding is being sought to equip ETP vehicles with automatic vehicle locating (AVL) systems.

MINNEAPOLIS HIGHWAY HELPER PROGRAM

The Minnesota Highway Helper program began in December 1987. The program initiated out of the Minnesota Department of Transportation's District Maintenance office, and was operated only during peak periods. In March 1993, the traffic management center in Minneapolis took over management of the program and increased operations to daytime off-peak hours as well.[17]

As of 1994, the Highway Helper program patrolled 109 centerline kilometers (68 centerline miles) of freeway. Seven pick-up trucks logged approximately 125,000 kilometers (78,000 miles) during the year, assisting 13,000 motorists.[17] According to program logbooks, about 34 percent of stranded motorists were assisted within 5 minutes of disablement. Meanwhile, 26 percent of motorists were assisted within 5 to 10 minutes of disablement, and 20 percent were assisted within 10 to 20 minutes.[17] Annual operating costs for the program are approximately $550,000.[17] A 1994 evaluation of the program yielded a benefit/cost ratio of 2.3 to 1.[37]

LOS ANGELES FREEWAY SERVICE PATROL

Los Angeles is home to the largest freeway service patrol in the U.S. The patrol was initiated in 1991, and consists of 144 tow trucks patrolling 610 centerline kilometers of freeway. The Los Angeles program contracts out the actual patrol activities to private wrecker services. Currently, 20 different towing companies are participating in the program.[17] The program is funded and administered through a cooperative effort between the following agencies:

- California Department of Transportation (jointly responsible for the overall supervision of the program).
- California Highway Patrol (jointly responsible for overall supervision and for dispatching patrols).
- Metropolitan Transit Authority (responsible for the contractual arrangements with the private towing companies).

Patrol routes and vehicle frequency were designed so that a patrol vehicle passes each point on the route every 15 minutes, which was recently verified by an evaluation of average response times.[17] Also, patrol vehicles are outfitted with automatic vehicle locating (AVL) systems that allow dispatchers to know the exact location of patrol vehicles and whether or not the unit is available to respond to a call.

On average, the Los Angeles service patrol program assists at over 750 incidents per day, equaling almost 250,000 assists per year. Funding for the Los Angeles service patrol program comes from state funds and a 0.5 percent local sales tax. Costs of the program are estimated to be between $15 million and $20 million, yielding a per assist cost of approximately $80.[35]

HOUSTON MOTORIST ASSISTANCE PATROL

The service patrol in the Houston region is known as the Motorist Assistance Patrol (MAP). This program began operations in its current form in 1989, and is an example of a cooperative venture between several public agencies and private-sector companies. Partners in the Houston MAP include the following:[36]

- Texas Department of Transportation (supervising dispatch and operations, providing space and personnel in the interim control center, partially supporting MAP personnel salaries, supporting necessary equipment purchases).
- Metropolitan Transit Authority (supervising operations, partially supporting MAP personnel salaries, supporting necessary equipment purchases).
- Harris County Sheriff's Department (providing deputies to operate the MAP vans, maintaining and operating the MAP vans).
- Houston Automobile Dealers Association (providing MAP vans).
- Houston Cellular (providing cellular phones, air time, and a toll-free number for motorists [CALLMAP]).

The program operates between 6 a.m. and 10 p.m. weekdays, patrolling 240 centerline kilometers of freeway. In 1993, Houston MAP assisted at over 25,000 incidents.[36] It is estimated that the MAP program saves 2,376,000 hours of delay on Houston freeways annually. The current funding for Houston MAP is $1.4 million per year, yielding a per assist cost of about $56.[17]

SAMARITANIA, INC.

The Samaritan program, operated by Samaritania, Inc., is an example of a privately financed service patrol. Samaritania, Inc., based in Franklin, Massachusetts, has established service patrols in the following locations:[12, 17]

- Albany.
- Boston.
- Cincinnati.
- Hartford.
- Indianapolis.
- Philadelphia.
- Providence.
- Washington, DC
- White Plains.
- Worchester.

Samaritania, Inc. seeks out large metropolitan areas, typically with populations greater than 100,000, that have significant incident traffic problems on area freeways. Potential corporate sponsors with annual receipts of over $200 million are contacted about sponsoring a service patrol. Samaritania, Inc. demonstrates the marketing and public relations benefits of such sponsorship. Once a sponsor is obtained, their logo is prominently displayed on the side of the service patrol van.

Local personnel in each area operate the patrols, and are trained in basic emergency medical procedures, traffic pattern analysis and reporting, and emergency vehicle repairs. If the motorist needs more assistance than the patrol driver can provide, the patrol driver will contact the appropriate organizations for the motorist.

Samaritania reports that 75 to 90 percent of all disabled vehicles encountered on patrol are returned to the freeway at no cost to the motorist.[17] Some of the patrols also provide traffic information to local radio and television stations for dissemination to motorists.

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MODULE 9. COMMUNICATIONS

TABLE OF CONTENTS

MODULE 9. COMMUNICATIONS

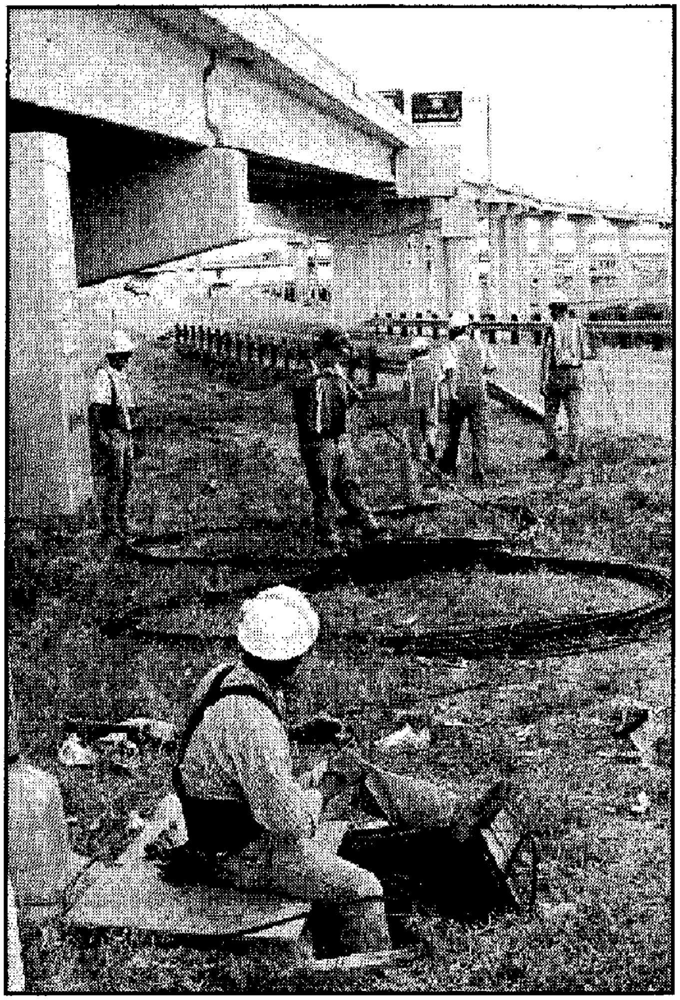

Figure 9-1. Fiber Optic Cable Installation in Fort Worth, TX.

9.1 INTRODUCTION

The communications subsystem is one of the most critical and expensive elements of a freeway management system. The function of the communications system is to link the devices in the field with the operating personnel in the control center. It is the backbone of the entire freeway management system because it allows the following types of information to be transferred from the field components and the control center: [1]

- Commands to the various field components.
- Data from the system detectors and sensors.
- Status checks of field equipment to detect malfunctions.

Typically, the communications system accounts for approximately 25 percent of the total capital costs associated with a freeway management system. Failure to plan, design, and properly maintain the communications system guarantees the entire freeway management system will have problems in achieving its operational goals and objectives. Poor planning and installation of the communication system can also result in high operating and maintenance costs. To avoid problems with the communications system, system planners, designers, and operators must be familiar with existing and emerging communication technologies and system architectures.

Three general types of communications systems are used in a freeway management system:

- A communications system allowing the transfer of surveillance data and control commands between field devices and the control center.
- A communications system allowing the computers within the control center to transfer data and displays between each other.
- A communications system allowing the operators in the control center to exchange data and information with other operators and field personnel outside the control center.

This module focuses on the first type of communications system (i.e., the communications system needed to transfer surveillance information and data, and control commands between the field devices and the control center). For information on the other types of communications systems, the reader is referred to Module 10.

MODULE OBJECTIVES

The objectives of this module are as follows:

- To outline the process that can be followed in planning and designing a new freeway management system or updating or modifying an existing freeway management system.
- To highlight the different types of communication technologies that are commonly used in a freeway management system.
- To provide insight into the issues associated with planning, designing, constructing, operating, and maintaining a communications system in a freeway management system.

MODULE SCOPE

The focus of this module is on the decision process for planning, designing, and selecting a communications system for a freeway management system. It is intended to help system designers and traffic engineers make informed decisions about communications systems. It is not intended to provide detailed information about the operation of different communications systems or technologies. For more detailed information about the different communications technologies, the reader should consult the *Communications Handbook for Traffic Control Devices* and the *Traffic Control Systems Handbook*.[1,2]

9.2 DECISION PROCESS

As with the planning and design of the other functional elements of a freeway management system, a systems engineering approach can also be applied to the planning, design, and use of a communications system for a freeway management system. An overview of the systems engineering approach is presented in **module 2**. The information in this section highlights some important issues that need to be discussed, evaluated, and decided upon as part of the systems engineering process. The user is encouraged to consult other reference materials, such as the *Communications Handbook for Traffic Control Systems* for a detailed discussion of the technical aspects associated with planning and designing a communications system for traffic control applications. [1]

PROBLEM IDENTIFICATION

The first step in planning and designing a communications system for a freeway management system is to identify the physical, institutional, and other factors that might affect the design of the communications system. System designers and planners need to collect information on the following attributes and characteristics about each of the other elements and subsystems that will be supported by the communications system. The types of information that should be gathered include the following:

- The type of data that will be transmitted by each field device.
- The content and format of the data transmitted.
- How much processing of data will occur in the field devices and where this processing will occur.
- The total number of field devices and where they will be situated.
- The type and presence of existing communications technologies near the freeway management system.
- The relative importance of the information and how a loss of communication from each device would affect the overall operation of the system.

Table 9-1 summarizes some physical, institutional, and other issues that might affect the planning and design of the communications system for a freeway management system.

One question that must be addressed in planning and designing a communications system is the type of data that will be transmitted over the communications medium: voice, data, video, or a combination of all three. A communications medium is the pathway over which a signal is transmitted (i.e., twisted wire pair, coaxial cable, fiber, radio, etc.). "Voice" is the chosen term for audio signals, since the impetus for modern communications systems was the need to transmit vocal messages over the telephone. While some freeway management applications, such as Highway Advisory Radio, still depend on voice communications, data is the most general type of information transmitted in a communications system in a freeway management system. Digital data is the most common form of transmitted information in today's communications systems. With digital data, information is represented by a combination of bits, where a bit can assume one of only two states: "0" or "1." Digital data can be physically transmitted as voltage differences between pairs of wires, light intensities in an optical fiber, frequencies in a transmission line, or phases of a radio wave. Video is animated imagery and represents the most demanding form of data transmission.

The requirements for sending video signals differ significantly from data communications requirements. Systems with

Table 9-1. Resources and Constraints Considerations in Communication Systems. [3]

PHYSICAL FACTORS

- Number and location of field cabinets to be served, and location of control center
- Location and type of existing communication facilities
  - Cable
  - Conduit
  - Pole lines
- Nature of terrain to be trenched and backfilled (conduit installation)
  - Roadway
  - Sidewalk
  - Structure
  - Railroad
  - Soil
- Nature of terrain to be spanned (aerial installation)
  - Waterway
  - Railroad
  - Elevated roadways
- Location of utility equipment and underground structures that may interfere with installation
- Air-path propagation characteristics
  - Trees
  - Hills
  - Buildings
- Climactic conditions affecting communications
  - Temperature extremes
  - Moisture
  - Lightning
  - Ice storms
- Planned or current construction activities
  - New conduit installed
  - Existing conduit removed/relocated

INSTITUTIONAL ISSUES

- Rights-of-way
- Franchise agreements between utility companies and government
  - Right of the agency to use utility conduits and pole lines
  - Responsibility of clearing ducts and utility adjustments
- Franchise agreements with CATV for government use
- Telephone company tariffs and policies
- Other agreements (formal and informal)
- National and local codes (National Electrical Code)
- Federal Communications Commission (FCC) rules and regulations
- Restrictions on work procedures and traffic maintenance
- Rules regarding different types of conduit, overhead cabling, conduit installation, junction boxes, antenna structures, etc.

OTHER

- Personnel and skill levels for communications maintenance
- Other maintenance resources (budget, contract, etc.)
- Vandalism threat
- Presence of contractors in area with skill/experience in installation of communication networks

video components generally require a greater bandwidth, and if transmitted digitally, higher signal rates. Bandwidth is the range of signal frequencies that a communications medium (or channel) will carry without excessive loss of signal strength. The bandwidth requirements for video communications vary depending on the type of transmission mode. Generally, three modes are available for transmitting video images back to a control center:

- Full motion analog video.
- Freeze frame/slow scan.
- Compressed video.

Each of these techniques for transmitting videos images to a control center is discussed in more detail in the **Techniques and Technologies** section below.

Another critical piece of information that needs to be determined before a communications system can be designed is the type of data that will be transmitted. Examples of the type of data carried by the communications system for freeway management purposes include the following:

- Volume, speed, and occupancy from field detectors.
- Alphanumeric messages for DMS displays.
- Codes to select/implement stored messages or control strategies.
- Device status and malfunction reports.
- Weather/environmental sensor data.
- Video control.

Another issue that affects the design of the communications system is how much processing of the data will occur in the field. Generally, those systems where most of the processing occurs at a central location have greater communications needs than those in which the processing of the data is distributed between the field devices and the control center. Generally, those systems where most of the data processing occurs at a central location require shorter polling cycles (the time required to communicate with all the field devices on a communications line once). Those systems that distribute the data processing generally have long polling cycles and more robust field storage capabilities. The advantages and disadvantages of having longer polling cycles are listed in table 9-2.

The total number of field devices, and their location also influences the overall design of the communications system. Generally, the more devices that need to transfer data and information within a freeway management system, the greater the communications requirements. Also, the type of communications architecture can change dramatically if the devices are dispersed over a wide geographic region. For example, using a wireless communications architecture may be more economical where few field devices are widely dispersed throughout an area. If, on the other hand, all the devices are found in close proximity, a wire-type of architecture may be more suitable.

Another important factor and/or constraint that may influence the architecture design and medium selection is the presence of existing communications systems. Often, in-place, usable cable, conduit, and field equipment can be used in a new design. Since the conduit/cable is often the major cost in a system, a plan to use existing equipment can become the least expensive communications alternative.

Table 9-2. Advantages and Disadvantages of Longer Polling Periods. [1]

Advantages	Disadvantages
• Usually results in lower data rate requirement for each field unit to perform the same functions. • Enables more field units to be serviced by a communication channel of given bandwidth or data rate. • Enables higher resolution surveillance data to be communicated. • Avoids use of data overflow schemes.	• Requires more extensive processing of data for the field devices. • Requires large field data base. • Delays transmission of data.

The relative importance of the information (and the impact the loss of the information has on the operation of the system) can have a significant impact on the type of transmission medium and architecture used in a system. Through policy, some jurisdictions may place certain constraints on the types of communications media or architectures possible. Examples of these constraints include the following: [1]

- Rejection of radio-based technologies.
- Preference for owned communications media over leased media.
- Avoidance of communication designs containing points of single failure that disrupt communication to many devices.

Maintenance of the system is also an important issue that needs to be considered in the initial planning and design of a communications system. The increasing sophistication of many newer communications media may require a level of maintenance experience and capability beyond what many local agencies may be willing to supply. Maintenance issues that need to be considered during the initial planning and design phases include the following:

- Who will maintain the communications (i.e., in-house forces, contract forces, or a combination of both)?
- How will maintenance of the communications system be funded?
- Can a simpler technology that can be maintained using in-house forces be used and still provide the same functionality as a more sophisticated technology?
- What kind of leased-line service can be used to reduce the need for in-house maintenance forces?

IDENTIFICATION OF PARTNERS AND CONSENSUS BUILDING

A final issue is what other organizations/ agencies will want, or if they would be willing to share resources in constructing and maintaining a communications system. Traditionally, transportation agencies have wanted to own and operate their own communications systems for traffic management purposes; however, the cost of installing and maintaining these systems can be substantial. As a result, many agencies are looking for methods to share the cost of installing, operating, and maintaining their communications systems. Some agencies are discovering that leasing their communication needs is the most cost-effective method. System planners and designers should attempt to identify other organizations and agencies that also need to install communications systems as potential cost sharing partners. However, along with sharing resources among agencies and organizations comes the need for building coalitions and consensus on the design of the system. Potential agencies and organizations that should be considered in the initial planning and design of a communications system include the following: (3)

- Other TMCs in the area.
- Media.
- Emergency service providers.
- Private communications providers.

The maintenance responsibilities of these agencies should also be defined during the initial planning and design of the system.

ESTABLISH SYSTEM GOALS AND OBJECTIVES

The next step is to establish goals and objectives for the system. The goals and objectives of a communications system are influenced by the goals and objectives of the other functions and systems included in the freeway management system. For example, an objective of an incident management subsystem might be to detect all incidents within two minutes of their occurrence. The goal of the communications system should be to make sure the control center has all the data it needs to detect incidents on the freeway two minutes after they occur. In this example, a communications media and architecture that results in a five-minute polling cycle of all the field detectors does not allow the incident management system to achieve its stated objective.

Agencies should develop both technical and nontechnical goals and objectives for evaluating the performance of communication alternatives. Technical goals and objectives relate to criteria that establish the effectiveness and efficiency of the communications system. Examples of nontechnical goals and objectives include the following: (3)

- The ability to provide and/or the potential for providing intra- and inter-agency data sharing.
- The potential for expanding the communication system to permit future growth and adding functions to the freeway management system.
- How much redundancy or reliability is built into the system.
- The life-span of the system (i.e., whether the system is permanent or temporary), and the potential for installing the system in phases.

ESTABLISH PERFORMANCE CRITERIA

Establishing performance criteria and measures of effectiveness is extremely important in the initial planning stages of a communications system. The criteria can be used not only to evaluate different design alternatives, but also to measure the reliability and expandability of the system. Agencies need to decide up front what represents a "good" level of operation for the communications system.

Most agencies use system reliability as the primary measure of performance for their communications system. System reliability is measured in two ways:

- Transmission errors.
- System uptime.

Transmission errors are primarily caused by noise in the communications system. Noise is any unwanted signal or disturbance of a signal that interferes with or distorts the original communication signal. Noise causes the receiver to produce incorrect outputs and errors in the bit stream that transmits the information. Noise can be caused by many factors including the following: [1]

- Temperature extremes.
- Natural radio or other electronic signals (such as lightning or cosmic/solar bursts).
- Human-made electrical signals (such as motors, car ignitions, power lines, etc.).
- Signals from another communication channel (i.e., crosstalk).

Transmission errors are measured in Bit Error Rate (BER). BER is the ratio of incorrectly transmitted bits to correctly transmitted bits. Values of about 10^{-6} or better for end-to-end communications represent an acceptable BER for most computer and traffic control communications systems. [1]

Most systems have processes to detect errors in communication signals. Table 9-3 describes the error detection techniques commonly used in traffic control systems. When an error in a message is detected, most systems either ignore the message until the next polling cycle, or request that the device retransmit the message. In either case, transmission errors reduce the effective throughput of the communications channel.

System uptime is also another common measure of performance of a communications system. System uptime represents the portion of the normal operating time of the system during which a link or the entire communications system is functioning properly. System uptime can be used to identify problem locations that might need special communication considerations (e.g., a link susceptible to outages due to construction activities or environmental conditions).

It should be noted that bandwidth is NOT a measure of system performance. Bandwidth is the range of signal frequencies that a medium or channel will respond to, or carry without excessive attenuation. [1] It is a measure of the characteristics of a system and does not tell anything about the performance of the system.

FUNCTIONAL REQUIREMENTS

The purpose of a communications system is to transfer information and data from one freeway management function to another with no loss in accuracy. Therefore, the functional requirements of the communications system need to describe how it can help the other elements of the system achieve their goals and objectives. For example, a functional requirement of a communications system might be to ensure that the volume, occupancy, and speed data are transported to the incident detection algorithm every 20 seconds. Likewise, if an objective of an incident management system is to ensure that appropriate aid is dispatched to an incident scene in response to any detected incident, a functional requirement of the communications system might be to have video images transmitted

Table 9-3. Commonly Used Error Detection Techniques. [1]

Techniques	Description
Parity (also known as vertical parity)	An additional bit is added to each data byte or character. The sum of the 1s in the byte and the additional bit must be an odd or even number as specified. This technique detects an odd number of bit errors in the byte.
Longitudinal Redundancy Check	An additional byte is provided after an entire message or portion of a message (block). A bit in the new byte is computed from the corresponding bit in each data byte in a way similar to the parity check. An odd number of bit errors is again detected. When used in conjunction with parity this is a powerful technique.
Checksum	An additional byte or character is added at the end of the message or block. An algorithm is used which computes the checksum byte as a function of the message bytes. The receiving station performs a similar computation and determines whether the checksum byte is consistent with the received data.
Cyclic Redundancy Code (CRC)	An additional two or more bytes are added to the message or block. Algorithms are used to compute these bytes which provide protection, particularly against bursts of errors.
Repeat Transmission	The entire message is repeated. At the receiving station the messages are compared and an error is detected if they are not identical.

directly to emergency service providers and police dispatchers.

The communications functional requirements need to be developed for every element in the system. The information that should be specified in the functional requirements for a communications system includes the following:

- The type of data required by each element in the system (i.e., voice, data, video, or a combination of all three of these).
- The need for one-way versus two-way communication between the element and the control center.
- The type of messages being transmitted (i.e., traffic flow data, text messages, video images, device commands, etc.).
- The frequency at which information is being transmitted or required (i.e., continuously, once every second, once every 20 seconds, once every minute, etc.).
- The desired level of control (e.g., monitoring traffic conditions vs. full operational control through field devices).
- The importance of the information (i.e., critical, important, non-critical).

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

Once the functional requirements of the communications system have been identified, the functional relationships, data requirements, and information flows also need to be identified. Generally, these relationships and requirements can be grouped in two categories: logical and physical.

Logical

The logical relationships and requirements of a communications system defines what information flows from one element to the next in the system. Generally, they can be represented by a series of data flow diagrams and process specifications that illustrate what type of information is used by each element in the freeway management system. Identifying the logical requirements and relationships requires that all the functional requirements of the system be broken down into smaller and smaller subfunctions until each process in the system can be specified. Process specifications describe the following in detail:

- The type of information needed to execute a process.
- How the information is processed or manipulated.
- What information or action is produced by the process.

The data flows is constructed by combining the data flows of the various elements (e.g., the incident management subsystem, the ramp control subsystem, the information dissemination subsystem, etc.) that are being installed in the freeway management system. The data and information flowing out of the elements are what needs to be transported by the communications system. Figure 9-2 illustrates, at a high level, a logical architecture for a typical freeway management system.

Once the logical relationships have been mapped out, the transmission mode (i.e., the direction of flow over a communications channel) can readily be determined. The following are the transmission modes commonly used in communications systems:

- Simplex.
- Half Duplex.
- Full Duplex.

Table 9-4 summarizes the characteristics and applications of each of these transmission modes. Most systems use either a half duplex or a full duplex transmission mode so that the status of the field devices can be checked and transmission errors corrected.

Physical

Once the logical relationships of the communications system has been identified, the physical design can be established. The physical design highlights how information flows from one element of the system to the next. It forms the basis for selecting the transmission media used to connect the different elements in the system. Factors affecting the selection of the physical architecture include the following:

- The number and location of the field devices.
- Distance between field devices and control center.

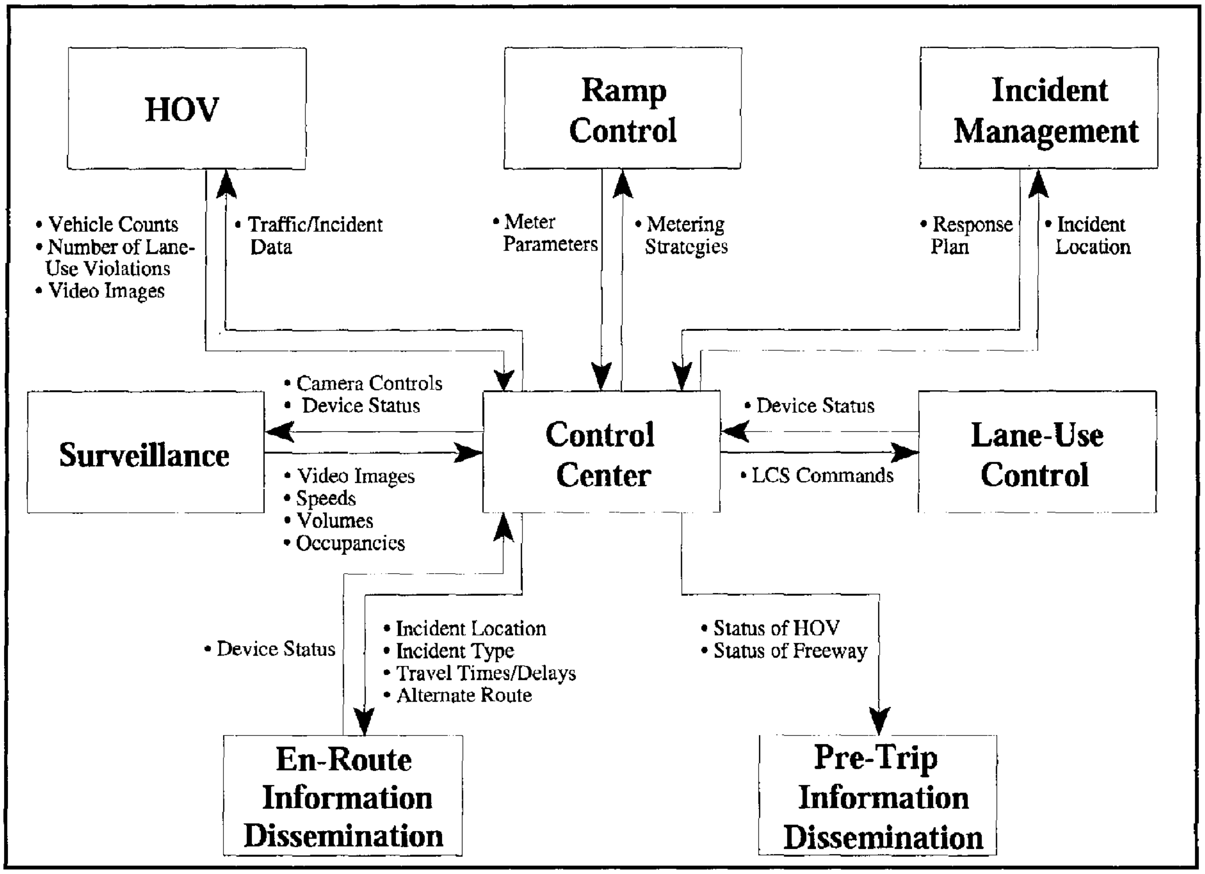

Figure 9-2. High Level Logical Architecture for a Communications System.

- Type and frequency of data being transmitted.
- Availability of right-of-way for placing communication media.
- Proximity of existing communications systems, including private communications systems.
- Presence of geologic or manufactured features that might prevent wireline connections.

The type and importance of the data have an impact on the design of the system and the type of error correction technique used. For example, with a centralized system using once-per-second communications, a single undetected error in detector data represents only one second's worth of sampling time. To discard this information would not be critical, since new information will be provided during the next polling cycle. If, on the other hand, the error occurred in a command to operate a dynamic message sign or other traffic control device, it might cause an unsafe condition on the freeway, or reduce credibility of the system. A distributed system having longer periods between updates (typically one minute for detector data, and possibly hours for controller information) requires more elaborate error correction techniques to avoid losing information caused by communication errors.

The physical architecture of most communications systems used in traffic management applications fall into the following five major categories: (1)

Table 9-4. Characteristics of Transmission Modes. [1]

Mode	Data Flow Direction	Characteristics	Comments
Simplex	Data flow in one direction only.	• Does not provide verification that data were received and acted upon. • Does not provide answer-back, status reporting, or validity checking.	• Commercial radio and television are examples. • Traffic control systems which provide no return information to a master controller or traffic operations center use this mode.
Half Duplex (HDX)	Data flow in either direction, but only in one direction at a time.	• Requires modem at each end of the line. • Requires control capability to assure proper operation. • Uses latency time or turnaround time (the time period required to turn the line around) for the process in which the direction of data transmission is reversed, which can be time consuming.	• In a copper wire transmission medium, HDX requires two wires but may be used with four wires (four wires provide improved interference characteristics).
Full Duplex (FDX)	Data flow possible in both directions at the same time.	• Acts like two simplex channels in opposite directions. • Permits independent, two-way, simultaneous data transmission • May raise cost of channel. • Reduces the one-way capacity if frequency multiplexing is used on a single channel.	• In a copper wire transmission system, some FDX modems require four wires while others require only two wires. In the latter case, the modem divides the channel into two subchannels to achieve simultaneous bidirectional service.

- Central.
- Distributed.
- Trunked.
- Backbone.
- Multimedia.

Characteristics of these communications architectures are summarized in table 9-5.

Central

A *Central* communications architecture is one that possesses only one level of communication before the signal reaches the field controller. In other words, all of the field devices link directly to the control center. Because data flows directly from the field devices to the control center, it is not processed along the way. As a result, only one data rate exists between the field controller and the control center. Because the field devices and the control center are linked directly, central communications architectures require only one

Table 9-5. Common Applications of Communications Architectures. [1]

Traffic System Communications Architecture	Common Application	Examples
Central	Communication requirements limited to a small number of field controller and video channels at each field location.	• Traffic signal systems controlled by computer at traffic operations center. • Small or medium sized freeway surveillance systems with limited video.
Distributed	Traffic control system computations performed at locations other than traffic operations center and field controllers.	• Closed loop traffic signal control systems.
Trunking	Achieves economies by concentrating data onto high speed channels for long runs to traffic operations center.	• Large freeway surveillance systems with long runs to traffic operation center.
Multimedia Channel	Geometrics and/or economics render single medium impractical.	• Signal systems and freeway surveillance systems with no right-of-way connection to traffic operations center requiring leased media to access control center. • Change from land line to wireless medium to cross a physical obstacle.
Backbone and Distribution System	Very heavy communication requirements (usually including video) that make the use of high speed channels economical for the longer transmission links.	• Large area-wide freeway surveillance systems and corridors.

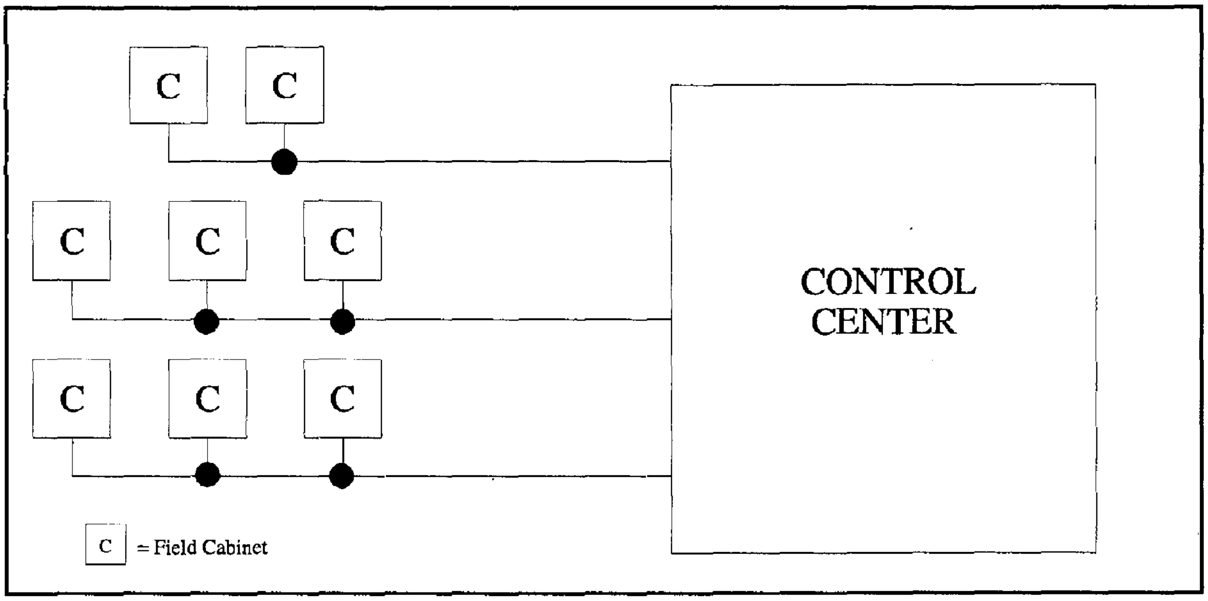

Figure 9-3. Illustration of a Central Communications Architecture. [1]

communication protocol. The primary advantage of this type of communications architecture is that a direct link is provided between each individual field device and the control center; therefore, if a link fails, communications are cut only to that one device. Figure 9-3 illustrates the concept of a central communications architecture.

Distributed

A *Distributed* architecture is generally used as follows:

- Where multiple levels of computations occur between the field devices and the control center.
- Where changes in the data rate occur between the field devices and the control center.

This type of architecture commonly uses field master controllers to collect data from many of the local control units, processes the data, and then transmits the processed information back to the control center (see figure 9-4).

Trunking

A special type of distributed architecture is a *Trunking* architecture. A communications system is trunked if the following holds true: [1]

- The communications system collects information from, and distributes it to several field controllers.
- At some field location, the data rate or bandwidth of the communication channel increases to require fewer channels for communicating with the control center.

Figure 9-5 shows an example of a trunked type of communications architecture.

Backbone

Another form of distributed communications architecture using multiple data rates is a *Backbone* type of architecture. This type of architecture is characterized by a high data rate backbone connected to a series of field communications hubs or nodes. Equipment at each hub transforms these high data rate

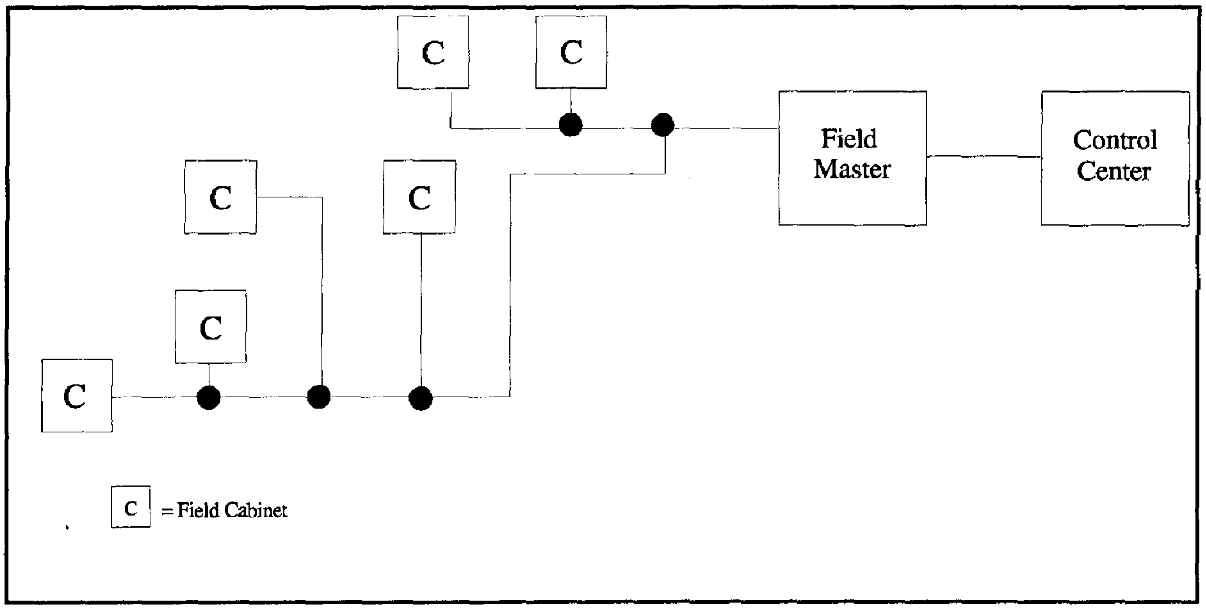

Figure 9-4. Illustration of a Distributed Communications Architecture. [1]

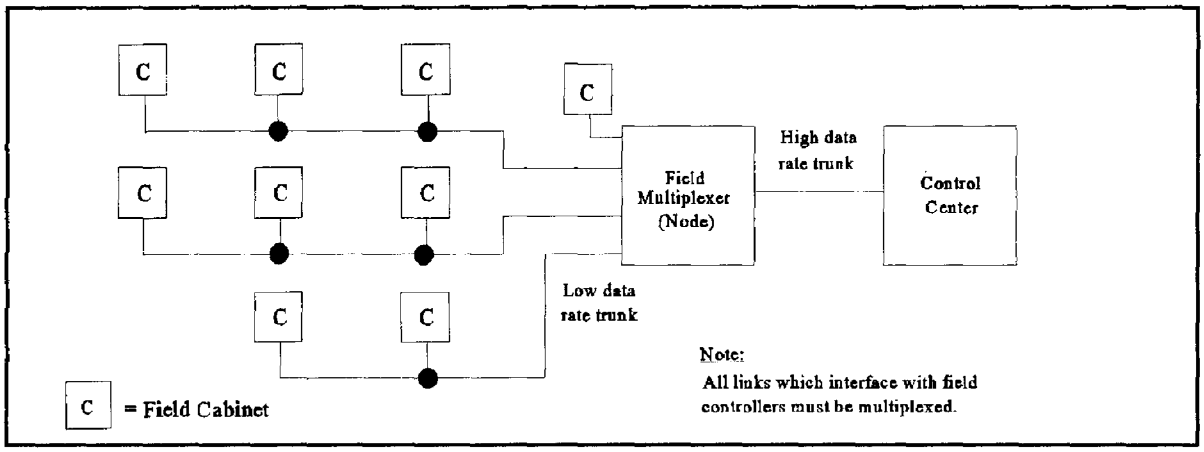

Figure 9-5. Illustration of a Trunked Communications Architecture [1]

channels into many separate low data rate distribution channels. Figure 9-6 shows an illustration of a backbone type of architecture.

Although it can be used with other high bandwidth communication media, the backbone type of architecture is commonly used with fiber optic networks. The four common types of topologies (i.e., network configurations) used with backbone architectures for fiber optic systems include the following:

- Unprotected Ring — Each node (i.e., a communications hub or field device) is connected to two others by unidirectional transmission links, creating a "closed" loop.

- Protected Ring — Two rings are used instead of one, thereby providing two unidirectional transmission paths that may run in opposition directions. Redundant opposite direction paths allow each node to communicate with every other node, even if the communication media is cut.

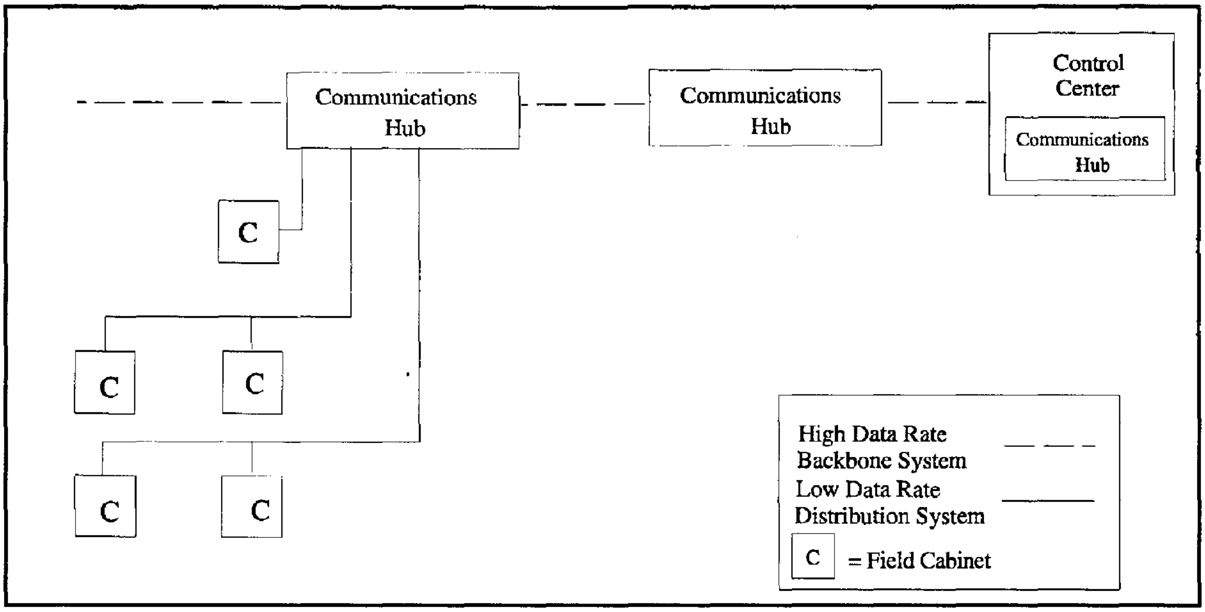

Figure 9-6. Illustration of a Backbone Communications Architecture. [1]

- Linear Drop — Nodes are connected in a string or chain, with transmission data being "dropped" at a designated node.
- Star — Communication links emanate from a source node (e.g., traffic control center) to multiple secondary nodes (e.g., a communication hub or field device).

Figure 9-7 illustrates each of these backbone architecture topologies.

Multimedia

Although not a communications architecture per se, planners and designers need to be aware of the impact changing communication media has on the architectural design of the communications system. A *multimedia* communication channel occurs where more than one medium is used to transmit data and commands to and from the control center and the field devices without altering the data rate and transmission protocol. This type of communication channel is generally used to breach natural or manufactured impediments (i.e., mountains, valleys, etc.) to provide wireline type of communication. Figure 9-8 illustrates the general concept of a multimedia communication link.

IDENTIFY AND SCREEN TECHNOLOGIES

After the functional requirements and system architecture have been established for a communications system, the next step is to identify and screen alternative communications technologies. The *Communications Handbook for Traffic Control Systems* describes a process for identifying, screening, and selecting the communications technologies in a freeway management system.[1] The steps in this process include the following:

- Identify generic or typical links consistently used through the communications architecture. Figure 9-9 illustrates some generic links that occur

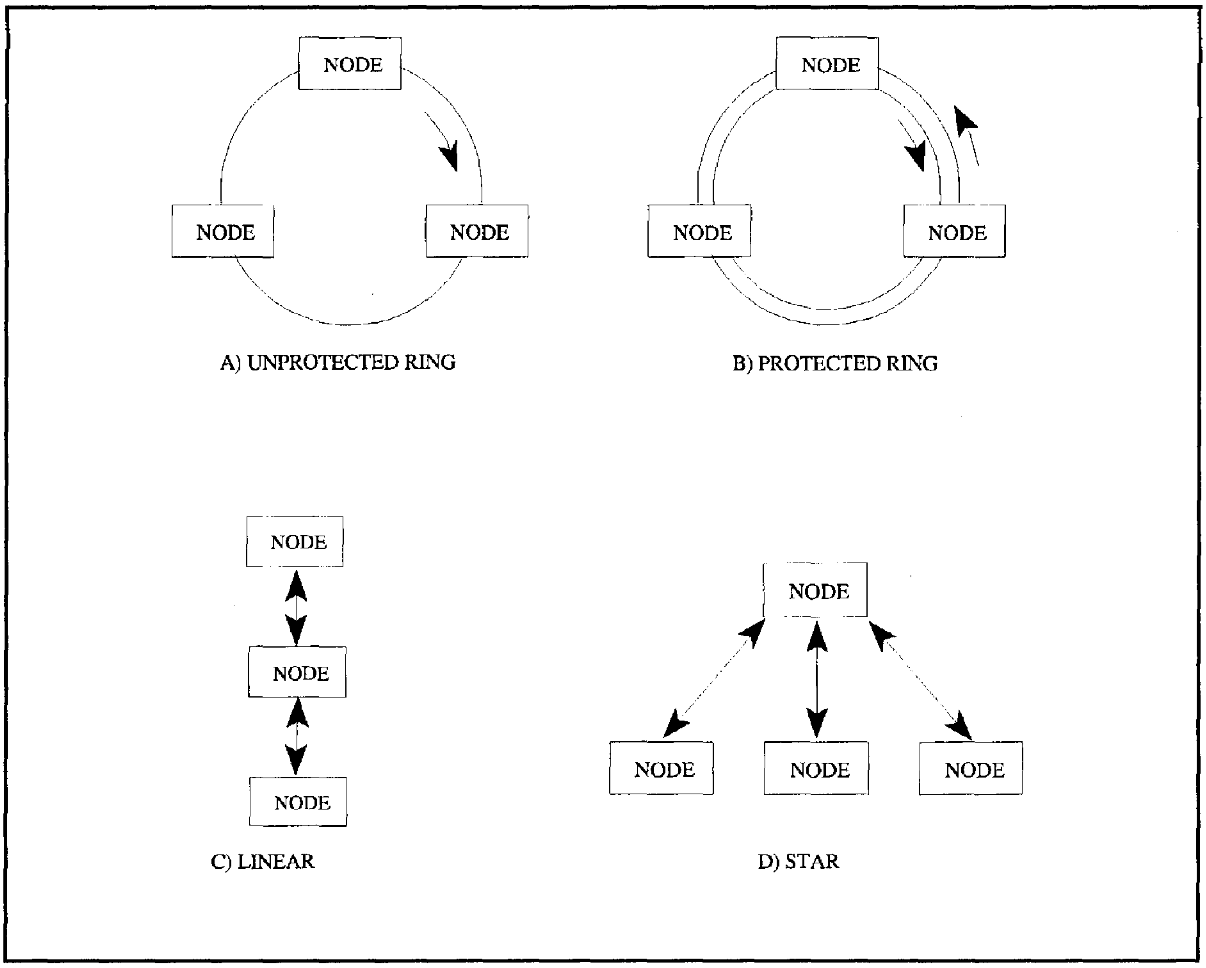

Figure 9-7. Traffic Control Communications Network Topologies. [1]

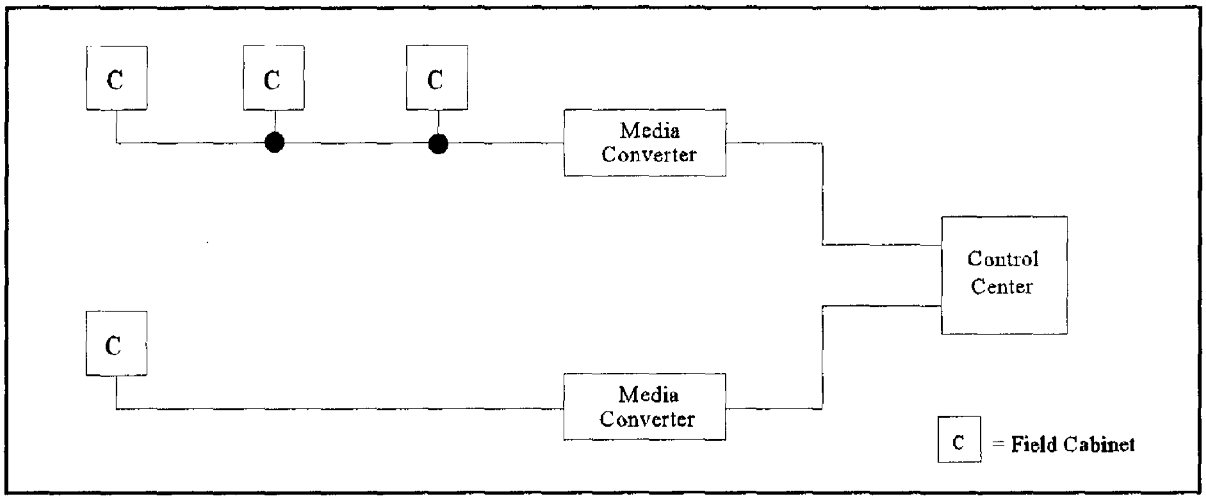

Figure 9-8. Illustration of a Multimedia Communications Channel. [1]

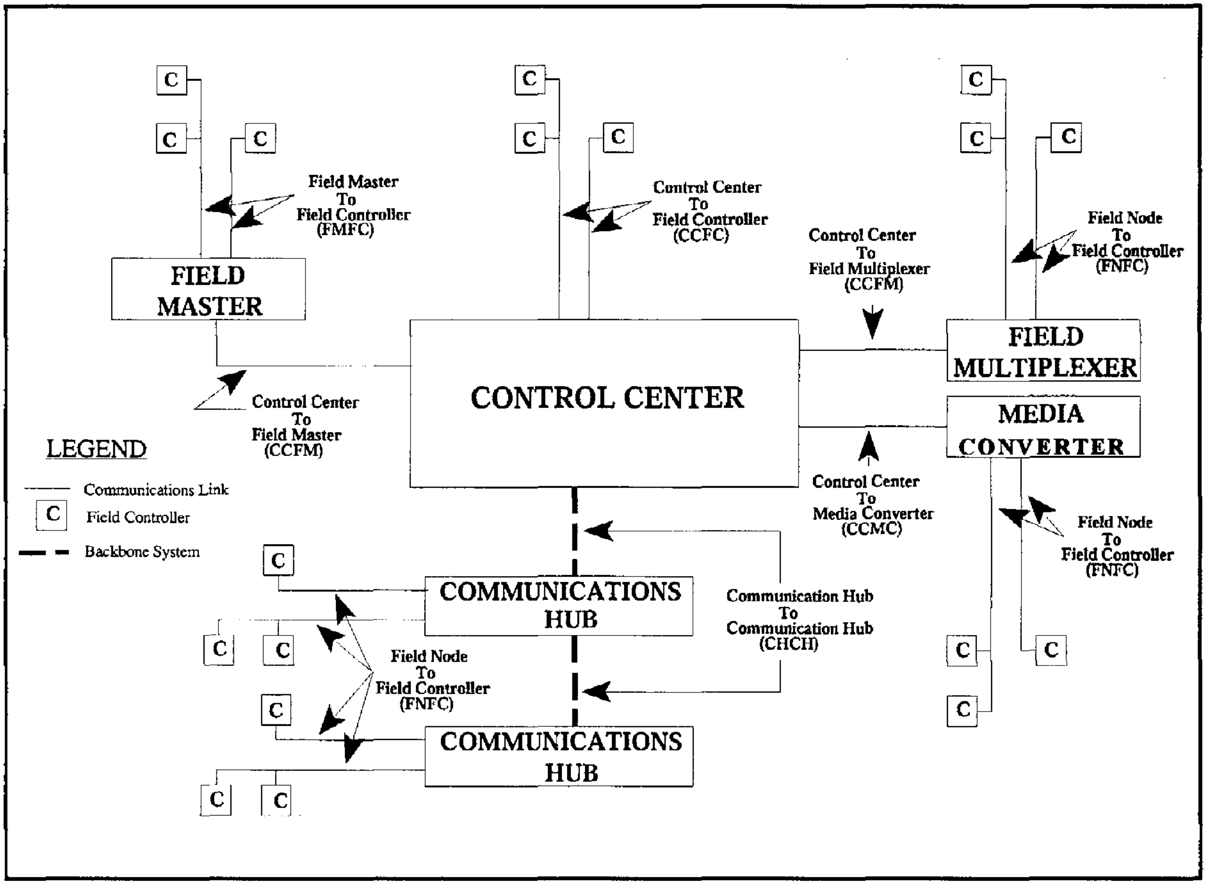

Figure 9-9. Illustration of Generic Communication Links. (1)

in communications systems, while table 9-6 summarizes the characteristics of these links.

- Using tables 9-7 and 9-8, identify candidate media for each generic communications link.
- Conduct a preliminary screening of the media to eliminate any that are impractical or unavailable in an area. The preliminary screening should also eliminate those media and technologies that are not compatible with institutional goals and policies.
- Estimate the data rate requirements for the communications channel serving each field device.
- Eliminate those media and technologies that cannot meet the data rate requirements of the field devices.
- Assess the potential for satisfying the communications requirements via leased communications systems.
- Assess the remaining technologies to decide the following:
  - Whether or not they satisfy the functional requirements of the system.
  - The interface requirements of the field controllers and other field equipment in relation to the communications media.

Table 9-6. Attributes of Generic Links in a Communications System. [1]

Type of Generic Communication Link	Attributes
Control Center to Field Controller (CCFC)	The type of connection between a control center and field controller where no computation or change in data rate occurs.
Control Center to Field Master (CCFM)	The type of connection between a control center and a field master that provides supervisory control to a group of local controllers. The master controller generally does not provide direct control over the site, but rather processes data and adds information and/or control commands.
Field Master to Field Controller (FMFC)	The type of connection between a field master and local field controller. The local field controller provides direct control and collects information from the specific devices at a site. The master controller processes data from a group of field controllers.
Control Center to Field Multiplexer (CCFX)	The field multiplexer site provides higher data rates to the control center link than does the field controller. While the data rates differ, the multiplexer performs no processing related to traffic system functional requirements.
Control Center to Media Converter (CCMC)	The type of communication that occurs between a control center and a device that converts the communication channel to a different type of media (e.g., from twisted pair to fiber optic).
Communication Hub to Communication Hub (CHCH)	This type of connection occurs between two communication hubs. This type of connection typically represents a high data rate backbone link.
Field Node to Field Controller (FNFC)	The field controller connects to a field node for either of the following purposes: • To provide a higher order of multiplexing by means of trunking or backbone systems between the control center and field node (CCFX, CHCH) by means of a field multiplexer. • To use a medium more suitable for communication to the control center while retaining essentially the same communication channel capacity (CCMC). The field node in this case consists essentially of back-to-back modems to service each medium.

Table 9-7. Relationship of Communication Technology to Generic Communication Link for Data Transmission. (1)

Communication Technology	Generic Communication Link						
	CCFC	CCFM	FMFC	CCFX*	FNFC	CCMC	CHCH**
Twisted wire pair voice grade channels	✓	✓	✓	✓	✓	✓	
Leased voice grade channels	✓	✓	✓			✓	
Switched voice grade channels		✓					
Fiber optics channels	✓	✓	✓	✓	✓	✓	✓
CATV channels	✓					✓	
Leased digital channels	✓			✓		✓	
Area Radio Networks (owned)	✓	✓	✓		✓	✓	
Terrestrial Microwave	✓	✓	✓	✓	✓	✓	✓
Spread spectrum radio	✓		✓		✓		

* Trunking Link **Backbone Link

CCFC = Control Center to Field Controller
CCFM = Control Center to Field Master
FMFC= Field Master to Field Controller
CCFX = Control Center to Field Multiplexer
CCMC = Control Center to Media Converter
CHCH = Communication Hub to Communication Hub
FNFC = Field

  - The types of controls needed to provide adequate environmental protection.

- Examine the feasibility of providing a backbone or trunking architecture for the field devices.

- Isolate those links where geometric or physical situations require a change in the communications media.

- Identify multiplexing strategies for each communications media.

- Develop life-cycle cost estimates for the alternative communications technologies for each system link. Cost estimates should include not only capital cost but also operating and maintenance costs.

- Using the estimate of the link costs, estimate the total communications systems costs.

- Assess the impact of the non-cost related factors on the total system costs. Examples of the non-cost related factors include the following:

Table 9-8. Relationship of Communication Technology to Generic Communication Link for Video Transmission. (1)

Communication Technology	Generic Communication Link				
	CCFC	CCFX*	FNFC	CCMC	CHCH**
Twisted wire pair voice grade channels					
Leased voice grade channels					
Switched voice grade channels					
Fiber optics channels	✓	✓	✓	✓	✓
CATV channels	✓	✓	✓	✓	✓
Leased digital channels	✓	✓	✓	✓	
Area Radio Networks (owned)					
Terrestrial Microwave	✓	✓	✓	✓	✓
Spread spectrum radio	✓		✓		

* Trunking Link ** Backbone Link

CCFC = Control Center to Field Controller
CCFM = Control Center to Field Master
FMFC= Field Master to Field Controller
CCFX = Control Center to Field Multiplexer
CCMC = Control Center to Media Converter
CHCH = Communication Hub to Communication Hub
FNFC = Field

- The risk of the leased communication costs escalating in the future.

- The differences in service reliability between owned lines, leased services, and radio communications.

- The ease of maintaining each communication alternative.

- Select the "best" communications system alternative.
- Review assumptions and iterate the process if necessary.

The *Communications Handbook for Traffic Control Systems* or similar references should be consulted for a detailed explanation of the analyses involved in each step, and example applications of the evaluation process.(1)

IMPLEMENTATION

National ITS Standards

In the past, some agencies have experienced problems maintaining and expanding their systems because they used communications equipment that did not conform to standard equipment interfaces and protocols. One method of ensuring maintainability and expandability is to specify communications equipment and system designs that use common standards. System planners and designers must recognize the importance of standards during the design process. The designer must prepare specifications in sufficient detail to ensure the desired level of standardization of field equipment functions and communication interfaces and protocols. Standards are available for the following elements in a communications system: [1]

- Serial data interfaces.
- Modems.
- Voiceband channels.
- Digital signals.
- Fiber optics.
- Integrated services digital networks.
- Compressed video.
- Local area networks.

The reader should consult the *Communications Handbook for Traffic Control Systems* for more details about the specific standards that relate to these elements.[1]

The advantages and disadvantages of incorporating standards into the design of a communications system are summarized in table 9-9.

Beginning in 1995, a group composed of infrastructure operators, manufacturers, system integrators, and representatives from the FHWA began developing a national communications standard. Communications standards were needed to ensure interoperability and interconnectivity of traffic control and ITS devices such as variable message sign control, camera control, vehicle classification, and general purpose data collection and device control.[4] This standard is known as the National Transportation Communications for ITS Protocol (NTCIP). It is designed to provide a communications interface that allows hardware and software products from different manufacturers to be connected in a traffic management system. The potential benefits of adopting the NTCIP standards for use in designing freeway management systems include the following: [5]

- Reduction in warehousing requirements and costs.
- Reduction in training needs for personnel.
- Improvement of staffing effectiveness if same personnel are used predominately for repairs and operations of unique equipment.
- Reduction in product costs of some devices if a more competitive procurement environment yields cost reductions.
- Mitigation of procurement issues associated with system expansion and spares.
- Reduction in downtime.
- Enhancement of interjurisdicational coordination and integration.
- Shared use of the communications network, providing the opportunity to share the costs of communications with other agencies (or at least avoid the cost of dedicated parallel communications systems).

For more information about NTCIP, the reader should consult the **Lessons Learned** section at the end of this module.

In addition, the National Architecture effort also spurred development of standards for other freeway applications, such as the following:

Table 9-9. Advantages and Disadvantages of Using Communications Standards. [1]

Advantages	Disadvantages
• Ensures the availability and compatibility of equipment spares for repairs and future expansion. • Allows system to be expanded to locations not contiguous to the existing system and accessible by land line. • Ensures the compatibility of test equipment. • Supported by a wide body of literature describing the functions of ports and modems designed to common communications standards.	• Some existing system architectures are incompatible with accepted standards. • May result in higher system costs since equipment with less than optimum data rate may be required to conform to standards. • May require higher level of maintenance personnel.

The technical edition of the *ITS Deployment Guidance for Freeway Management Systems* lists possible standards for the following different applications within Freeway management systems:

- GIS Applications
- DMS Applications
- CCTV Applications
- ETTM Applications
- ATIS Applications
- Center-to-Center Communications
- Center-to-Roadside Communications
- Roadside-to-Vehicle Communications
- Vehicle-to-Vehicle and In-Vehicle Communication
- Center-to-Remote Access Communication
- Center-to-Vehicle Communication

If circumstances dictate the use of nonstandard equipment, agencies should procure sufficient spare devices for use well into the future. Agencies should also consider acquiring an inventory of specialized parts (e.g., custom integrated

- Transit Communications Interface Protocols (TCIP).
- Dedicated Short Range Communication (DSRC).
- Location Referencing.
- ITS Data Bus.
- FM ATIS Broadcasting.
- Navigation Messages.
- MayDay Reporting.
- Navigation Human Interfaces.
- ATIS Message Set

circuitry) that may become difficult to purchase in the future.[1]

Installation

The use of proper installation techniques and procedures is critical to installing a successful and functioning communications system. Failures and unreliable performance in a communications system commonly occur because proper installation procedures were not followed. Examples of improper installation techniques associated with wireline communications systems that can affect overall performance include the following:[1]

- Improperly installing fiber optic cable and coaxial cable connections.
- Exceeding the maximum pulling tension on the cable.
- Using a tighter radius than recommended by the manufacturer when bending a cable.
- Improperly splicing cables.

Installation and construction inspection personnel should receive appropriate related training before starting installation.

Three basic methods of installing cable are commonly used to connect devices in a freeway management system:

- Cable in Conduit.
- Direct Burial.
- Aerial Mounting.

Table 9-10 summarizes the advantages and disadvantages of each of these installation options.

9.3 TECHNIQUES AND TECHNOLOGIES

This section discusses the transmission media that are commonly used in communications systems for traffic management applications. This section also discusses some options available for transmitting video images to a control center. This section is intended only to highlight several major characteristics and issues associated with these media. For more detailed information on any of these media, the reader should consult the *Communications Handbook for Traffic Control Systems* or similar references.[1]

Communication media can be divided into the following two categories:

- Land-Line.
- Wireless.

The media contained in each of these categories are discussed below.

LAND-LINES

Land-lines (i.e., wire cable), whether leased or owned, are by far the most prevalent form of traffic control system communication media.[1] The three primary land-line transmission media commonly used in freeway management systems include the following:

- Twisted Wire Pair.
- Coaxial Cable.
- Fiber Optic.

Table 9-11 provides an overview of the land-line communication technologies that will be

Table 9-10. Advantages and Disadvantages of Installation Methods for Land-Line Communications Media.

Installation Method	Advantages	Disadvantages
Cable in Conduit	• Most secure because cable is placed in conduit that is buried approximately 1 m underground. • Requires the least maintenance if adequately protected by markouts and tight permitting process. • Access to cable provided through junction boxes.	• Frequent junction boxes required, especially when bending cable. • Can be damaged by excavation or installation of sign posts, guard rail posts, etc. • Relatively more expensive than other installation methods.
Direct Burial	• Cable, which is protected by extra insulating jacket, is buried directly in the ground. • Eliminates need for conduit and junction boxes. • Easier to install than conduit and aerial methods. • Suitable for use where roadside development is limited.	• Greater susceptibility to damage by excavation. • More difficult to maintain and repair. • Requires good control of excavations through permitting process.
Aerial Mounting	• Cable hung from existing utility poles in or near right-of-way. • Least expensive installation method (often ¼ the cost of installing cable in conduit or direct burial). • Not susceptible to damage by excavation. • Relatively easy to repair.	• Normally requires yearly rental fee on utility poles. • May also be assessed fee for relocating existing utilities on poles. • Because sun can deteriorate cable, it must be replaced approximately every 15 years. • Susceptible to damage from tree limbs, etc. during wind storms.

discussed and some of their notable features. Each of these media is discussed below.

Twisted-Wire Pairs

Twisted-wire pairs are the most prevalent type of communications media used in traffic control applications. A twisted-pair cable consists of sets of two wires wrapped around each other. The twisting of each pair reduces interference from external sources because the pairs of conductors carrying the signal are always immediately next to each other in the cable. Therefore, the induced signal from the interfering source will affect each conductor of the pair similarly. Figure 9-10 provides an illustration of one conductor in a twisted-wire pair cable.

Since the receiver is measuring only the difference in voltage between the conductors, the fact that both conductors have the same induced voltage will not be noticed. The design of the cable also reduces crosstalk between lines, because the same current is flowing in opposite directions in each conductor (see figure 9-11). Therefore, the electric field radiates from the two conductors in opposite directions (radially around each wire). This results in the two fields canceling each other out. [1]

Table 9-11. Summary of Land-Line Technologies and Their Features. [2,6]

Features	Twisted-Wire Pairs	Coaxial Cable	Fiber Optics
Transmission Media	Copper Wires	Center conductor is copper clad aluminum Outer conductor uses aluminum	Glass or plastic fibers
Transmission Range	14 to 24 km (8.7 to 14.9 miles) with repeaters	Commercial subscriber network repeaters at 0.5 km (0.31 mi); 1 km (0.62 mi) or more on dedicated systems; maximum of approximately 60 repeaters	Rarely a limitation when drop/insert units used at communications hubs or drop points
Principal Multiplexing/ Modulation Technique Used	Time Division Multiplex (FSK)	Frequency Division Multiplexing to divide channel bandwidths; Time Division Multiplexing to communicate data	Time Division Multiplex (FSK)
Carrier Frequency Band	300 to 3000 Hz	5 MHz to 350 MHz	850 to 1,550 nanometers
Bandwidth/Channel Bandwidth	Will exceed 2.7 Hz for most systems	6 MHz/channel	Various
Data Rates per Channel	1,200 to 3,100 bps Higher rates possible with different modulation techniques	Up to 7.5 Mbps based on channel subdivision	Up to 2.4 Gbs
Government Regulation of Channel or Service	None	May require licensing from local and state authorities, FCC provides legislation	None
Types of Information Supported	Data, voice, slow scan TV	Data, voice, video	Data, voice, analog TV, Codec
Owned or Leased	Owned	Either	Owned

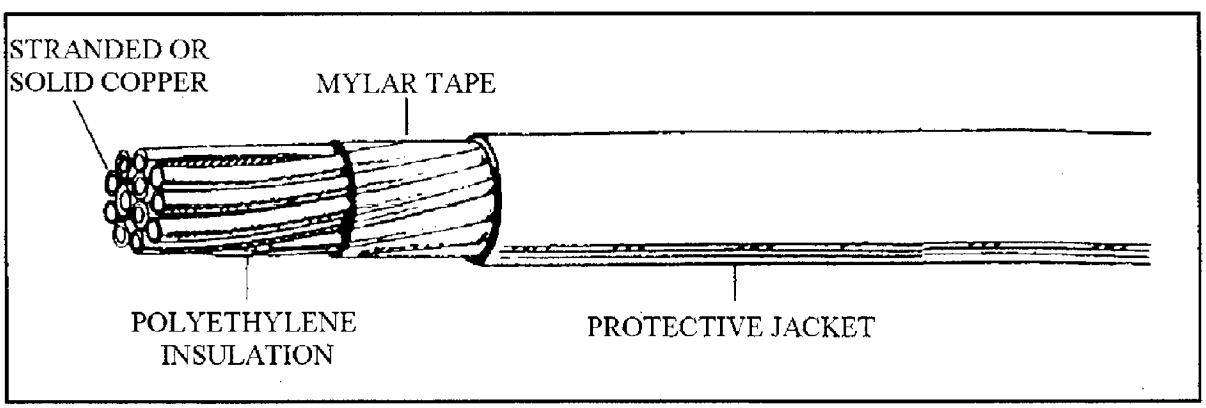

Figure 9-10. Illustration of a Twisted-Wire Pair Cable.

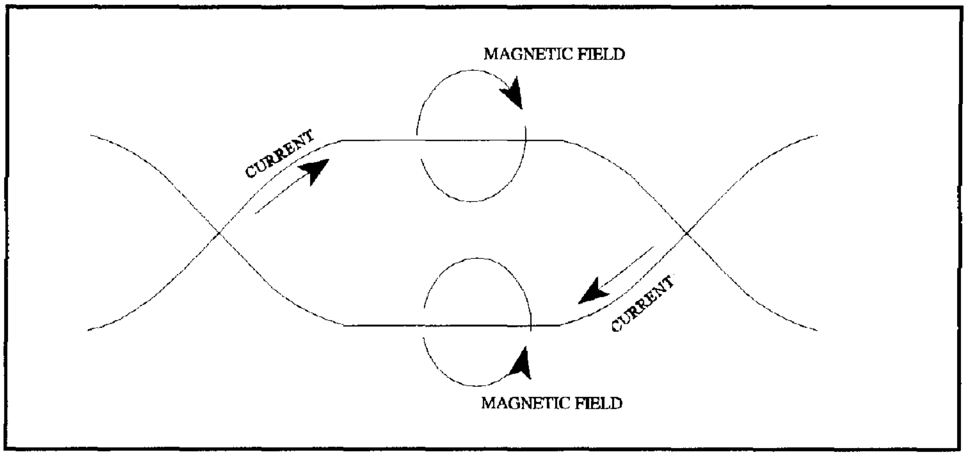

Figure 9-11. Crosstalk Reduction by a Twisted-Wire Pair. [1]

Most twisted-wire pair cabling used in traffic control systems is usually of the voice-grade type. This means the usual bandwidth (the range of signal frequencies a medium or channel will respond to, or carry without excessive loss in signal strength) ranges from 300 Hz to 3000 Hz, the audible frequency range of the human voice. Twisted-wire pair cabling is commonly used in voice telephone communications. A voice-grade cable will accommodate a data transmission rate of 1,200 bits per second (bps), which is adequate for transferring small amounts of data (i.e., loop detector data). When higher data transmission rates are required (for trunking applications), the twisted-pair cable must be conditioned by adding electronic equipment, such as loading coils, to improve the transmission characteristics of the line.

Twisted-wire pair technology consists of two insulated copper wires wrapped around each other and used to convey signals. Twisted wire is manufactured in standard numbers of pairs (6, 12, 18, 25, 50, 75, 100, 150, 200, 300, 400, 600, and 1200) in wire gauges 19, 22, 24, and 26 American Wire Gauge (AWG). [2] The maximum number of twisted pairs of wires manufactured in a single cable is 2600. [7]

The advantages and disadvantages of twisted-wire technology are summarized in table 9-12.

Twisted-wire pair technology is an inexpensive communications medium whose acquisition cost is lower than that of both coaxial and fiber-optic technologies; however, long term operating costs are dependent on installation considerations and are higher when life-cycle costs are considered. [6] The extent of such costs will vary greatly with the different installation and maintenance procedures required to support the installation method used and the terrain covered. For example, aerial installations can be damaged or links severed by sources ranging from falling trees to storm related damage. By comparison, buried cable affords protection from those threats, but may be subject to construction-related severance and will reflect higher installation costs. [1]

Twisted-wire pairs can be stranded together to form color coded binder groups that can then be wrapped around a common axis to increase the number of conductors in a given cable. The amount of twist in a given binder group is used to control how much crosstalk occurs.[1] A cable consisting of multiple

Table 9-12. Advantages and Disadvantages of Twisted-Wire Pairs. [1,6,7]

Advantages	Disadvantages
• Represents a low cost form of transmission. • Easy to splice. • Requires no special interface equipment. • Electrical characteristics are very favorable to basic analog transmission.	• Data cable splicing is not recommended. • There is a bandwidth limitation in that twisted-wire pair tends to attenuate high-frequency electrical signals, thereby limiting the ability to transmit digital information at high data rates. • Bandwidth limitation prevents transmission of live television images, though recent developments permit transmission of slow-scan television. (Prototype equipment is available for transmission of full-motion television over twisted-pair copper wire.) • Low security.

twisted-wire pairs can transmit several channels of data. In a full-duplex network, every two pairs can provide one channel.

The electrical characteristics of twisted-pair copper strongly support basic analog transmissions; however, its capability to transmit digital information at high data rates is limited by attenuation of high-frequency electrical signals.[7] The attenuation of high-frequency signals increases with increased cable length and decreased diameter. [1]
Noise can be a source of problems with some twisted-pair cable communications systems. Most modems used with twisted-pair systems, however, can filter out signals, many sources of noise below 750 Hz, but in noisy high frequency environments, other types of communications media may be more appropriate. Sources of potential noise in a twisted-pair communications system include lightning, high voltage power lines, and large electric motors. [1,6]

The use of equipment from multiple vendors can increase the difficulty in separating a given signal and transmission noise. [6] Noise may also rise if the twisting of the wire pair does not completely cancel the induced electrical fields. Moisture in twisted-pair cable networks can also lead to increased crosstalk and cable noise by introducing signal reflections (cable splices are the primary source of moisture entry). [1]

Several features of twisted wire pair communications should be considered during the design process. Fundamental concepts that should be considered by system designers include the items summarized in table 9-13. Besides those items listed in table 9-13, other items that should be considered during the design and installation processes including the following: [1,2]

- Maximum allowable transmitter power.

- Signal level expected at the receiver.

- Limitations on the number of drops on a multipoint line.
- Wire gauge.
- Environmental effects, such as moisture entry, noise, and transients.
- Aspects involving the number of repeaters, special functions of the system, and testing.
- Susceptibility to inadvertent electrical surges resulting from maintenance activities (consideration should be given to the provision of transient protection for sensitive electrical devices connected to the cable).
- Installation should not exceed the maximum pulling strength of the cable. Installation specifications should require either hand-pulling or tension monitoring using a strain gauge.
- Consideration of the use of existing facilities should take into account the limitations of the system, potential to expand, and physical plant responsibilities.

Finally, it should be noted that this transmission medium offers little security. It may be easily tapped and the electromagnetic field it radiates can be read by sensitive electronic devices. (6)

Coaxial Cable

Coaxial cable technology can transmit either data or video via several communications channels. (2) Its name is derived from its characteristic shape, essentially a set of two concentric circles. As shown in figure 9-12, the cable consists of an unbalanced pair made up of an inner conductor within an outer conductor held in a concentric configuration by a dielectric material that separates the two conductors. (7) Physical structure characteristics typical of coaxial cable include the following: (1)

- A center conductor composed of copper clad aluminum.
- An outer conductor composed of aluminum as a braided metal fabric, corrugated semi-rigid metal, or a rigid metal tube.
- A dielectric composed of solid polyethylene or polyvinyl chloride, foam, Spirafil, or inert gas (when gas is used, the center conductor is kept in place by spacers or disks).
- An outer jacket composed of low density, high molecular weight polyethylene.
- Optional armor for use in direct burial in gopher areas.
- Cables that vary greatly in size and construction. Typical traffic control applications commonly use a 19.05 mm semi-rigid coax for trunk lines, with smaller diameters used for connections between the trunk and field drops.

Table 9-14 summarizes the major advantages and disadvantages of coaxial communication technology.

A coaxial cable system uses frequency-division multiplexing (FDM) and time-division multiplexing (TDM) to fit all traffic control signals on a single conductor. FDM is used to subdivide the cable bandwidth into appropriate channels for data, video, and voice transmission, and TDM is then used to communicate the data.(1)

Table 9-13. Design and Installation Considerations Relating to Twisted-Wire Pairs. [1,2]

Consideration	Design Factors/Options
Number of wire pairs required for startup and expansion	• Total number of field drops • Maximum number of drops allowed on each channel • Network configuration
Cable routing and installation techniques	• Field drop locations • Existing communication facilities • Cable termination requirements • Cost
Installation methods	• Underground, in conduit • Underground, by direct burial • Aerial, using existing/new utility poles • Support of cable or conduit by bridges, overpasses, and other structures • Need for submarine cable
Cable size	• Minimum bending radii • Cable weight
Cable size affect on conduit design	• Available conduit and pole spacing • Size of manholes and junction boxes • Required bend of conduit at entry to cabinet/junction box • Aerial cable weight
Attenuation levels	• Signal frequency • Conductor size • Cable length • Number of splices and connections
Susceptibility to electrical transients from natural phenomena such as lightning	• Storm frequency • Terrain • Type of cable
Moisture prevention	• All splices on telephone terminal blocks should be inside weatherproof cabinets, or in waterproof splice enclosures for aerial installations • Installation must be performed such that the cable does not drag on the pavement or rub against jagged conduit ends causing cuts or abrasions • Be aware of cable jacketing imperfections • Seal cable ends during pulling operations to prevent moisture entry
Thorough testing after installation including at least:	• End-to-end continuity for each pair • The insulation resistance for each conductor (to ground and to the paired-conductor) • Attenuation

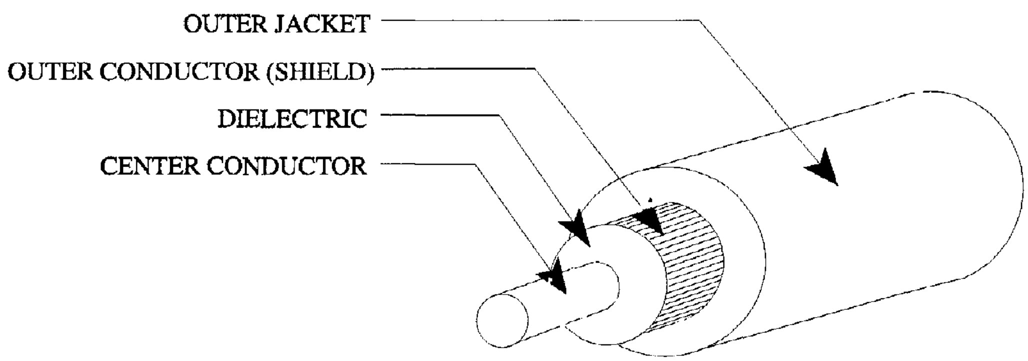

Figure 9-12. Illustration of Coaxial Cable Design.

Table 9-14. Advantages and Disadvantages of Coaxial Cable. [1,6,7]

Advantages	Disadvantages
• Because of its physical structure, coaxial cable is more immune to electromagnetic interference and has a much higher bandwidth than twisted-pair cable. • Minimal signal losses. • Low signal leakage. • Higher bandwidth allows for transmission of video signals (cable television using coaxial cable can transmit as many as 75 independent video signals) and for the transmission of digital data at very high rates. • Bandwidth of coaxial cable permits theoretical transmission rates as high as 700 million bits per second (Mb/s). These rates are more favorable than typical twisted-pair rates that are limited to less than 24 Mb/s for short distances.	• Splice connections are susceptible to noise and transient problems. • Cannot be spliced together by manual strip and twist method. Inherent nature of cable, and the importance of conductor alignment, make the coaxial cable much more difficult to splice. • Lower communication reliability than fiber optic. • Higher maintenance and adjustment effort required compared to fiber optic. • Low security. • Cannot be conventionally "tapped." Requires termination.

The typical coaxial communications system can be used for two-way communications by dividing the frequency spectrum into two parts. The upstream channels (generally inside the control center) use one range of frequencies to transmit data, while the downstream channels transmit in the opposite direction (from the field to the operations center). Filters and amplifiers are used at the repeater locations to carry the signals simultaneously in both directions. [2]

The coaxial network branches out from the operations center via a series of splitters, directional couplers, taps, and repeaters. Splitters are used to divide and combine signals within the tree-like network depending on their destination. Directional couplers are used to combine signals onto cables by direction. Taps are then used to divert signals to and from the trunk line at field drops. Repeater amplifiers are supplied to boost the signal along the system based on transmission frequencies, cable size, number of connectors, and design tolerances of the system. [1]

Coaxial cable's physical structure is less affected by electromagnetic interference than twisted wire pairs. [7] Repeater amplifiers have low noise levels and can deliver strong signals over a wide range of output levels; however, coaxial cable does experience moderate signal attenuation losses. Coaxial systems amplify the signal at each repeater, instead of regenerating it. As a result, background noise is also amplified at each repeater. This phenomenon limits the number of repeaters that can be placed in series to approximately 60 (this limit has not been reported to have affected traffic control systems using this technology). [1]

The attenuation in a given coaxial cable varies as a function of frequency, temperature, and cable size. Attenuation levels roughly double each time the bandpass frequency quadruples. Temperature variations can also degrade performance. For example, every 10-degree increase in temperature above 68 degrees results in approximately a 1 percent increase on attenuation.[6] Amplifiers are designed to compensate for the effects of temperature, though technicians must occasionally retune them. Unfortunately, the modems that are commercially supplied for coaxial systems often have temperature settings that fall below NEMA specifications. Use of these modems can result in interference with adjacent channels and the disruption of system communications if their temperature limits are exceeded. [1]

While only one cable may be required in a coaxial system, the design of a coaxial network is more complex than that of a twisted pair network. The higher frequencies and lower tolerances associated with noise and interference among coaxial cables translate to both higher skill level and test equipment requirements to support a coaxial network. [1] As indicated in describing the previously cited potential modem problems, it is essential that the designer have a thorough understanding of the equipment required by these systems.

Similar to twisted wire pairs, coaxial cable may be installed underground in a conduit, by direct burial, or overhead on utility poles. Generally, coaxial network connections can be spliced using press-fit connectors that clamp over the ends of the wires and are then screwed together. Many alternative connector and splicing arrangements can be employed for inserting tabs at midpoints in the cable and for ending cable runs. Given these factors, a design must consider the following: [1]

- The placement of amplifiers, couplers, splitters, and pilot generators.

- Provision of power for the amplifiers (repeaters).
- Compensation for temperature extremes and rate of change.
- Minimization of electromagnetic interference (EMI) and radio-frequency interference (RFI).
- Allocation of frequencies to the channels.

Contingent on the method of installation, the installer must ensure the following: [1]

- All conduit has gentle bends between pull boxes. (Severe bending of the conduit may cause the outer conductor to collapse and/or the inner conductor to permanently shift.)
- The maximum pulling tension specified by the manufacturer is not exceeded.
- All splices and connections are made in waterproof cabinets to reduce exposure to moisture and noise ingress.

During the installation process, care should be taken to ensure good quality control. Adequate construction supervision and thorough testing of the entire installed network are needed to maintain good quality control. Testing should consist of an end-to-end examination conducted under various weather conditions that exemplify operations at different temperatures.

Fiber Optic

Fiber optic communication provides a high volume, cost-effective means of transmitting either data or video via several communications channels with immunity to electrical interference. [1] Its name is derived from the medium's use of an optical fiber to transmit light by means of internal reflection off the surrounding surface cladding. Essentially, light impulses are coded and transmitted into a glass fiber structure. The fiber itself confines and guides the beam of light between origin and destination points. Upon reaching its destination, the light signal is detected, converted to electrical pulses, and decoded to an appropriate output. [7] The advantages and disadvantages of fiber optic communications media are summarized in table 9-15.

Fiber optic technologies are more expensive to acquire than comparable metallic transmission media; however, fiber optic cable has a reduced life-cycle cost when compared with copper transmission media, and is increasingly being used to replace coaxial cable systems. [7] Because of the high cost of fiber optic systems as compared with copper transmission, they are typically used for trunking applications in which large amounts of information must be transmitted over long distances or for high-speed local area networks that are to be distributed over a campus area. [2]

Fiber optic communications rely on light to act as a signal carrier within an optical fiber composed of a core region, cladding, and a coating. To transmit video, voice, and other data, the information is converted to a coded pulse of light, and introduced into the optical fiber, and is transmitted by internal reflection of the light wave within the fiber. Depending on the entry angle of the light into the fiber, the light will travel different distances. [2] Light waves that enter the core at an angle greater than the critical angle reflect and propagate within the core. Those light waves that enter at less than the critical angle refract into the cladding and attenuate. [1] As the light travels through the fiber, its bandwidth changes due to the spreading of the light pulses. As the pulses spread, they overlap and may interfere with

Table 9-15. Advantages and Disadvantages of Fiber Optic Communications.[1,7]

Advantages	Disadvantages
• A pair of light tubes can support many more circuits than a metallic path. • Immunicty from electromagnetic interference (EMI) and radio-frequency interference (RFI). • High integrity for data transmission. • Emits no radiation and it is difficult to tap a fiber tuve without detection of the resulting signal loss, thus represents a highly secure means of communication. • Use of small cable diameters and low-weight cable. • Small bending size, small bending radius, and light weight. • Safety in hazardous environments. • Extremely flexible - can be installed to support a low-capacity (low-bit-rate) system and, as the system's requirements expand, can use broadband capabilities of optical fibers and convert to a high-capacity (high-bit-rate) system simply by changing the terminal electronics.	• Designing a fiber optic network tends to require substantial engineering effort due to complexity of networks, light distribution characteristics and medium, and other factors. • Splicing tends to require elaborate equipment and expertise.

each other. [2] This dispersion effect limits the transmission speed and, if the pulse spreads so that the last portions of one pulse arrive after the first portions of the following pulse, may diminish the signal to a point that the receiver can no longer distinguish individual pulses.[1]

Several supplementary equipment items are needed with fiber optic communications systems. These items include modems, multiplexors, and repeaters. Fiber optic modems transmit data over a dedicated pair of fibers (e.g., between a controller and a traffic operations center) by converting an electrical signal to an optic signal and vice versa. This technology allows for full duplex communications over one or two fibers. Conversely, multiplexors transmit voice, data, and/or video over a fiber backbone network. [1]

Multiplexors combine many low- to medium-speed digital data channels into high-speed channels. In fiber optic systems, two types of multiplexors are used: electrical and optical. As implied by the name, electrical multiplexors combine signals electronically, and result in a combined electrical signal that drives the fiber optic transmitter. Single fiber optic channels can be used to carry multiple signals, using wavelength-division multiplexing. This technique is useful for long distance backbone and trunk lines, but is not cost-effective for local distribution uses. [1]

After entering a fiber, a pulse is carried by the optical fibers to the receiving station, where it is either received or regenerated. At the final receiving station, the light pulses are converted to electric signals, decoded, and converted to the original form of information. To correct pulse dispersion, fiber optic repeaters convert the optical signal back to its original form and then back to an optical signal.[1]

In systems with multiple drops placed in series, common practice uses drop/insert units, which perform the following functions:[1]

- Interception of the optical signal.
- Conversion of the signal to an electrical form for use by the device.
- Injection of a response if necessary.
- Modulation of the electrical signal back to an optical signal.
- Retransmission of the optical signal.

In a daisy-chain multiple drop configuration, the failure of any drop/insert unit results in the loss of all the remaining units beyond that point. This situation can be avoided by using units that contain a passive transfer feature. [1] The passive transfer feature uses a separate battery back-up for each unit which provides continued communication to the downstream units in case of an electrical power failure in the controller. [2]

Fiber optics can also be used to transmit video signals in one of three manners: [2]

- Baseband — transmits unmodulated video signals.
- Modulated — extends the transmission range, using amplitude modulation or frequency modulation.
- Multiplexed — enables transmission of several video signals on the same fiber.

Because of its dielectric nature, fiber optic communication medium is unaffected by electrical signals. As a result, many problems such as radiative interference, ground loops, and lightning-induced damage (when fiber optics have been installed in a cable without metal) can be avoided with fiber optic technology. This property makes fiber optics an ideal communication medium in a noisy electrical environment.

Fiber optics is, however, affected by dispersion and attenuation. The negative impacts of these two factors increase with the number of modes, and limit the length of a given fiber optic link. To limit the effects of dispersion, graded-index fiber can be used. Graded-index multimode fiber design limits the dispersion created by multiple modes by permitting light waves traveling different length paths to travel at similar axial speeds. Attenuation is caused by the following factors: [1]

- Absorption — where propagating light interacts with impurities in the silica glass.
- Scattering — where geometric imperfections in the fiber cause light to be redirected out of the fiber.
- Microbends — which may occur during fiber or cable manufacture.
- Macrobends — which can result from improper installation practice (e.g., exceeding the minimum bending radius).

The extent of the effects of dispersion and attenuation vary depending on the baud rate transmitted. Typical multimode fibers have a bandwidth of 400 MHz-km at a wavelength of 1300 nm. Such a fiber can sustain a baud rate of 400 MHz over a distance of 1 km (0.6 mi) but only 100 MHz over a distance of 4 km (2.5 mi). Traffic control systems that use multimode fiber at the low baud rates typical of distribution channels for small signal control systems will typically be limited by attenuation considerations. (1)

As with the other land-line transmission media, fiber optic cables may be installed underground in a conduit, by direct burial, or overhead on utility poles. Recent traffic control system designs have specified conduit installation of the fiber cables. (1) The proper design of a fiber optic communication system requires a knowledge of the transmission characteristics of the optical sources, fibers, and other devices (such as connectors, couplers, and splices, etc.). Transmission criteria that affect the choice of fiber type used in a system include the following: (7)

- Signal attenuation.
- Information transmission capacity (bandwidth).
- Source coupling.
- Interconnection efficiency.

Interconnection efficiency is usually measured by signal attenuation, the loss of signal strength within the fiber, plus the loss of signal strength in the splices and connectors. (7)

Fiber optics can be installed using single or multimode technology. Single mode fiber boasts higher capacities than multimode fiber and is preferred for long-distance communications. (7) As a result, single mode fiber is recommended over multimode fiber for any communications link that serves as, or could evolve into, part of a backbone network; (1) however, multimode fiber optic systems are sufficient for most transportation related applications. (7)

Splices or connectors are commonly interconnection devices used to install fiber optic systems. To reduce attenuation, interconnection must result in a highly accurate alignment of the fibers so that light can be successfully transmitted between them. Two tools exist for interconnection purposes: splices and connectors. Splices are used to join lengths of fibers together permanently, while connectors are temporary devices that can be disconnected and reconnected as needed. Designs must compensate for the losses introduced by splices and connectors used for interconnection purposes. They also need to provide a closure system that offers environmental protection and mechanical support. (1)

Field splicing of fiber optics is grouped into two methods: fusion and mechanical. Fusion splicing yields lower losses but also requires more time to complete. (2) For temporary connections of individual fibers in controlled environments, connectors and distribution systems are used together. Inexpensive interconnection cables (patch panels) can be used to end the distribution cable. Within these cabinets, small fiber counts of 12 to 48 fibers can be spliced, ended, and stored. Larger distribution frame shelves can be used to end as many as 144 fibers at major hubs. For traffic applications, fibers can be pulled into a breakout box and cable assembly with factory-installed jumper cables on one end and distribution cables on the other. Up to 24 fibers can then be connected from the equipment cabinet to a pull box. (1)

WIRELESS

Several forms of wireless communications technologies commonly used in freeway management systems include the following:

- Areawide radio networks.
- Terrestrial microwave links.
- Spread spectrum radio.
- Cellular radio.
- Packet radio.
- Satellite transmission.

Table 9-16 summarizes the characteristics and features of the wireless communications technology used in freeway management systems. The first three of these communication media are generally owned by the public agency while the last three can generally be leased from commercial providers.

In general, owned communication technologies offer several advantages and disadvantages as compared with commercially leased wireless communication technologies, as summarized in table 9-17.

Area Radio Network

Area radio networks derive their name from their ability to broadcast signals to an area as opposed to a specific location. [2] Table 9-18 summarizes the advantages and disadvantages of area radio networks applied to traffic control systems. [1]

Area Radio Networks operate in the 150 MHz to 960 MHz bands; the 450 to 470 MHz and 928 to 960 MHz bands are the most commonly used. [4] Bandwidth channels in the 25 KHz range are often used for data transfer and can support a signal rate of 9.6K bits/second; however, they will not support video transmission. [1] Depending on antenna location, the signals generally radiate uniformly in all directions and rely on the scattering and reflection properties of the signal to propagate throughout the area. During propagation, signals may "bend" slightly over changes in the ground surface, reflect off buildings or other obstacles, or penetrate into buildings.[1] Because of potential signal degradation, repeaters are sometimes used. [2]

In most applications, radio transmitters use the same transmit and receive channels. Voice communications use receivers all tuned to the same broadcast channel, and users respond only to the messages directed to them. This feature represents a potential limitation in data transfer applications and requires that protocols be established to permit multiple transfers of data on one communication channel. The protocols available vary and include both polling techniques (each data source receives exclusive use of the transmitted channel for a short period) and multiple access contention techniques (compensation is provided for collisions caused by simultaneous transmissions). [1]

While the scattering and reflection of radio signals allow the signal to propagate into built up areas, they also reduce the signal strength. Terrain barriers and weather factors can also interfere with the performance of area radio networks.

Operation of area radio networks requires an FCC license. The design of radio communication systems is complex and often requires special expertise. It is recommended that, if a preliminary study shows the usefulness of a radio network, an engineer with the necessary background be retained to evaluate system needs further.

Table 9-16. Wireless Communication Technologies and Their Associated Properties.

Technology	Principal Multiplexing/ Modulation Technique Used	Carrier Frequency Band	Bandwidth/ Channel Bandwidth	Data Rates per Channel	Transmission Range or Repeater Spacing	Government Regulation of Channel or Service	Types of Information Supported	Owned or Service	Constraints on Use
Area Radio Network	Time Division Multiplex, Modulation technique varies	15-174 MHz 405-430 MHz 450-470 MHz 928-960 MHz	25 KHz channels	9.6 Kbps	Several kilometers	FCC licensing of channels for each network	Data	Owned	Channel availability, line of sight in 900 MHz band, multipath sensitivity, geometries
Microwave	Time Division Multiplex, Modulation technique varies	928 MHz to 40 GHz	Various	Up to 7.5 Mbps depending on channel allocation	Varies, may extend several kilometers	FCC licensing of channels except for channels in 31 GHz band for each installation	Data, voice, analog TV, Codec	Owned	Channel availability, line of sight availability, multipath sensitivity, geometries, weather
Spread Spectrum Ratio	Time Division Multiplex, Modulation technique varies	902 to 928 MHz	Various	200 Kbps (typical)	0.8 km (0.5 mi) to several km	No license in the 902-928 MHz band for the network	Data, Codec	Owned	Line of sight, geometries, protocol compatibility
Cellular Radio	Because of narrow channel width, usually only simple polling or other multiple access techniques	825-845 MHz for mobiles, 870-890 MHz for base stations, 20 MHz in reserve	30 KHz per channel	1.2 to 14.4 kbits/sec, depending on modem type used	3.2 - 16 km (2-10 mi) per sector or "cell"	FCC has divided U.S. into 734 service areas, two cellular operators licensed/area	Voice, data	Service	Transmission cost, data transfer limitations
Packet Radio	Multiple access protocol	800 and 900 MHz bands	12.5 and 25 KHz channel widths	4.8 to 8 kbits/sec; 19.2 kbits/sec in major cites	16 - 32 km (10-20 mi) per base station		Data	Service	Service limited to major cities, time delay in delivery
Satellite Transmission	Frequency Shift Keying, Minimum Shift Keying, Phase Shift Keying	C Band (4-6 GHz) Ku Band (2-4 GHz)	Various	Various, depending on system complexity	Essentially unlimited, based on coverage area	FCC allocates frequencies for fixed satellite communication	Data	Service	Availability in some geographic areas, cost

Table 9-17. Advantages and Disadvantages of Owned Radio Communications. [1]

Advantages	Disadvantages
• No need for physical medium since signal propagates through the atmosphere. • No cost of major land-line installations and maintenance. • Used to span natural barriers or provide communications link between points where rights-of-way are not available. • Flexible implementation. • Commercial off-the-shelf equipment available. • Used in a number of traffic control systems.	• Relatively complex design (compared to land-line communication systems) since the local operating environment (e.g., terrain, potential sources of interference, available frequencies, etc.) must be investigated and taken into account for the design process. (However, a variety of theoretical models can be used to predict radio wave propagation for a given set of conditions.) • Limited choices of operating frequencies based on regulatory issues. • Path line of sight constraints (e.g., in the microwave region of 900 MHz and above, line of sight to the receiving antenna(s) generally required). Propagation relationships govern the actual obstacle and adjacent structure clearance required. • Fading considerations. • Turnaround time considerations. • Limited bandwidth. • Requires external antennas and cable. • May require repeaters. • Specialized maintenance.

System designers should consider the following items when installing an area wide radio network: [1]

- Maximum distance to be covered.
- Antenna requirements, including line-of-sight requirements.
- Transmitter power requirements.
- Operating frequency characteristics.
- Receiver sensitivity.
- Line losses at the antenna.
- Required polling intervals.
- Radio transmission considerations such as bending, clearance of obstacles, propagation over bodies of water; and the effects of weather.

Table 9-18. Advantages and Disadvantages of Area Radio Networks. [1]

Advantages	Disadvantages
• Can operate traffic controllers or other traffic control devices. • Can provide voice communications to highway maintenance vehicles. • Can propagate into built up areas and buildings. • Can support 9600 baud data rate. • Can prove cost effective depending on application.	• Terrain may limit range. • Limited channel availability in metropolitan areas. • Requires antenna at each controller site. • Turnaround time excessive for some applications. • Service reliability may limit use of some applications.

Microwave

Microwave systems convey point-to-point messages at very high frequencies that allow for reuse at small distances. [7] The advantages and disadvantages of terrestrial microwave links are summarized in table 9-19.

Microwave systems are expensive due to the infrastructure costs required to interconnect communications. [6] These infrastructure requirements are directly attributable to the operating frequency in use. Higher frequencies require smaller antennas that in turn have fewer extensive infrastructure needs; however, the larger antennas typically required by 2 GHz and 6 GHz systems cost more to purchase, are more difficult to install, and require stronger support structures due to their higher wind loads. [1]

In terrestrial microwave technology, microwave signals are radiated through the atmosphere along a line-of-sight path between highly directional microwave frequency transmitting and receiving antennas. Use of microwave radio allows transmission in both directions simultaneously. [1]

To convey signals, microwave systems use both analog and digital transmission techniques. The analog systems typically use frequency modulation techniques to manipulate the available bandwidth into channels for multiple voice, data and/or video communications. Conversely, digital microwave systems require the use of other modulation techniques including Amplitude Key Shifting, Frequency Shift Keying, and Phase Shift Keying. [1] These techniques do not afford secure transmissions. [7]

Microwave-based "line-of-sight" systems rely on radio waves that travel in paths approximating a straight line. Because of this routing technique, microwave communications are limited by both the effects of the curvature of the earth and the local topography. Interference problems can be overcome to some extent through modification of antenna heights and relative positions. How much compensation can be applied to sources of interference depends on the nature of the interference. For example, as the length of microwave paths increases, the effects of fading also increase due to factors such as atmospheric conditions, ground reflections, and water reflections along the propagation path.

Table 9-19. Advantages and Disadvantages of Terrestrial Microwave Links. [1]

Advantages	Disadvantages
• Useful as a point-to-point trunk. • Can transmit data and a limited number of full motion video channels. • Can control groups of traffic control devices. • Can use both analog and digital transmission.	• Require line of sight path. • In most cases, require FCC license. • Channel availability limited. • May have little choice in operating frequency. • Possible interference due to rain, snow, and atmospheric conditions. • May require antenna tower. • Available bandwidth usually limited.

Rainfall, heavy fog, and other atmospheric factors can reduce the power of the signal below a usable level. This type of fading affects a wide band of frequencies and may last several hours. [7]

Other types of interference vary by season. For example, multipath fading occurs when there is no wind to break up the atmospheric layers. Such conditions are typical of early mornings and nights during the summer season. This type of fading is typically experienced over a limited frequency range and recurs frequently, but lasts only a few seconds. It can be reduced by either "frequency diversity" or "space diversity" techniques, depending on the severity of the problem. [7]

Several aspects of microwave communications should be considered during the design process. The fundamental concepts include the items summarized in table 9-20.

Spread Spectrum Radio

Spread spectrum radio systems operate by transmitting a signal bandwidth over a wide range of the frequency spectrum. To receive such a broadband transmission, the signal is compressed to the original frequency range at the receiver. The major advantages and disadvantages of spread spectrum radio are summarized in table 9-21.

The infrastructure equipment necessary to operate an unlicensed spread spectrum communication system is readily available. Local area traffic control uses will require equipment levels very similar to land-line systems. In contrast, vehicle-to-vehicle communications have no infrastructure requirements. Because of the low-power requirements and general availability of required system components, this communications medium is considered a low-cost technology. [6]

Spread spectrum radio relies on low-power transmitters to provide short-range communications by spreading a signal's transmission spectrum, an application of code division multiplexing. Such systems operate by transmitting a signal bandwidth over a wide range of frequencies and then compressing the signal to the original frequency at the receiver. Each network in an area is operated using a different code,

Table 9-20. Microwave Communication System Design and Installation Considerations. [2,3]

Consideration	Design Factors/Options
System selection factors	• Spectral efficiency requirements. • Performance requirements. • Equipment complexity economics.
Transmission beam is narrowly focused	• Requires precise location of the transmitting and receiving devices. • Antenna towers must be rigid enough to withstand high winds without excessive antenna deflection.
Frequency availability	• FCC allocates a portion of the radio frequency bands of the electromagnetic spectrum for government and public service use. • Most civil government and industrial microwave radio systems operate in the 6, 11, 18, and 23 GHz bands. • Some bands require site licensing, others do not. • Bands above 6 GHz are the easiest to obtain and least costly, but are subject to power fading capabilities.
Repeater spacing	• Geography of a given radio route. • Terminal equipment technology. • Can use point-to-point communications in a daisy chain fashion; path availability and network geometry must be carefully considered. • Transmitter power permitted by the FCC. • Typical repeater spacings in the 6 GHz spectrum are 32 to 40 km (20 to 25 mi), and 1.6 to 4.8 km (1 to 3 mi) in the 23 GHz spectrum; longer spacings are possible when the effects of fading are expected to be minimal.

thereby permitting different networks in the same area to use the same frequency band. [6]

Pseudorandom noise direct sequences (PN) and frequency hopping techniques (FH) are used to provide the necessary expansion of the signal. [6] The PN spreading technique relies on a wide baseband signal to modulate the original baseband signal while the wideband signal's amplitude is continually changed between two states. In contrast, the FH technique uses very short transmissions carried on different frequencies ranging in number from a few hundred to the thousands. [1]

Spread spectrum technology was originally developed by the military to resist enemy radio interception and jamming during World War II. Spread spectrum broadcast techniques allow receivers to decode spread spectrum signals even if background noise levels exceed the signal level and they can resist the effects of multipath interference.

Table 9-21. Advantages and Disadvantages of Spread Spectrum Radio. [1]

Advantages	Disadvantages
• Very flexible installation. • Does not require cable installation and maintenance. • Does not require FCC channel use approval in 902-928 MHz band. • Works extremely well in a high-noise environment. • Currently in use for many industrial process control applications. • Uses low transmitter power. • Can be used in a mixed system of wired or radio interconnected controllers. • No land-line interconnect required. • Relatively low equipment cost. • Potential for broad range of traffic control system applications.	• New technology for traffic control and surveillance applications. • Uncertain range 0.48 to 9.7 km (0.3 to 6 mi); function of area topography. • Higher bandwidth than radio fixed frequency transceivers. • Requires external antenna and cable. • Requires more sophisticated equipment and specialized technicians. • Unprotected channel space.

This technology is considered to have a security advantage over similar wireless transmission techniques; intentional interference with spread spectrum communications is extremely difficult unless the transmission technique is known. [6]

Severe electrical storms have the potential to cause sporadic interference, but the effects are generally short-term. [6] Line-of-sight obstructions can affect transmissions, though obstacles in the 902-928 MHz band generally can be avoided through bending. Though spread spectrum radio itself is noise resistant, it can cause significant interference with other communications systems using the same broadcast frequencies. [1]

Spread spectrum radio currently permits digital communications between equipment in the 200 to 300 Kbps range. This allows uses including communications between a field master and local controllers in closed loop systems, communications between field points and field controllers, and transmission of low-end compressed video. [1] Vehicle-to-vehicle communications can also be supported with this technology. [6]

Fundamental design and installation considerations that should be kept in mind when using Spread Spectrum Radio communications have been summarized in table 9-22.

Cellular Radio

Cellular radio is a new data transmission medium that has grown rapidly since its introduction in 1983. The Federal Communications Commission has designated 666 channels in the 800 MHz band for cellular service purposes. Cellular communication systems are small radio sectors, or "cells" that provide

Table 9-22. Spread Spectrum Radio Design and Installation Considerations. [1,6]

Consideration	Design Factors/Options
System selection and implementation factors	• Maximum peak output power. • Maximum effective radiated power. • Maximum antenna height. • Minimum processing gain. • Favor line-of-sight alignments.
Frequency availability	• Must ensure compliance with FCC regulations. • Potential interference with/from other licensed services.
Operating range	• Varies by application but typically ranges from 0.8 km (0.5 mi) to several kilometers. • Generally used for short-range communications with multiple users. • Repeaters may be required.
Potential for expansion	• Number of users in code division multiplexing systems can be increased by increasing the code length. • Limitations to number of users based on noise levels at receiver. • In FH systems, increasing bandwidth will increase system capacity.

communications coverage in a series of small, slightly overlapping areas. [7] The cells are sized to reflect the density of users in a given area, and typically cover between 0.8 and 8 km (0.5 to 5 mi) each. [6] An antenna is placed in each cell so that, within a given system of cells, antennas relay signals through the system via a series of communications with their closest counterparts. The frequencies used for transmission in one set of cells can be reused in another set of cells by keeping the two signals far enough apart to avoid interference. [7]

With mobile cellular units, the mobile unit establishes a communications link with the closest antenna, and commences communications through that link. The cellular service provider then monitors the strength of the signal link via a mobile telephone switching office (MTSO). The original link antenna will typically be used until the signal power diminishes due to increasing distance and/or interference between the mobile unit and the antenna.

Once the MTSO determines that the signal power has diminished to an established level, the link will shift to the next closest antenna, if that level can better support the link. The communications link then transfers to the antenna closest to the mobile unit. This process of transferring and switching frequency assignments typically requires only milliseconds to complete and often remains undetected during voice communications. [7] In some instances, this transfer process may result in a "click" that users can hear. In other instances, the system may drop a call if no other antennas are available to support the link.

The advantages and disadvantages of cellular radio are summarized in table 9-23.

The cost for cellular "airtime" varies widely, depending on the provider's service plan and the area of concern. Additional variability in operating costs arises in transmitting data by cellular means and is dependent on the type of modem used. [1] Cellular service can be expensive, depending on usage. Basic service charges apply no matter whether a cellular telephone user originates a call or receives an incoming call. The specification of additional service features beyond the basic operating programs will result in additional fees being assessed.

The costs associated with the use of cellular technology for communications between permanent installations is much higher than those of other communications media. However, it should be noted that cellular radio technology can significantly improve the efficiency of personnel who spend substantial periods traveling in vehicles, and it can be the most cost-effective alternative for temporary communication purposes. [7]

Early cellular communications were handled through analog technology. Currently, conversion programs are underway to transfer operations to digital operating systems to achieve enhanced system quality and capacity. Additional details are offered in reference 8.

In general, noise and interference levels associated with cellular communications typically increase as the distance between the communications source and the nearest receiving tower increase. One major shortfall of cellular technology rests in the fact that it was not originally designed to support data transfer. The switching process historically has caused interruptions that require retransmission of the entire message. Problems with data transmission become especially apparent when operating in the overlap area between two cells. Within this area of overlap, cellular communications may begin "hopping" between the frequencies of the two cells, potentially resulting in data link severance. [8] Consequently, cellular providers often suggest that cellular users do not transmit data via cellular networks while they are in motion. [6] Voice communications are less affected by this form of interference; the audible effects often remain unnoticed. Noise and interference can be reduced through selection of appropriate modems and the use of digital transmission technology. An in-depth analysis of the cellular technologies available is contained in reference 8.

Cellular technology is not currently appropriate for continuous communication service, due to the service costs involved; however, applications that require communications at infrequent intervals or to some remote locations may prove ideal for cellular use. Areas that do not have owned land-line service, those where provision of land-line service is cost prohibitive, and locations of temporary installations may be candidates for communications systems that use cellular technology. [1] Potential traffic control applications include the following: [6]

- Communications with hazardous-materials teams.
- Control of remote equipment.
- Communications with traffic signal/ ramp meter repair crews.

Table 9-23. Advantages and Disadvantages of Cellular Radio. [1]

Advantages	Disadvantages
• May prove cost effective for infrequent communications. • Eliminates need to connect to a telephone company service point or provide owned land-line. • Effective for controlling portable variable message signs. • May prove effective for temporary installations. • Network covers 93% of U.S. population.	• "Airtime" cost excessive for continuous communication service. • Actual data throughput reduced due to protocol overhead. • Remote areas may not have service.

- Communications with motorist call boxes.

- Transmission of dispatch data.

- Control of portable variable message signs/highway advisory radio units.

- Communications with management and other staff members.

During the design and installation process, consideration should be given to the following attributes associated with cellular telephone technologies:

- Local service concerns such as coverage and cost.

- Available data transmission options.

- Compatibility with other equipment (especially important for data transfer).

- Security implications of this communications medium.

A recent report noted that some features of cellular technology as used in portable CMS and HAR applications can be exploited. To prevent the exploitation of portable cellular units, call-back diagnostic features that require the cellular phone on field units to be continuously transmitting should not be used. Continuous monitoring of the telephone bill for each unit (often automatically done by cellular phone companies) is strongly recommended. Further details are offered in reference 9.

Packet Radio

Packet radio services were designed for the transmission of data via wireless means. The distinction between packet radio and the evolving cellular packet data technology is becoming increasingly blurred, except that packet radio does not support voice communications. Table 9-24 summarizes the advantages and disadvantages of packet radio service.

Packet radio operates in the 800 and 900 MHz bands and relies on a system of base stations placed between user terminals to

Table 9-24. Advantages and Disadvantages of Packet Radio Service. [1]

Advantages	Disadvantages
• Designed for data transmission. • Cost effective for short messages. • Can eliminate need for leased or owned land-line. • At least two major providers.	• Not cost effective for continuous communications. • Not cost effective for lengthy file transfers. • Service currently limited to major cities. • Time delay in delivering packet.

convey communications from origin to destination. Radio base stations are positioned on towers or other large structures so that they provide coverage areas of 16 to 32 km (10 to 20 mi). The base stations are connected to backbone communications networks through which they can direct packets of information over one or more frequency pairs. [1]

This technology permits remote terminals to use the same frequency pair for transmitting and receiving data. Multiple access protocol algorithms are employed to reduce the probability of collisions between transmissions from remote terminals. [1]

Packet radio technology is expensive and is not cost effective for file transfers or continuous communication purposes. Specific costs will depend on the service provider and will likely include an initial subscription fee, monthly service fees, and modem and terminal charges. [1]

Noise and interference levels will vary depending on the access protocol used and the provider's quality of service. The packet radio system itself monitors noise and/or interference problems. For example, the ALOHA algorithm transmits data and then waits for the destination base station to confirm that it has received the signal. If the transmission is not acknowledged, the signal transmission is repeated and confirmation is again sought. [1]

The destination of communications can also affect performance issues. Some packet radio service providers offer service adequate for mobile purposes, while their service inside buildings has been characterized as inferior. [8]

The best source of design and installation considerations can be found in project specifications and information available through local packet radio providers. At a minimum, the following factors should be considered in evaluating the feasibility of using packet radio in a freeway management application: [1]

- Number of channels available.
- Channel width.
- Radio frequency protocol.
- Coverage area.
- Raw data transfer rates.
- Modem and terminal requirements.

Satellite Transmission

Satellite communications make use of space-based equipment to relay signals transmitted from earth. Unlike other means of communication, because of the relay equipment's location in space, satellite transmission technology is less dependent on the relative location of transmitters and receivers. [7] Table 9-25 summarizes the basic advantages and disadvantages of satellite communications.

The cost of making frequent satellite transmissions is generally considered excessive in comparison with that of other technologies. As with the other technologies examined, advances in the satellite industry will continue to enhance the economics of communications via satellite transmission. [1]

Satellites in orbit are used to convey signals between earth stations. To transmit a signal, an earth station first receives the data from its source (such as a telephone network) and converts it to a form suitable for radio-frequency transmission. The signal is then amplified to power levels of between one watt and several kilowatts, and is sent to an antenna where it is directed toward the satellite. After being received by the satellite, this signal is then shifted to a down-link frequency band, amplified, and reradiated toward earth. Antennas at various earth stations within the intended coverage area can then receive the transmission from the satellite and, after converting the signal to a usable form, transfer it to other communication media for distribution. [7]

Table 9-25. Advantages and Disadvantages of Satellite Communications. [1,7]

Advantages	Disadvantages
• Cost of circuits independent of their length. • Cost effective for long-haul circuits. • Downlink signals can be received over a wide area. • Cost effective for point-to-multipoint distribution applications (e.g., cable TV). • Uplink signals can originate over a wide area. • Flexibility for "quick setup" or mobile applications. • Provides option to links that cannot be achieved by earth-based communication media.	• Not proven cost effective for local communications. • Limited number of service providers. • Channel leasing costs subject to increases. • Most transportation agencies have no need for the frequent long distance transmission capabilities of satellite technology.

Satellites receive signals transmitted from earth (up-link) on frequencies in one band and then retransmit them back to earth (down-link) on frequencies in a different band. Currently, the C band (5.925-6.425 GHz uplink and 3.7004.200 GHz downlink), and the Ku band (14.0-14.5 GHz uplink and 11.7-12.2 GHz downlink) are designated for use by the FCC. (1)

Satellite access is dominated by two types of networks: preassigned access and demand assigned access. Preassigned access networks, which are best suited to heavy volume trunk service, assign fixed subsets of telephone channels to various destination points. This type of hierarchy is desirable if large subsets are used and load variations among destinations are small. In contrast, demand assigned access is more appropriate for use in communication systems where the demand volumes are lower. This approach makes uses of a pooled collection of channels assigned and used on an as needed basis. (7)

Satellite systems are generally considered to support all-weather operations; however, very severe weather may affect earth-based equipment and interfere with operations. Potential interference problems also exist between some mobile satellite systems and use of the Global Positioning System, and should be investigated for a given application. (6)

Long-haul trucking companies are currently using mobile satellite technology for dispatching purposes. Using inexpensive transmission and reception equipment, messages can be relayed between individual trucks and their dispatching centers, and the truck's location can be monitored. Such technology can also be used for dispatching transportation maintenance crews and emergency equipment from freeway management centers. Unfortunately, these technologies are still being refined and their usefulness in metropolitan areas has been limited due to interference from buildings, trees, and power lines. (7)

Several aspects of satellite communications should be considered during the design process. Table 9-26 illustrates some fundamental concepts that should be considered.

9.4 LESSONS LEARNED

DESIGN PRINCIPLES

Four fundamental principles that should be followed in the design of a communications system for freeway management applications include the following:

1. **Design for "Understandability"** — The communications system should be designed so that its functions, specifications, and processes are easily understood by those who will be responsible for operating and maintaining the system. The underlying principle for achieving understandability is to "Keep It Simple." Simpler designs are easier to operate and maintain. Another general rule-of-thumb is to stay in the mainstream of communications design and not pioneer anything unless it is clearly on the horizon for common communications carriers.

2. **Design for Redundancy** — Many operational problems experienced by existing freeway management systems are caused by communication failures. Designing a communications system where individual field devices or communication hubs can be reached even when a link has been disrupted can help maintain system performance and credibility. Redundancy can be provided

Table 9-26. Satellite Communication System Design and Installation Considerations. [1,7]

Consideration	Design Factors/Options
System selection and implementation factors including data rate and type of satellite	• Long distance communications more cost effective than short distance • High data rates demand strong signal levels at satellite. Requires either: - Low earth orbits; - Higher antenna gain at satellite; or - Higher radiated power transmission level from earth. • Low earth orbits require more satellites to cover a given area continuously • Geosynchronous satellites have lower data transmission rates • Geosynchronous orbits have potential access problems due to local geography • Short transmissions efficiency can be enhanced by using data networks that are better suited than standard gateway connections
Operating frequency	• Availability of desired frequencies • Frequency characteristics vary with propagation effects and equipment performance • FCC regulations govern
Potential for expansion	• Can be achieved by adding satellites • Feeder link traffic limited by FCC transmitter power restrictions

in a system by using dual ring and self-healing types of system architectures. Examples of functional specifications that can improve the reliability of the communication system include the following:

- Provide a redundant communication backbone.
- Limit the number of controllers on one communication channel.
- Provide adequate power margins to account for component degradation without adversely affecting the performance of the system.
- Provide adequate environmental controls (i.e., ventilation, heating, humidity control, pest control, etc.) in field cabinets.
- Provide adequate lightning protection.
- Provide adequate power surge protection.

3. **Design for Maintainability** — An agency can take several steps during the initial planning and design of a communication system that will enhance an agency's ability to maintain the system, including the following:

   - Critically assess the agency's capability to provide timely maintenance of communication equipment and lines. Either a less complex technology or leased communication channels may be preferred if adequate support cannot be provided.
   - Establish a maintenance plan well ahead of the installation of the system. In preparing construction bidding documents for installing the system, specify the type and level of

training that will be provided to the personnel responsible for maintaining the communications system. The training should be specified to occur during the installation of the system.

- Ensure that adequate documentation on the design and operations of the communication system is provided. The documentation should include all communication line connection and controller and field device channel communication assignments.

- Obtain the appropriate quantity and type of communication testing equipment.

- Establish a mechanism to coordinate the use of the right-of-way by utility companies so that construction and maintenance activities do not present a threat to the communication cable and conduit.

4. **Design for Expandability** — Ability to expand the system to meet future growth is a critical feature that can only be incorporated at the initial design phase. Several items that system planners and designers can use to ensure expandability include the following:

    - Use standard design, equipment, and protocols (such as NTCIP).

    - Provide spare communications channel capacity.

OWNED VERSUS LEASED COMMUNICATIONS

Using a leased communications network is an alternative to owning the infrastructure of a communications system. Several forms of leased communications systems are commonly used in freeway management systems, including services available through Local Exchange Carriers (LEC's), cable TV providers, and metropolitan area network providers. [1] Leased telephone services fall into three categories: terminal equipment, switching equipment, and transmission facilities. These categories encompass such leased services as office communications service, analog and digital point-to-point services, foreign exchange service, wide area network service, broadband video transmission service, switched digital data service, and channel bank termination service within central offices. [7] Several aspects of leased operations should be considered when evaluating their potential use.

Usually, the transmission characteristics and performance of telephone company channels are equivalent to those of a twisted-pair cable network. Because the lessor is paying for a dedicated communications system, they do not have to be concerned with the engineering aspects of the facility. For example, the distance of the transmission line, amplification needs, and other issues should all meet preestablished specifications and tolerances, thereby releasing the lessor of responsibility to maintain the required infrastructure. [7] Table 9-27 compares user-owned and leased wire-pair cable. These findings can be easily extrapolated to other means of communication.

The use of leased telephone company channels is most appropriate in areas where a high volume of voice or data communication is required between separate facilities. They may be used in areas where it is not cost-effective to locate other forms of communication technologies (due to physical or political constraints), or in temporary applications. [7]

Leased services may also encompass the use of coaxial cable communication systems through cooperation with community

Table 9-27. Comparison of User-Owned and Leased Wire-pair Cable.

Feature	User-Owned	Leased
Capital Cost	High - especially when installed underground in new conduit.	Reasonable - involves connection from access points to cabinets and from central facility to manhole(s) or other cable access.
Ongoing (Maintenance) Cost	Reasonable - owner has full maintenance responsibility.	High - lease costs almost always tied to general service rate increases. Agency must maintain connection described above.
Response to Maintenance Requirements	May be better or worse than leased line service depending on jurisdiction's capability.	In some cases can be specified.
Maintenance Responsibility	Always borne by the owner.	Sometimes difficult to determine whether problems are the responsibility of the lessor or lessee.
Control of Communication Network	Excellent - owner is user and can fully control.	Less control - communication traffic requirements and limitations on leased channel may impede use.
Design of Communication Network	Completely flexible since designer/owner starts from scratch.	Constrained by telephone company cable network. In most cases it is generally compatible with signal system requirements.
System Expansion	Cost determined by location of expansion.	Accessibility to expansion site usually available.
Reliability	Excellent - with proper maintenance procedures.	Good to poor - depends upon lease contract terms and level of owner's maintenance function.

antenna television (CATV) providers. Franchise agreements sometimes require CATV suppliers to provide such services. [2] Several features of CATV result in both advantages and disadvantages, as summarized in table 9-28.

After deciding on the requirements of the leased system, various configurations can be explored to evaluate system cost. Typical cost evaluations will include providers' fees and charges, costs associated with constructing any connections between the provider's termination point and the lessor's equipment, and any special hardware costs

Table 9-28. Advantages and Disadvantages of CATV.

Advantages	Disadvantages
• Single 6 MHz channel adequate for data transmission. • Network already in place. • Design efforts and initial installation cost much lower than a dedicated coax system. • Franchise agreement may provide for government use of CATV cable and bandwidth at reduced rates or free, reducing recurring costs. • Second separate coax institutional network (I-net) may exist for the express purpose of providing bi-directional services to commercial subscribers. • I-nets generally provide good levels of service to subscribers.	• Most CATV networks designed and installed with emphasis on downstream transmission of video signals to cable subscribers. • Video channels take up most available bandwidth. • Bandwidth available to traffic control may be very narrow, ranging from a single 6 MHz channel to 4 or 5 channels. • Single 6 MHz channel does not support full motion video transmission in addition to data communications. • Frequencies of available channels often least desirable in susceptibility to noise and interference. • Quality of video signal required for CATV considerably less than required for data. • CATV subscribers sometimes concentrated in residential areas. • Service to CBD and industrial areas sparse or nonexistent. • Area of coverage and network layout may not coincide with control equipment locations. • Traffic control system may have to compete with other public I-net users for more desirable channels.

required for interfacing with the provider's equipment. [1]

To illustrate the items that must be evaluated, consider leased telephone lines. These lines typically have a low initial installation cost as compared to an owned network of similar size, especially if underground installation is required.

However, the monthly lease cost may be much higher than the recurring costs of an owned network. Furthermore, because telephone company rates and charges are established by tariff and are subject to approval by State regulatory agencies, future costs cannot be guaranteed by the telephone company.

The leasing tariffs and the method by which they are calculated vary from State to State. Some tariffs are based on the "drop-to-central office mileage" (the distance from one drop [traffic signal controllers, a ramp meter, etc.] to the telephone company central office). Other tariffs use "drop-to-central office fixed," in which a fixed charge per drop is assessed, whatever the distance. Additional charges are usually assessed when communications between central offices are required in the path from field to central equipment. These charges may be the most significant element of the total cost. Alternatives to leasing communication lines for great distances through multiple central offices should be explored. [3]

The transmission technique in use depends on the communication medium that is being leased. Local telephone companies (often called local exchange carriers, or LECs) offer both voice grade service and digital private line data services. Such systems support communications between control centers and field devices or maintenance shops through synchronous transmission speeds of 2.4, 4.8, 9.6, or 56 Kbps. LECs also provide coded video transmission capabilities via higher capacity digital transmission channels such as T1. [2] Most digital transmission facilities provided by telephone companies are based on the use of digitized voice channels. These providers typically do not use the same conversion process as modems to transform voice information to digital transmissions. Reference 2 provides additional details concerning this subject. Other communications vendors offer leased transmission techniques including high capacity DS1 and DS3 circuits, voice grade, digital data service, and fractional T1 circuits. [2]

In certain circumstances, leasing fiber optic networks should also be considered. Leasing of fiber optic technology would be most appropriate for traffic control applications that require high-capacity links.[2]

Interference encountered in leased systems varies depending on the communications medium used and the service provider. Specifications should be made in the lease contract about how much noise and interference are permissible.

The limit of the potential traffic control applications for leased technologies is dependent on the technology that is being used. Leased twisted-pair telephone lines are frequently used for traffic surveillance and control system applications such as the interconnection between a central computer and remote field equipment (e.g., traffic signal controllers, variable-message signs, freeway ramp meters, traffic counting equipment, etc.). [7] Other potential applications information can be found listed under each of the technology sections presented in this module.

Leased communications require agreement on a contract between the lessor and the service provider. The development and use of a leased communication system require close cooperation with the service provider at all levels of personnel including engineering, sales, and data transmission representatives. [7] At a minimum, the concerns summarized in table 9-29 should be addressed.

NTCIP

The National Transportation Communications for ITS Protocol (NTCIP) is a standard communication protocol for transmitting data and messages between electronic devices used in ITS, freeway management systems, and arterial traffic control systems. It uses the OSI (Open

Table 9-29. Leased Communications Service Design and Installation Considerations.

Consideration	Design Factors/Options
Desired system features	• Data characteristics including desired transfer rates and bandwidth required. • Acceptable level of noise and interference. • Operational aspects of the system (e.g., once-per-second/dial-up communications, full/half duplex, etc.). • Number of field drops and their locations (e.g., controller/ ramp meter cabinets).
Characteristics of the leased channels and equipment restrictions	• Type and number of channels to be provided (insure both up and downstream channels are provided for CATV applications). • Data transfer rates. • Transmission characteristics and quality. • Frequency allocations. • Any system limitations.
Availability of service	• Time required to initiate service. • Facilities the provider will use to supply service to field locations. • Future expansion capability. • Location of the nearest access point to the provider's transmission line from each of the lessor's field locations.
Understanding of contract requirements	• Rules regarding leased circuit terminations at the central facility, including any equipment which the jurisdiction must furnish. • Division of work between the provider and user in connecting to field locations (i.e., is complete service connection provided or will lessor need to make connections to the provider's equipment). • Respective maintenance responsibilities of the provider and the jurisdiction. • Maintenance response priorities. • Testing criteria and requirements prior to acceptance. • Rates and charges; both one-time charges and monthly fees. • Pending rate increase requests, if any, and an estimate of expected increases in leasing rates. • Expiration/renewal terms.

Systems Interconnection) Reference Model for providing communications links between devices.[10,11] The OSI Reference Model is based on a concept developed by the International Standards Organization (ISO). The model is called the ISO OSI Reference Model because it deals with connecting systems that are "open" for communications with other systems. The OSI model consists of seven hierarchical layers. Each layer performs a related subset of the functions required to talk with another system. Each layer relies on the next lower layer to perform other functions and to conceal the details of those functions. It in turn provides "services" to the next higher layer. These layers are defined in such a manner so that changes in one layer do not require changes in the other layer. Table 9-30 identifies each layer and gives a brief description of the functions associated with each layer.

NTCIP is a common set of codes, procedures, and relative timing relationships (i.e., communications protocols) that follow the OSI model to allow different types of field devices to communicate with one another without the need of a physical conversion box or reliance on a single vendor to supply all the equipment in the system. [11,12] Rather than defining a unique format for each combination of data items that need to be communicated, the NTCIP defines a structure that uses a modular approach for delivering generalized messages. By defining a series of message pieces that can be collected into groups of data items, system software designers can create virtually any useful message structure without requiring new programming in the field device. NTCIP promotes two important features that could not previously be provided in traffic control systems:

- *Interoperability* — the ability to connect devices of different types to the same communications medium.
- *Interchangeability*—the ability to exchange devices of the same type, but from different vendors, without any lossof functionality or modification to the rest of the system.

To date, four profiles have been developed for different traffic management applications.[10,12] A profile defines the standard communication protocols that are appropriate for the different types of traffic management applications. The Class A profile allows messages to be routed from one device to the next. The Class B profile allows devices to talk with one another over a low speed, low capacity communications system where routing is not required. Class B can be used where legacy communications exist, typically twisted-pair copper wire. The Class C profile supports file transfer and sequencing and routing, while the Class E profile provides routing, sequencing and file transfer capabilities over a point-to-point communications link.

Table 9-31 shows the specifications applicable in each layer of the OSI for the different classes. Additional NTCIP profiles will be developed to satisfy various system architectures and communications media as the need arises.

Besides defining how communications between devices will occur, the NTCIP also defines what information is contained in a data stream (i.e., object definitions). The NTCIP uses a hierarchical method of addressing where data elements are stored in a database, similar to that used widely on the Internet. [12] The hierarchical method allows data to be grouped into logically related data elements. Each of these logical groupings can be expanded over time as new elements are added to the group, without running out of addresses in the group or limiting other groups to fewer addresses. Currently, object definitions have been developed for traffic signals, but object definitions for other traffic management elements (i.e., variable message signs, CCTV camera controls, ramp meters, vehicle detection/count stations, highway advisory radio, etc.) are under development.[13]

More information about NTCIP can be obtained through the Internet at http://www-atms.volpe.dot.gov/ntcip/.

Table 9-30. Layers of Open Systems Interconnection Reference Model. [10]

OSI Layer	Description
Layer 7: Application	Defines procedures for file transfers, access methods, and management of messages.
Layer 6: Presentation	Defines the syntax and semantics of transmitted information. It provides services such as encryption, text compression, and reformatting.
Layer 5: Session	Defines the procedure for different communications equipment to establish dialogues. Provides the control structure for communication between applications. It establishes, manages, and terminates connections (sessions) between cooperating applications.
Layer 4: Transport	Defines the organization of data passing to and from the lower layers. Involves breaking longer messages into packets for transmission.
Layer 3: Network	Defines how packets of data are routed from source to destination. Provides upper layers with independence from the data transmission and switching technologies used to connect systems. It is responsible for establishing, maintaining, and terminating connections.
Layer 2: Data Link	Defines methods for ensuring data integrity such as error correction. It sends blocks of data (frames) with the necessary synchronization, error control, and flow control.
Layer 1: Physical	Defines the mechanical, electrical, and procedural characteristics used to establish, maintain, and deactivate the physical link.

SHARED RESOURCE PROJECTS

The need for increased communications capabilities has led many agencies to consider shared resource projects. Shared resource projects refer to those projects where the private sector would use public highway rights-of-way, previously viewed as entirely within the public domain, to install telecommunications hardware (principally fiber-optic lines, but also including cellular towers). In return, the private sector would "compensate" the public sector, either through barter or cash. In barter or in-kind arrangements, private parties install the communications system. In return for providing telecommunications capacity and/or services to the public agency, they receive access to the right-of-way for installing their own capacity. In cash arrangements, private parties install the telecommunications system, receiving access to the right-of-way in return for monetary compensation to the public agency. Hybrids of the barter and cash alternatives can also be created in which in-kind (communications capacity) and monetary compensations are combined as consideration for private access to right-of-way for private sector use. [14]

At the outset, potential shared resource partners must address the threshold legal and

Table 9-31. Specified Protocols for NTCIP Profile Classes. [10]

OSI Layer	Profiles			
	Class A	Class B	Class C	Class E
Application	STMF	STMF	Telnet FTP SNMP	Telnet FTP SNMP
Presentation	Null	Null	Null	Null
Session	Null	Null	Null	Null
Transport	UDP	Null	TCP	TCP
Network	IP	Null	IP	IP
Data Link	PMPP	PMPP	PMPP	PPP
Physical	EIA 232E FSK	EIA 232E FSK	EIA 232E FSK	EIA 232E FSK

STMF = Simple Transportation Management Framework
SNMP = Simple Network Management Protocol
FTP = File Transfer Protocol
UDP = User Datagram Protocol
TCP = Transmission Control Protocol
IP = Internet Protocol
PP = Point-to-Point Protocol
PMPP = Point-to-Multipoint Protocol
EIA 232E = standard modem interface
FSK = Frequency shift keying

political issues that, if unresolved, can preclude shared resource arrangements. Some of these issues are summarized in table 9-32. In some situations, new statutes or regulations will be required to permit private sector access to right-of-way or to conduits in the right-of-way. In other cases, careful contractual arrangements can ensure effective private sector longitudinal access without violating legal or regulatory constraints; for example, using leasing rather than easements to convey rights. [14]

Most other issues can be addressed without resorting to legislative or regulatory changes. For example, the issue of bond tax exemption can probably be addressed through attention to the ways that bond issues are structured and bond proceeds are used. In some cases, the number of options available is limited by regulation, resulting in little (or even no) choice but to pursue legislative changes (e.g., where cash compensation is precluded by statute). Even under these circumstances, shared resource projects can be effective without legislative initiatives so long as the potential partners are willing to accept an option that is within currently accepted boundaries. [14]

Often, the choice made among ways of addressing these issues is based on preferences and an evaluation of the pros and cons of each option. The choices between exclusivity and multiple partners, allocation of infrastructure relocation and liability for repairs, and selection of barter over cash compensation are often based on preference rather than necessity. [14]

Table 9-32. Issues Associated with Shared Resource Project Development. (14)

THRESHOLD LEGAL AND POLITICAL ISSUES	
Public sector authority to receive and/or earmark compensation	The public sector may be precluded from receiving cash payments, but may still be free to engage in barter arrangements, particularly if they are structured as procurements. In general, state departments of transportation (DOTs) have less flexibility; municipalities and authorities such as turnpike and transit agencies have greater flexibility in dealing with cash flows.
Authority to use public right-of-way for telecommunications	Shared resource arrangements may be precluded if state law mandates free access for utilities or if pubic agencies are not allowed to discriminate among utilities (e.g., permit access for telecommunications but disallow access for gas and sewerage).
Authority to participate in public-private partnerships	Because shared resource arrangements are a form of public-private partnering, legal authority to enter into such agreements is a basic requirement. In some cases, "implied authority" is not considered sufficient and specific legislation or "express authority" must be passed.
Political opposition from private sector competitors	Shared resource arrangements may trigger political opposition, though not necessarily prohibition, from private sector companies resisting the establishment of bypass networks that they perceive as competing with the services they offer. Opposition may be slight when the bypass system is limited to transportation needs, but it is likely to be stronger if the system supplies a greater range of public sector communications needs.
Inter-agency and political coordination	In addition to investing effort in coordination among agencies in the same political jurisdiction, the lead pubic agency may also have to orchestrate agreements between geographically proximate political jurisdictions to ensure continuity for fiber for their private partner(s).
Lack of private sector interest in shared resources	At its core, shared resource arrangements depend on private sector interest in expanding telecommunications infrastructure. Reluctance to enter into partnerships with pubic agencies for access to right-of-way may stem from insufficient market demand for increased communications capacity, cost factors such as more stringent installation specifications along roadway right-of-way, and administration or managerial burden of compliance.
FINANCIAL ISSUES	
Valuation of public resources	Before entering into shared resource agreements, the public sector needs to have some idea of the value of the assets it brings to the partnership; that is, continuous or sporadic access to its right-of-way for placement of private (communications) infrastructure.
Tax implications of shared resource projects	Partnerships between public and private entities may pose unique tax issues, particularly bond eligibility for tax-exempt status when proceeds may benefit profit-making private organizations.
Valuation of private resources	Valuation of the private resources provided in barter arrangements helps the public sector determine whether it is receiving a fair market "price" for its resource.
Public sector support costs	Although shared resource arrangements provide cash revenue or telecommunications infrastructure without public sector cash outlays, such compensation is not without cost since the pubic sector must use agency labor hours for administration, coordination, and oversight.
PROJECT STRUCTURE ISSUES	
Exclusivity	Shared resource arrangements may limit access to pubic right-of-way to a single private sector partner in any specific segment, that is, grant exclusivity. From the public sector point of view, exclusive arrangements have both advantages (administrative ease) and disadvantages (potential constraints of competition among service providers, lower total compensation received by the public sector).
Form of real property right	Shared resource arrangements can be structured in any of several legal formats (easement, lease, franchise, license) with variations in the property rights conveyed. Moreover, the property right may involve access to the right-of-way itself for privately owned infrastructure, or be limited to access to (or use of) publicly owned infrastructure.
Type of compensation	Compensation to the public sector may be in the form of goods (in-kind), cash, or combinations of both. Moreover, in-kind compensation can include not only basic fiber-optic cable but also equipment to "light"* fiber, maintenance, and even operation and upgrading.
Geographic scope	Projects can be extensive in scope, covering long segments of roadway, or more focused on specific areas. The option that is best in any individual context depends on other factors, such as considerations of administrative burden, service interests of potential bidders, an i private willingness to install infrastructure in an area larger than their primary area of interest.

*"Light" fiber refers to fiber optics supported by equipment for transmission and receipt of communications signals; "dark" fiber refers to physical fibers devoid of supporting telecommunications equipment.

Table 9-32. Issues Associated with Shared Resource Project Development (Cont'd). [14]

CONTRACT ISSUES	
Relocation	Allocation of responsibility for infrastructure relocation in case of roadway improvements affects private partner willingness to pay for right-of-way insofar as it carries a financial responsibility as well.
Liability	Similarly, allocation of legal liability among partners affects the financial risks assumed by each one. Liability includes responsibility for system repair, consequential damages (economic repercussions), and tort actions.
Procurement issues	Shared resource arrangements face many of the same issues as other procurements regarding selection and screening of private vendors or partners.
System modification	Shared resource arrangements may or may not include explicit provisions for system modification; that is, technological upgrading to keep abreast of technical improvements and expansion of capacity to meet subsequent needs.
Intellectual property	Intellectual property involves intangible components (e.g., software programs) of the operating system that might not be available to the public sector partner when the partnership is dissolved after the lease period unless specifically addressed in the contract.
Social-political issues	Social-political issues involve equity among political jurisdictions or population segments within the right-of-way owner's domain. More specifically, two issues may affect how shared resource arrangements are structured: most-favored community issues — comparable compensation for all communities engaging in shared resource arrangements, and geographic and social equity — equitable access to and benefit from shared resource arrangements.

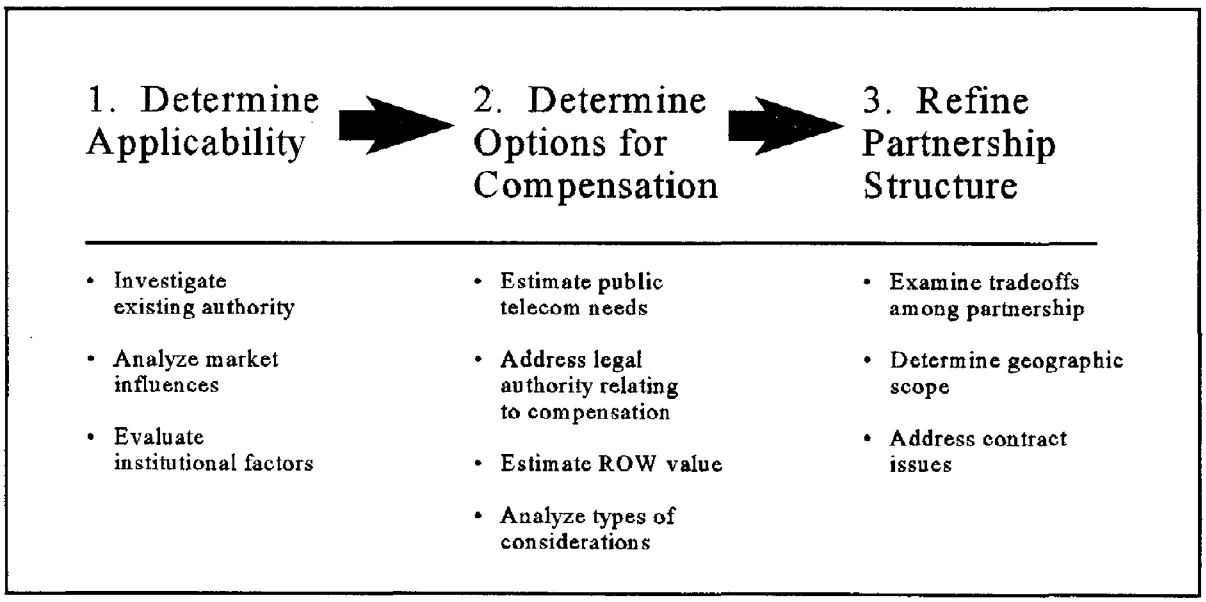

Figure 9-13. Key Decisions and Supporting Information in Evaluating the Need for a Shared Resource Project. [14]

Although shared resource projects have been heralded as an innovative approach to satisfying public sector needs, they are only one of several ways to provide for these communications needs. They are hardly the universal solution. Before initiating a shared resource project, public agencies must evaluate their telecommunications needs (including private sector-supplied services), and then evaluate the appropriateness of each alternative in light of specified needs. Figure 9-13 graphically summarizes the basic stages in developing a shared resource project. [14]

In addition, the public sector needs to realize that shared resource partnering is market-driven. Because it is market-driven, an upper limit exists to how much compensation will be paid. Furthermore, private agencies will not wait extended periods for access rights to a public agency's right-of-way. Therefore, public agencies must be ready to act when the opportunities present themselves.

The highway right-of-way has no "inherent" value. Concerning telecommunications access, value is derived from the potential revenue telecommunications companies can gain by using the right-of-way as tempered by the cost of other rights-of-way that might be available at that time.[14]

Similarly, market conditions dictate response time for prospective partnering. As market forces and technology change, demand for access to highway rights-of-way may also change. In fact, timing can be a critical factor in the choice among options in structuring a shared resource project. Because the window of opportunity is often narrow and because private sector partners can have access to non-highway right-of-way for infrastructure, public agencies interested in effecting shared resource partnerships must address the associated issues in a timely fashion; otherwise, a public agency may have to wait until market expansion or industry restructuring generates new demand for right-of-way use.[14]

For more information about the issues associated with shared resource projects, the user should consult *Shared Resources: Sharing Right-of-Way for Telecommunications.* [14]

TRANSIENT PROTECTION

Electronic traffic control equipment is subjected to a wide range of electromagnetic threats, including lightning, electrostatic discharge, internally and externally generated inductive switching transients, and radiated electromagnetic interference (EMI) from radio, TV, radar, and mobile communication transmitters. Lines providing electrical power and cable interconnecting equipment to sensors, communications systems, or peripheral hardware provide a direct path for the conduction of disruptive and damaging electrical transients and other EMI into traffic control equipment. In general, traffic control and communications systems can be protected against transients through the following mechanisms: [15]

- Proper grounding of power supply and communications systems.
- Adequate shielding of equipment and interface cables.
- Proper bonding and corrison control.
- Use of terminal protection techniques such as amplitude limiters and filters.
- Good interface designs that use balanced line inputs and fiber optics.

The most severe electromagnetic threat to traffic control equipment is lightning. To determine the level and extent of protection required against lightning-induced transients, the traffic control professional must know the lightning threat levels at traffic controller inputs, the rates-of-occurrence of lightning transients, and the effects of the lightning discharges on electronics within traffic control equipment. The lightning levels will vary depending on the type of interface, the length of the interconnecting lines or cables, and whether the lines are shielded or not.

NCHRP Report 317 Transient Protection, Grounding, and Shielding of Electronic Traffic Control Equipment describes techniques for protecting against transient and electromagnetic interference.[15]

COMMUNICATIONS WITHIN THE CONTROL CENTER

Providing adequate communications systems within the control center is critical to the success of the control center. In general, the types of communications systems implemented in a control center need to allow operators to communicate with the following personnel:

- Other control center operators.
- Supervisory personnel.
- Maintenance dispatchers/forces.
- Computer system operators/ maintainers.
- Incident management personnel.
- Public relations personnel.
- Media.

In general, the types of communication systems that need to be included in the design of the control center include the following:

- Local area computer networks where information and data can be transferred from one computer terminal to another.
- Voice communications systems

Module 10 provides more information about these types of communications systems.

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MODULE 10. CONTROL CENTER

TABLE OF CONTENTS

MODULE 10. CONTROL CENTER

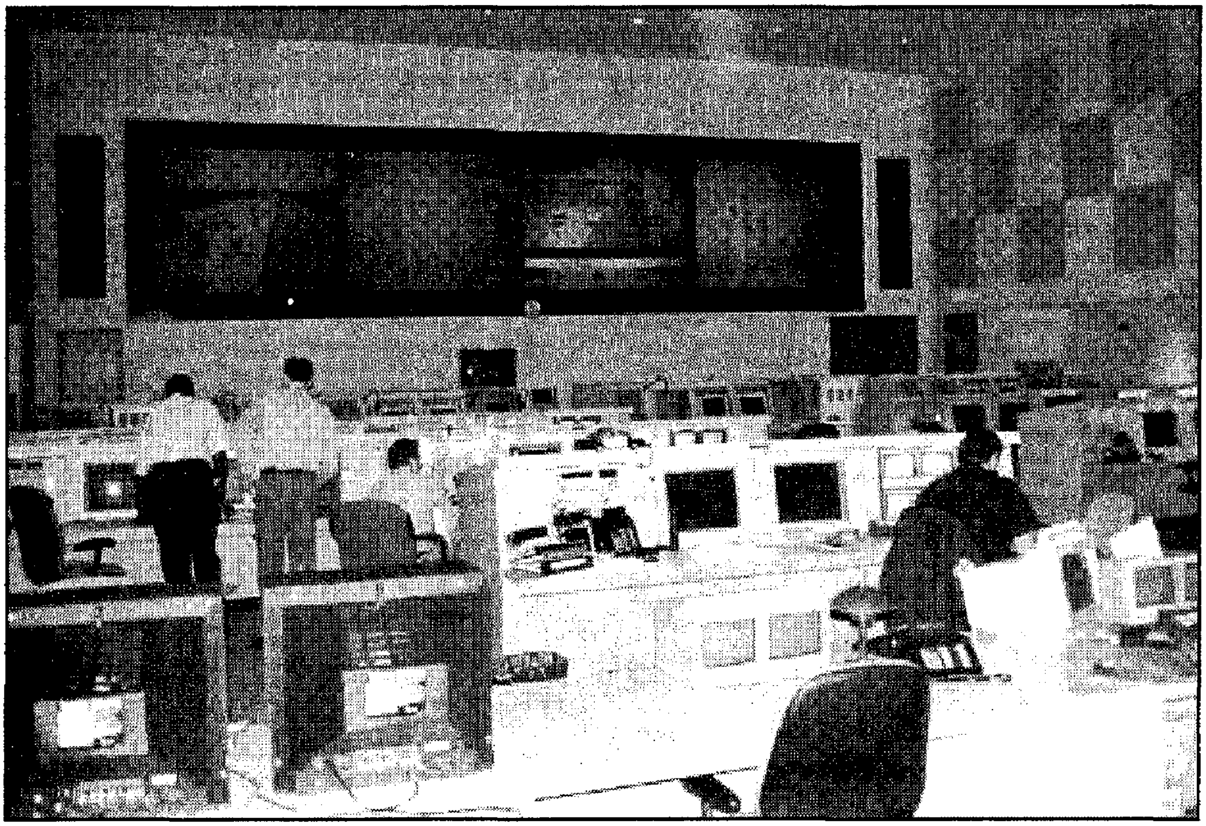

Figure 10-1. The Control Center of the TranStar Freeway Management System in Houston, TX.

10.1 INTRODUCTION

The control center is the hub or nerve center of a freeway management system. It is where data about the freeway system is collected and processed, and fused with other operational and control data to produce "information." The information is then used by system operators to monitor the operations of the freeway and initiate control strategies to affect changes in the operations of the freeway system. It is also where agencies can coordinate their responses to traffic situations and incidents. Furthermore, the control center is also the focal point for communicating traffic flow information to the media and the motoring public. Because of its critical role in the successful operation of a freeway management system, it is essential that the control center be designed to allow operators to control and manage the functional elements of the freeway management system.

All too often, system designers have viewed technology and/or automation as the design goal for the control center. Unfortunately, this view is not supported by experience, and can cause operational problems when it is allowed to bring undue influence on the design of the control center. In one operational control center, for example, expert design resulted in an automation scheme in which the support system would determine the "best" pattern of variable message signs to present motorists with warnings of wrong-way drivers in the travel lanes. Under the design principle, the operator would review the automatic decisions and could change them after they were initiated, if necessary. After the system became operational, however, it was found that the surveillance system could not detect the difference between roadway maintenance equipment working in a closed lane and wrong-way drivers in the travel lane. The error resulted in the automatic closure of a large area of a freeway. This problem arose from a faulty *allocation of functions* to a higher level of automation than was feasible, a common design flaw. Its primary cause was that the design emphasis was on technology rather than on the performance of the total system. [1]

One way to avoid such design problems is to begin with a user-centered approach to designing a control center. [1] A user-centered approach applies system engineering and human factors principles to developing a system design that focuses on what the system is supposed to accomplish rather than on technology. The distinguishing features of a user-centered design philosophy as compared with other approaches include the following: [1]

- **The design focus is on the operator, not the designer.** In the user-centered design, the user (i.e., the operator) is viewed as a critical system component. The characteristics, capabilities, and limitations of the user need to be defined and considered during the requirements analysis and design of the system. Ideally, the user should be involved in the design process at its earliest stages and this involvement should continue throughout the design and testing phases.

- **The selection and acquisition of system components are based on validated functional requirements.** Many control centers have been designed adhering to a *technology-centered design approach* where the focus in designing the system has been on hardware and software. The user-centered design focuses on *what* needs to be accomplished by the system, not *how*. Therefore, system components are selected on the basis of an analysis of the functional requirements of the system. A *validated requirement* is a functional capability (e.g., identify sensor locations at which occupancy exceeds 30 percent during a 2-minute period) that has been formally stated and objectively evaluated.

- **The process is iterative.** Systems are best developed through an *iterative* process, in which a design is tested and validated in a series of stages. This is particularly important in control center design, where the multiple iterations can uncover problems — and opportunities — that are not apparent until they are viewed in the total system.

- **The process extends throughout the life cycle of the control center.** The fact that a new control center has been built and put into operation does not suggest that it is "complete." As the managers and operators of the control center become familiar with the system, they will make recommendations for adding many excellent design features and procedural changes to improve their abilities to control traffic on the freeway.

A user-centered design approach applies system engineering principles to develop a system that views the user (i.e., the operator) as critical to the overall success of the system. Figure 10-2 illustrates how the user-centered design process can be used to identify the elements of a control center. The first step in the design process is a mission analysis, which uses the goals and objectives of the system to define what it is the control center is supposed to do. After the mission analysis, a functional analysis identifies which functions will be performed by various elements (both human and technological) in the control center. Once the functional analysis has been completed, the tasks needed to accomplish each function can be analyzed. The task analysis involves breaking tasks down into their individual elements to include a detailed description of both manual and mental activities that the operators must do, and their duration, frequency, and complexity. The task analysis leads directly to defining operational characteristics and needs for the control center.

MODULE OBJECTIVE

The goal of this module is to identify some major factors and issues that should be considered in the planning and design of a control center. The specific objectives of this module are to identify the some major issues that must be considered designing, operating, and maintaining a control center for a freeway management system.

MODULE SCOPE

The purpose of this module is to help system planners and designers identify some major issues and factors affecting the design and operations of a control center for a freeway management system. It focuses on how the characteristics, capabilities, and limitations of the operators should be accounted for in the design of the control center. This module is not intended to be a detailed discussion of the human factors requirements affecting the design of the control center. For detailed information about the human factors requirement, the user should consult the *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) or other references. [1,2,3]

10.2 DECISION PROCESS

PROBLEM IDENTIFICATION

The first step in the design process for a control center is to identify its purpose or role in the overall freeway management system. The functions of a control center can vary from location to location, depending upon the local operating goals and philosophies for the freeway management system. For example, some agencies may be more interested in disseminating information about traffic and travel conditions to travelers, while other agencies may want to influence traffic behavior through control mechanisms, or to manage incidents by closely interacting with other agencies. The design of the control center needs to support the desired operating philosophy. An agency whose primary goal is information dissemination may want to design a control center that allows easy access to the information in the system by users outside the control center. An agency that wants close interaction with other operating agencies (fire, police, emergency services, etc.) may want to provide a physical location in the control center for those agencies to dispatch their emergency responses. Common roles/functions of a control center in freeway management systems include the following:

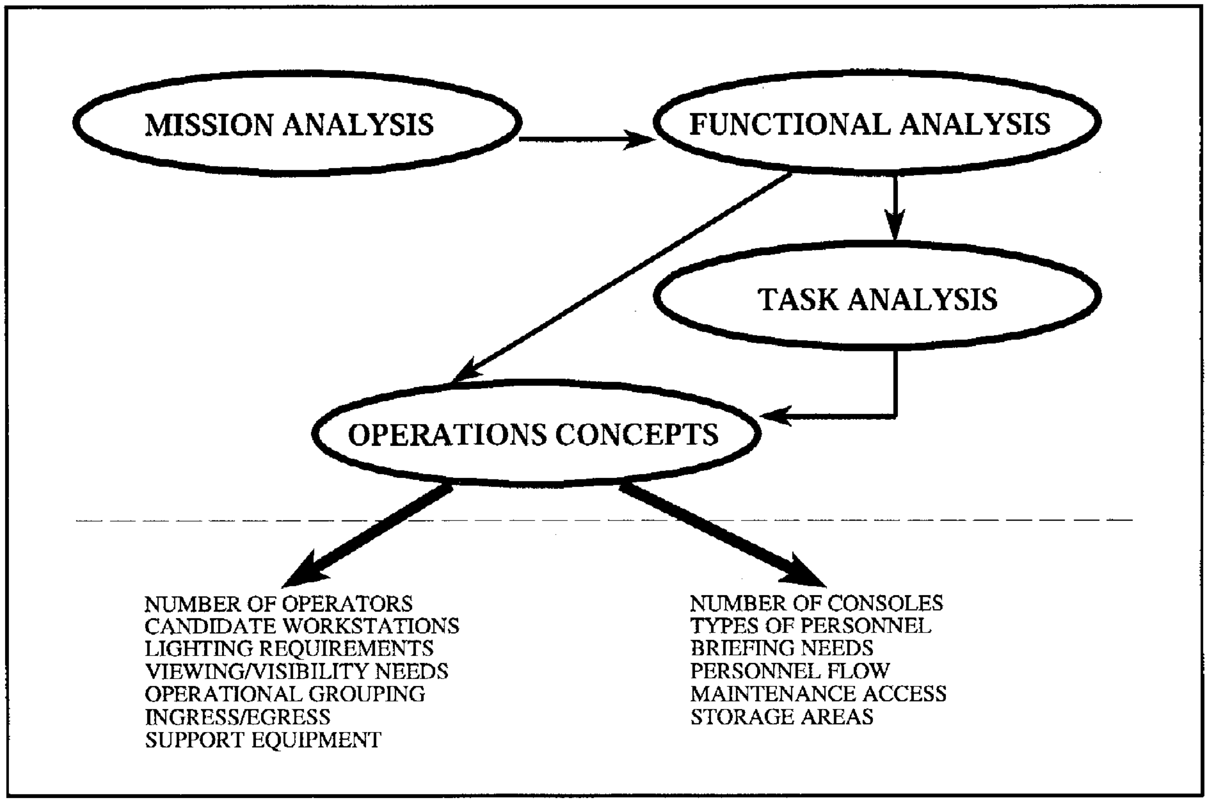

Figure 10-2. A User-Centered Design Approach. [1]

- A location for coordinating and implementing freeway management strategies and controls.
- A dispatching center for incident management and maintenance forces.
- A location for doing maintenance and repairs of malfunctioning or damaged field equipment.
- A central location for distributing freeway traffic and travel information to travelers, elected officials, and the media.
- A command post for coordinating the response to major emergencies.

Designing and constructing a control center can be costly (often millions of dollars). In the past, some agencies have found that their control center facilities have been inadequate to satisfy future growth. Planning accordingly for system expansion is important for agencies. Systems can expand their operations in many ways, including the following:

- Increase the number of freeways and/or roadway facilities covered.
- Add new freeway management functions to the existing functions of the system.
- Permit joint or cooperative operations of several agencies from one location.
- Serve as command post for major emergencies.

With these potentials in mind, agencies can plan for future expansion in the control center by providing the following:

- Adequate space in the operations room to install additional operator consoles/ workstations.

- Sufficient space and capacity to install additional computers and peripherals.

- Spare or expandable communications capabilities.

- Additional office space for operations and maintenance personnel from different operating agencies.

IDENTIFICATION OF PARTNERS AND CONSENSUS BUILDING

Regardless of whether the control center will be operated by a single agency or by several agencies in a joint operation, agencies need to identify potential partners, and build consensus and support within these organizations. A big question that must be addressed in the initial planning stages is who needs to be in the control center. Depending upon local needs and operating philosophy, operating personnel can come from the following agencies:

- State transportation agencies.

- Local transportation agencies.

- Police and emergency service providers.

- Local transit authorities.

- Private media and traffic reporting services.

Joint operations can be structured administratively to occur in different ways, such that varying levels of functional and management control are centralized or individual control is maintained. Joint operation can be structured through the following: [4]

- Sharing physical resources that are common to each agency's operation, but operating each system or agency component individually. This could occur through use of a common communications system (e.g., the TranStar System in Houston, TX).

- Operating individual or multiple systems under one designated management structure where operational control is centralized. This could occur by time of day where peak periods are under central control and off-peak is under local jurisdictional or functional agency control. Typically, the participating parties establish operating guidelines that are carried out by an individual agency or group, with the goal being to establish coordinated ongoing operations.

- Delegating day-to-day operations to another agency or group (including a private entity). This type of operation could entail turning the operations and maintenance of individual devices over to another agency under a defined set of conditions (e.g., Transcom operation of certain DMSs and HARs in the region surrounding New York City).

The ability to engage in joint operations is not an easy objective and usually occurs from ongoing relationship building. While a variety of strategies can be undertaken to foster cooperative joint operations, no single technique or action is always appropriate. Each community must assess its unique situation and develop a specific strategic plan that conforms to that situation. [4]

ESTABLISH GOALS AND OBJECTIVES

Before beginning on the actual design of the control center, participating agencies need to establish common goals and objectives for the control center. These common goals and objectives are used to develop principles for designing the functional and physical components of the control center. Examples of the types of issues that agencies need to address in establishing goals and objectives for a control center include the following:

- The functions to be carried out in the control center (e.g., traffic management, dispatching, incident management, etc.).
- The degree to which various elements in the system can be accessed and controlled by potential users of the system.
- The level of automation and the role of the operator in the system.
- The level and types of access that users outside the system (e.g., media, administrative, traffic reporting services, etc.) have to the information (i.e., databases, video, incident reports, etc.) produced by the system.
- The amount and type of customized equipment and software that will be permitted in the design of the control center.
- The level and manner in which existing and planned elements of the system will be integrated.
- The types of operator interfaces (i.e., displays, data entry screens and devices, etc.) that will be provided.
- The hours and operating conditions under which the control center will be staffed.

DEFINE FUNCTIONAL REQUIREMENTS

After establishing design goals and objectives, the functional requirements of the control center can be defined. Functions are broad statements that describe every operation and activity required to meet the defined objectives. Table 10-1 lists some possible generic functions of freeway management control centers. Note that these functions describe what it is the system does, and do not define whether activities are done by humans, by automated equipment, or by a human using a computer.

A *Mission Analysis* is an exercise that may be useful to agencies in identifying the functions of a control center. A mission analysis is used by system planners and designers to identify the operational capabilities required in the control center. Traditionally, two methods are used to conduct a mission analysis: a mission profile and scenario development. A mission profile is a detailed description of normal system operations that occur during a given system activity or over a given interval of time. It consists of listing all the activities to be done by various elements in the total system—operators, supervisors, automated subsystems, sensors, etc. The list also includes any activities done simultaneously (e.g., automated tasks done by system hardware, operator assessments, operator decisions). Activities are described at a high level and no attempt is made to define the roles of the operators or automated system in doing them. This technique provides an organized, high-level framework of system requirements that will support subsequent, detailed design analysis. (1)

With the scenario development technique, descriptions of specific scenarios—nonroutine but typical situations that would burden (challenge) the capabilities of the control center—are sometimes useful in providing an understanding of the control center's functions. The scenarios should describe what actions and information are needed to manage traffic during different

Table 10-1. List of Possible Generic Functions Performed in Freeway Management Control Center. [1]

Input	Throughput	Output	Support
• Detect vehicle locations • Detect vehicle speeds • Detect vehicle types • Sense roadway surface conditions • Receive BIT reports • Receive ad hoc component status reports • Sense visibility conditions • Verify incident data • Monitor incident clearance • Receive traffic volume reports • Receive probe vehicle reports • Receive ad hoc travel time reports • Receive ad hoc roadway condition reports • Receive O-D Data • Receive commercial rail traffic data • Receive ad hoc commercial rail traffic reports • Receive weather service data • Receive ad hoc weather reports	• Assess current load • Anticipate near-term traffic conditions • Select best traffic control option • Determine need for ITMS support • Track special vehicles • Predict traffic conditions given options • Determine remedial maintenance needs • Assess predicted traffic conditions given options • Assess traffic management effectiveness • Determine software upgrade needs • Determine hardware upgrade • Determine personnel upgrade needs • Determine preventative maintenance needs • Determine source of anomalies • Identify anomalies in traffic patterns	• Control railroad crossings • Post route advisories on information outlets • Provide route advisories to other users • Post speed advisories on information outlets • Provide speed advisories to other users • Post travel advisories on information outlets • Provide travel advisories to other users • Post mode selection advisories on information outlets • Provide mode selection advisories to other users • Transmit electronic maintenance requests • Issue special maintenance requests • Issue upgrade requests • Transmit electronic incident services requests	• Store electronic network data • Retrieve electronic network data • Store electronic incident data • Store hardcopy of incident reports • Retrieve electronic incident data • Retrieve hardcopy of incident reports • Perform database management • Provide traffic management training • Provide maintainer training • Provide incident management training • Provide special events training • Develop strategic traffic management plans • Develop special event traffic management plans

Table 10-1. List of Possible Generic Functions Performed in Freeway Management Control Center (Cont.). [1]

Input	Throughput	Output	Support
• Receive interagency incident data • Receive ad hoc incident response reports • Receive interagency emergency response data • Receive ad hoc emergency response data • Receive interagency data from alternate transportation modes • Receive ad hoc reports from alternate transportation modes • Receive interagency special events reports • Receive ad hoc special event reports • Receive public comments • Receive requests for public relations activities • Receive requests for historical data • Receive requests for simulation studies	• Predict multimodal demand given options • Determine ITMS responsibilities • Determine need for incident services • Determine appropriate ITMS responses • Assess multimodal demand and capacity • Identify demand regulation options • Assess predicted multimodal demand • Monitor compliance with other advisories • Monitor general compliance with advisories • Assess survey data • Assess ad hoc public comments • Plan public confidence enhancements	• Issue special incident services requests • Issue requests for information • Issue requests for on-site traffic control • Transmit electronic incident reports • Issue special incident reports • Transmit electronic incident management reports • Issue special incident management reports • Provide historical traffic data • Provide simulation reports and recommendations • Provide public relations information	• Develop traffic management contingency plans • Receive directives • Develop policy • Specify procedures • Implement policy and procedures • Perform fiscal planning • Perform budget tracking • Perform evaluations • Perform personnel selection • Maintain personnel records • Maintain communications with incident responders • Coordinate multi-agency incident response • Coordinate multi-agency response to other emergencies • Coordinate multi-agency transportation planning

operating situations such as freeway incidents, major traffic stressors (e.g., large athletic events, inclement weather), or strategic planning episodes.

DEFINE FUNCTIONAL RELATIONSHIPS, DATA REQUIREMENTS, AND INFORMATION FLOWS

In defining the functional relationships, data requirements, and information flows for a control center, the following three tasks must be done:

- Allocating control center functions the operators, computer/machine components in the system, or a combination of both.
- Analyzing the tasks required to complete each function.
- Establishing how data flow from one function to the next.

Each of these tasks is discussed below.

Function Allocation

In the design of the control center, function allocation involves assigning system functions to machine components, human operators, or a combination of human and machine components. Using criteria similar to those shown in table 10-2, each function (or process) is assigned to a human or machine component. Properly allocating functions is critical to ensuring that operators in the control center perform tasks that are within their capabilities and do not become overloaded. The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) presents techniques for allocating functions to human operators and machine components. The reader is referred to this document for details on the allocation procedures.(1)

The allocation of functions in the control center is usually the first point in the design process at which critical decisions must be made about the role of the operator. It is also a point at which mistakes, if not identified and corrected in design iterations, can cause serious design deficiency. One common misconception that occurs in allocating functions is that designers presume that a single set of functions should be handled solely by an operator and another set should be handled solely by machines. In fact, many critical functions in the control center can best be handled by the integrated efforts of humans and machines. Identifying these partly automated tasks requires detailed study and analysis. Failing to identify them properly and assign proper interface strategies causes serious operational problems. General guidelines and design considerations for allocating functions in a control center include the following:(1)

- If environmental constraints limit human performance, the function should be allocated to a machine.
- Events that cannot easily be perceived by humans (such as changing levels of traffic moving past a point on a freeway) should be allocated to machines.
- When a function requires a response that is beyond the speed or accuracy of human capabilities, it should be allocated to a machine.
- If the speed and volume of information derived or needed by a function is beyond the capabilities of a human, it should be allocated to a machine.

Table 10-2. Criteria for Assigning Functions to Humans and Machines. [1]

Humans Excel in ...	Machines Excel in ...
Detection of certain forms of very low energy levels	Monitoring (both men and machines)
Sensitivity to an extremely wide variety of stimuli	Performing routine, repetitive, or very precise operations
Perceiving patterns and making generalizations about them	Responding very quickly to control signals
Ability to store large amounts of information for long periods — and recalling relevant facts at appropriate moments	Storing and recalling large amounts of information in short time periods
Ability to exercise judgement where events cannot be completely defined	Performing complex and rapid computation with high accuracy
Improving and adopting flexible procedures	Sensitivity to stimuli beyond the range of human sensitivity (infrared, radio waves, etc.)
Ability to react to unexpected low-probability events	Doing many different things at one time
Applying originality in closing problems (i.e., alternative solutions)	Exerting large amounts of force smoothly and precisely
Ability to profit from experience and alter course of action	Insensitivity to extraneous factors
Ability to perform fine manipulation, especially where misalignment appears unexpectedly	Ability to repeat operations very rapidly, continuously, and precisely the same way over a long period
Ability to continue to perform when overloaded	Operating in environments that are hostile to man or beyond human tolerance
Ability to reason inductively	Deductive processes

- If the information produced by a function is beyond the memory capabilities of a human, it should be allocated to a machine.
- If a function is to be performed continuously, it should be allocated to a machine.
- If the interruption of, and response to, unusual or unexpected events are

required, the function should be allocated to a human.

Following is a list of additional guidelines that can be used to help in allocating functions in a control center:[1]

- Allocate functions so that they make the best use of human abilities.
- Avoid decisions based solely on the ease or difficulty of automation; consider how allocating different functions between humans and machines affects total system performance.
- Avoid allocating functions in such a way that both humans and machines are forced to work at their peak limits all or most of the time.
- Allocate functions to humans so that they can recognize or feel that they are making an important and meaningful contribution to the performance of the system.
- Allocate functions between humans and machines so that a natural flow and processing of information can occur.
- Assign tasks that require extremely precise manipulations, continuous and repetitive tasks, or lengthy and laborious calculations to a machine.
- Design human/system interfaces on the presumption that the human might at some point have to take control of the system.
- Use hardware and software to aid the operator; do not use the operator to complement a predetermined hardware/software design.

Task Analysis

After functions have been allocated to human operators and system components, the next step in designing a control center is to identify the tasks that make up system functions. Each function includes one or more tasks. A task is an independent action, carried out either by an operator or by a machine, that results in an identifiable outcome. Tasks can frequently be decomposed into discrete subtasks that represent activities that are distinct enough to be analyzed separately, but are clearly contributing to the completion of an identified task.[1]

Once the tasks have been identified, they can be grouped to form operational flow or process diagrams. The operational flow diagrams allow designers to identify the actions, information requirements, processes, and decisions that need to be made to accomplish a function. Figure 10-3 illustrates an operational flow diagram for dealing with traffic incidents. Operational flow diagrams are useful tools in the design process, because they allow designers to identify the following elements easily:

- The types of data and communications requirements in the control center.
- The decision-support aids needed to complete operational tasks.
- The data-storage requirements of various processes and tasks in the control center.
- The types of outputs and decisions produced by each task.

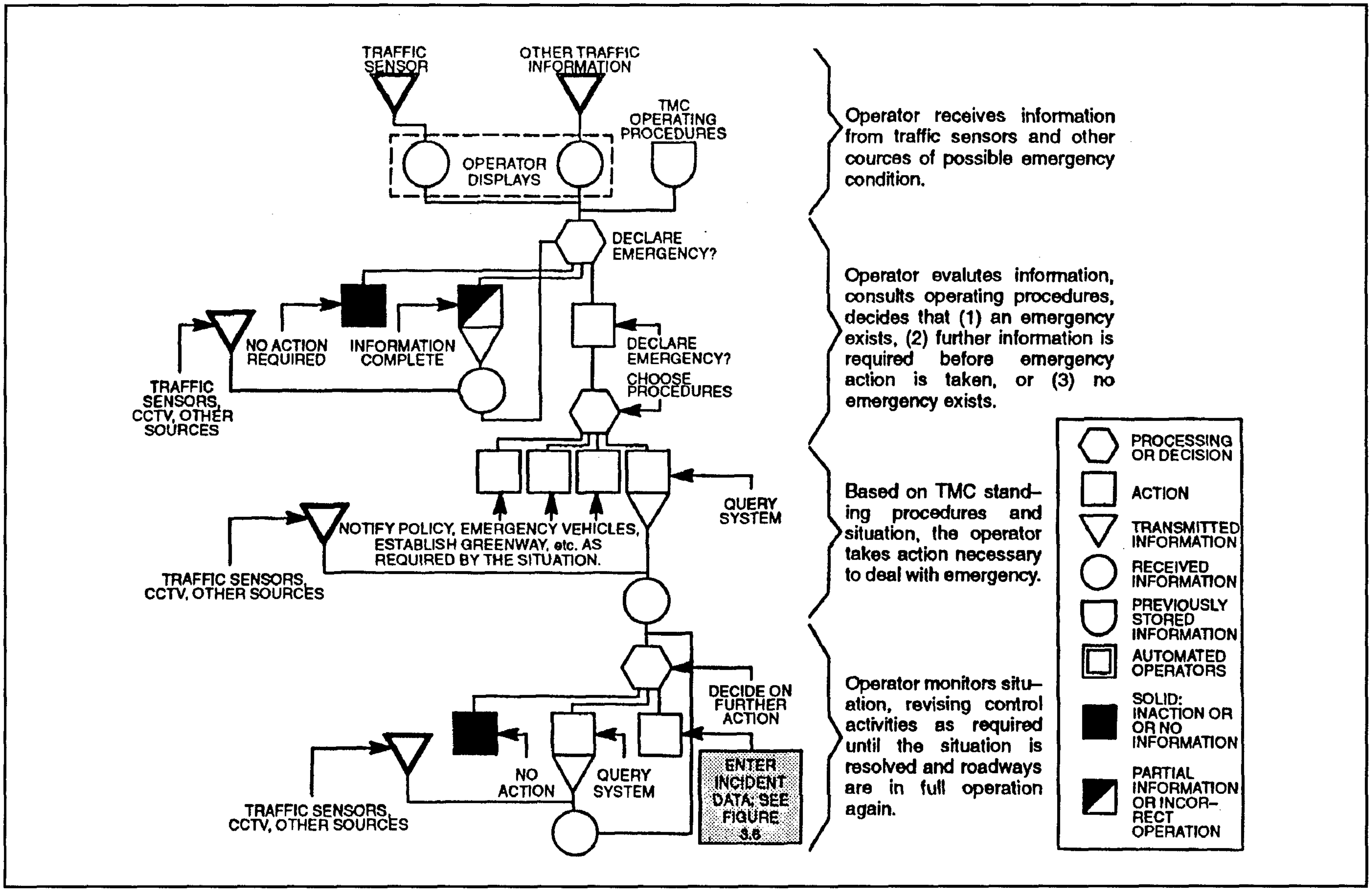

Figure 10-3. Example of Operational Flow Diagram for Managing an Incident. [1]

Data Flows

Establishing data flows is a critical step in designing a control center. Data flows describe the type and frequency of data needed to execute each function of the control center. This step in the design process is important because it allows system designers to assess the communications requirements of each component in the control center. Establishing the data flows also helps to identify the structure of the data streams needed to operate each function of the system.

One way to depict data flow is through data flow diagrams. With data flow diagrams, large circles are used to represent sources and destinations of data. The sources/ destinations can be either subsystems or functions within subsystems. Lines connecting data sources and destinations are used to represent the type of data that flows between two elements of the system. Each data type is labeled so that designers know what information is flowing between components. An example of a typical data flow is provided in figure 10-4. Data flow diagrams need to be prepared for each level of design detail and for each subsystem within the control center.

IDENTIFY AND SCREEN TECHNOLOGIES

Only after the functions of the control center have been identified and the data flow requirements have been assessed should designers begin designing the physical layout and the support elements and related technologies of the control center. In planning the control center, system designers need to be concerned with the following elements:

- The physical environment in which the operators and equipment will function.
- The design and operations of the operators' workstations.
- The design of the controls and displays that the operators will use to operate the system.
- The design of the interfaces through which the operators will be presented with information and initiate control decisions.

The following sections relating to these issues were extracted from the *Human Factors Handbook for Traffic Management Center Design* (First Edition).[1]

Physical Environment

The control center's physical environment consists of design elements that allow the system — both human and machine components — to function effectively. The following lists some physical elements that designers must consider:

- Atmospheric (heating, ventilation, and air conditioning).
- Visual (primary and supplementary lighting).
- Acoustic (background noise and interior acoustical properties allowing operators to communicate).
- Physical design of the work space (access, dimensions, and fixtures).

The requirements for some of these elements are mandated by public law (e.g., access for the disabled). The design of other features of the control center should be based on established design practices (e.g., lighting

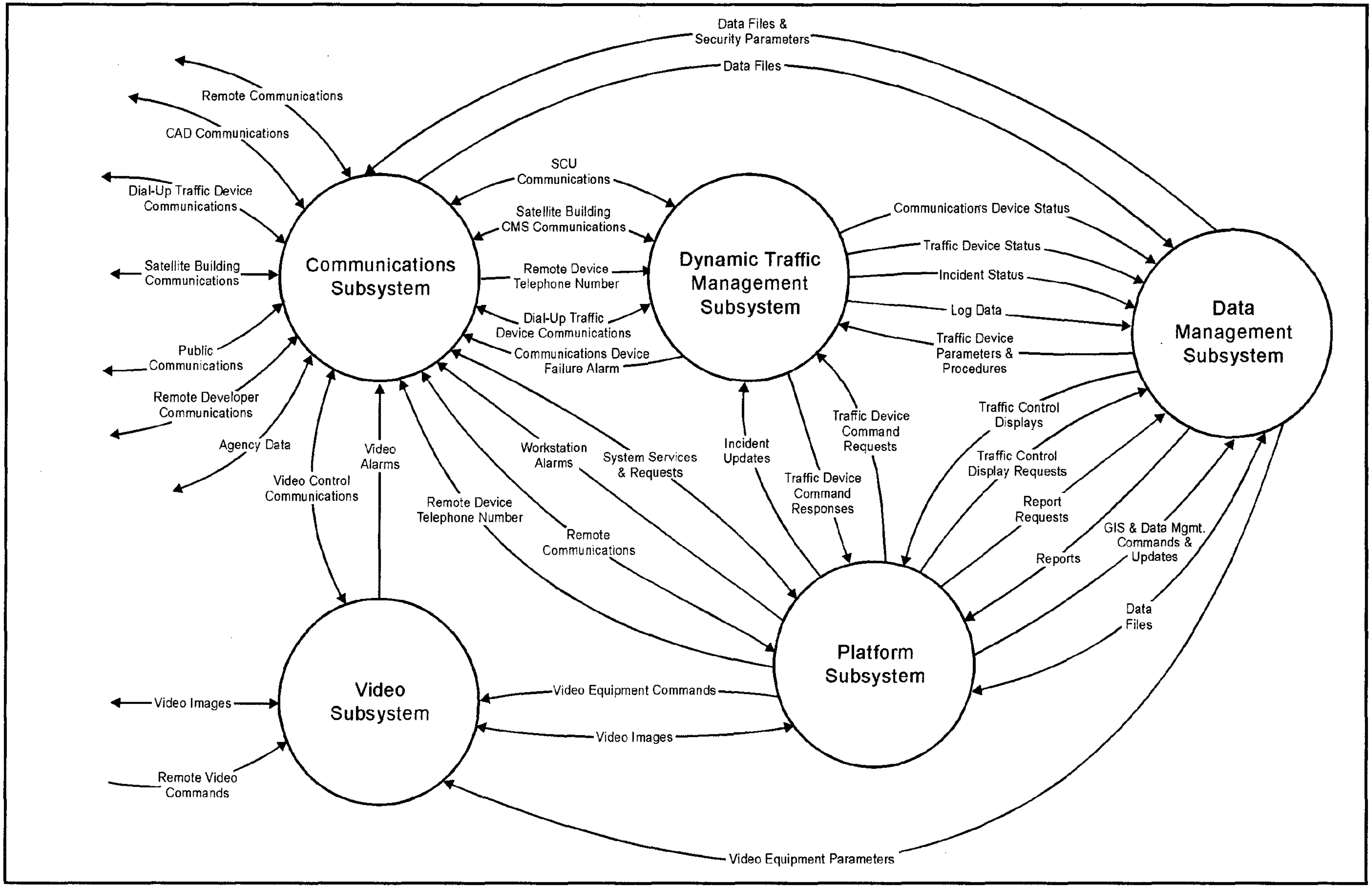

Figure 10-4. Data Flow Diagram of the TranStar System in Houston, TX. [(5)]

standards for designated work areas). The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) provides guidelines and requirements that can be used to design the physical environment of a control center.[1]

Workstations

At the same time the design team is considering how the control center work space will be used, it should begin designing and specifying the workstations that will be used in the control center. A typical operator workstation is shown in figure 10-5.

When workstations are to be configured from commercial off-the-shelf components, this task will require catalog searches and negotiations with vendors. Sometimes—when, for example, the control room is too small to hold separate workstations—customized fixtures designed specifically for the control center under development may be required. The layout of workstations and other furniture and fixtures should be specified as part of the overall work space design. In designing workstations, comfort and suitability should be considered as separate issues, both of which are supported with many experience-based guidelines. The *Human Factors Handbook for Traffic Management Center Design* (First Edition) summarizes many of these guidelines. [1]

Poorly designed workstations and supplemental furnishings (e.g., chairs) can cause discomfort and perhaps occupational injuries (e.g., back strain, cervical stress disorder, carpal tunnel syndrome, and repetitive stress disorders). Poor workstation design can also limit productivity. A good design will contribute to productivity and employee health and morale. Designing the workplace to accommodate the characteristics and capabilities of human operators is sometimes called *ergonomics*. The strong movement toward ergonomic suitability has created many sources of information that support proper workstation design; however, an experienced ergonomist or human factors engineer should be consulted before a large investment is made in workstations.[1]

Controls and Displays

Integral to any control center workstation are the means by which operators enter and retrieve information. Controls allow the operators to guide certain traffic parameters (e.g., traffic flow) within the limits of the center's mission. Displays provide information that operators need to monitor the status of the system and make control decisions. Several methods used to display information to operators in a control center including the following:

- Static display boards.
- Video/CRT monitors.
- Projection television systems.
- Video walls.

Advantages and disadvantages of each of these display devices are discussed in the section 10.3 of this module.

Poorly designed controls and displays can affect the operations of the control center and the operators themselves. Inadequate controls and displays can cause cognitive information processing deficiencies, faulty situation assessments and decisions, inaccurate data and command entry, occupational stress, and a general loss of operating efficiency.

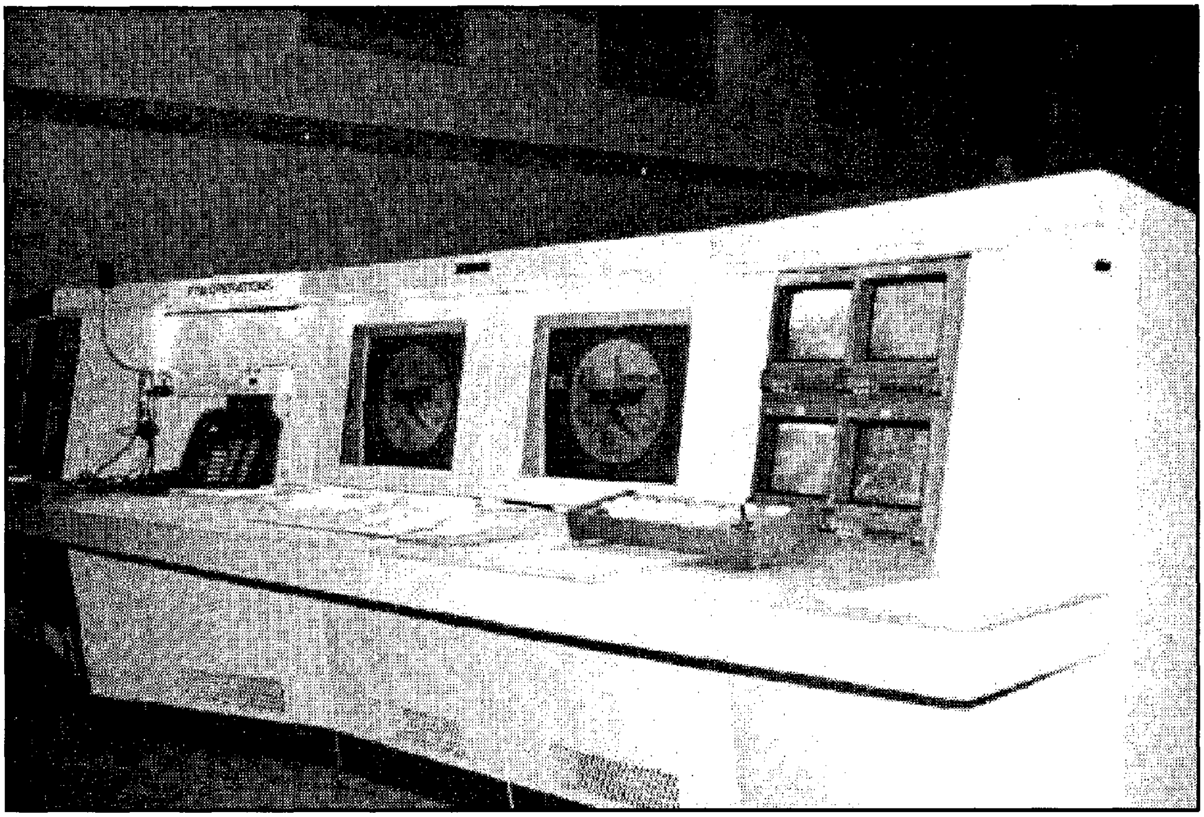

Figure 10-5. Typical Operator Workstation in the Houston TranStar Freeway Management Control Center.

Activities associated with the design and specification of controls and displays are actually subprocesses of the workstation design effort. Controls and displays are considered separately because of the established body of knowledge and standards associated with each of them.

Control center controls and displays should be designed according to (1) the type and quantity of information that they must process and (2) the capacities and demands of the operators who will use the information they provide.[1] Results of a task analysis will suggest information requirements. In turn, these requirements will drive control and display designs.

Once display types have been determined, the guidelines and standards presented in the *Human Factors Handbook of Advanced Traffic Management Center Design* (First Edition) can be used to specify display quality.[1] Emphasis should be placed on the development of display performance standards. Brightness, contrast, and resolution of visual displays, for example, should satisfy operators' requirements for clarity and visual comfort. Designers should be aware, however, that designing controls and displays is an iterative process. A given display, although acceptable when viewed on its own merits, may represent an inappropriate design solution when it is integrated into the control center.

User Interfaces

If the smooth execution of system functions is desired, interfaces between operators and computers must be designed properly. The guidelines and standards for user-computer interface design are relatively new, and less stable than designers typically prefer. The status of these standards and guidelines will present the most significant challenge to the control center configuration effort.[1]

Many troublesome human factors problems existing in operational control centers are derived from poor user interface design. One common problem is the use of command line interfaces that require operators to memorize commands that have little, if any, inherent meaning. Another common interface problem can be attributed to "error traps" — procedures that carry an unacceptable risk of user errors. Some of these errors may have negligible effects, while others may be devastating to the performance of the system. The steps involved in designing acceptable user interfaces include the following:[1]

- Develop an interface concept. This concept should be based upon a knowledge of the types of interfaces available, and their strengths and weaknesses. The types of tasks to be performed through user interfaces should be considered and should be what drives the design process, rather than technology.

- Develop criteria to govern the design and evaluation of the interface. These criteria include design requirements, dialog strategies, and training requirements. The criteria should also be verified by experienced operators, traffic engineers, and others who have experience in interface design.

- Develop a "look and feel" of the user interface and conduct initial testing of the interface, using simulations of various levels of realism. (The level of realism associated with a given simulation is also called *fidelity*.) This type of simulation activity provides an excellent opportunity to incorporate *rapid prototyping*. Rapidprototyping involves using special software tools to develop and evaluate interface prototypes. Rapid prototyping techniques offer speed, flexibility, and realism to the design effort.

- Develop user interface for full implementation.

- Conduct user acceptance testing of the interface. User expectations and perceptions do not always agree with those of the developers. Rigorous evaluation procedures must be employed during acceptance testing. Preliminary tests of training plans, user aides, and user documentation should also occur.

- Incorporate the user interface into the control center design. Design consistency and suitability should be assessed. Final development of a training plan, a training implementation plan, and user documentation should also be completed.

EVALUATION

As different elements of the control center are installed, they need to be evaluated to ensure that they meet generally accepted principles of human factors engineering. Human factors testing and evaluation should not be a one-shot, pass-or-fail activity conducted near the end of the design or implementation phase. Instead, human factors testing and evaluation should occur throughout the design and implementation process. The most important principle to follow in testing and evaluating the human factors elements of the design is to *test early and often.*[1]

Testing should be conducted by someone who has experience in conducting human factors evaluations. Through human factors evaluations, system operators can be assured of the following:[1]

- The design of the control center will meet accepted standards of human factors engineering and will be tailored to the specific requirements of the system.
- Mistakes and problems in the design of the control center will be detected and corrected early, without compromising the budget or schedule.
- Operators will be more easily trained.

Human factors testing and evaluation should be both formative and summative. Formative evaluations result in an iterative process where various levels of design are evaluated and modifications to the design are made on the basis of the results of the testing. Summative evaluations produce a formal pass/fail judgement of design features. The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) provides more detailed information on how to conduct these evaluations.[1]

In conducting human factors evaluations of control center design, obtaining opinions from the following individuals is recommended:[1]

- The control center operators themselves.
- The operators of control centers in other cities.
- The managers and supervisors of the control center.
- Representatives from other agencies who will be operating in the control center or have experience with control centers (i.e., fire/police dispatchers, air traffic controllers, etc.)
- Independent human factors specialists.

10.3 TECHNIQUES AND TECHNOLOGIES

PHYSICAL DESIGN

The size of control centers varies considerably, depending on the design objectives and functions performed by the system. A functional analysis is needed as part of designing the control center. Factors that affect the design of the system include the following:

- The hours and days of operation.
- The types of information displays that will be used in the center.
- The types of monitoring and control strategies in the system.
- The desirability of interagency staffing.
- The need for media and public access to the control center.
- Whether the control center will function as a communications or dispatching center.
- Whether the control center will also function as an emergency operations center.

The size of traffic control centers varies widely throughout the United States. Some control centers, such as TransGuide in San

Antonio, Texas, and Transtar in Houston, Texas, occupy as much as 4,800 m^2 (52,000 ft^2); however, many more successful control centers occupy less space. For example, the control center in Minneapolis, Minnesota occupies only approximately 950 m^2 (10,000 ft^2). Generally, most traffic control centers are between 1,600 m^2 (18,000 ft^2) to 2,300 m^2 (25,000 ft^2).

A typical traffic control center has the following work areas within the building: [6]

- Operations room.
- Computer and peripheral area.
- Communications area.
- A gallery for viewing and training.
- A conference room.
- System support offices.
- A break room.
- A media room.

An example of a typical floor plan for a control center is shown in figure 10-6.

The operations room is the hub of the control center. It houses the operators' workstations and display boards/video terminals used to display information about conditions in the network to the operators. The size of the operations room is dictated by the number of operator workstations that will ultimately be in the control center, and the type and location of the information displays.

The computer/peripheral area houses the computers needed to run the freeway operations center. The size of the computer room depends upon system design decisions regarding how much computer capability will be based at the control center as compared with that installed at hub locations in the field. Often these rooms require strict environmental controls (i.e., heating and air-conditioning). Many locations also have strict access control for this area. Figure 10-7 is an example of a typical computer/ peripheral area in a freeway management control center.

The communications area can be a stand-alone area or can be combined with the computer/peripheral area. The communications area is the terminus for data entering and exiting the control center from the field. It also serves as the distribution point for transmitting data to the rest of the system (i.e., the computer and video control systems).

Many locations like to provide a gallery or viewing area of the operations room. From this area, tours of the control center can be conducted without interrupting the operations in the control center. This area can also be used as a training center where trainees can monitor the operators without disturbing them.

Many control centers also have an area set aside for the media (see figure 10-8). Some control centers use the gallary area to service this function, but others have set aside a separate area as a media area. From this area, the media can watch what is going on in the operations center without interrupting the operations. Often, these areas have several telephones and video terminals that are available for use by the media during incidents or emergencies.

One unique feature of the Houston TranStar System is a media cabinet located in the foyer of the building. As shown in figure 10-9, the cabinet contains power, video, and audio jack that can be used by the media

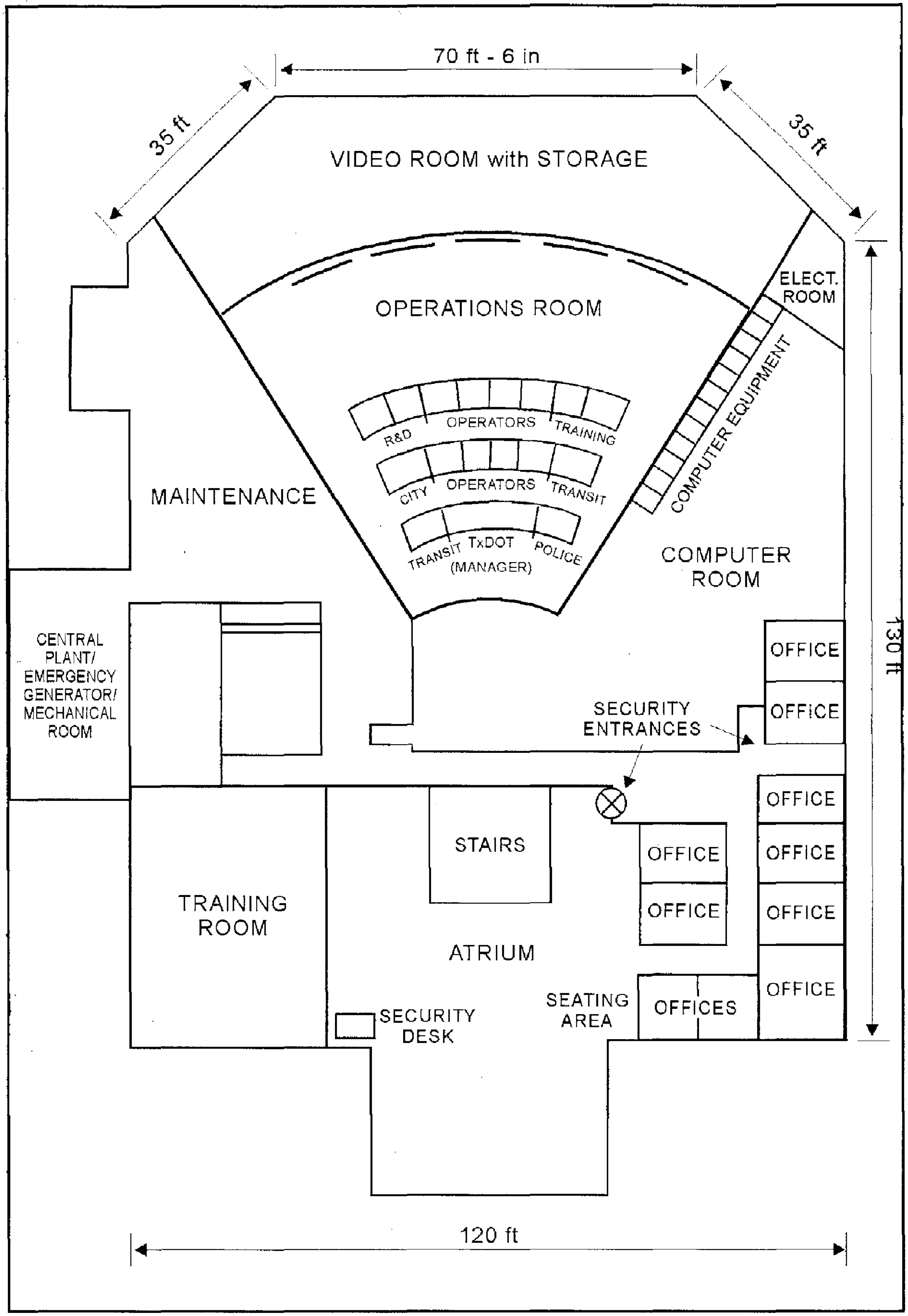

Figure 10-6. Floor Plan of the TransGuide Control Center in San Antonio, TX.

Figure 10-7. Example of a Computer/Peripheral Area in a Control Center.

Figure 10-8. Example of Media / War Room in a Freeway Management Center.

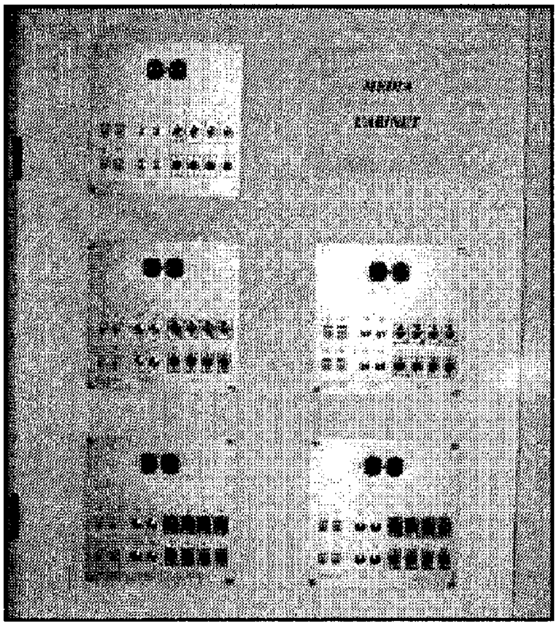

Figure 10-9. Media Cabinet in Houston TranStar Center.

when conducting interviews or reporting on traffic situations. Cables run from the cabinet in the foyer to a cabinet located in the parking lot, where similar connectors are provided for the crews to tie into their respective vans.

Besides these common areas, office space should be provided to those working in the control center. The number of office spaces, again, depends upon what functions will be carried out in the control center. Generally, office space is required for the operations supervisors, the system support staff, the maintenance supervisors, and the engineering and administrative staffs.

Some agencies have included space for their system maintenance personnel at their control centers. If maintenance operations will be based at the control center as well, the space provided at the control center is based on the number of electrical maintenance personnel that will be stationed there. In addition, if the control center is also expected to serve as an Emergency Operation Center (EOC), then additional space is needed for such items as dormitories, a large kitchen, and showers. Some locales may have mandated structural requirements for an EOC that are more stringent than for regular commercial office space.

Lighting

Lighting is an important consideration in the design of a control center. Viewing a large situation map with LED signals or a bank of CCTV monitors, for example, is not compatible with high levels of general illumination. On the other hand, many operators' tasks cannot be performed in low levels of illumination. The lighting scheme and choice of luminaries must be viewed as an integrated whole, and not designed piecemeal. [1]

The greatest challenge in designing the lighting in the control center revolves around the need to provide dim general illumination and higher levels of local illumination. Usually, a low level of illumination is provided in the operations room because of the nature of the tasks and displays used. Most centers provide supplemental lighting at each operator console. Some general recommendations related to lighting in control centers are as follows:[1]

- Indirect lighting should be employed to provide overall illumination for the control room.
- Canister fixtures should be employed to provide supplementary illumination over work areas.
- Adjustable fixtures should be used in work areas where more intense illumination is required.

For more detailed recommendations on lighting issues, the reader is referred to the

Human Factors Handbook for Advanced Traffic Management Center Design (First Edition).[1]

Acoustics

Communications between operators can be critical, especially in emergencies. Common sources of noise in a control center include the following:

- Alarms.
- Radio/telephone communications.
- Operator conversations.
- Data processing equipment.

Overall, the noise level in a control center should not be high enough to interfere with normal speech between operators. The objective in designing for noise is to balance the different sound sources so that local speech is unaffected, but is sufficient to mask intrusive noise from adjacent spaces. Some general recommendations for reducing the impact of noise in the control center include the following:[1]

- Identify possible noise sources (including machines, telephones frequently in use, loudspeakers, and radios with speakers) during the design phase and eliminate them.
- If noise sources cannot be eliminated, consider strategies for reducing noise level, including textured or sound-deadening wall and ceiling materials.
- Consider placing noisy functions that are not tied to normal operator activity in a separate room or in an area enclosed by acoustic partitions.

The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) should be consulted for more detailed recommendations and specifications for accounting for noise in control centers.[1]

Heating and Cooling

Operator comfort and performance can be affected by temperature and air quality. In designing a control center, designers must be concerned about two issues related to the thermal environment of the control center: the general heating, ventilating, and air conditioning (HVAC) standard and the effects of local thermal conditions related to special equipment such as computers and video display units. Sometimes, special rooms in the control center, such as the computer/peripheral room or the communications area, may require separate heating and cooling standards. The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) summarizes the heating and cooling standards applicable to control centers. General standards that should be considered in the design of the heating and cooling system for control centers include the following:[1]

- Actual ventilation should be ensured by introducing fresh air into any personnel enclosure.
- Within permanent structures, effective temperature shall be maintained at not less than 18°C (65°F), and not greater than 29.5°C (85°F).
- Approximately 45 percent relative humidity should be provided at 21°C (70°F). The humidity should decrease with rising temperatures, but should remain above 15 percent to prevent irritation and drying of body tissues.

- The temperature of the air at floor level and at head level should not differ by more than 5.5°C (10°F).

- The exhausting of air from instrumentation (video display units, system units, etc.) should be so accomplished as to avoid discomfort to users and others close to the equipment.

- Units should be designed so that forced-air exhausts are not directed toward the operating position, or toward other workers in their work positions.

- External surfaces that can be touched during operation shall have a surface temperature that does not exceed 50° C (122°F). Surfaces intended to be touched during normal operation should not exceed 35°C (95°F).

- Heat build-up from equipment under the work surface (around the operator's knees and legs) greater than 3°C (5.5°F) above ambient should be avoided.

INFORMATION DISPLAYS

A dominant feature in nearly every control center is a large information display board or screen. These devices are used to provide a broad overview of the status of the system to both operators and visitors in the control center. Three different kinds of information displays are generally used in control centers: static wall maps, projection television screens, and video walls. [7]

Static Wall Maps

Static wall maps were used extensively in systems designed in the 1960s and 1970s. These types of displays provide the geographic layout of the roadway system and show the location of the system's resources, such as detector stations, signals, signs, and cameras. Tiny light bulbs or light-emitting diodes (LEDs) connected to sensors in the field are used to display information about the status of the system. In some freeway management centers, different colored lights are used to depict various traffic flow conditions (e.g., green for free flow, yellow for moderately congested, red for congestions, and flashing red for incident location). Since these displays are generally large painted maps, making modifications to these displays as the infrastructure changes is difficult and costly. Figure 10-10 shows a typical static wall map used in a freeway management center.

Projection Television Systems

Projection television systems have also been used to display traffic information in control centers. The primary advantage of this type of system over static wall maps is that they are extremely flexible as to what can be displayed to the operator. Besides showing status information on computer-generated maps, operators can also display live video from CCTV cameras and television images on the screen. Because the images are usually generated by computer, the operator can zoom to various levels of detail on the display. The primary disadvantage of projection television, however, is that the resolution can sometimes make the image become blurry. Furthermore, because of its sensitive optics, it frequently requires realignment and adjustments. Figure 10-11 shows an example of a control center with a projection television map display.

Video Walls

Video walls are being used almost exclusively in new freeway management control centers. A video wall is a matrix of television monitors used as a single display. Each individual monitor can be used to

Figure 10-10. Example of Static Wall Map.

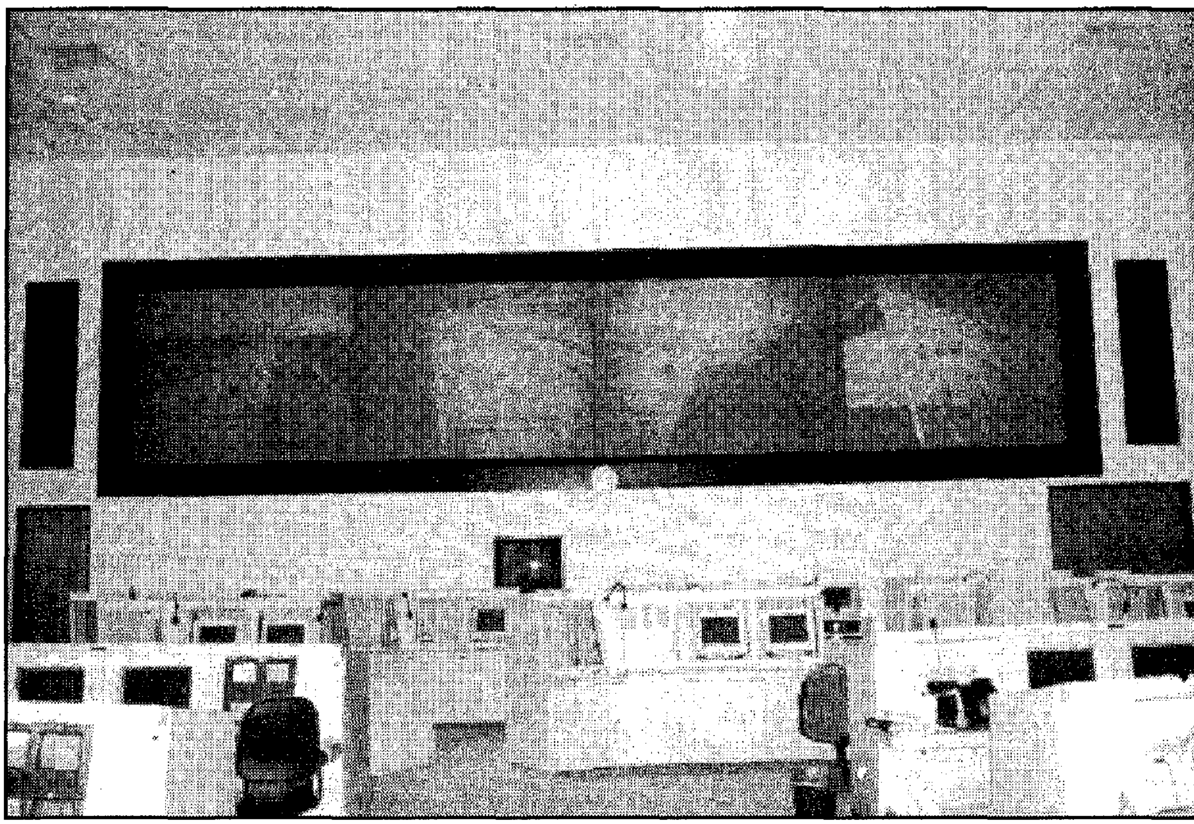

Figure 10-11. Example of a Projection Television Display.

display a single image or can be used to compose part of a larger display. By using a video wall, the operators in the control center have the flexibility of customizing the presentation of the information as conditions warrant.

Design Guidelines and Recommendations

The following guidelines and recommendations are provided to help in designing visual displays in control centers:[1]

- Avoid too much detail on large maps or status boards.
- Limit the number of colors for maps, target symbols, alphanumeric headings, etc.
- If moving objects are displayed on a map, keep the number at a minimum and display only those that move slowly.
- If the display area must have a low ambient illumination in order for individual operator displays to be used effectively, use white or luminescent markings against a dark background for maps as status boards to help operators maintain dark adaptation.
- If color-coded object information is to be used on a large map display, use only a neutral color, such as gray, for the map background; this allows the color targets to have maximum effect (contrast).
- When front projectors are to be used to project information on a large map display, ensure that the projectors are positioned so that they are not readily visible (i.e., causing obstructions and glare) to the operating personnel.
- Determine and provide the properly sized alphanumeric characters and/or symbols on the large-screen displays for the maximum viewing distances at which each set of characters and symbols must be read.
- Consider using unambiguous coding techniques to help operators in discriminating between old and new data.
- Orient maps with north to the top.
- Color codes should agree with commonly accepted practices:
  - *Flashing Red*: Emergency.
  - *Red*: Alert.
  - *Yellow*: Caution, recheck.
  - *Green*: Safe, go ahead.
  - *White*: Used when no right or wrong entry or condition exists.
  - *Blue*: Can be used to denote advisory, but use should be avoided.

OPERATOR WORKSTATION DESIGN

Considerable changes in workstation design have occurred as freeway management systems have evolved over the last three decades. In the past, most control centers were designed with multiple workstations, each with a specific function. For example, one workstation controlled the video surveillance system, another controlled the variable message signs, another controlled the ramp metering system, etc. This type of design required the operators to move between a series of workstations to implement a control strategy in a specific situation. Today, most control consoles are being designed so that a single operator can operate all of the subsystems from a single workstation. This generally results in better operational control over the system; however, in some situations, two or more operators may be competing for control of the same camera or monitor. Methods of setting priorities whereby multiple functions can be performed at a single workstation need to be established in a control center.

The design of individual workstations in a control center varies depending upon the functions to be performed by the operators. All workstations should be designed to anthropological standards. The placement of video display monitors and input devices (e.g., keyboards, mouse, trackballs, switches, etc.) should also conform to recognized standards and guidelines. Many centers have poor ergonomic designs that contribute to operator stress and discomfort. Common ergonomic design problems include the following:[7]

- Monitors placed above operators' seated line of sight.
- Operators having to look over consoles, monitors, and other equipment to view monitors on the wall.
- Inadequate or improper labeling of control features.
- Console heights not adjustable to extremely short or extremely tall operators.

Glare is one of the most common problems with video display units incorporated into workstations. Glare is generally caused by either lighting sources at the workstation or at other nearby video display units. Glare problems can be eliminated by the following means:[7]

- Provide glare shields between video display units and light sources.
- Cover light sources, including windows.
- Use task lighting.

The *Human Factors Handbook for Advanced Traffic Management Center Design* (First Edition) provides detailed standards and recommendations that should be followed in the design of operator workstations.[1]

COMMUNICATIONS SYSTEMS

In general, system designers need to be concerned with three types of communications systems when designing a freeway management system:

- The type of communications system that links the field devices with the control center and permits the transfer of data and commands. This type of system generally requires a high speed, high capacity type of transmission medium.
- The type of communications system that links the computer systems inside the control center that are responsible for processing information and commands, generating displays and reports, and interfacing with the control center operators. Most freeway management systems in operation today use local area networks (LANs) to connect their computer and display equipment in the control center.
- The type of communications system that permits operators in the control center to converse with other personnel (and also the public) by voice.

Because of the costs and criticality of the first type of communications system, it is covered in **Module 9**.

Local Area Networks

The term Local Area Network (LAN) is commonly used to describe the type of communications system that links the digital computers internal to the control center. By definition, an LAN is any telecommunications system that serves a limited geographic area (typically a single building or campus). The term "network" refers to the fact that multiple users are interconnected.[8]

No single LAN design is ideal for use in a control center. The design of the LAN needs to support the functions and the types of data exchanges in the control center. The simplest type of LAN permits the exchange of information between computers and computer-like devices (such as word processors, operator workstations, database managers, etc.). More complex forms of LANs are required to support the transmission of video and audio information besides data.

Components

While the complexity of the LAN varies depending on the type of data being transmitted, every LAN has the following basic components:[8]

- User workstations.
- Supporting processing equipment.
- Peripheral equipment.

The user workstations are the most visible component of the LAN. In control center applications, workstations may consist of conventional PC computers, intelligent workstations, or terminals. All these devices have the following common functions:[8]

- Display output to users, usually using a device such as a video display monitor.
- Receive data from users entered from a keyboard, mouse, or other input device.
- Interface with the communications medium, a function that includes formatting and transmitting data at the appropriate time and rates.
- Processes data, depending upon the LAN design, the capabilities of the workstation, and the type of software used.

Supporting processors, known as servers, are connected to the LAN to execute functions that cannot be provided by individual workstations. Generally, servers are used for the following applications:[8]

- Execute large computer programs that exceed workstation capacities.
- Provide centralized data storage and retrieval functions (file servers).
- Interface with external communication facilities (communications servers).
- Interface with peripheral devices.

The capacity of the supporting processors can vary from that of a PC to that of a large mainframe computer. The number and type of supporting processors depend on several factors including the following:[8]

- The design of the LAN.
- The number of users sharing the supporting processors.
- The functions being performed by each processor.

In most control centers, a variety of peripheral devices are supported on the LAN, including the following:[8]

- Printers.
- Plotters.
- Telex.
- Fax machines.
- Modems.
- Optical character readers.
- Scanners.

In some systems, the LAN is also used to support video and voice transmissions via connections to television equipment and the telephone system.[8]

In larger LANs, a special processor, known as the network control station, is often used to monitor the communications traffic on the LAN continuously, and to accumulate statistics on workstation usage, transmission quality, and network configuration.[8]

Planning for an LAN

Quite often, LANs are selected more on the basis of vendor recommendations than on technical or application requirements; however, when planning an LAN system, the first consideration should be the selection of the type of system or topology that is most appropriate for the application requirements. Generally, three types of topology (i.e., physical shape) are commonly used in designing LANs: a star topology, a bus topology, and a ring topology. Figure 10-12 illustrates each of these topologies. Advantages and disadvantages of each topology are summarized in table 10-3.

For simple system requirements, such as a few PCs and a file server, an Ethernet type of system may be quite appropriate. However, for large numbers of PCs with large data-transfer volumes, a token ring system is more likely to be the best selection. A rule-of-thumb is to use a baseband LAN for small office systems requirements and a token ring for large or host computer-oriented (mini/mainframe) systems.

Connections between LAN nodes can be established over twisted-pair cable, thin coaxial cable, standard coaxial cable, or optical fiber. Each of these alternatives has increasing capacities. Twisted-pair (telephone) cable is smaller and cheaper than other communications media, but is subject to electrical and radio interference. Coaxial can carry higher frequencies and data rates than twisted-pair but is more difficult to manipulate physically. Optical fiber is popular because of its small cable diameter, protection against electromagnetic or radio interference, low attenuation, and large bandwidth, but is generally more expensive to install than the other media. Factors that influence the selection and implementation of communications media used in the LAN include the following:[8]

- The amount of data being transferred between devices (i.e., capacity levels).
- The potential for external interference.
- The physical distance between devices.
- The potential for future expansion.

The ability to diagnose and predict its own failure is an important factor in designing an LAN. Simple layouts and well-established procedures should facilitate quick repair.[8] In addition, system planners should anticipate expansion needs in the design of the system. The internal design of the

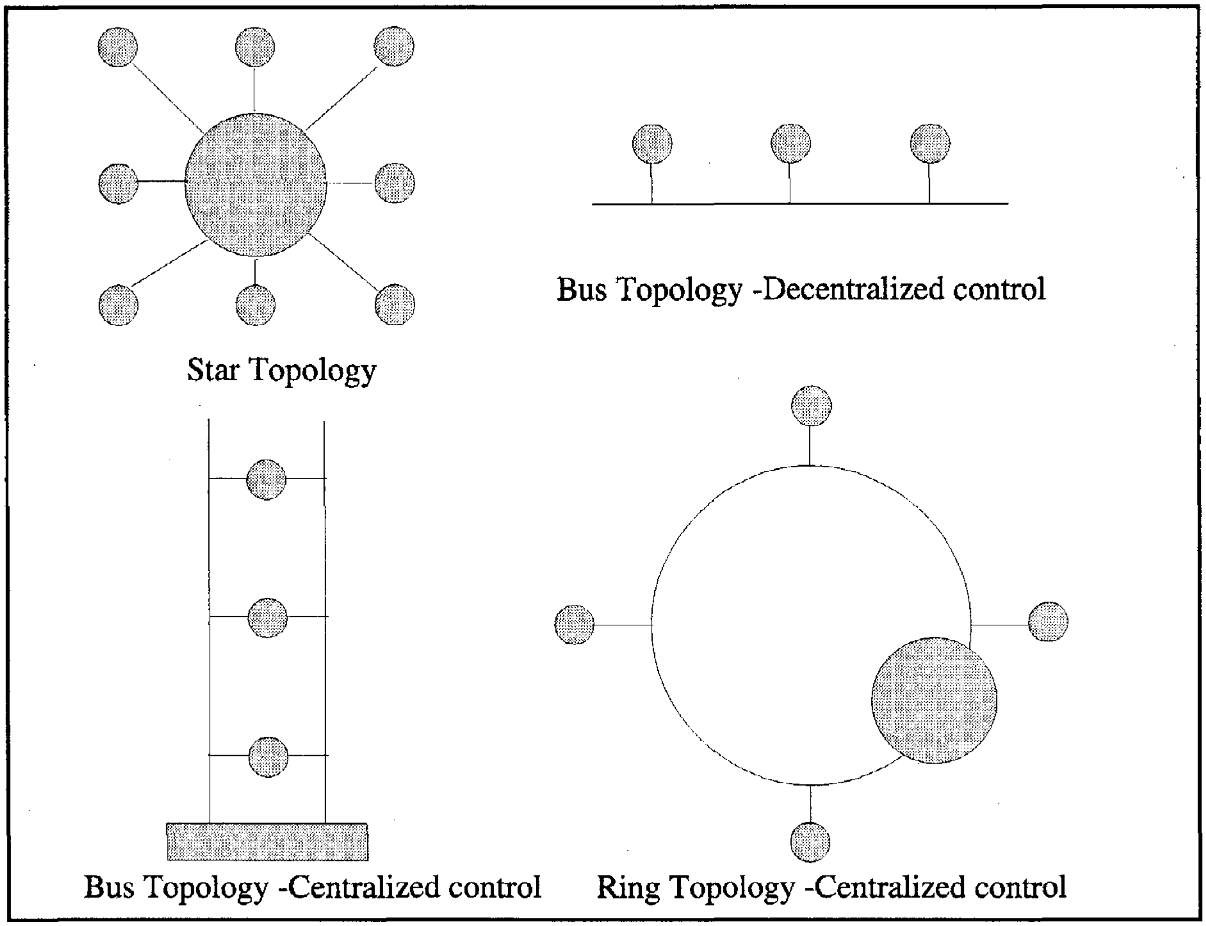

Figure 10-12. Examples of Popular LAN Topologies. [8]

building should incorporate adequate routing ducts and conduits to hold all future growth needs. In addition, access rooms should be provided to ease the job of adding and maintaining an LAN.[8]

Voice Communications

Systems within the control center are also needed that allow operators to talk with individuals outside the control center. The types of voice communication systems needed in a control center depend primarily upon the functions to be performed by the system, existing communications systems, local availability, and agency preference. Common types of voice communications systems included in the control centers include the following:

- Intercom.
- Direct line telephone connects.
- Switching telephone systems.
- Radio.
- Cellular telephones.

Figure 10-13 shows some of the voice communications devices used by operators at a control center.

Voice communications are commonly being used in control centers for the following purposes:

Table 10-3. Advantages and Disadvantages of Common LAN Topologies

Topology Type	Attributes	Advantages	Disadvantages
Star	• Communication protocols. generally controlled by central processor. • Polling techniques used to initiate data transfers. • Used by popular computer operating systems (e.g., UNIX and OS/2).	• Permits purchase of lower-cost user workstations.	• All workstations disabled in event of central computer failure. • System expansion costly.
Bus	• Topology on with both the Ethernet and token bus protocols based. • Individual workstations initiate data transfers.	• Network growth can be readily accommodated.	• Each processor must provide the capacity required to execute the user's application software. • Generally results in more expensive workstations.
Ring	• Each node receives "token" transfer data. • A token is a digital code that allows workstation access to the network. • Each node transfers data in turn.	• "Tokens" can be passed in either direction around the ring.	• Limited exclusively to token passing techniques.

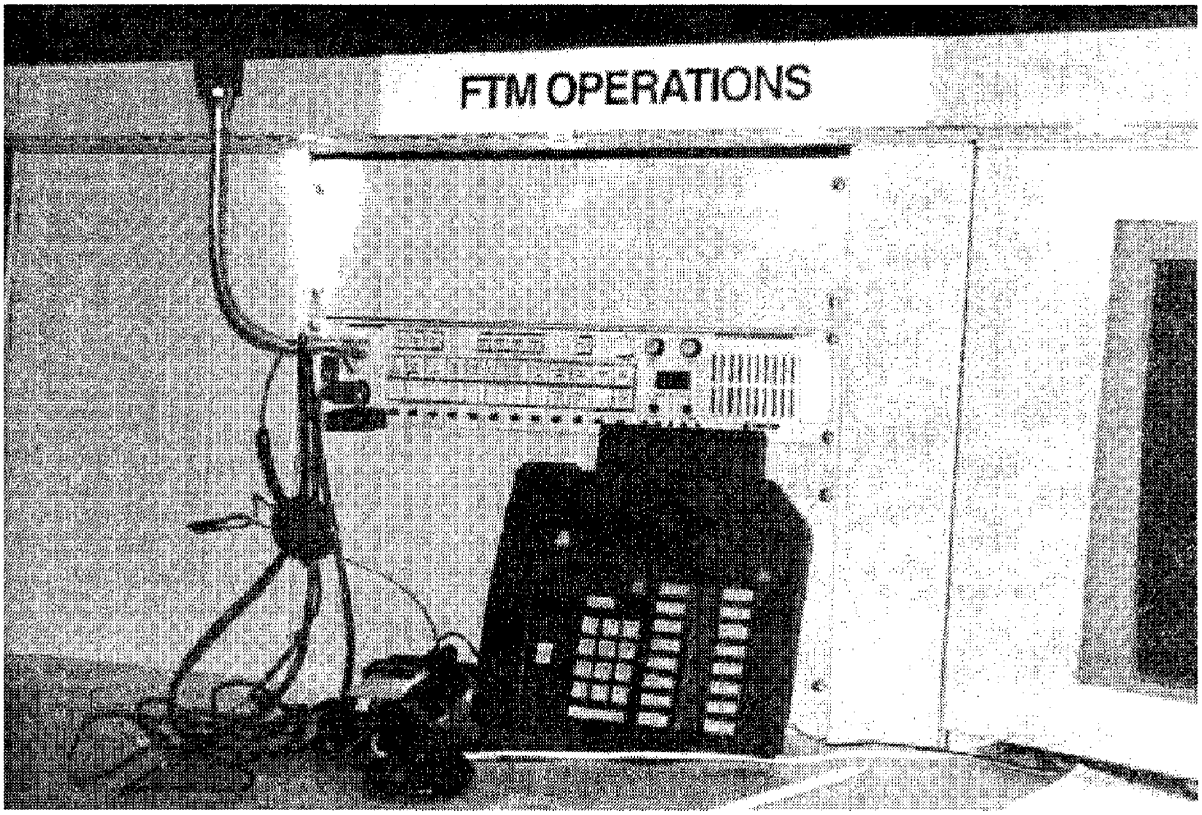

Figure 10-13. Typical Communications Devices Used by Operators in a Control Center.

- Communications with incident response teams (including fire, police, emergency medical service providers, hazardous material teams, etc.).
- Control of remote and portable equipment (e.g., highway advisory radios, and variable message signs).
- Communications with operations and maintenance field personnel.
- Communications with motorist call boxes.
- Transmission of dispatch information, data, and calls.
- Communications with management and administrative staff, both internally and with outside agencies.

STAFFING

No rigid rules exist for determining the number of operators in a control center. The number of operators in a control center primarily depends on the functions that are being performed, the number of facilities covered, and the operating objectives and philosophy of the center. Table 10-4 shows the ultimate staffing requirement of a traffic operations center in Orange County. The primary function of this traffic control center is to detect and clear incidents from the freeway at all hours of the day. It also supports those individuals involved in the continued planning and operation of the system, and houses the staff responsible for developing operational strategies for special events, providing lane closure recommendations for construction contracts, and responding to major traffic incidents. It also houses maintenance dispatching

Table 10-4. Staffing Plan for Orange County Traffic Operations Center. [9]

Function	Number	Hours	Grade
CALTRANS			
TOC System Manager	1	0700-1600 M-F	Senior Engineer
Assistant Manager	1	1000-1900 M-F	Associate Engineer
Receptionist/Clerical	1	0800-1700 M-F	Receptionist
Area Traffic Engineer	5	0700-1600 M-F	Assistant Engineer
Area Traffic Technician	10	0700-1600 M-F	Engineering Technician
TOC System Operators	9	3 Shifts, 7 Days/Week	Engineering Technician
Software Support Programmer	1	0700-1600 M-F	Assistant Engineer
Electronic Maintenance Specialist	1	0700-1600 M-F	Electrical Leadworker
Maintenance Dispatch Supervisor	1	0700-1600 M-F	Maintenance Supervisor
Maintenance Dispatcher	6	3 Shifts, 7 Days/Week	Maintenance Man II
Assistant Maintenance Dispatcher	2	2 Shifts, M-F	Student Assistant
CALIFORNIA HIGHWAY PATROL			
System Coordination Officer	1	0700-1600 M-F	Lieutenant
Duty Officer	6	3 Shifts, 7 Days/Week	Traffic Officer
Media Information Officer	2	2 Shifts, M-F	Media Information Officer

functions for all of the Orange County Caltrans District offices.[9]

Generally, the types of personnel needed in the control center of a freeway management system include the following:[10]

- Electronic/maintenance technicians.
- Control center technicians.
- Communications specialists/operators.
- Software programmers.
- Computer system operators.
- Operations supervisor or director.

Generally, those centers whose functions include significant interaction with police officers in the field should consider including a police liaison officer on their staffs. A police liaison officer fosters stronger interagency cooperation and can aid in dispatching appropriate police responses to incident scenes.

Qualifications

Overall, the level of qualifications for control center operators should be directly related to the design of, and functional allocation within, the center. If the operators' functions are repetitive, predictable, and non-critical, operators with low qualifications can be used; however, if unique problems are frequent, rapid reactions are required, and/or criticality is high, operators need to have higher levels of training and expertise. As a rule, operators must possess good verbal skills, a degree of computer literacy, and good reasoning skills. Some agencies also require operators to have a good working knowledge of the freeway system and some dispatching experience.[7]

The qualifications for control center operators also vary from center to center. For example, some locations employ part-time students as operators. These students are under the supervision of a manager or a senior operator. Some control centers use operators taken from the agencies' technical staff of traffic engineers or computer scientists. Often, these operators have other assigned technical duties, or may be given special projects to work on along with their duties in the control center. A few centers require their operators to have college engineering or technical degrees. Operators should possess the following characteristics no matter how much education and experience they have:[10]

- Ability to make good judgment calls quickly and accurately.
- Ability to handle stressful situations.
- Good oral and written communication skills.
- Good understanding of the transportation language.
- Good technical skills and good interpersonal skills in dealing with nontechnical personnel.
- Ability and willingness to follow standard operating procedures.
- Initiative to learn more about the operations of the other functions in the control center.
- Willingness to provide suggestions/ideas to promote a more efficient operation.
- Computer literacy.

Training

The training of operators is critical to the success of a freeway management system. Operators need to be provided with three levels of training: technical, operational, and managerial. Both formal and informal training is needed before the system becomes installed, as the system goes on-line, and after the system has been operating for some time.[10]

How much training is required by operators in a control center depends on the functions to be performed and the level of technical competence of the operations staff. Technical training is required in a variety of areas associated with system operations and maintenance, including diagnostic procedures for all hardware as well as for new upgrade procedures.

The basic level of training needed by system operators includes the following:[7]

- General principles, operating philosophies, and concepts of freeway management.

- An overview of the system, including the system schematics, field subsystems, communications, central subsystems, and proposed or planned system functions to be added.

- Operation and interpretation of system software and displays.

- Basic radio and communications codes and procedures.

- Standard operating procedures.

- Communicating with other agencies such as fire, police, etc.

At most control centers, new operators generally receive one-on-one, on-the-job training with an existing operator.

Besides basic training, operators need to be provided with continuous advanced training. This advanced training can be adaptable to specific issues and needs of the operations and maintenance staff. Areas in which advanced training may be provided include the following:[7,10]

- Emergency response procedures.

- Hazardous material spills procedures.

- Major accident and disaster clearance procedures.

- Roadside fire response.

- Multijurisdictional extended pursuits.

- Release of information to the media.

Methods of providing advanced training include the following:[7]

- Lectures or short-courses.

- Videotape.

- Simulated events or table top exercises.

- Computer simulators.

- Site visits to other control centers.

Sufficient training should also be provided when a new element or application is added to an existing system. This is usually accomplished through contract specifications with training line items.[10] In preparing contract specifications for training, the following should be specified:[11]

- The maximum number of persons to attend each formal training session.

- The minimum number of days for each training program. (Defining what a day is may also be important.)

- Who will develop and supply all the necessary manuals, displays, class notes, visual aids, and other instructional materials for the training program.

- Outlines of lectures and demonstrations, and samples of all training materials. These materials should be submitted to the agency for review some specified time before their proposed use. Agency approval should be specified before the training courses can be scheduled.

- Where training is to be conducted (e.g., at a local site designated by the agency or at the contractor's facility). If the training is to be provided at the contractor's facility, the specifications also need to define who is responsible for paying the transportation and subsistence costs of the agency personnel.

- All training should be conducted during normal business hours of the agency and the training site.

Staffing Sources — Agency versus Outsourcing

Being able to attract and maintain qualified control center personnel can be difficult for many agencies. Agencies have two basic options for staffing their control center: with personnel from with the agency, or by outsourcing. A pure agency staff has the advantage that managers and team leaders have a single personnel management system to deal with, and team cohesiveness is easier to establish and maintain. Outsourcing involves hiring private personnel to perform some or all of the functions in the control center. The primary advantage of outsourcing is the immediate availability of highly-qualified personnel. Seasonal and special events can be adequately staffed with limited training and start-up time. In addition, private employment agencies are not subject to the civil service regulations and policies that public agencies must follow. Private agencies can be more competitive and can pay the market salary rates that make it easier to attract and retain qualified people. To some degree, many agencies already employ outsourcing techniques to perform some functions in the control center (such as computer maintenance, software development, etc.). Those types of positions that can potentially be outsourced include the following:[12]

- Field and electronic technicians with communications or electronics experience.
- Team managers or leaders from a variety of backgrounds.
- Control center and communications technicians with knowledge, experience and training from other private sector hardware and software systems.
- System programmers and computer systems analysts with knowledge and familiarity of control algorithms.

SECURITY

Security surrounding control centers largely depends on the nature of the center and its objectives. Because of the vast differences in the purposes and capabilities of these centers, the appropriate levels of security to protect them vary widely, as do the perceptions of security risk. Many original freeway management control centers around the country were developed strictly as a traffic control measure and, as such, their operators did not see any particular threats to the facility. This stemmed from a perception that there would be little intrinsic value in attempting to attack or otherwise break into such a facility. In contrast, many facilities currently being brought on-line incorporate police, transit, emergency management, and traffic operations. These facilities are perceived to represent a much more likely target for computer hackers, theft of data, and even potential terrorist activities.[13]

Several generic security measures can be taken to limit physical access to facilities.[14,15] A recent article in an architectural magazine notes that "effective security is an interplay of three elements: natural and architectural barriers, including anything from landscaping strategies that discourage access, to the number, location, size, and type of doors and windows; human security, including the protection provided by guards and other personnel; and electronic security, provided by any one of the array of systems now available."[15]

Obviously, location of the facility will play a central role in determining what security measures are appropriate. Here again, the needs of staff should be considered in selecting what countermeasures are employed.[14] Communication systems, power supplies, access points, physical integrity of the building, and several other issues are all directly affected by security considerations. In addition, what countermeasures can be used is affected by building codes regarding access and egress during emergencies such as fires. Yet another layer of regulatory codes is associated with the Americans with Disabilities Act, which can affect aspects ranging from physical security barriers to systems that must accommodate both the blind and deaf.[15] Security systems also must be designed so that they are not too obtrusive, intrusive, or otherwise intimidating to employees.

Computers in the control center are also a source of security concern for many operating agencies. According to one source, the majority of all computer security losses have been attributed to errors or omissions. Major sources of other computer security losses include dishonest and disgruntled employees, and external threats such as disasters. Only a small percentage of security losses were credited to outside sources, such as hackers.[16] The point was thus made that "the two most heavily publicized types of security problems, hackers and viruses, are among the least serious threats to most systems." The threat from viruses (on a percentage basis) was also apparently small. As much as 80 percent of all computer-related damage was estimated to be caused internally. Nevertheless, because of the publicity surrounding hackers and viruses, an undue amount of attention is often focused on protecting against external threats.[16]

The extent of the risk to computer systems will vary greatly from agency to agency. The determination of how much security is necessary reverts to the need for risk assessment. Multiple layers of firewalls and other security measures may be warranted in some systems. Several publications are available that offer further detailed exploration of computer security measures that can be implemented.[16,18,19,20]

AUTOMATION

The acceptable level of automation varies from site to site. In some locations, the long-term goal for their systems is to be fully automated while, at other locations, the goal is for the operator to continue to be a critical element in the operation of the system. Each philosophy has significant implications with regard to the overall design of the control center.

The role of the operator in a system can be defined in terms of whether a human or a machine makes the decisions (i.e., closes the loop) in a task or process. The role of the operator in the decision-making process can be placed into four categories:[1]

- Direct performer.
- Manual controller.
- Supervisory controller.
- Executive controller.

Under direct performer control, the human operator performs all the functions of the system. In manual control, the machine components are heavily involved in the decision-making process as sensors and effectors, but the actual loop-closing aspect of the function is solely the responsibility of the human. In supervisory control, a machine component is allowed to close the loop under supervision of a human operator who may intervene and adjust or override the machine's decision. With executive control, the machine is totally responsible for performing all functions of the system—the operator is only there to keep the machine operating.

A continuum of operator roles exists that defines how much automation is needed to accomplish a function. At one end of the continuum, a function is allocated solely to the human, and at the other end, solely to the machine. In between, performance of the function is shared by human and machine components. As shown in figure 10-14, the continuum can be divided into four major regions; each region defines a generic operator role in relation to automation. Because it is a continuum, how much automation occurs varies within each region.

How much automation is acceptable in a control center varies from center to center, depending upon the experience of the operators, the operational goals and philosophy of the agency, and the sophistication of the system. In many locations, routine functions in the control center can be automated. For example, different control centers use different methods for generating messages for display on variable message signs, including the following:

- Messages are entered manually.
- Messages are entered manually with computer assent.
- The operator chooses from selection of canned messages.
- The computer determines a response plan with the assistance of an operator.
- The computer determines and carries out a response plan.

With the current state of technology, it is recommended the operator always remain "in the loop." Automation systems should be designed to help and support the operators. Operators should be fully aware of what information the system software has, what the automated systems is doing, why it is doing it, and what it is going to do next. At a minimum, the operator should be able to switch off the automated system to prevent future problems or to correct improper decisions.

If automated systems are to be used, the level of automation should be gradually increased throughout implementation. Initially, an operator should be present in the control room to review and approve all automated system actions. A detailed log of automation failures should be kept. As failures are eliminated, the role of the operator in the decision-making process can be reduced.

JOINT OPERATIONS

Joint operation can be structured through the following: [4]

- Sharing physical resources that are common to each agency's operation, but operating each system or agency component individually.
- Operating individual or multiple systems under one designated management structure where operational control is centralized.

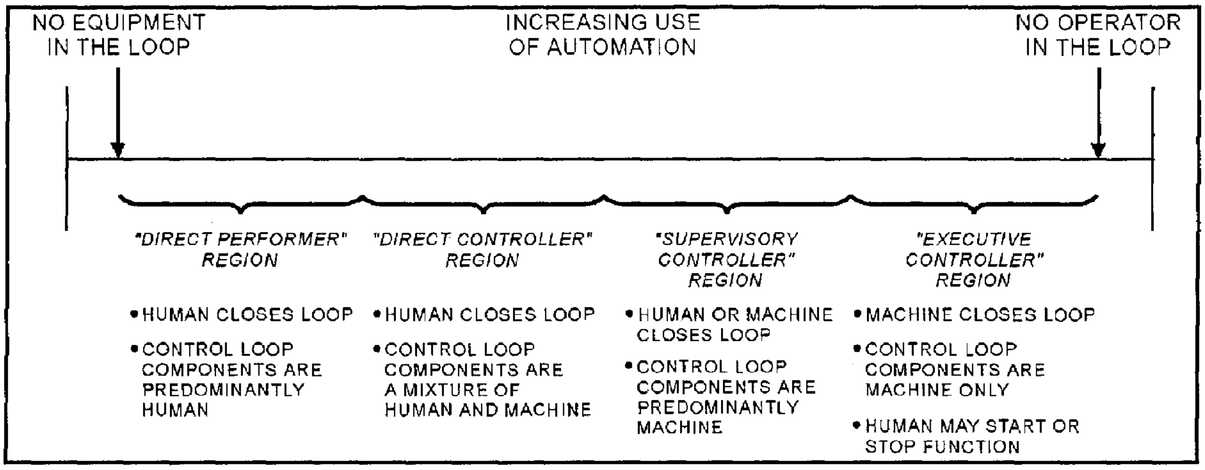

Figure 10-14. Continuum of Operator Roles in Relation to Automation.[7]

- Delegating day-to-day operations to another agency or group (including a private entity).

The ability to engage in joint operations is not an easy accomplishment and usually occurs because of ongoing relationship building. A variety of strategies can be undertaken to foster cooperative joint operations. No one individual technique or action is appropriate for all areas; instead, each community must assess its own unique situation. Strategies that can be employed to foster cooperative and joint operations in a control center include the following: [4]

- Ensure that each agency is represented in the initial stages of the design and program development of the control center.

- Emphasize how projects and programs can affect/address needs and problems of each agency throughout the development process. Look for ways to widen the focus of the initial goals of the system to help other agencies improve their operations.

- Approach joint operations with an open attitude about how overall results can be enhanced by sharing resources.

- To facilitate sharing and build trust among agencies, start joint operations with a relatively small and noncritical task. Building confidence and trust around these smaller elements will facilitate the accomplishment of larger tasks in the future.

- Develop an open-ended and flexible system architecture such that new systems and changes in hardware and operating procedures can be accommodated easily.

- Add functions and responsibilities under joint operations at a manageable rate.

- Develop standard operating procedures for how the devices in the system can be used by each agency in the control room. These operating procedures should be scenario-based and describe the roles and responsibilities of each agency in the scenario.

- Cross-train the staff from each agency so that they can do the jobs of the other agencies' staffs, and so that each operator has an understanding of the roles, responsibilities and limitations of each agency in the control center and can serve as a backup or substitute in crises.

- Provide a mechanism for positively, reviewing and debriefing each others' operations with the idea of improving the overall operations and capabilities of the system.

10.4 LESSONS LEARNED

SYSTEM CAPABILITIES

It is important to consider system balance when deploying a freeway management system. System balance is achieved when all of the elements of the system are operating at their optimum, designed operating levels. A system becomes unbalanced when one of its elements is forced to operate beyond its capabilities. System operators should not be expected to do more to manage traffic than what the system was designed to do. Information should not be distributed and strategies should not be employed that are beyond the capabilities of the system to monitor and carry out. Erroneous information, and inappropriate and/or inadequate strategies erode public and political support for the system.

OPERATIONS MANUAL

Even though Federally funded projects require an Implementation Plan prior to actual system implementation, preparing an Implementation plan is a good professional practice, regardless of the funding source of the project. The plan defines system objectives, deployment elements to achieve those objectives, a general operations plan of how the elements will work together, a staffing plan for operations and maintenance of the system, and a commitment of resources for operation and maintenance of the system. The Operations Manual will define in more detail the actual day-to-day operations in the control center. It is essential that the manual be prepared in advance of system turn-on and used in the training of operators. In addition to the control console operation (the physical operation and adjustment of hardware and software), the Operations Manual must provide consistent and appropriate responses to similar traffic situations. Consistency can be provided by developing response plans for different levels of incidents, congestion, and traffic situations. The response plans should indicate what actions should be taken by elements of the system for a given traffic situation. Response plans should be well documented and placed in an Operations Manual. The Operations Manual also identifies who is responsible for carrying out specific actions. Figure 10-15 outlines the basic areas and topics to be included in the Operations Manual.

EFFECTIVE USE OF SYSTEM OPERATORS

Operators can be valuable in assessing the quality of operations, and in identifying potential operational and design changes in a system. The system should be designed to support operators and their task of maintaining traffic flow. Because they deal with traffic situations on a daily basis, they are often in a position to know what works, what does not work, and what needs to be done to improve the system. They can provide valuable insight into not only what additional hardware and functions are needed at the center, but also ways to improve the effectiveness and efficiency of the overall operation of the system.

In existing practice, the skills level of the individuals staffing and operating freeway management centers varies widely from system to system. Some agencies use

General Information About the TMC
- Mission and functions of the TMC
- Relationship of the TMC to other transportation agencies
- Organizational relationship of the TMC within the agency responsible for administration
- Diagrams depicting the physical layout of the TMC

Policies and Procedures on Internal Operations and Maintenance of the TMC
- General information on items such as address, main telephone number, fax number, e-mail, etc.
- Hours of operations
- Contact procedures in the case of emergencies involving the TMC
- Telephone procedures
- Personnel
  - Organizational chart
  - Description of duties for each position
  - Training (required classes and training manuals)
  - Rules of conduct
- Equipment
  - Authorized use
  - Maintenance
- Facility management
  - Security procedures and authorized access
  - Backup power
  - Custodial services
- Software
  - Backup procedures
- Media
  - Access to center
  - Media guidelines
- General public, transportation professionals, and VIP's
  - Access to center
  - Conduct of tours
- Disaster recovery plan

Policies and Procedures on Traffic Management
- Incidents (accidents, stalled vehicles, spilled loads, etc.)
  - Identification (vehicle detection, 911 calls, traffic reporters, etc.)
  - Verification (CCTV cameras, police, or DOT personnel)
  - Response plans (ramp metering, traffic signals, VMS, HAR)
  - Documentation of incidents
- Congestion
  - Monitoring
  - Response plans
- Planned events (including roadway closures and maintenance)
  - Obtaining necessary information on planned events
  - Response plans
- Field equipment malfunctions
  - Dispatching of repair crews
  - Documentation
- Interjurisdicational coordination
  - Other TMCs
  - Transit agencies
  - Other agencies (highway patrol, police, fire, etc.)
- Information distribution
  - Media
  - Value-added packages of transportation information
  - General public

Figure 10-15. Recommended Topics to be Covered in Operations Manual. [21]

students as operators, others use maintenance personnel, and still others use engineers. The key to operation of a successful freeway management center is to have highly qualified and motivated individuals who are both knowledgeable about traffic operations and technically competent.

SYSTEM MAINTENANCE

System maintenance is often overlooked by agencies. The performance of any operational traffic control system, whether a traffic signal system or a freeway management system, depends on the commitment of the operating agency to provide effective maintenance for the system. Agencies should not underestimate the budgetary or staffing requirements to properly maintain the control center and the system as a whole. Agencies must recognize that it takes highly skilled individuals to maintain today's complex systems. Public agencies should be aware of the costs associated with attracting, training, and retaining individuals with the requisite skills.

All personnel needed to operate and maintain the system should be placed under the management of the same individual in the agency's administrative hierarchy. The individual having the administrative responsibility for the control center should report to the same individual who has overall authority for traffic operations and maintenance functions of the agency. This individual may be the Head of Traffic Operations in larger agencies, the Head of Traffic Operations and Maintenance in medium-sized agencies, and the Head of Transportation in smaller agencies. This administrative structure will aid in accomplishing the following:

- Achieving a balance between funds to operate and maintain the system.
- Effectively addressing conflicts between operations and maintenance personnel.
- Developing a high level of technical expertise in operating and maintenance personnel.
- Facilitating interaction and opening lines of communications between operations and maintenance personnel.
- Facilitating interagency and intraagency communication and sharing of data and information.

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MODULE 11. ECONOMIC ANALYSIS

TABLE OF CONTENTS

MODULE 11. ECONOMIC ANALYSIS

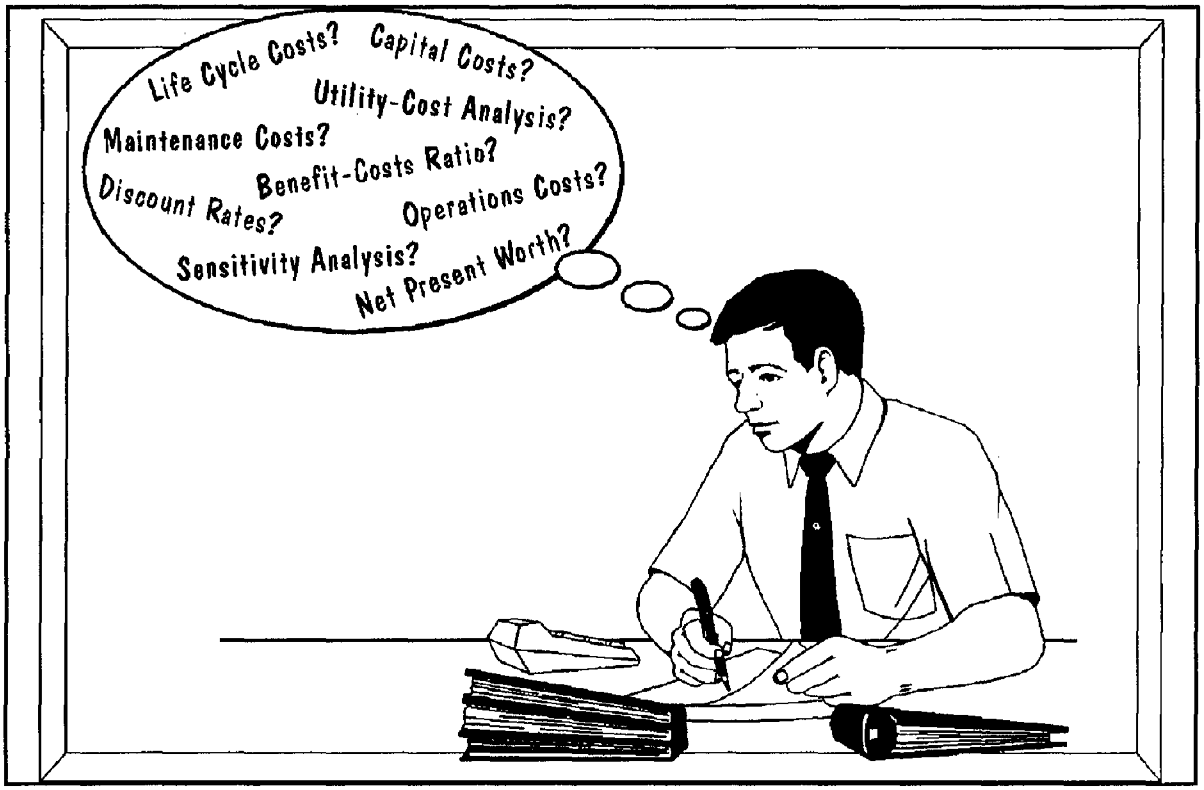

Figure 11-1. An Economic Analysis Has Many Components.

11.1 INTRODUCTION

Since freeway management systems are designed, constructed, and operated and maintained with public funding, it is critical that economic analyses are conducted to ensure that public funds are spent prudently. In addition to being used to determine which alternative system offers the most potential, economic analyses serve to justify the cost-effectiveness of system installations to elected officials who oversee public funding, as well as to the public whom these elected officials serve. If funding for new freeway management systems, or funding for operating and maintaining existing systems is to continue, it is critical that elected officials and the public be made aware of the benefits of the freeway management system.

PURPOSE AND SCOPE

This module serves to give guidance to planners and designers responsible for the economic justification of freeway management systems. Planners and designers must be familiar with the costs and benefits expected from freeway management systems in order to justify the installation and continued operation of these systems. This module provides typical capital costs associated with the design and construction of freeway management systems, as well as typical continuing costs associated with their operation and maintenance. Also provided in this module are typical quantifiable and nonquantifiable benefits that can be expected from the implementation of freeway management systems.

SYSTEM GOALS AND OBJECTIVES

The primary function of freeway management systems is the real-time management of recurrent and nonrecurrent congestion. It is the goal of planners and designers to provide efficient, cost-effective freeway management systems that meet defined system goals. A successful freeway management system meets or exceeds defined system goals, thus producing benefits such as delay reductions and increased safety to freeway users that outweigh the system's initial capital costs and its associated lifetime operating and maintenance costs.

INTERRELATIONSHIP OF SYSTEM ELEMENTS

Costs associated with freeway management systems, whether capital costs or operation and maintenance costs, are readily available and easily measured in monetary terms. However, benefits accrued from various freeway management system elements are sometimes more difficult to quantify, due to the interrelationships that exist among the various system elements. For example, dynamic message signs (**Module 7**) and ramp meters (**Module 5**) both contribute to reducing freeway congestion. The benefits of each of these elements could be measured (via travel time studies, vehicle counts, etc.) if they were implemented alone within the freeway section. However, the benefits of stand alone systems are not necessarily additive. Rather, the effects of these components interact with each other. In the above example, the provision of real-time information via dynamic message signs might cause some drivers normally intending to enter the freeway to utilize another route to their destination. This would reduce the traffic demands at the entrance ramps, and influence the magnitude of benefits that would be achieved with a ramp metering system that was also implemented in the freeway corridor.

STRUCTURE OF MODULE

The next section of this module, Estimating Costs and Benefits, describes the types of costs and benefits normally associated with freeway management systems. The section that follows, System Evaluation, describes the different economic analysis techniques that are available to evaluate and justify freeway management system expenditures, and to compare various system alternatives. Using the cost and benefit estimating procedures described subsequently, designers and planners can utilize their cost and benefit data to conduct economic analyses.

11.2 ESTIMATING COSTS AND BENEFITS

SYSTEM COSTS

Types of Costs

Costs associated with freeway management systems can be classified as follows:

- Capital costs.
- Continuing costs.

Capital costs include all costs associated with the design and construction of freeway management systems (or component thereof). Items classified as capital costs include:

- Design costs.
- Right-of-way costs.
- Equipment costs.

- Construction costs.
- Software development costs (including system integration).

Continuing costs are those associated with ongoing operations of the freeway management system. These costs include the following:

- Equipment and infrastructure maintenance costs.
- Equipment replacement costs.
- Staffing costs to operate the system (operations personnel, clerical personnel, public information personnel, etc.).
- Utilities costs.
- Leasing costs (communications, control center space, etc.).

Sources of Cost Information

Each freeway management system is (presumably) a compilation of components and techniques designed to meet specific goals and objectives of the region. Technology used for freeway management is constantly being improved. In addition, the unique characteristics of each system (the components employed, the method of their integration, etc.) heavily influence the costs of previous systems. Consequently, "typical" costs associated with freeway management systems are generally not available.

Those involved in the planning, design, and evaluation of such systems are well-advised to communicate directly with vendors of the various system components to obtain the most recent cost estimates. As an alternative, personnel in other locations who have recently implemented freeway management systems with components of interest can serve as a source of cost information. However, the reader must be cautioned that these cost experiences can be heavily influenced by site-specific factors, and so may have little (if any) relevance to the freeway management system project of interest.

SYSTEM BENEFITS

Types of Benefits

An economic analysis requires the measurement of the benefit of a new or improved system relative to the existing system. To do this, the analysis compares existing conditions with those anticipated from the improvements. It must always be remembered that a freeway management system can produce a number of benefits, some of which can be quantified (e.g., the reduction in total system delay) and some of which cannot (e.g., improvement in driver perception of the transportation agencies in the region). Furthermore, while some of the quantifiable benefits can be converted to monetary value (e.g., a reduction in fuel consumption and motorist delay), other benefits do not easily lend themselves to monetary conversion (e.g., the reduction in vehicle emissions).

Traditionally, benefits analyses for traffic operations projects such as freeway management systems have typically focused on the reduction in road user costs, which can be categorized as follows:[(1)]

- Reductions in motorist travel time.
- Reductions in vehicle operating costs.
- Reductions in accident costs.

Vehicle operating costs typically are broken down as follows: [(2)]

- Fuel consumption.
- Lubricants.
- Vehicle maintenance (labor and parts).
- Vehicle depreciation.
- Interest on loans.
- Other wages.
- Overhead.

In many instances, analysis of alternative accident costs is problematic because of a lack of available data. Consequently, an evaluation may be limited to travel time and vehicle operating costs only. [3, 4]

Although not easily quantifiable in terms of dollar benefits, the effect of a traffic control system on vehicle emissions is typically a key issue. Improved traffic control systems often provide the potential for emission reductions. Fortunately, most traffic simulation models available for evaluating traffic control systems include vehicle emissions estimates as part of the measures-of-effectiveness outputs. Because of the complexities and variabilities associated with vehicle emissions, these values should be used primarily for order-of-magnitude comparisons between the various alternatives.

Sources of Benefit Information

As with cost estimates, estimates of benefits of a freeway management system cannot simply be obtained from the literature. Existing traffic conditions before system implementation, the existence and stability of working relationships between agencies, the specific combination of subsystems incorporated into the overall freeway management system all contribute to its overall success and impact in the region. Experiences with past projects indicate that benefits of freeway management may be quite substantial. [5,6] However, the analyst should focus his or her attention on identifying recent projects that bear some resemblance to his or her own situation.

Generally speaking, traffic simulation analyses provide an objective mechanism to help assess the traffic impacts of certain combinations of freeway management subsystems (traffic simulation models are discussed briefly in **Module 2**). Unfortunately, one of the major limitations of most of these models is the limited representation of how drivers actually respond to the introduction of these subsystems with respect to their route, departure time, and mode choice decisions. These limitations should be taken into consideration when interpreting the outputs of simulation. Again, sensitivity analyses are important to developing an understanding of how reasonable the simulation estimates are, and how much confidence the analyst should place in them accordingly.

IMPORTANCE OF LIFE CYCLE COST CONSIDERATIONS

Frequently, in efforts to secure capital funding for freeway management systems, the continuing costs associated with operating and maintaining these systems are not given proper consideration. Continuing costs are just as important as, if not more important than, capital costs. Adequate funding for operations and maintenance, including funding to replace system components when their useful lives have expired, is essential for successful freeway management.

When conducting economic analyses for freeway management systems, a system's continuing costs must be accounted for along with its capital costs. Along this note, capital cost savings resulting from low bid procurement procedures can often result in greater continuing costs down the road. Capital cost savings associated with installing equipment that is inferior in terms of constructability and design features may ultimately increase the system's costs over its useful life, due to a reduced capability to handle future technology advances, more frequent replacement of equipment, etc.

Another reason for using life-cycle costs is to account for the fact that different system components often have quite different useful service lives. For example, Table 11-1 presents estimated service lives of some common freeway management system components. As the table illustrates, component service lives can range from 5 years or less to as much as 20 years. [8]

11.3 SYSTEM EVALUATION

The evaluation of the economic viability of the alternatives selected for consideration provides an objective basis for deciding which alternative, if any, should be funded. It also provides information that can be used to gain political and public support of the alternative determined to be the most beneficial (indicating the expected reduction in motorist costs or burdens for the money that will be invested). The alternatives evaluated represent a trade-off between various combinations of system components or subsystems, and can become quite complex.

A number of different considerations are required in any economic analysis of a freeway management system. The analysis itself can involve one or more of the analysis tools available. Some of the major considerations and analysis tools available are discussed in the following sections.

DEFINITION OF SYSTEM ALTERNATIVES/COMPONENTS

The decision process described in **Module 2** and emphasized in each of the other modules in this handbook is intended to provide an objective, systematic method of determining appropriate analysis alternatives. Once again, it is worth reiterating that the analyst and/or designer must base alternatives on the goals, objectives, and functions that the freeway management system is intended to achieve. The development of alternatives for analysis then evolves naturally from these intended functions. One of the options that should be evaluated is the "do nothing" alternative. This is an important benchmark to be used for evaluating the benefits of investments in freeway management alternatives.

As indicated earlier in this module regarding system benefits, a key consideration during this alternative development phase is to fully recognize the synergies that can develop from implementing certain combinations of components or subsystems of a freeway management system. For example, the implementation of closed-circuit television may not only assist in the detection and verification of an incident, but also prove useful to agencies in verifying whether a real-time traffic message is properly displayed on a nearby changeable message sign. At the same time, it is important to realistically assess how certain components or subsystems will actually perform, given the presence of other components in the system. For instance, it may be inappropriate to consider a series of inductive loop detectors installed over a section of freeway as detecting X number of incidents per day (estimated from previous incident experiences elsewhere) when a toll-free telephone hotline has also been established for cellular telephone users in the region to call in and report incidents.

Table 11-1. Selected Freeway Management System Component Service Lives [8]

Freeway Management System Component	Estimated Service Life (yrs)
Surveillance:	
Inductive Loop Detectors	5
Automatic Vehicle Identification	10
Automatic Vehicle Location	10
Video Imaging/Closed Circuit Television	10
Vehicle Emissions	10
Call Boxes	10
Toll Facilities:	
Plazas	20
Readers	10
Ramp Control:	5
Ramp Meters	
Information Dissemination:	
Dynamic Message Signs	20
Highway Advisory Radio	20
Information Kiosks	7
Communications	
Wireline	20
Transportation Management Center	
Computer Hardware	5
Computer Software and Integration	5-20

Experience suggests that the vast majority of incidents will likely be detected from the hotline, rather than from the loop detectors.[7] Additional information concerning incident detection technologies is presented in **Module 8**.

ASSIGNING BENEFITS TO ALTERNATIVES

Also, as stated earlier in this module, it is sometimes very difficult to properly assess the benefits associated with the implementation of a freeway management system, when the system is comprised of several different components which interact and affect traffic in some unknown manner.

The possible interrelationship between dynamic message signs and ramp metering subsystems was offered as one example. On the other hand, truck lane restrictions and a ramp metering subsystem could generate possibly adverse interactions (e.g., by having all trucks in the lane where ramp vehicles were attempting to merge).

Unfortunately, no hard and fast rules are available to determine how the introduction or elimination of specific components or subsystems affects the impact of other components in a freeway management system. The analyst must rely on judgement and experience to generate a best-guess in these instances. The uncertainty inherent in the analysis of benefits is why sensitivity analyses are so important to include as part of the analysis plan. (Sensitivity analysis is discussed briefly later in this module.)

ESTIMATING LIFE-CYCLE COSTS

When estimating the costs of a freeway management system alternative, it is critical to include not only the capital costs associated with designing, purchasing, and/or constructing the system alternative, but also the ongoing operating and maintenance costs that will be required to keep the alternative operational until it reaches the end of its useful life cycle. These life-cycle costs are the most appropriate way to evaluate freeway management system components.

Data from vendors or other operating agencies should be consulted when attempting to identify the various costs associated with a particular freeway management system alternative. In the absence of available data, some analysts have taken a percentage of the capital costs of a component as a measure of the operations and maintenance costs. The recent *ITS Architecture Cost Analysis*, for example, estimates operations and maintenance costs for many of the ITS technologies to be implemented in the future as between 2 and 10 percent of expected capital costs of those technologies. [8]

ANALYSIS TECHNIQUES

Net Present Worth

Description

Computation of an alternative's net present worth involves a conversion of all costs and benefits of an alternative that are incurred at the alternative's initiation and throughout its useful life (life-cycle) to an equivalent current value.[9] The current value of the equivalent costs is subtracted from the current value of the equivalent benefits of the alternative. If the benefits exceed the costs, the alternative can be justified economically. Furthermore, comparisons among alternatives are straightforward; the alternative that provides the greatest additional benefits over costs (sometimes referred to as "excess benefits") is said to have the greatest net present worth.

Example

An analysis of alternative communication systems for a traffic control system in a central business district provides an excellent example of the application of the net present worth method to alternatives evaluation.[10] Alternatives considered included installed twisted-wire pair (TWP), lines leased through the telephone company (TELCO), or installed fiberoptic lines. Table 11-2 summarizes the estimated capital and maintenance costs for each alternative over its 15-year lifespan. As the table illustrates, the TWP alternative provides the lowest net present worth of costs to the agency ($1,925,764).

Other Considerations

This analysis approach is perhaps the simplest to explain and the most understandable to the general public. Unfortunately, the net present worth method does not necessarily convey the relative economic merits of various alternatives as compared to the risk associated with the investment in that alternative. Most freeway management systems must compete for limited funds with other types of transportation improvement projects. Two alternatives may be capable of generating the same amount of excess benefits over their costs. However, if one alternative requires only a fraction of the cost of the other

Table 11-2. Example of a Net Present Worth Evaluation (Adapted from10)

Alternative	Capital Costs($)	Annual Maintenance Costs($)	Maintenance Net Present Worth ($)[a]	Total Net Present Worth ($)
Twisted-Wire Pair (TWP)				
Conduit: 15,600@$50	780,000	39,000	367,501	
RCU: 196@$1,200	235,200	23,520	221,631	
Modems: 33@$180	5,940	594	5,597	
Cable: 76,000@$1	76,000	3,800	35,808	
1,600@$1.50	2,400	120	1,131	
2,000@$2	5,000	250	2,356	
Prep: 62,400@$3	187,200	0	0	
TOTAL NPW	**1,291,740**		**634,024**	**1,925,764**
Leased Telephone Lines (TELCO)				
Conduit: 3,920@$50	196,000	9,800	92,346	
RCU: 196@$1,200	235,200	23,520	221,631	
Modems: 33@$180	5,940	594	5,596	
Cable: 3,920@$1.80	7,056	353	3,326	
3,920@$3.30	12,936	647	6,096	
Other: 196@$143	28,028	0	0	
Annual Lease Charges:	0	138,336	1,303,553	
TOTAL NPW	**485,160**		**1,632,548**	**2,177,708**
Fiberoptic Lines				
Conduit: 15,600@$50	780,000	39,000	367,501	
RCU: 196@$1,500	294,000	29,400	277,039	
Modems: 33@$415	13,695	1,370	12,910	
Cable: 78,000@$3	234,000	11,700	1010,250	
Prep: 62,400@$3	187,200	0	0	
TOTAL NPW	**1,508,895**		**767,700**	**2,276,595**

[a] Annual Maintenance Costs multiplied by present worth factor (7%, 15 years) of 9.4231

RCU = Remote Communications Unit

alternative, the partners receive a better return on the investment by choosing the lower-cost alternative (and are risking a lower amount of capital in so doing). Consequently, a benefit-cost analysis, as described in the next section, provides a more accurate picture of the relationship between the potential benefits and costs of freeway management system alternatives.

Benefit-Cost and Incremental Benefit-Cost Analysis

Description

The Benefit-Cost (B/C) analysis technique is perhaps the most widely accepted methodology for evaluating transportation improvement alternatives. The B/C ratio is simply the equivalent benefit of an alternative divided by the equivalent cost of that alternative:

$$B/C = \frac{\text{(benefits of alternative i)}}{\text{(costs of alternative i)}}$$

Benefit-cost comparisons are possible when the benefits of an improvement can be assigned a monetary value. If the benefits of an alternative exceed its costs, the improvement is economically justifiable. Furthermore, the ratio of each alternative provides a convenient basis for comparison, providing a measure of the dollars of expected benefit of an alternative for each dollar spent on that alternative.

If system alternatives being analyzed build upon each other in terms of the costs, quantities, complexities, etc. of components that meet the system goals and objectives, it may be more appropriate to consider an incremental benefit-cost analysis. For this approach, the benefits and costs considered for each alternative are not the totals, but rather the additional benefits achieved and costs incurred over the next expensive (and presumably effective) alternative. This analysis considers, in effect, whether an investment necessary to achieve the next incremental step in the system can be justified in terms of the incremental benefits that would be achieved.

Example

Table 11-3 presents the results of a benefit-cost sketch-planning analysis of alternatives to address mobility and congestion problems in Salt Lake City, Utah.[11] Analysts identified five alternative improvement categories:

- Highway capacity expansion (HWY) to add freeway lanes.
- Transportation system management (TSM) actions (enhanced bus service in the corridor).
- HOV lane addition.
- Light Rail Transit (LRT) addition to the corridor.
- Travel Demand Management (TDM) action to collect tolls within the corridor.

Capital, operation, and maintenance costs for both the highway and transit agencies were calculated for each alternative, based on available literature. Benefits estimated for each alternative consisted of estimated travel time savings, vehicle operating cost reductions, reduced vehicle emissions, accident cost reductions and other external benefits, and revenues generated through additional parking fees. Based on the assumptions made, some of the alternatives were estimated to experience negative benefits (sometimes referred to as dis-benefits) in one or more of these categories.

Table 11-3. Example of a Benefit-Cost Analysis [11]

	Benefits and Costs (in millions of dollars)				
	HWY	TSM	HOV	LRT	TDM
Benefits					
User	22.5	21.8	24.1	20.6	-16.6
Revenues	0.0	0.0	0.0	2.5	33.1
External	-21.0	2.0	4.3	5.7	22.7
Emissions	-0.9	0.6	2.3	1.9	5.0
TOTAL	0.6	24.4	30.6	30.7	44.2
Costs	4.7	5.9	8.	48.1	14.7
B/C Ratio	0.12	4.14	3.45	0.64	3.01

As table 11-3 illustrates, the TSM alternative was estimated to provide the highest B/C ratio (4.14). This indicates an expected $4.14 benefit to be received for every $1 spent by the public agency on the alternative. The HOV and TDM alternatives also provided a reasonable B/C ratio, returning $3.45 and $3.01, respectively, for every $1 invested on that alternative.

The HWY and LRT alternatives, however, resulted in B/C ratios less than 1. This indicates that these alternatives are not attractive investments, providing only $0.12 and $0.64 benefits per $1 invested. It should be noted that significant external disbenefits (expected accident increases due to increased vehicle demand on the facility) caused the relatively poor result for the HWY alternative. For the LRT alternative, the high capital cost required was the main factor causing the low B/C ratio.

As an example of the incremental B/C analysis, suppose that the TSM alternatives described above had initially consisted of potential bus service improvements on four different routes in the corridor. Estimated benefits and costs for each route might have been as shown in table 11-4. Examining the economic viability of each route separately clearly shows that the expenditures on routes 1 through 3 would be justified (B/Cs for each greater than 1), whereas those for route 4 would not (B/C less than 1). Furthermore, if the analyst had only considered the four routes together without analyzing them incrementally (using the numbers in the last column of table 11-4), he or she would have incorrectly concluded that the TSM improvements should be made to all four routes.

Other Considerations

The benefit-cost (or incremental benefit-cost) analysis methodology provides an objective means of comparing the quantifiable and monetarily-based benefits of an alternative to the costs of that alternative. Unfortunately, not all quantifiable benefits are easily converted to a monetary value (the reduction in vehicle emissions, for example). Likewise, some benefits are not easily quantified (e.g., the improvement in public perception of a transportation agency due to improving the availability of traffic information in the freeway corridor).

Table 11-4. Example of an Incremental Benefit-Cost Analysis

	TSM Components (Bus Service Improvements)				
	Route 1	Route 2	Route 3	Route 4	Total
Benefits	7.1	10.0	7.3	2.0	26.4
Costs	1.0	2.0	2.9	4.0	9.9
B/C Ratio	7.1	5.0	2.5	0.5	2.7

Because of this, alternative analyses are often needed to help assess which alternative systems or subsystems meet their objectives in the most economical manner. The utility cost analysis, described below, is one such analysis approach.

Utility-Cost Analysis

Description

Although a benefit-cost (or incremental benefit-cost) analysis is a direct method of determining whether a freeway management system alternative is economically viable, such an analysis can be performed only if the benefits to be accrued can be estimated in monetary terms. For many goals and objectives of freeway management, this is not possible. In these cases, a utility-cost analysis approach is commonly utilized. The term cost-effectiveness is sometimes used interchangeably with the term utility-cost analysis.(12)

In a utility-cost analysis, utility measures of performance goals or objectives are created to estimate system benefits. Typically, a project team or expert panel subjectively rates (from 0 to 10 or on a similar scale) how well an alternative is expected to achieve each of the objective or performance criteria. Weighting factors (summing to unity) are also estimated for each of the objective or performance criteria, and multiplied by the rating given to that objective/criterion. These "utilities" of each of the objective/criteria are then summed to determine the total system utility. Dividing the system utility by total system cost represents the utility-cost factor for a particular system. The basic steps in a utility-cost analysis are as follows: (4, 9)

- Define goals and subgoals (done as part of the decision process).
- Weigh each goal.
- Weigh each subgoal.
- Rate the utility of each goal/subgoal.
- Compute utility-cost ratio.

Example

Figure 11-2 illustrates a computational procedure presented elsewhere, that rates each alternative of a traffic control project against the specified requirements for that project. (13) The ability of each alternative system to meet each requirement is rated 0 to 10. Zero indicates that the system does not satisfy the requirement at all, while 10 indicates total satisfaction. This internal rating scale measures how well an alternative system satisfies a requirement. Multiplying the individual rating by a relative weight creates the utility value for that requirement. The sum of individual utility values gives an overall utility rating for each alternative.

Other Considerations

It is tempting to use the utility cost ratio only to compare alternative system designs, selecting the one with the greatest ratio. However, this conclusion may prove faulty because a simple, inexpensive system with low utility and low cost may have the same ratio as a sophisticated, but more expensive system with high utility and satisfying all defined requirements. The analyst must also assess whether the low-cost option satisfies all of the system objectives and functions. Conversely, the analyst must determine if funds are available to implement the more expensive alternative. If the alternative exceeds available funds, one or more of the components may need to be removed or modified, leading to a new rating of expected performance and a new utility cost ratio.

Value Engineering

Description

Value engineering is an organized effort directed at analyzing the function of an item with the purpose of achieving the required function at the lowest overall cost.(14) The relationship between value and function is expressed as follows:(15)

Value = (Functional Performance)/Cost

From this equation, it is evident that value is increased in one of two ways:

- Value is increased by reducing costs, if performance is maintained.
- Value is increased by increasing performance (but only if increased performance is needed and the user is willing to pay for it).

A critical step in any value engineering is to identify and assess the function(s) of the item or service under study. These functions are categorized as basic or secondary. Basic functions are those which are absolutely essential in order for the item or service to perform its purpose. Secondary functions are those related to esteem, appearance, or convenience. Finally, the basic functions are organized into a logical, hierarchial sequence. This makes it possible to identify the principle function(s). It is these principle function(s) which are used to judge value.(16)

Example

An evaluation of candidate channelizing devices to be used during a work zone lane closure on a section of freeway are presented in tables 11-5 and 11-6. Six alternative channelizing devices are considered:

- Type I Barricades.
- Type II Barricades.
- Vertical Panels.
- Cones.
- Tubes.
- Drums.

Key measures of functional performance to be included in the analysis are mean detection of an array of each type of device at the closure, and the mean distance at which drivers change lanes upstream of the closure when each device is present. Table 11-5 summarizes these distances.(16) Table

		Ability of Alternative Systems to Meet Each Requirement Rating (0 to 10)					
Requirement	Relative Importance of Each Requirement Sum = 100	Alternative System 1		Alternative System 2		Alternative System 3	
1. Intensity of CCTV coverage	25	4	100	7	175	10	250
2. Spacing of mainline monitoring station	25	2	50	6	150	8	200
3.	8	5	40	4	32	7	56
4.	4	10	40	6	24	6	24
5.	16	10	160	7	112	7	112
	etc.						
	100		390		493		642

Relative weight scale
How important is this requirement in this jurisdiction? The total of these values must equal 100.

Internal rating scale
How well does this alternative system satisfy this requirement? The range of this value is between 0 and 10 where 0 means the system cannot accomplish this function, and 10 means the requirement is totally satisfied.

Utility value
Obtained by multiplying the internal rating scale by the relative weight of each requirement. These values are summed to determine the total utility of each alternative.

Figure 11-2. Example of Utility Cost Analysis. [13]

11-6 then provides the costs and resulting value estimates for each device.

Engineering judgement must be used to some degree in value engineering analyses. As can be seen in table 11-6, no one device provides the best value for both functional performance measures in both day and night conditions. In this analysis, vertical panels and drums were said to be "good values" (entailing lower costs for unit functional performance) for combined day and night use at freeway work zones. They were at or near the bottom of cost per unit of detection distance or lane change distance for both day and night conditions.[16]

Other Considerations

A project team or expert panel approach is used in this analysis process, just as for a utility-cost evaluation. The principal difference between value engineering and utility cost evaluation is in how item performance is accounted for in the analysis. Whereas the utility cost approach assigns a subjective measure of utility to otherwise nonquantifiable performance measures, the value engineering approach depends on the ability of the analyst (or project team) to define a quantifiable measure of performance for the primary function(s) of the alternative being evaluated.

Table 11-5. Mean Detection and Lane Change Distances for Channelizing Devices. [16]

Device Type	Mean Array Detection Distance (ft)		Mean Lane Change Distance Before Taper (ft)	
	Day	Night	Day	Night
Type I Barricades	4,250	3,150	640	660
Type II Barricades	4,100	2,800	400	810
Vertical Panels	4,400	3,300	370	500
Cones	4,400	1,450	460	250
Tubes	3,200	1,900	620	350
Drums	4,200	3,000	540	560

Table 11-6. Example of Alternative Channelizing Device Values. [16]

Device Type	Device Array Cost ($)	Cost Per 100 ft Array Detection Distance ($)		Cost Per 100 ft Mean Lane Change Distance ($)	
		Day	Night	Day	Night
Type I Barricades	40	0.94	1.27	6.25	6.06
Type II Barricades	45	1.10	1.61	11.25	5.56
Vertical Panels	22	0.50	0.67	5.95	4.40
Cones	18	0.41	1.24	3.91	7.20
Tubes	22	0.69	1.16	3.55	6.29
Drums	25	0.60	0.83	4.63	4.46

Sensitivity Analysis

Description

Uncertainty is a part of most economic analyses of freeway management system alternatives. Quickly changing technology results in cost estimates during construction and operations that may differ from those obtained during the data collection phase of the analysis. Estimates of benefits are commonly based on simulation analyses or upon documented experiences of other agencies that have implemented similar alternatives. The extent to which these experiences will be realized in the project of interest are generally not known until after implementation.

It is always tempting to avoid an explicit evaluation of uncertainty by basing the analysis on a "conservative" estimate of the uncertain variables. Unfortunately, the analyst may not always know whether a conservative estimate—in the sense that it is supposed to lead to an underestimate of net benefits—requires a value that is higher or lower than the most likely estimate.[12] The simplest way of allowing for uncertainty is by means of a sensitivity analysis: systematically varying the value of key assumptions and parameters to objectively evaluate their importance. A sensitivity analysis is appropriate for any type of economic analysis (net present worth, benefit-cost, utility-cost, or value engineering).

Example

The example presented earlier for the benefit-cost analysis provides an excellent example of the importance of conducting sensitivity analyses in economic evaluations. The results presented in table 11-3 indicated that bus scheduling improvements (labeled as the TSM category) provided the best benefit-cost ratio, followed closely by the addition of an HOV lane and transportation demand management (TDM) alternatives. Building additional freeway capacity (HWY alternative) and a light rail transit (LRT alternative) were computed to have benefit-cost ratios less than 1. However, these results assumed that a significant increase in vehicle demand would be generated by the addition of freeway capacity, and that this would increase accident rates and costs significantly. Likewise, TDM actions were assumed to result in significant decreases in travel demand, significantly reducing travel demands.[11]

Analysts tested the sensitivity of the results to this assumption by computing a benefit-cost ratio for each alternative without assuming significant changes in demand. In other words, they evaluated the effects of these alternatives upon existing travel demand patterns. The results, shown in table 11-7, indicate extreme sensitivity to the assumption about changes in future demand. Whereas the HWY alternative was not viable (benefit-cost ratio less than 1) when significant accident cost increases were assumed to occur, the alternative becomes the most attractive alternative (benefit-cost ratio of 4.60) when accidents are not assumed to increase significantly over the existing levels.[11]

Other Considerations

The range of variation of key assumptions and parameters in a sensitivity analysis can either be a specified amount, say 10 percent above and below the central estimate, or can be related to the inherent uncertainty associated with the central estimate itself. In the latter case, the ranges would represent best-guess estimates of possible "high" and "low" values of the parameters, not necessarily uniformly distanced from the most likely value.

A properly conducted sensitivity analysis quickly shows which estimates are most important and gives the engineer a general idea of the following: [2]

- Those aspects which justify further work to narrow the range of uncertainty.
- The qualitative uncertainty associated with the scheme as a whole.

When a quantitative evaluation of uncertainty about benefits associated with freeway management is required, traffic simulation may be useful (although it is possible to evaluate uncertainty using mathematical expectations, this approach is usually too complicated for all but the simplest applications). The analyst can vary each of the parameters systematically, and determine the influence of that parameter upon the overall estimates of performance obtained with simulation.

Table 11-7. Example of Sensitivity Analysis of Benefit-Cost Ratios. (Adapted from 11)

	Benefit-Cost Ratio				
	HWY	TSM	HOV	LRT	TDM
Benefit-Cost Ratio (with accident increases)	0.12	4.14	3.45	0.64	3.01
Benefit-Cost Ratio (without accident increases)	4.60	4.42	4.25	0.74	3.94

11. 4 REFERENCES

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SUGGESTED READING

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GLOSSARY

Acoustic detector: Detects vehicles by using microphones along with signal processing technology to listen for sounds associated with vehicles.

Active infrared detector: Detects vehicle by transmitting electromagnetic energy.

Add-a-lane: A general implementation approach whereby an HOV facility is created by adding roadway capacity to an existing freeway facility, usually by widening the freeway or modifying the median or outside shoulder. This is the primary way HOV facilities have been created.

Add-drop (multiplexer, unit): A device connected to a time division multiplexed channel which obtains data from the channel and provides data to the channel.

Address: The identification code for a specific drop on a multidrop line so the unit alone will respond to a transmitted message.

Aloha: A contention technique channel access control scheme.

Amplitude: The maximum value of a sine wave.

Amplitude Modulation (AM): A method of transmitting information by varying the strength of a carrier waveform in accordance with the instantaneous value of the intelligence-bearing signal.

Analog: Information represented by continuous and smoothly varying signal amplitude or frequency over a certain range; such as in human speech or music.

Area radio network: A point-to-multipoint radio communication system.

Articulated bus: An extra-long, high-capacity segmented bus that has the rear portion flexibly but permanently connected to the forward portion with no interior barrier to hamper movement between the tow parts. The seated passenger capacity is 60 to 80 persons with space for many standees, and the length is from 60 to 70 feet. The turning radius for an articulated bus is usually the same or less than that of a standard urban or inter-city bus.

Asynchronous data transmission: A mode of data transmission in which the time between sequential message characters is unpredictable.

Attenuation: The loss in signal strength (weakening of power) associated with the transmission process. Attenuation is usually expressed as the ratio of received signal strength to transmitted signal strength. This ratio is often expressed in decibels, a logarithmic unit for expressing dimensionless ratios.

Attenuation distortion: The distortion of a transmitted signal caused by the nonuniform loss or gain at different frequencies.

Automatic gain control: A circuit which enables a communication receiver to provide a steady level of output when the carrier level of the input signal varies.

Automatic Vehicle Identification (AVI): Vehicles equipped with transponders are identified when they come within range of a roadside communication unit. Most common application is for automatically collected tolls on tollways; however, system is also used as a means of automatically collecting travel time information along freeways.

Automatic Vehicle Location (AVL): Enables the approximate location of a vehicle to be determined and tracked as it traverses the transportation network. Commonly used by emergency services and transit agencies to track location of vehicles. Also can be used to monitor traffic conditions by obtaining probe reports from vehicles traveling in the network.

Avalanche photodiode: A highly sensitive detector device used in fiber optic communication systems.

Average vehicle occupancy: The number of persons divided by the number of vehicles traveling past a selected point over a predetermined time period, usually expressed to two or three significant figures (e.g., 1.2 or 1.26).

Backbone: A high capacity communication system to which a number of drops are connected. The drops may service lower capacity distribution systems.

Bandwidth: (1) The range of signal frequencies that a medium or channel will respond to, or carry, without excessive attenuation. (2) The amount of green time available to a platoon of vehicles in a progressive signal system.

Barrier-separated HOV facility: An HOV lane that is physically separated from adjacent general purpose traffic by some type of barrier. A concrete barrier is the most commonly used approach, but wide buffers, moveable barriers, and pylons may be used. A barrier-separated HOV lane may be a one direction/reversible facility or a two lane bi-directional facility.

Barrier separation: A physical barrier (either concrete or guard-rail) that is used to separate an HOV facility from general purpose freeway traffic.

Baseband: A method of communication in which a signal is transmitted at its original frequency without being impressed on a carrier.

Baud: A unit of signal speed equal to the number of signal symbols per second, which may or may not be equal to the data rate in bits per second.

Benefit-cost ratio: The ratio of the dollars of benefits achievable for a given outlay of costs, both of which have been adjusted to a common time increment.

Binary: A number system using the base 2; it is commonly used in computers and data communication.

Bit: A binary digit, the smallest element of information in a binary system. A "1" or "0" of binary data.

Bit error rate: The ratio of incorrectly transmitted bits to correctly transmitted bits.

Bit rate: The speed at which bits are transmitted, usually expressed in bits per second.

Broadcast: The simultaneous transmission of a message to all receivers on the channel.

Buffer-separated lane: A HOV lane that is separated from the adjacent mixed-flow freeway lanes by a designated buffer. Different widths of buffers are currently in use with various HOV lanes.

Buffer strip, HOV buffer separation: A roadway area that is used to physically separate an HOV lane from a regular use lane. Generally, no vehicles are allowed in this area, but if the buffer is sufficiently wide (more than 14 feet), it may be considered a refuge for disabled vehicles. The buffer strip is not considered a safe enforcement area.

Bus and carpool lanes, preferential lanes, or HOV lanes: A form of preferential treatment in which lanes on streets and highways are reserved for the exclusive use of high occupancy vehicles, transit buses, carpools, vanpools, or all of the above.

Bus lane (bus primary lane, preferential bus lane): A lane reserved primarily for buses, during at least portions of the day.

Bus priority system: A means by which transit buses are given an advantage over other traffic (e.g., preemption of traffic signals or bus priority lanes).

Busway: A separated roadway designed for exclusive or predominant use by buses in order to improve bus movement and travel times.

Bypass lane: See *queue bypass* (HOV)

Byte: A sequence of adjacent bits used to represent a single character of information. The most common byte sizes are 8 bits and 16 bits.

Cable loss: The loss or attenuation of signal power in a cable as a result of its electrical or optical properties.

Call box: Located at given locations along the side of a freeway. Motorist can request various services (such as police, fire, or ambulance) by pressing certain buttons.

Capacity: The maximum number of vehicles (vehicle capacity) or passengers (person capacity) that can pass over a given section of roadway or transit line in one or both directions during a given period of time under prevailing roadway and traffic conditions.

Carpool: Any vehicle, usually an automobile, carrying two or more occupants, including the driver, or a group of people sharing automobile transportation.

Carrier: A signal compressed of a single frequency. A characteristic of this signal is changed (modulated) in accordance with the information being transmitted.

Carrier detect: Indicates to the sender that the receiving modem has received the transmitting modem's carrier.

Carrier sense multiple access: A contention technique channel access control scheme.

Cellular radio: A communication technique using low power transmitters to service geographical areas or cells. Frequencies may be reused for other messages in non-adjacent cells.

Cellular telephone tracking: Uses radio frequency receivers and triangulation techniques to determine a vehicle's location by measuring signals resulting from cellular phone usage within a vehicle.

Central Business District (CBD): That portion of a city which serves as the primary activity center. Its land use is characterized by intense business activity that serves as a destination for a significant number of daily work trips.

Central communication unit: A unit commonly used at the traffic operations center coordinating the operation of time division multiplexed communication with field controllers.

Changeable message sign (CMS): See Dynamic message sign

Channel capacity: The maximum signal rate which a communication channel can sustain. It is usually measured in bits/sec.

Channel throughput: See "channel capacity."

Channel: A path of communication from a transmitter to one or more receivers over a path. A frequency band or type of transmission is also a characteristic of a channel.

Checksum: A communication error detection technique.

Clear to send: The signal sent to the transmitting computer that both modems are ready to perform their functions and that transmission may begin.

Closed-Circuit Television (CCTV): Uses video cameras to provide visual surveillance of the freeway system.

Coax: See "coaxial cable."

Coaxial cable: A cable with a single central conductor having a common axis with a second outer cylindrical conductor.

Code division multiplexing: A multiplex technique commonly used in spread spectrum radio communications which selects the appropriate signal from others in the same frequency band by means of a unique code.

Codec: A coder decoder. The terminology is commonly use for equipment which transmits and receives coded video information. Coding compresses the video information so that it may be transmitted over a digital channel with a lower bandwidth than would otherwise be required to carry the signal.

Collision: The simultaneous transmission and reception of signals by elements of a communications system based on contention techniques.

Coded TV: Signals encoded in connection with codecs. See "codec."

Communication: Transfer of information from one location to another so that meaning is understood.

Communications architecture: An organization of communications channels and communication terminals.

Communications buffer: A register in a communications terminal which interfaces with a computer and provides temporary storage for data passing between these units.

Communications hub: A location at which data is transferred between backbone and distribution communications systems.

Communication medium: The composition of the path along which a communications signal is propagated, such as wire pair, coaxial cable, optical fiber, or airpath.

Communication overhead: That portion of the communication character stream which is provided for identification of the drop, control of symbol transmission and detection, and correction of errors.

Compliance rate: The number of eligible HOVs on an HOV facility divided by the number of total vehicles on the HOV facility (eligible and ineligible), expressed as a percent.

Concurrent-flow lane: An HOV lane that is operated in the same direction as the adjacent mixed-flow lanes, and is designed for use by HOVs during all or portion of the day. The lane is separated from the adjacent general-purpose freeway lanes by a standard lane stripe or a buffer. Concurrent-flow HOV lanes are ususally found on the inside lane, but may also be on the outside lane.

Conduit: A cylindrical structure, usually of steel of polyvinyl chloride, which provides protection for communication cable.

Conditioned line: A communications cable specially compensated to provide improved transmission characteristics.

Connector: Hardware installed on cable ends to provide physical connection between electrical devices.

Contention: Communication systems which permit more than one transmitter to send simultaneously. Message interferences are detected and the signal is retransmitted at a later time.

Contiguous flow lane: A non-separated concurrent flow lane (also see non-separated lane).

Contraflow lane: A lane on which, during certain hours of the day, HOVs operate in a direction opposite to that of the normal flow of traffic (commonly the inside lane in the off-peak direction of travel). For freeway applications, the lane is typically separated from the opposing direction travel lanes by pylons or movable concrete barrier.

Crosstalk: Interference or presence of unwanted signals from one transmission channel, detected on another (usually parallel) channel.

Cyclic redundancy code: A commonly used error detection code included in the transmitted signal.

Decibel: A logarithmic unit for the ratio of two powers.

Delay: The time lost by a person or a vehicle during travel due to circumstances which impede the desirable movement of traffic. It is the travel time difference between congested and free-flow travel times.

Demodulation: The process of extracting transmitted information from a modulated carrier signal. The opposite of modulation.

Diamond: A uniform traffic control symbol used on signing and pavement markings to designate the restricted usage on preferential (HOV) facilities.

Dielectric: An insulator occupying the space between two conductors such as the inner and outer conductors of coaxial cable.

Digital: Information in discrete or quantized form; not continuous.

Directional coupler: Combines signals propagating in one direction on a cable onto another cable while substantially isolating signals from the opposite direction.

Dispersion: A general term for those phenomena that cause a broadening or spreading of light as it propagates through an optical fiber.

Distortion: An unintended modification to the wave form of a communications signal caused by the media or by devices in the transmission path of the signal.

Distribution system: The portion of the communication system which services the field traffic controller.

Download: The transmission of messages from the control center or field master to a local controller for intermediate or long term storage in the local controller.

Drop: Receiver on a transmission line. A drop may also act as a transmitter in a two-way communications network.

Dynamic message sign (DMS): Signs that use electronics or mechanics to vary the visual word, number, or symbolic display as traffic conditions warrant. The term is used interchangeably with changeable message signs and variable message signs.

Dynamic range: The range of signal levels for which a receiver function properly. The lowest signal level is determined by noise level considerations and the upper level is determined by detector or receiver distortion, saturation, or power level limitations.

Earth station: The terrestrial equipment component of a satellite-based communication system.

Electromagnetic spectrum: The entire available range of sinusoidal electromagnetic wave frequencies.

Electromagnetic wave: Electric and magnetic waves are time varying electric and magnetic fields in a volume of space which are related by Maxwell's equations. Electromagnetic fields provide the basis for the wire line, wireless, and optical communication technologies.

Embedded detector: Traffic detector system that consists of sensors in or below the surface of the roadway.

Emergency telephone: Located at given locations along the side of a freeway. Motorists can contact a dispatcher to report conditions and request help.

Enforcement: The function of maintaining the rules and regulations to preserve the integrity of a preferential (HOV) facility.

Enforcement area: A dedicated space in which enforcement can be performed. Enforcement areas can be delineated within an available shoulder or provided at specific locations.

Environmental detectors: Used to detect adverse weather conditions such as ice, fog, or flooding.

Error control: The methodology of detecting communication system errors and responding to this information.

Error detection: The process by which sufficient redundant or check information is included with data that are transmitted so that the receiver can, within certain ranges of error, identify erroneously received data.

Exclusive facility, freeway right-of-way: An HOV roadway or lane(s) located within a freeway right-of-way that is physically separated from the general purpose freeway lanes and designated for HOVs for all or portions of the day. Physical separation is usually via a concrete barrier, but separation can also be via a wide painted buffer. Examples include those located in Hartford, Connecticut and on the Shirley Highway in northern Virginia. (See also *barrier-separated facility* and *buffer-separated facility*).

Exclusive facility, separate right-of-way: An HOV roadway or lane(s) located in a separate right-of-way that is usually, but not always, designated for the exclusive use by buses. The facility is typically operated two-way and includes two lanes. Examples of this facility are located in Ottawa, Ontario and Pittsburgh, Pennsylvania. (See also *busway*).

Exclusive lane: A preferential lane separated by a wide buffer or physical barrier form general purpose lanes. (see also *barrier-separated lane* and *buffer-separated lane*)

Express bus service: Bus service with a limited number of stops, either from a collector area directly to a specific destination or in a particular corridor with stops en route at major transfer points or activity centers. Express bus service is usually routed along freeways or HOV facilities where they are available.

Fading: Variation in the field strength or other properties of a received radio wave signal as a result of changes in the electromagnetic field propagation characteristics of the transmission path with time.

Fiber optics: Technique for the transmission of light from a transmitting source through a bundle of tiny and flexible glass fibers.

Forward error control: A form of error detection and control which uses codes in the transmitted message to correct the errors. It is useful for certain types of errors.

Freeze frame video: A transmission process for video signals over voice grade channels. Periods of time extending from several seconds to approximately one minute may be required. Also known as "slow scan" video.

Frequency: The number of oscillations of a signal per unit of time: usually expressed in cycles per second (cps) or Hertz (Hz).

Frequency band: The range of frequencies occupied by a signal or which can be transmitted by a communication channel.

Frequency division multiplexing: Divides the total channel bandwidth into a series of subchannels, each of which occupies a subband of frequencies.

Frequency Modulation (FM): A method of data transmission whereby the frequency of a sinusoidal waveform (carrier) is changed in accordance with the information that is to be transmitted.

Frequency Shift Keying (FSK): The binary form of frequency modulation, in which a 0 is represented by one frequency and a 1 represented by another frequency.

Full duplex: A transmission link providing simultaneous transmission and reception in both directions.

Gas discharge tube: A device used to protect electronic field devices from electrical transients on the communication or power lines.

General purpose, mixed-flow, mixed-use lane: Lanes adjacent to or affected by an HOV facility that are available for use by all vehicles (i.e., single-occupancy vehicles, HOVs transit, trucks, etc.).

Graded index fiber: An optical fiber whose core has a nonuniform index of refraction. The core is composed of concentric rings of glass whose refractive indices decrease from the center axis. The purpose is to reduce dispersion and thereby increase fiber bandwidth.

Guard band: A region of unused frequencies that separates the different frequency regions within an FDM transmission system. The guard bands facilitate the separation of the signals.

Half duplex: A transmission link providing both transmission and reception in both directions, but not simultaneously.

Half power point: The upper and lower frequencies which identify the bandwidth of a communication channel or receiver. The power level of the channel or amplification of the receiver at these frequencies is at 50 percent of the highest value.

Harmonic: Frequencies other than the fundamental basic frequency of a repetitive wave. When the waveform of the fundamental departs from a sine wave, harmonics are introduced at integer multiples of the fundamental frequency.

Headway: The time or distance spacing between successive vehicles in a given traffic lane measured from the front of the vehicles.

Hertz (Hz): A measure of frequency. One Hertz equals one cycle per second.

Highway Advisory Radio (HAR): A low-powered radio (generally AM) station devoted to presenting travel-related information to the public.

High Occupancy Vehicle (HOV): Motor vehicles carrying at least two or more occupants including the driver. An HOV could be a transit bus, vanpool, carpool or any other vehicle that meets the minimum occupancy requirements, usually expressed as either two or more, three or more, etc., persons per vehicle.

High-Occupancy Vehicle (HOV) lane: A preferential lane that is reserved for the use of high-occupancy vehicles.

High-Occupancy Vehicle (HOV) system: The collective application of physical facilities to support HOV operations, including HOV lanes, park-and-ride lots, park-and-pool lots, and/or other supporting facilities that are administered so as to effectively integrate all physical elements into a unified whole.

Hub: See "Communication hub."

Incident detection algorithm: Computer software developed to automatically identify incidents on the basis of field data received from detection equipment.

Index of refraction: The ratio of the velocity of light in free space to the velocity of light in a given material.

Inductive loop detector: Coil of cable embedded in the pavement surface that creates a magnetic field. Vehicle is detected when this magnetic field is disturbed.

Information theory: a mathematical treatment of the generation of information and the limitations on its transmission rate over communication channels.

Injection laser diode: An electronic transmitting device used for fiber optic communication.

Input/output unit: That portion of an electronic communication unit which interfaces with a digital computer.

Insertion loss: The loss of power that results from inserting a component, such as a connector or splice, into a previously continuous path or at its termination.

Interference: A disturbance that changes the shape of a communications transmission wave.

Junction box: A mechanical unit, usually installed in the ground, which provides an enclosure for connection at cable junctions.

Kiosks: Video monitors mounted on a cabinet, in a wall, or on a counter top which travelers can access and request travel-related information

Kiss-and-ride: An access mode to transit whereby passengers (usually commuters) are driven to a transit stop and left to board the vehicle, then met after their return trip.

Land-line: A communications medium consisting of twisted-wire pairs, fiber optics or coaxial cable.

Lane: A portion of a street or highway, usually indicated by pavement markings, that is intended for one line of vehicles.

Leased channels (also leased lines): Communication channels which are leased from a communications service carrier or supplier such as the telephone company. The lessee has the full time use of these channels during the lease period. Maintenance of the channels is performed by the communications service carrier.

Level of Service: A descriptive measure of the quality and quantity of transportation service provided the user that incorporates finite measure of quantifiable characteristics such as travel time, travel cost, number of transfers, etc. Operating characteristics of levels of service for motor vehicles can be found in the latest edition of the *Highway Capacity Manual*, Transportation Research Board Special Report.

Light Emitting Diode (LED): A solid state device with illumination properties similar to that of a low power incandescent lamp.

Linear drop: Nodes connected in a string or chain with transmission data being "dropped" at a designated node.

Link control signals: Modem control signals which control or identify modem states to establish the need for communication, its direction, and the readiness state of the modem.

Local exchange carrier (LEC): The seven Regional Bell Operating Companies and independent telephone companies which provide "local" telephone service.

Longitudinal redundancy check: A communication error detection technique.

Magnetometer: Small cylinders containing sensor coils that operate in a manner similar to inductive loops. Developed as alternative to loop detectors for special situations.

Medium: See "Communications medium."

Messenger cable: A structural cable used to support communication cable installed on poles or bridges.

Microwave: Electromagnetic energy occupying the frequency band ranging from approximately 225 Mhz to 100 Ghz.

Microwave radar: Transmits electromagnetic energy toward vehicles on roadway. Traffic parameters are calculated by measuring the return signal frequency from vehicles.

Mixed-flow, mixed-use: See *general purpose.*

Mode: A particular form of travel (i.e., walking, bicycling, traveling by bus, traveling by carpool, traveling by train, etc.).

Mode shift: The shift of people from one mode to another (i.e., non-separated single-occupancy vehicles to HOVs or vice versa).

Modem: A device used at both ends of a communications channel to transmit and receive data. Contraction of Modulator Demodulator.

Modulation: The process by which a characteristic of one wave (the carrier) is modified by another wave (the signal).

Multimode fiber: A type of optical fiber that supports more than one propagating mode.

Multipath transmission: Rapid transmission along a path other than the direct path between transmitter and receiver, often used by reflection and by various atmospheric effects. It may result in facing or interference.

Multiple access contention: See "contention."

Multiplexing: A communications technique which allows more than one item of information to be transmitted or received over the same channel.

NEMA controller: A traffic signal controller conforming to the NEMA TS1 or NEMA TS2 standard specification. NEMA is the abbreviation for National Electrical Manufacturers Association.

Node: See "Communications hub."

Noise: Unwanted signals not present in the original transmitted information; disturbances that tend to interfere with normal operations of the communication system.

Nonintrusive detector: Traffic detector system that consists of sensors mounted on a structure above the pavement.

Non-proprietary protocol: A communication protocol available to all prospective users and for which technical information is available.

Nonrecurring congestion: Caused by a random event (e.g., incident, maintenance activity, special event, etc.) and has the effect of reducing capacity on a specific section of freeway.

Nonseparated (HOV) lane: An HOV lane that is not separated from adjacent mixed-flow freeway lanes (i.e., delineation is via a standard dashed pavement stripe).

Occupancy: Percent of time a given section of roadway is occupied.

Off-peak direction: The direction of lower demand during a peak commuting period. In a radial corridor, the off-peak direction has traditionally been away from the CBD in the morning and toward the CBD in the evening.

Packet radio: A radio data transmission technique based on sending data in defined groups or "packets." This technique is often used to provide all transmitters on the channel the opportunity to access the channel when they have data to transmit.

Parallel data transmission: A method of simultaneously transmitting all of the bits that make up a digitally encoded character. Parallel transmission requires a separate wire for carrying each bit.

Parity: A communication error detection technique.

Park-and-pool lots: Facilities where individuals can rendezvous to utilize carpools and vanpools except the lot is not served by public transportation.

Park-and-ride lots: Facilities which serve as a transfer terminal for automobiles and bikes and which are normally served by public transportation. They can include spaces used by persons transferring to carpools or vanpools whether officially designated for that purpose or not.

Passive infrared detectors: Do not transmit energy, but detect vehicles by measuring the amount of energy emitted by objects in the field of view.

Peak hour: That hour during which the maximum amount of travel occurs. It may be specified as the morning peak hour or the afternoon or evening peak hour.

Peak period: The period during which traffic levels rise from their normal background levels to maximum levels. These periods are for morning, evening, and mid-day peaks and include the appropriate peak hours.

Personal Data Assistants (PDAs): Computer products with radio frequency communications to allow users to obtain various types of travel information.

Phase: The fractional part of the period of sine wave which has elapsed since the wave had the value of zero.

Phase Modulation (PM): A technique to transmit information using a sine wave carrier. The sine wave has its phase changed in accordance with the information to be transmitted.

Pixel: The smallest area on the screen of a graphics CRT display that can be discretely displayed.

Polarity: The sign of the voltage rise from a reference point (usually ground) to a point in a circuit.

Polling: A centrally controlled technique of sequentially calling a number of drops to permit them to transmit information back to a field master or to the traffic operations center.

Polling cycle: The time period required to poll all of the drops on a channel one time.

Power budget: A convenient methodology for analyzing the power reception and signal to noise ratio capability of a communication link.

Power fading: See "fading."

Power margin: The difference between the power received and the power required for reception.

Preferential parking: Parking lots or spaces reserved exclusively for HOVs only as a means to encourage ridesharing. They are usually located closer to a terminal or building entrance than other vehicle spaces and may also enjoy a reduced parking fee.

Preferential treatment: In transportation, giving special privileges to a specific mode or modes of transportation (e.g., bus lanes or signal preemption at intersections).

Presence: Detection mode in which signal from traffic detector is sent as long as the vehicle is in the detection area. Used to measure volume and occupancy.

Present worth factor: A coefficient used in engineering economics which relates a uniform series of end of period payments to value of those payments at the present time. Also known as "uniform-series present worth factor."

Private line: See "leased channel."

Processing gain: In spread spectrum communications, processing gain is a measure of the additional noise penetrability achieved by the use of additional bandwidths and coding schemes.

Proprietary protocol: A communication protocol which is the intellectual property of a communication manufacturer or supplier and which is not available for use by others.

Protected ring: Two rings used instead of one, thereby providing two unidirectional transmission paths that may run in opposite directions.

Protocol: A set of codes, procedures, and relative timing relationships by which data are transmitted over a communication channel, such as a twisted pair wire, fiber optic, etc.

Pulse: Detection mode in which a short signal from the traffic detector is sent when a vehicle is detected. Typically used to provide volume counts.

Pulse dispersion: See "dispersion."

Queue: A line of waiting vehicles or persons, e.g., traffic at a bottleneck location or signal, or buses at a park-and-ride facility, or persons in line to board a bus.

Queue bypass: An HOV facility that provides a bypass around a queue of vehicles delayed at a ramp meter, toll plaza, bridge, tunnel, ferry landing, or other bottleneck location.

Queue bypass lane: See *queue bypass.*

Ramp metering: A system used to reduce congestion on a freeway facility by managing flow from on-ramps. An approach ramp is equipped with a metering device or a traffic signal that allow the vehicles to enter a facility at a controlled rate.

Ramp meter bypass: A form of preferential treatment in which bypass lanes are provided at a ramp meter for the exclusive use of high-occupancy vehicles.

Real-time expert system: Software that provides decision support for operations personnel.

Receiver: A part of the communication system which accepts and translates (decodes) signals into commands or data functions.

Receiver sensitivity: The minimum optical power required to achieve a specified level of performance, such as a Bit Error Rate.

Recurring congestion: Typically predictable and occurs at locations where demand exceeds capacity, or at geometric bottlenecks (e.g., lane drops, high-volume entrance ramps, etc.).

Refraction: The change in direction of an electromagnetic wave resulting from changes in the velocity of propagation of the medium through which it passes.

Regeneration: The process of demodulating and remodulating a digital signal for retransmission.

Remote Communication Unit (RCU): A field receiving and field equipment interface commonly used for traffic system communications. It converts communication signals into signals which are used by field equipment such as controllers and converts detector and controller state data into communication signals.

Repeat transmission: A communication error detection technique.

Repeater: A device used to amplify and/or regenerate attenuated signals.

Repeater amplifier: A device used to amplify attenuated signals.

Request to send: A signal from the computer indicating it wants to send data.

Reversible-flow lane: A lane on which the direction of traffic flow can be changed to match the peak direction of travel during peak traffic periods.

Reversible lane: See lane, reversible flow

Ridesharing: The function of sharing a ride with other passengers in a common vehicle. The term is usually applied to carpools and vanpools.

Rodding: Use of a probe to test or clean communication conduits or duct.

Separated roadway, barrier separated facility: A physically-separated, access-controlled, HOV facility. It is usually located in the median of an urban freeway and separated from the regular travel lanes with a barrier. They can be used either as single-lane, reversible flow facilities or as two-way, single (or multiple) lane facilities.

Serial data transmission: A method of digital data transmission whereby the bits that represent an item of information are transmitted sequentially over a single channel.

Serial port: A portion of a computer, modem, or device which is used to interface the serial communication bit stream with the functional circuitry of the device.

Service patrol: Utilize public or private vehicles (i.e., pickup trucks, vans, or tow trucks), and operate on mobile patrol or on standby to handle incidents and provide motorist assistance.

Settling time: The time required to reverse the direction of transmission in a half duplex system.

Shoulder lane: An HOV lane that is created on an existing median or outside shoulder of a freeway.

Signal: The physical form of the data or message carried by the communication channel.

Signal preemption: A technique for altering the sequence or duration of traffic signal phasing using vehicle detection in order to provide preferential treatment for buses and emergency vehicles.

Signal-to-Noise-Ratio (SNR): The ratio of signal power to noise power at a communication receiver. A measure of the quality of a communications channel that regulates the received signal strength to the strength of the unwanted signals (noise) that combine with the desired signal during transmission.

Simplex: A transmission channel capable of transmission and reception in one direction only.

Single mode fiber: An optical fiber that supports only one mode of light propagation.

Slotted aloha: A contention technique channel access control scheme.

Slow scan video: See "Freeze frame video."

Speed: Rate of motion. Ratio of travel distance and travel time.

Splice: An interconnection method for joining the ends of communication cables.

Splitter: A device for bifurcating a wireline communication channel into separate physical paths.

Spread spectrum radio: A technique for spreading the power of a radio channel over a bandwidth which is many times the bandwidth required to communicate at the signal rate. The transmitted power density (watts per cycle) is low.

Star: Communication links emanated from a source node (e.g., traffic operations center) to multiple secondary nodes.

Start bit: A flow control bit forming a portion of the communication protocol.

Stop bit: A flow control bit forming a portion of the communication protocol.

Study period: The time during which a study is being conducted which could be one or more parts of a day, all day, or more than a day.

Support facility: A facility that enhances HOV operation, including park-and-ride lots, park-and-pool lots, transfer terminals, or other physical improvement that is considered a supporting element of the operation.

Support program: Any of a number of services that enhance the public acceptance or usage of the HOV system, including ridesharing, employer-sponsored programs, public information, and marketing.

Surveillance, Communications and Control (SC&C): A remotely operated system of monitoring and managing the operation of an HOV and/or freeway facility to better assure acceptable traffic operation and improved responsiveness to incidents. Major elements are (a) Surveillance — collection and processing of data by detectors and visible verification by closed circuit television; (b) Communications — presentation of operational information to motorists through signs, delineation, signals, and/or auditory means; and (c) Control—application of traffic restraints or direction of flow by signs, barrier gates, and signals.

Switched telephone line: A commercially available telephone channel providing dial-up service.

Symbol: A single unit communication transmission format.

Synchronization: In synchronous data transmission, the process by which a transmitter and a receiver coordinate their operation so as to properly identify the bits and characters that make up a digitally transmitted message.

Synchronous data transmission: A type of data transmission in which there are no start and stop bits. Timing is derived through synchronizing characters at the beginning of each message or block of data.

T1 (system): A standard digital signal transmission hierarchy which permits signals to be sent at the various rates described in the standard.

Take-a-lane: A general implementation approach whereby an HOV facility is created by consuming or borrowing use of a mixed-flow lane on a freeway facility, usually by pavement markings and signing. This approach has rarely been applied.

Tap: A signal splitting device which permits a small amount of power to be siphoned from a communication line for use at a local drop point.

Telco central office: A location which terminates communication lines to customers. A switched or leased line is routed from the customers' facility to a central office. Connections are made between central offices before the line is routed to its destination.

Telephone central office: See "Telco central office."

Terrestrial microwave link: A microwave link with both termini on the earth (as compared with a satellite).

Thermal noise: Thermal agitation of electrons in the load resistance of the receiver.

Time division multiplexing: Shares time on a channel and enables a traffic operations center or field master to communicate at different times with each controller on a communication channel.

Traffic Management System (TMS): Any of various measures to improve the operation of a facility without construction of additional roadway lanes, such as: dynamic message signs (DMS), ramp metering and closed-circuit camera surveillance, and loop detection to detect and respond to emergencies.

Transient: A voltage of short duration. Often used to describe extraneous voltages appearing on the signal lines resulting from lightning and similar disturbances.

Transmitter: A part of the communication system which provides the transmission signal power to the modulated waveform.

Transportation Demand Management (TDM): The operation and coordination of various transportation system programs to provide the most efficient and effective use of existing transportation services and facilities. TDM is one category of traffic system management actions.

Transportation System Management (TSM): Actions that improve the operation and coordination of transportation services and facilities to effect the most efficient use of the existing transportation system. Actions include operational improvements to the existing transportation system, new facilities, and demand management strategies.

Trunk: A transmission link joining two points, which is distinguished by its large information carrying capacity and by the fact that all signals go from point to point without branching off to any separate drops except at the end points.

Turnaround time: See "settling time."

Two-way HOV facility: An HOV facility in which both directions of traffic flow are provided for at least during portions of the day (see also bi-directional).

Ultrasonic detector: Transmits sound waves and detects vehicle by measuring return waves.

Unprotected ring: Each node (i.e., communications hub or traffic control equipment) is connected to two others by a uni-directional transmission link, creating a "closed" loop.

Upload: A periodic transmission of data from the field controller to the traffic operations center or field master.

Vanpool: A prearranged ridesharing function in which a number of people travel together on a regular basis in a van, usually designed to carry six or more persons.

Variable message signs (VMS): See Dynamic message signs

Vehicle probes: Vehicles on given freeway section act as moving sensors (or probes) to provide information about traffic conditions.

Video compression: The processing of video data by codecs to achieve lower communication signal rates. See "codec."

Video grade channel: A communication channel which transmits signals with the approximate frequency range of 300 Hz to 3000 Hz.

Video image processing: Image processors receive information from video cameras and use algorithms to analyze the video image input.

Violation: An infraction of the rules and regulations for roadway use. In an HOV context, a violation can include vehicle and occupancy eligibility.

Violation Rate: The total number of violators divided by the total number of vehicles in an HOV lane or lanes.

Volume: Number of vehicles passing a given point over a period of time.

Wavelength: The physical length of an electromagnetic wave.

ABBREVIATIONS

AASHTO: American Association of State Highway and Transportation Officials
CBD: Central Business District
DOT: Department of Transportation
FHWA: Federal Highway Administration
FTA: Federal Transit Administration (formerly UMTA)
ITS: Intelligent Transportation Systems
LOS: Level of service
LRT: Light rail transit
MUTCD: Manual on Uniform Traffic Control Devices
MPH: Miles per hour
P&P: Park-and-pool
P&R: Park-and-ride
ROW: Right-of-way (also R.O.W.)
RRT: Rapid rail transit
TDM: Transportation demand management
TSM: Transportation system management
UMTA: Urban Mass Transportation Administration
VPH: Vehicles per hour
VPHPL: Vehicles per hour per lane
3+: Three or more persons per vehicle
2+: Two or more persons per vehicle

EHTR

A GUIDE FOR

HIGHWAY TRAFFIC REGULATION IN AN EMERGENCY

DRAFT

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1967—DRAFT.

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Bureau of Public Roads

A GUIDE FOR HIGHWAY TRAFFIC REGULATION IN A NATIONAL EMERGENCY

CONTENTS

Contents | Page

Contents

Contents

Contents

Contents | Page

Contents

List of Appendixes (continued)

Contents

A GUIDE FOR HIGHWAY TRAFFIC REGULATION IN AN EMERGENCY

Chapter I.---INTRODUCTION

That highways are the indispensable arteries of our national economy and defense, of our regional and local agriculture, industry, and commerce, and of our individual livelihood, social interchange, and recreation, is a universally accepted commonplace. The following brief statistics attest to that fact. In the United States, the 103 million registered drivers among our 200 million total population drove our 94 million motor vehicles more than 930 billion miles on our 3.7 million miles of roads and streets in the single year 1966. Put in a more homely fashion, four out of five Americans old enough to drive have a driver's license. There is a vehicle for every two persons (almost); 26 vehicles for every mile of road; and a mile of road for every square mile of land. The average passenger car travels nearly 10,000 miles a year. The average truck-trailer travels over 41,000 miles a year.

In times of peace, this tremendous volume of travel is rolled up because the full extent of our Nation's road and street network is available for the general use of the public, unrestricted by controls save those, of relatively minimum kinds and degrees, effected for the protection of the public's health and its social and economic welfare.

The problems of disaster

In times of catastrophe, occasioned by floods, earthquakes, hurricanes, blizzards, and similar violent phenomena of nature, highways have themselves suffered severe physical damage. The remaining available highways have served invaluably in the immediate efforts to save periled lives and in the rehabilitation period that is catastrophe's painful aftermath. Not a year passes but one or more regions of our country suffers nature's buffetings. And because of this very frequency, we, as a Nation, are by experience competent in coping with them.

The experience of war on our own soil has not been faced by this Nation for more than a century. In that unfortunate internal strife that lasted four weary years, adequate transportation--or more commonly, lack of it--

was frequently an important factor in the tide of battle. More recently, that "last" great general war, World War II, again demonstrated the vital essentiality of transport both in and near theaters of military operation and to them from distant sources of production and supply. In our own country, highways are undamaged by attack although they suffered from neglect. Shortages and rationing brought about a 12 percent decline in motor-vehicle registrations. Traffic volumes dropped 42 percent on rural roads and 33 percent on city streets. But necessary travel continued. Intercity bus travel more than doubled. City bus and rail traffic increased 60 percent. Truck-trailer travel, which accounts for the bulk of intercity highway freight movement, declined only 7 percent.

So we have seen and weathered natural catastrophes, and the strains of large-scale warfare as it has been waged in the past. But in a time of disaster following an enemy nuclear bomb attack, should it come, past experience will stand us in small stead. Not one locality, but many, may be devastated simultaneously. Physical destruction within and near them may be awesomely intense or total. And over and beyond these target areas, in vast and interlacing patterns, will be the unseen, deadly danger of radioactive fallout, constantly shifting with the weather, terrain, and time.

Some highway sections will be physically destroyed or obstructed beyond immediate repair. Many more and longer sections will be invisibly rendered impassable, or passable only under limiting conditions, by radioactive fallout. Heavy demands may be placed on the surviving and untainted usable roads and streets: first, for rescue, first-aid, evacuation, firefighting, demolition, and similar civil defense activities; later, for the movement and care of the surviving population, the restoration of industry and commerce, and military operations. Highways may face further abnormal strain in the postattack and recovery periods, since they are likely to be called upon to supplement or even supplant damaged rail, water, and pipeline transport.

Thus, for an extended period, in time of national emergency following an enemy attack, normally available highway capacity may be greatly reduced in many areas. At the same time the usage demand for essential needs may increase. Some routes will be blocked or closed. Some maybe wholly reserved for civil defense or military operations. And, on some, rationing of road space will probably be required in order to give appropriate priority to traffic movements essential to sustenance of the population and to restoration and maintenance of industry and the national economy.

Some indication of the effects of a nuclear attack on our highway network, and the regulation that would be required to meet traffic needs, is illustrated in figure 1.

Highway regulation in an emergency

In recognition of this vital and complex problem, the U. S. Bureau of Public Roads, at the direction of the President, has been charged with the responsibility of arranging to safeguard and facilitate public highway travel in time of national emergency. One specific charge (among others) is to develop plans and procedures for emergency highway traffic regulation in cooperation with appropriate Federal, State, and local agencies and organizations.

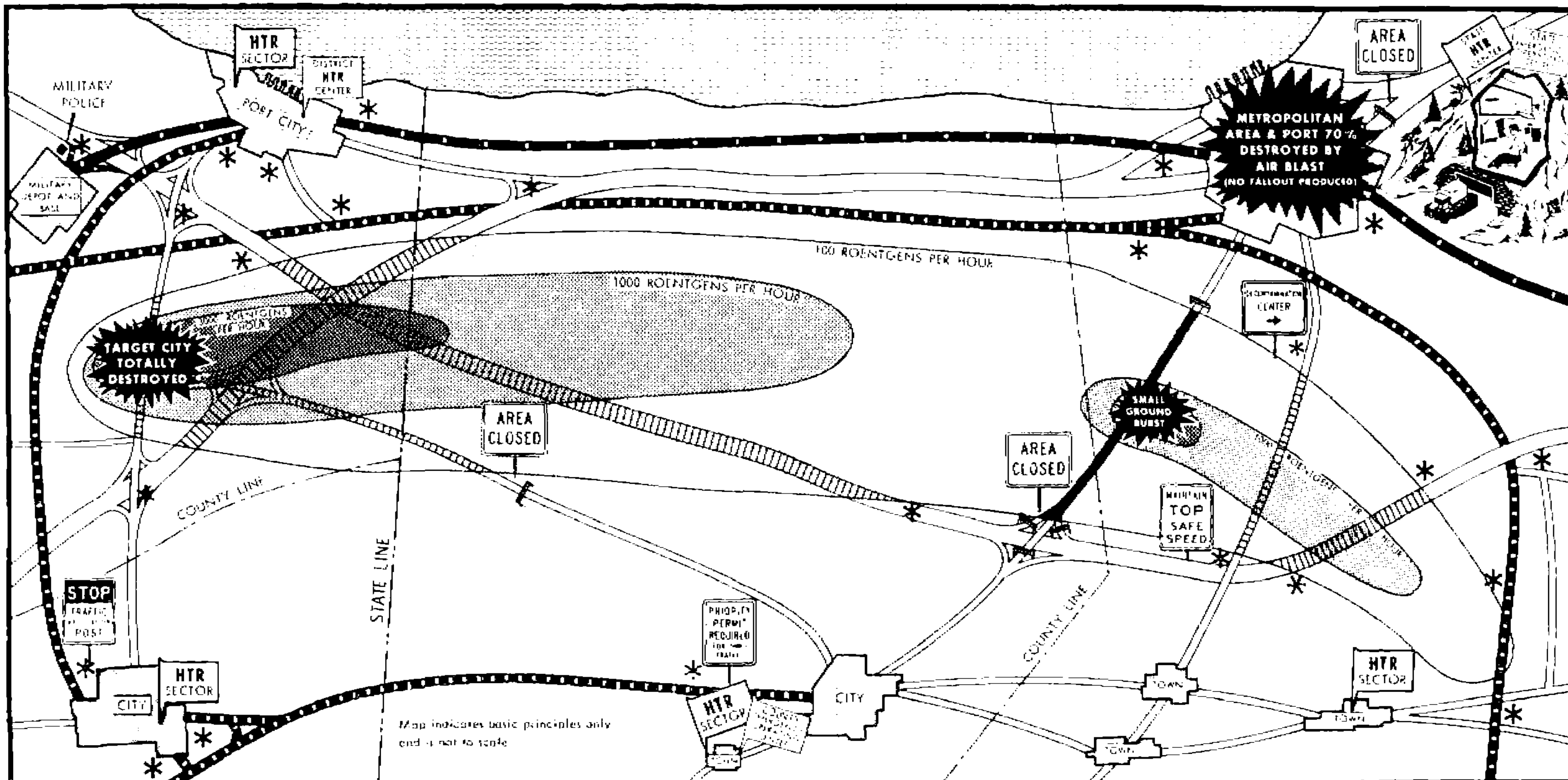
In this undertaking, Public Roads has consulted with and had the advice of both civil defense and military authorities. It was early evident that detailed plans for emergency highway traffic regulation could best be formulated and put into operation individually by each State. Accordingly, in developing a general concept and a basic plan for emergency highway traffic regulation, Public Roads has worked closely with the States through their State highway departments and the American Association of State Highway Officials; with the police through the International Association of Chiefs of Police; and with the organized highway users through the National Highway Users Conference.

A plan of operation

Briefly, the plan envisions, in the postattack period, an immediate survey of the road and street network both for physical damage and for radiation hazard. Barricades and warning signs will be placed where needed. Estimation of the traffic capacities of facilities remaining available for use and of possible traffic demand, would follow. If traffic regulation is found necessary, road space permits will be issued for priority traffic movement on routes

Figure 1.---

APPLICATION OF HIGHWAY TRAFFIC REGULATION



CLEAR ROUTES

Roads, streets and highways not regulated or restricted.

REGULATED ROUTES

CLASS A — Roads that lie within radioactive areas. Traffic may proceed as directed.

CLASS B — Highways temporarily reserved for military civil defense, or other special movements.

CLASS C — Routes designated for movement of essential traffic. Road use permit required.

UNUSABLE ROADS

These highways are unusable because of intense radioactivity and / or total destruction.

HTR POSTS

* Temporary locations manned by police to control traffic, check permits, and enforce regulations.

CONTAMINATED FALLOUT AREA

Radioactivity is invisible, intensity measured in roentgens per hour.

HIGHWAY SIGNS for EMERGENCIES

STOP TRAFFIC REGULATION POST — Designates official HTR post. All vehicles must stop to be checked.

DECONTAMINATION CENTER → — Guides persons to emergency aid centers registration, medical, welfare.

MAINTAIN TOP SAFE SPEED — Expedites movement through radioactive areas.

AREA CLOSED — Barricade and/or sign close a roadway entering a dangerous area.

PRIORITY PERMIT REQUIRED FOR THRU TRAFFIC — Notifies drivers that route beyond is regulated. A permit is required to proceed.

which would be otherwise heavily congested. These activities will be conducted at a State center and at subordinate district and sector centers as needed. Actual traffic regulation on the road will be at strategic check-points (posts) set up on each regulated route section.

It will be a basic principle in the operation to permit as much unregulated traffic as possible. Regulation will be instituted only where and for as long as is necessary. The organization will necessarily continuously adapt and modify its operations to meet the constantly changing situation.

The emergency highway traffic regulation operation will involve a close-working, three-party team: the State highway departments, aided by local highway departments, to assess damage and estimate capacity of usable highways; representatives of the organized highway users, to estimate probable traffic movement and issue trip permits for priority shipments; and the State police, assisted by local police, to actually control regulated traffic movements. This is admittedly an over-simplification; much of the work will be a joint endeavor.

In close association with the three-party team will be liaison representatives of the civil defense organization and of the military command. The Bureau of Public Roads, while playing an important role in the development of emergency highway traffic regulation plans and preparedness, would have limited functions in the actual operation; probably only that of coordination among the States where and when needed.

It is important to emphasize at the outset that the emergency highway traffic regulation organization is not responsible for the provision or allocation of motor vehicles to shippers; nor for designating priorities of cargo movements. These are the assigned functions of other emergency transportation agencies. The emergency highway traffic regulation organization will accept the priority certificates of such agencies without question; and it will have the responsibility, in issuring trip permits, to accommodate all priority shipments. But the organization will have to balance these traffic needs against limiting highway capacities. Sometimes, even for priority shipments, decisions may have to be made as to who goes first and who waits or takes a longer route.

Even from this brief introductory resume, it will be evident that highway traffic regulation in a national emergency, in these United States, may indeed be a herculean undertaking. Under extreme conditions brought about by a massive nuclear attack, it is possible that as many as 100,000 persons might be engaged, during a considerable period of time, in the struggle to keep essential highway transportation from costly congestion and complete stagnation. The real eventuality, if it should come, may not attain the maximum possible anticipated scale but prudence dictates that planning, organization, preparation, and the recruitment and training of personnel for emergency highway transportation regulation must be rapidly undertaken and carried forward unremittingly until we have reached a full state of readiness. The only and awesome alternative is chaos.

Scope of this guide

The nature, scope, and operation of emergency highway traffic regulation in time of emergency brought about by an enemy nuclear attack are discussed at some length in this guide, which the Bureau of Public Roads has prepared in collaboration with representatives of the civil defense and military authorities, the State highway departments, the police, and the organized highway users. The guide is neither a full-fledged plan of preparation and operation, nor a detailed training manual. Rather, it is the foundation upon which each State can build its own plans for its own organization.

In essence, the function of this guide is to help insure that all State plans will work effectively, individaully and collectively. For in times of catastrophe, even more than in peacetime, the needs of the Nation and its people know no political boundaries or highway jurisdictions. All available roads and streets must be used to best advantage as a continuous, coordinated transportation network. If highways are the arteries of our Nation in time of peace, they are more so in time of war.

Chapter II.---WHO'S WHO IN EMERGENCY HIGHWAY TRAFFIC REGULATION

Since this guide is addressed to a diverse audience of varied background, it seems appropriate at the outset to name and describe briefly the several agencies and organizations that are concerned with emergency operations, especially as related to emergency highway traffic regulation. Some of them are often referred to by their initials, which are given here in parentheses after their full names.

And speaking of initials, for the sake of convenience and brevity in this guide, the long phrase "emergency highway traffic regulation" will often be shortened to "EHTR."

Much of the responsibility for transportation and traffic regulation in a national emergency was originally assigned to the U. S. Department of Commerce, in which were lodged the Bureau of Public Roads and the Office of Emergency Transportation. These agencies and their responsibilities have now been transferred to the new U. S. Department of Transportation, which was created late in 1966. Working arrangements within the new Department are being effected just as this guide reaches its final stages of preparation. However, the planning and preparation for emergency highway traffic regulation that have been developed heretofore should be affected but little, if at all, since the Bureau of Public Roads, prime mover in the work, and the Office of Emergency Transportation are being transferred essentially intact from the Department of Commerce to the Department of Transportation.

Office of Emergency Planning (OEP)

This agency, which is a part of the Executive Office of the President, advises and assists the President in coordinating and determining policy for all emergency preparedness activities of the Federal Government, including development and planning the emergency use of resources such as manpower, materials, industrial capacity, transportation, and communications; planning government organization in an emergency; preparing for stabilization of the civilian economy in an emergency; planning for rehabilitation after enemy attack; and developing plans and coordinating preparations for the continuity of Federal, State, and local governments under emergency conditions. Thus the OEP gives overall policy direction to all other emergency planning agencies. It is assisting the States to develop plans for management of resources, including transportation and construction, in time of emergency; and in a national emergency period OEP would move from planning and policy formulation to operations, changing its title to Office of Defense Resources. The Office of Emergency Planning has eight regional offices across the country.

Office of Civil Defense (OCD)

This agency, which is in the Department of Defense, is engaged in a wide range of activities related to national emergency problems. It is responsible for programs for emergency civilian shelter; for radiological, chemical, and biological warfare defense; for communications, including a national warning network; for emergency assistance to State and local governments in civil defense problems, including evacuation, fire control, debris removal, water supply, health and sanitation. The OCD also administers programs of financial assistance and donations of Federal surplus property to the States for civil defense preparedness purposes. The Office of Civil Defense has eight regions, corresponding to those of the Office of Emergency Planning. In addition, each State and Territory, and many counties and cities, have their own civil defense organizations.

State Emergency Operating Centers

Each State has its own civil defense organization, under the direction of the Governor. The State Emergency Operating Center, in time of emergency, will become the headquarters of the State government, with the Governor and heads of regular and emergency operating agencies and supporting staff located there and directing operations of their respective agencies from the center. Liaison representatives will provide close coordination with Federal civil and military agencies and activities. The State Centers are sites readily reached in time of disaster, protected against blast and radiation, and equipped for immediate activation and for housing and sustaining the designated staff.

Office of Emergency Transportation (OET)

This agency, now in the newly formed Department of Transportation, is responsible for developing and coordinating overall policies, plans, and procedures for the provision of centralized control of all modes of transportation in an emergency, for the movement of passenger and freight traffic of all types; and for determining, when necessary, the proper apportionment and allocation of the total civil transportation capacity or any portion thereof to meet overall essential needs. The Federal Government is committed to the principle of centralized control of all forms of transportation in an emergency, to assure priority for essential civil and military movements in the national interest. In a national emergency, OET will have responsibility for establishment and control of priority needs on a broad, overall basis; the priorities would be administered by the appropriate Federal transportation agencies.

It is important to emphasize that other transportation agencies under the general direction of OET, will control and issue priorities for the movement of materials and persons. Issuance of road space permits for vehicles carrying priority materials or persons will be the function of the emergency highway traffic regulation organization.

Military Traffic Management and Terminal Service (MTMTS)

This agency, which is a part of the Department of Defense, has a broad spectrum of military transportation functions and responsibilities. Among them is responsibility for all defense activities and interests pertaining to highways. This agency has represented the Department of Defense in the development of the concepts and plans for emergency highway traffic regulation. In time of emergency, military commanders will be responsible for traffic movement and control in theaters of operation--areas in which active military operations are in progress--and this is to be expected. Elsewhere, however, the military will recognize the jurisdiction and responsibility of the emergency highway traffic regulation organization. It is anticipated that military liaison officers will be stationed at EHTR control centers. They will request priorities for highway movement of military personnel and material.

It is worth noting that the Department of Defense position on this subject should remove any doubt, either in civilian or military minds, regarding military reliance on civilian operation of emergency highway traffic regulation, or the mistaken belief that " ... the military will take over the program and run it, when the time comes."

Bureau of Public Roads (BPR)

This agency, now in the newly formed Department of Transportation, was founded in 1893, essentially as a research organization. In 1916, its major function became the administration of Federal financial aid to the States for new construction and improvement on selected systems of primary and secondary roads and streets. Recently its major effort has involved the building of the National System of Interstate and Defense Highways.

With its background of long and close relationship with the State highway departments, it was logical for Public Roads to be assigned responsibility for highways in time of an emergency. This responsibility includes the program for emergency highway traffic regulation which is the subject of this guide. Public Roads has approached the EHTR problem on a basis of cooperation, with actual operation to be carried out by State and local agencies which would be close to the scene and well adapted to do the job. In time of actual emergency, the BPR role would consist of providing advice and assistance to the States as requested, and liaison between the States as necessary to provide for smooth functioning of the program.

The Bureau of Public Roads has 10 regional offices across the country, and a division office in each State (usually in the capital city).

Highway departments

Every State has a State highway department, although the name and nature of the agency vary among them to some degree. In many States, the State highway department is responsible for a primary system of highways (continuous through cities on main streets or freeways), which is a modest portion of the total road mileage in the State but carries a sizable proportion of all traffic. Some State highway departments are also responsible for a State secondary road system; and a few are responsible for all or most roads in the State, even the local ones. In general, however, the secondary roads are the responsibility of the counties (except in a handful of States), and the local roads and streets are the responsibility of the local rural and urban governments. "Responsibility" means planning, design, right-of-way acquisition, construction and reconstruction, repair, maintenance, and operation. It also means financing this work from available revenues, primarily the gasoline tax and vehicle registration fees in the case of the States, and general tax revenue for the local governments. However, the States receive sizable highway improvement grants from the Federal Government, the funds for which come entirely from Federal highway user taxes. Similarly, many States provide State aid to the counties and local governments for highways.

Because of their long experience in cooperating with the Federal Government, their broad operations and large corps of personnel, and their considerable managerial and technical capacity, the State highway departments generally have been assigned responsibility by the Governors of their respective States for emergency highway traffic regulation. In some cases, however, another State agency has been assigned this responsibility, although it necessarily will work closely with the State highway department. (In this guide, when "State highway department" is mentioned it is intended to refer to the State agency responsible for emergency highway traffic regulation, unless the context indicates otherwise.) In preparing for and operating emergency highway traffic regulation, the State will enlist the cooperation and assistance of county and local rural and urban highway departments as necessary.

With only a few exceptions, each State highway department has divided its State into working areas for purposes of administration and operation. In most of the States these areas are called districts; in the rest, divisions. (In this guide they are called districts hereafter, but divisions should be understood where applicable.) This areal subdivision, with existing office headquarters, staff, and equipment at each, is an additional cogent reason for having the State highway department responsible for the EHTR organization.

It should be recognized that, in time of national emergency, the State highway departments will have many responsibilities in addition to emergency highway traffic regulation--repair and replacement of damaged and destroyed roads and bridges, for example--but such subjects are beyond the scope of this guide.

American Association of State Highway Officials (AASHO)

This organization is composed of the highway departments of the 50 States, Puerto Rico and the District of Columbia and the Bureau of Public Roads, who joined together in 1914 to foster the development of a nationwide connected network of roads and streets to serve the needs of the country. Functioning through committees, it continually seeks to improve highway design, construction, operation, maintenance, administration, and financing both in principle and in practice. Results of many studies involving both research and evaluation of experience have been adopted by the Association as policies and standards which serve as guides to the member highway departments and others.

The Association has a Committee on Emergency Planning, with membership representing each State highway department, whose stated objective is to cooperate with the Bureau of Public Roads and other agencies and organizations in developing methods of maintaining, regulating, and allocating highway space to obtain maximum usage of vital highway transport in time of national defense emergency or major natural disaster.

Police

Every State has a police agency, with a range of authority and responsibility but universally including law enforcement (including traffic laws), highway patrol, and traffic control (in a direct sense only; however, traffic control provided by means of signs and signals is generally the responsibility of the highway departments). All counties and local rural governments, and all cities, also have responsibilities for the police function, in a police department as such, or through a sheriff's office or other means; and here, too, the police responsibility usually includes highway or street patrol and traffic control. In addition, from the very nature of these and other police functions and responsibilities, the police commonly are trained and experienced in coping with accidents and emergencies, often under disaster conditions occasioned by bad weather, fire, flood, explosion, etc. As a consequence, the police are especially well fitted for the field operation of emergency highway traffic regulation.

International Association of Chiefs of Police (IACP)

This organization of Federal, State, county, and local police officials has among its objectives the improvement, through research and study of experience, of police administration and operations, including that of road and street traffic regulation. Because of its representation throughout the country and in all levels of government, this Association was the logical group to call upon for collaboration in developing concepts and general plans for emergency highway traffic regulation.

National Highway Users Conference (NHUC)

This private-industry organization, which was founded in 1932, is the broadest-base grouping of highway users, comprising an affiliation of 25 national associations with close interest in the full development of highway transportation in the public interest. Included are the national associations of petroleum producers, motor-vehicle and tire manufacturers, and commercial and private truckers, the American Automobile Association, the National Grange, and organizations of bakers, bottlers, cattlemen, and so on. The NHUC carries on a considerable amount of research, study, and publication concerned with the improvement of highways and their use. Affiliated with the National Conference--but autonomous in action--are State Highway User Conferences in every State (except Alaska), comprising in total some 2,800 organizations of business and industry concerned directly or indirectly with highways and their use. Because the National and State Conferences embody a large pool of men directly experienced in many aspects of highway transportation, they have been enlisted to assist in the planning and operation of emergency highway traffic regulation, as respresentatives of the highway users.

Interstate Commerce Commission (ICC)

Some of this Federal regulatory agency's responsibilities relating to the regulation of motor vehicles, particularly with regard to usage and safety, have been transferred to the new Department of Transportation. In the event of a national emergency, the responsibilities assumed from ICC by the Department of Transportation, as well as those remaining with the ICC, will be wholly concerned with vehicle usage and regulation, as contrasted to highway usage and regulation. Hence functions under ICC control would impinge little, if at all, on emergency highway traffic regulation.

Chapter III.---ORIGIN AND EVOLUTION

The emergency highway traffic regulation program as it is now conceived and developed did not spring from theory to full-fledged plan, at once. A brief account of its development is presented here as a matter of interest.

For half a century, the Bureau of Public Roads has been concerned with the defense implications of the Nation's highway network, and in its studies has consistently sought the advice of the military establishment. Public Roads has also sought and obtained the full cooperation of the State highway departments in helping to determine and meet the highway needs of the national defense. Included among the series of outstanding study reports published by Public Roads over the years are two especially indicatory of this interest: Highways for the National Defense (1941) and Highway Needs of the National Defense (1949).

Need for emergency traffic regulation

Consideration of highway needs of the national defense, however, was limited for many years to concern for provision of adequate routes for military use and war production service. Enemy invasion was considered almost inconceivable; enemy air, sea, or sabotage attacks were visualized as possibly heavy but presumably localized. The vital importance of an organized program for highway traffic regulation in an emergency was forcibly brought home by the congestion on the refugee-choked roads of Europe in the early part of World War II. Subsequently, highway traffic regulation became a wartime commonplace.

After World War II, however, the subject was largely forgotten, although emergency readiness planning in the thermonuclear age was authorized by the Congress in the Civil Defense Act of 1950; and the Bureau of Public Roads, by Presidential Orders, was assigned an advisory role under this broad tent.

Concepts and plans emerge

But it was not until 1958 that Public Roads potential capabilities for planning in relation to wartime traffic problems were officially recognized. At that time, at the recommendation of the Secretary of the Army to the Director of the Federal Civil Defense Administration, the Bureau of Public Roads was formally assigned responsiblity for developing an emergency highway traffic regulation program. In 1959, as a part of its National Plan for Civil Defense and Defense Mobilization, the Office of Civil and Defense Mobilization published Annex 12--Directed Movement, in which section I-D defined emergency traffic regulation and section V-D outlined the emergency responsibilities of the Bureau of Public Roads. (These OCDM issuances have since been superseded by a new national plan, cited later.)

Meanwhile, the cooperation of the State highway departments had already been enlisted, following a presentation by military, civil defense, and Public Roads officials at the annual meeting of the American Association of State Highway officials in 1957. In 1958, AASHO created a standing Emergency Planning Committee, which it enlarged in 1962 to include at least one member from each State highway department.

Assistance and cooperation of the highway users in developing plans for, and participation in, emergency highway traffic regulation was formally arranged in 1962 by an exchange of letters between the Bureau of Public Roads and the National Highway Users Conference. Endorsement of the participation of the highway users by the State highway departments was evidenced by a resolution adopted by AASHO in 1962. Furthering this objective was a letter written in 1963 by the Under Secretary of Commerce for Transportation to each State Governor, urging formal recognition of the State Highway User Conference as participants in the State's emergency highway traffic regulation plan (see appendix A).

Early in the planning for emergency highway traffic regulation, it became apparent that State, county, and local police would play a vital role in the EHTR operations. To reach individually the great number of agencies involved was impracticable, however, and the Bureau of Public Roads turned to the International Association of Chiefs of Police, where it found a willing response. During June 1964, at four regional meetings arranged by IACP, Public Roads officials reviewed the EHTR program in some detail and solicited the support and cooperation of police officials throughout the country.

Thus, by 1964, the national organization of the three parties involved in the emergency highway traffic regulation team--AASHO, NHUC, and IACP--had joined with the Bureau of Public Roads in the continuing work of planning and developing the EHTR program.

The Bureau of Public Roads position in emergency operations was formally reaffirmed by a series of documents in 1962. Executive Order No. 10999, signed by the President (see appendix B), directed the Secretary of Commerce, among other things, to " ... Develop plans for a national program, in cooperation with all Federal, State and local government units or other agencies concerned, for technical guidance to States and direction of Federal activities relating to highway traffic control problems which may be created in an emergency ... " The Secretary of Commerce delegated this and other highway-related emergency responsibilities to the Federal Highway Administrator. The Bureau of Public Roads then formally stated its emergency responsibilities, with the approval of the Secretary of Commerce, in a brief statement recorded as a part of the Federal Code of Regulations (see appendix C).

As this guide is written, many of the emergency responsibilities assigned by the President to the Secretary of Commerce are being transferred to the Secretary of Transportation. Those delegated to the Bureau of Public Roads will remain with it in the new Department.

Planning moves forward

By 1962, concepts had crystalized sufficiently on emergency highway traffic regulation to permit their exposition in some detail, and the Bureau of Public Roads issued Policy and Procedure Memorandum 50-7 (see appendix D) as a general guide to EHTR planning and organization in the States. PPM 50-7 superseded two earlier documents on the same subject. In 1963, Public Roads issued Instructional Memorandum 50-4-63 (see appendix E) as a supplement to PPM 50-7, providing further information, including a discussion of the role of the organized highway users. A revision of PPM 50-7, to contain updated ideas and information, including that contained in IM 50-4-63, is now being prepared; review and concurrence of interested agencies and organizations will be sought before the new document is issued.

As planning for emergency highway traffic regulation progressed step by step, the Bureau of Public Roads frequently consulted with other civil and military agencies, enlisted their collaboration, and received their support and endorsement for the EHTR program.

The Office of Emergency Transportation, for example, noted its full concurrence and approval in a letter written in 1963 to all its Executive Reservists (see appendix F).

Also in 1963, the Office of Civil Defense, in its Memorandum No. 31-63 to all of its regional directors (see appendix G), noted that the Bureau of Public Roads and the State highway departments were developing a system of emergency highway traffic regulation and stated that OCD considered the program to be a high priority activity. The OCD memorandum also encouraged interchange of information between the State civil defense and State highway department officials.

The Department of Defense has maintained its interest in emergency highway traffic regulation since the significant expression by the Secretary of the Army in 1958, already noted. Department of the Army Regulations No. 500-70 issued in 1963, prescribe Army policies and responsibilities relative to planning and operations in support of civil defense. That regulation makes it clear that the military role in civil defense will be to support the normal or emergency civil authorities unless they are destroyed or overwhelmed. The regulations also prescribe that the Department of the Army is to represent all Department of Defense agencies at the State emergency highway traffic regulation centers in claiming road space priorities for military movements on public highways.

In 1964, the Department of Defense issued its Directive No. 3005.7 which states the Department's policy on emergency requirements, allocations, and priorities for military use of civil transportation. This document specifically assures that Department of Defense emergency transportation planning and operation will conform to national policies and guidance, which are recognized to be the responsibility of a civilian agency, the Office of Emergency Transportation.

Early in 1964, the U. S. Continental Army Command undertook a study to determine the military organization structure required to assure that appropriate military representatives would be assigned to emergency highway traffic regulation centers as needed. This undertaking resulted in meetings of local military representatives and State highway officials throughout the country. (Because the memorandum on this subject from the Adjutant General to the Continental Army Command, dated March 3, 1964, so clearly states the military position in relation to civilian operation of emergency highway traffic regulation, it is included here in appendix H.)

As civil and military planning for a national emergency progressed, the old OCDM national plan was eventually superseded by a new National Plan for Emergency Preparedness, formulated by the Office of Emergency Planning. The Annex 12--Directed Movement of the old plan was replaced in 1964 by the new plan's Chapter 6--Transportation (see appendix I), covering all aspects of civil transportation in a national emergency. The Chapter 6 text was prepared by the Office of Emergency Transportation, assisted by all Federal agencies concerned with transportation, including the Bureau of Public Roads. While there is much that is new, the previously established basic EHTR principle was reiterated: "Emergency highway traffic regulation would be primarily the responsibility of the State highway departments, in coordination with State civil defense and police organizations and organized users of highways, operating under the general supervision and guidance of the Bureau of Public Roads."

Steps along the way

Along the way toward formulation of the EHTR program, there have been some landmarks worth noting. In 1962, in conjunction with a national civil defense exercise, the pattern of organization and operational procedures thus far developed for emergency highway traffic regulation was tested in the State of Oklahoma. This test, participated in by the Oklahoma Department of Highways, Highway Patrol, and Civil Defense Agency, the State and National Highway Users Conferences, the Army Transportation Corps, and the Bureau of Public Roads, disclosed many areas where additional planning was needed.

Furthering the scope of EHTR planning, in the spring of 1963, representatives of the Bureau of Public Roads, the

Army Transportation Corps, and the National Highway Users Conference visited England, France, and Germany to observe emergency highway traffic regulation planning in those countries.

Also in 1963, the Oklahoma Department of Highways organized a conference of the State highway departments concerned with the needs for, and the problems of, establishing radio communication among the departments, most of which already had intrastate systems. This conference recognized that interstate communication is essential for effective emergency highway traffic regulation operations.

In August 1964, the Bureau of Public Roads convened the two-week Salem Conference on Highway Traffic Regulation in an Emergency, at Winston-Salem, N. C. Federal and State agencies concerned with the EHTR program, as well as the NHUC and the IACP, were represented. All viewpoints on the program were explored and a great deal of progress was made in crystallizing policy and planning.

In February 1965, the first of a series of regional conferences, sponsored by the American Association of State Highway Officials, and devoted entirely to consideration of the emergency highway traffic regulation program was held in Minnesota. Similar conferences around the country have been held in Colorado, Illinois, Pennsylvania, North Carolina and California.

In April 1966, the Bureau of Public Roads conducted a two-day Conference on Emergency Planning in the Highway Field, primarily for discussions among its own headquarters and field office emergency planning staff. Representatives of other Federal and State agencies and organizations concerned with the subject were also present and participated. Emergency highway traffic regulation held a prominent place in the discussions.

Many less formal and smaller conferences and meetings have been held among representatives of the Bureau of Public Roads, State highway departments, State police, National and State Highway User Conferences, and civil defense and military agencies. In all of these meetings, large or small, a sincere and continuing effort is being made to promote and improve really effective readiness to carry out highway traffic regulation in a national emergency.

Chapter IV.---ASSUMPTIONS AND CONCEPTS

After a nuclear attack on the United States, it is practically certain that all or most roads and streets in and close to blast areas will be physically impassable. In addition, a large mileage of other roads and streets may have to be closed or put under restricted use because of the fallout contamination, at least for some time.

Highway demand and supply

How much traffic will need or want (not necessarily the same thing!) to use the available roads is hard to conjecture. Initially, and for some time, there will be a considerable volume of traffic for emergency activities, for military movements, and for evacuation of surviving population groups and provision of food and other needs for them. Later there will be large and continuing traffic movements, transporting goods and machinery of all kinds from locations where they are available to areas where they are lacking.

It can be supposed that in and around blasted areas the survival rate of motor vehicles will be higher than that of their owners. On the other hand, many vehicles may be unusable because of shortages of motor fuel and of vehicle service and repair facilities. These shortages, apt to be prolonged, and in time controlled by rationing, may curtail highway usage.

Nevertheless, it seems apparent that the need for emergency highway traffic regulation is a practical certainty. The need will be urgent in some localities and for some time after the attack. Regulation may be necessary on critical routes for an extended time, well into the recovery and rehabilitation period.

However, it is a reasonable principle that emergency highway traffic regulation should and will be exercised only on those routes on which, and at such times as, traffic demand exceeds traffic capacity, on those routes on which areas where highway users must be protected from exposure to radiological or other hazards, and on those routes which are needed for special purpose movements.

Theoretically, the EHTR organization will be concerned with and responsible for emergency highway traffic regulation and control on all of the 3.7 million miles of roads and streets in the United States. However, it is doubtful, that any very large proportion of this huge total will require regulation. However, in some areas, all roads may be closed or regulated as class A routes because of radioactive contamination or hazard. In addition, it seems quite likely that there may not be any massive need for class C regulation; that is, traffic restriction because of capacity limitations. What needs there may be, are likely to occur in and near devastated urban areas. Experience indicates that in peacetime most roads and streets, except those of the highest level--and even those, except in peak hours--operate well below their potential capacity. While congestion is a constant subject of discussion among planners, engineers, and the general public, it does not exist in reality except on urban arterial streets and a relatively limited mileage of principal intercity highways in the latter case, only near urban areas or during peak periods as on weekends or summer vacation time. This is not to say that peacetime highway congestion problems are not real and serious; they are, but they are concentrated rather than spread throughout the entire road and street network. It seems entirely probable that the situation will not be dissimilar in time of emergency; although many localized critical congestion problems will arise.

In any case, whatever the emergency traffic needs may be in extent and location, the EHTR organization will be seeking to locate and overcome the bottlenecks, rather than to establish and regulate a vast highway system.

<u>Emergency responsibilities assigned</u>

Obviously, the determination of need for and provision of emergency highway traffic regulation cannot be left to chance or to extemporization in the midst of crisis. The widespread destruction and damage to our communications and transportation systems and disruption of normal government operations resulting from a large-scale nuclear attack could well force some States, counties, and cities to be self-sufficient for some time, and wholly dependent on the capability of their own agencies. Designation of such agencies for emergency responsibilities, and careful advance planning of their emergency organization and operations, are the only alternatives to complete and helpless chaos.

Logically, emergency functions have generally been assigned to those existing agencies which have identical or similar functions in normal times. Thus, the highway and police departments of the States and their political subdivisions, which are responsible for the construction, maintenance, operation, and traffic regulation of roads and streets in peacetime, should have these same responsibilities in time of national emergency--under far more difficult circumstances, of course. Organized highway users, who in normal times are daily involved in managing vehicle movements, in time of emergency logically should be used to augment and aid the highway and police agencies in emergency highway traffic regulation. Together, the highway-police-user team can determine the availability and provide the best use of the highway systems to meet the priority transportation needs established by other appropriate agencies and thus serve the interests of the surviving population, industrial production, reconstruction, and rehabilitation.

It should be evident that advance organization and detailed planning and preparation are necessary in a high degree:

... because emergency highway traffic regulation will be needed at the earliest possible time after an enemy nuclear attack;

... because the EHTR operation requires close cooperation and coordination among Federal, State, and local government agencies; and

... because the EHTR operation may have to be initiated within a State or lesser area independently and in isolation from outside contact.

PREMISES FOR PLANNING

The Federal role in this undertaking, assigned to the Bureau of Public Roads, is essentially that of guiding, assisting, and coordinating the State and local governments in their planning and operations. In exploring the prospects for highway transportation following a nuclear attack, Public Roads made certain logical assumptions which, taken as premises, inevitably led not only to the conclusion that emergency highway traffic regulation was necessary but also to conclusions as to the form of organization and operation best suited for it.

The assumptions made by Public Roads are just that: they are not axioms; but they are believed to be sound and reasonable. They are properly based on the exception of necessity to meet extreme conditions, as any good planning effort must be, since plans developed to cope with a major situation may readily be modified for one of smaller magnitude, while lesser plans would be impossible to enlarge expeditiously in time of urgent need.

It is assumed, first, that a thermonuclear attack on the United States could cause widespread death and destruction from blast and heat effects in and near numerous target areas, with heavy radioactive fallout probably extending considerable distances from these areas and drifting widely so as to contaminate in greater or lesser degree many other areas across the whole United States.

The effects of such a nuclear attack on highway transportation and the consequent actions to be taken have been assumed by Public Roads to be as follows:

Damage anticipated

Many highway route sections in and near blasted areas will be impassable because of physical destruction of pavements and bridges, clogging with debris, and, in some locations, flooding from ruptured dams and levees.

Many route sections in widely spread areas will be impassable or dangerous to use in greater or lesser degree because of radioactive fallout, which will decay with time and may shift rapidly with changing weather conditions.

Early use and repair required

Routes that are physically impassable, and especially those too dangerous to use because of radiation (invisible to motorists), must promptly be closed to traffic.

Routes to and around blasted areas must be opened as quickly as possible, by removing rubble and repairing physical damage where it can be done promptly and safely, or by arranging detours on existing connecting routes that are still traversable.

Routes through radioactive areas which can be traversed without serious peril to travelers should be used to the extent possible, but travelers must be alerted to the hazard.

As radioactive contamination decays or shifts, the limits on closed and restricted-use routes must promptly be changed, to expedite traffic movement but at the same time to protect the public.

Routes neither physically obstructed nor contaminated must be used to maximum advantage; some probably with full- or part-time regulation on a priority of need basis.

Rehabilitation operations

Repair and reconstruction of damaged highways should be undertaken, as manpower, equipment, and materials are available, with priority attention to locations where work can most readily and quickly be completed and where traffic service needs are greatest. High levels of radiation in and around blast areas will inhibit reconstruction there for long periods of time, however.

As surviving population groups are resettled and industries established in new locations, during the national recovery period, highway systems in some areas may have to be revised considerably from their old patterns, or even designed and built completely anew.

Obviously, many road construction contracts in force at the time of attack will be suspended and ultimately cancelled; however, some may require emergency or subsequent major revision and expedited completion.

ROUTE TYPES IN AN EMERGENCY

From these premises developed by the Bureau of Public Roads it became evident that usable highway routes in a postattack period will be of two general types: those that are clear and open without restriction for travel, and those that must be regulated in some form. (A third type, of course, comprises those routes that are completely closed by physical obstruction or heavy radiation contamination; but obviously these would not be available for traffic use.)

Incidentally, the term "highway route" as commonly used in this guide does not necessarily mean an existing, continuously marked route stretching across one or several States, such as the numbered State, U. S., or Interstate system routes. "Highway route" as used here simply means a road and/or street section or series of connecting sections serving to carry traffic from one point to another. Under postattack conditions a route between two cities may switch back and forth between primary and secondary roads, for instance; and the route would probably change from time to time as contamination conditions change and as roadway damage is repaired. A regulated route may be relatively short, both in length and in period of use under regulation.

Clear Routes - Clear routes will be highway sections without any restrictions or regulations on traffic use; they will be freely available for use just as in normal times. Their route markings probably will be unchanged, although some secondary routes may be marked temporarily as primary detours.

Regulated Routes - Regulated routes will be specific highway sections on which traffic use will be controlled by the EHTR organization for any one of three reasons (or any combination of them): hazardous because of radioactive contamination; need for special use or purpose; and insufficient capacity for the actual or expected traffic volume demand. Therefore, three separate classes of regulated routes are recognized:

Class A Regulated Routes - These are routes that lie within contaminated areas, and which must be identified to and used by travelers with special precautions.

Class B Regulated Routes - These are routes that are temporarily wholly reserved (at least during specific hours) for a special purpose; generally this will be for large-scale civil defense or military movements.

Class C Regulated Routes - These are routes which the traffic volume is, or is expected to exceed the capacity and on which all traffic must be controlled in order to facilitate and insure the movement of priority cargo or persons.

Class B and class C routes, of course, may also fall under the restrictions of class A; and class B operation may be performed during specific periods on class C routes.

The EHTR organization, through its own and any other means available to it, must determine as promptly as possible which highway routes within its jurisdiction are wholly blocked and which are in contaminated areas. It must then determine existing and attempt to forecast probable future traffic volumes, and learn of priority movement needs. On the basis of such information, the EHTR organization will determine which routes must be regulated as classes A, B, and C, and which can be left unrestricted. This operation, of course, will be a continuing process, for conditions will constantly be changing.

Where radiation is found to be at a level which would endanger the health or life of highway users, barricades will be placed to warn users of such danger. Where radiation danger is not too great, routes through the contaminated area may be opened to traffic under carefully controlled conditions as class A routes. It may be necessary for vehicles to traverse the contaminated area at the highest safe speed, and occupants of the vehicle must be urged to keep careful note of their total exposure to radiation.

Only trained personnel can determine the existence and strength of the radiation danger. The motorist cannot perceive or sense it. Thus, the EHTR staff must determine with certainty that a route through a contaminated area can be opened to traffic, and how long a human being may safely stay within the area, in orther words, whether drivers can cross the area safely at reasonable speeds. (Appendix J provides considerable technical information on the detection and measurement of radiation and on limitations of highway use through contaminated areas.)

Operating regulated routes

It is expected that manpower available to the EHTR operation will not generally be sufficient to man and enforce closure points on highway routes that are physically impassable or too highly contaminated for travel. Barricades and warning signs often will have to suffice to stop approaching travelers, and to advise, if possible, of alternative safe routes to destinations beyond. Many of the class A routes--those through contaminated areas but open to limited use--will not be manned, either. Here, too, signs often will have to suffice, warning the traveler of hazard and the necessity of quick transit. (Appendix K provides information on standards for road signs and markings for civil defense.)

On highway routes open to traffic under priority-controlled operation or for special use--class B and C routes--EHTR personnel, usually police, will be stationed at major entry points, such as primary route intersections. Other intermediate or less important entry points will be manned as available personnel permits. Their function primarily will be to regulate traffic flow and accommodate priority movements; but they will also warn of radiation danger if it exists, and provide information about unrestricted travel routes in the vicinity.

Within the broad bands of priorities by appropriate authority established, the transportation regulatory agencies will determine, on an individual case-by-case basis, specific priorities for particular transportation movements. The specific priorities thus established for the movement of particular cargoes or persons will be accepted as controlling in the emergency highway traffic regulation operation. The EHTR staff will make decisions of precedence of movement only when the number of equal-priority vehicles seeking road space at the same time exceeds the particular route capacity. At that point, the EHTR staff must resort to its own judgment.

Chapter V.---PLANNING

As previously noted, the National Plan for Emergency Preparedness developed by the Federal Government prescribes that "Emergency highway traffic regulation would be primarily the responsibility of the State highway departments, in coordination with State civil defense and police organizations and organized users of highways, operating under the general supervision and guidance of the Bureau of Public Roads." This principle sets the basis for EHTR planning and organization and, if necessary, its activation and operation: that both the preparation and the activity can best be carried on at the government levels close to the scene and by the agencies responsible and equipped for related peacetime duties.

State and Federal roles

In furtherance of both the principle and the prescribed delegation, the Bureau of Public Roads in its PPM 50-7 (appendix D) has called upon each State highway department to prepare a detailed plan for emergency highway traffic regulation, which should be incorporated into the State's overall emergency plans. Most of the States have by now developed such plans. But although these have been accepted by Public Roads as basic documents, more detailed planning is clearly needed in practically all of them, so that, if and when the times comes, EHTR operations can be instituted and carried on without undue confusion. In the early days of a postattack period, it is strongly understating the situation to observe that there will be confusion enough even if, through careful planning and effective action, the available highways are used to full advantage.

Planning at the State level is particularly appropriate because there are such considerable variations sectionally in the United States: in population, density, concentration of industry and commerce, and other influences of susceptibility to enemy target choice, for example, as well as in topography, land use, and so on. Too, the peacetime responsibilities and functions of State highway and police agencies vary from State to State, as do relationships among State and county and local governments.

Consequently, as in many other federally guided and financially aided activities, both peacetime and emergency, the Federal role in emergency highway traffic regulation planning has been to develop concepts and basic forms of plans, in cooperation with other interested agencies--primarily, of course, the highway and police departments and organized users, together with civil defense and military authorities. Neither Bureau of Public Roads directives nor this guide can satisfactorily provide all the details of organization and operation that are appropriate and essential to each individual State.

General principles

In guidance of each State's detailed EHTR planning, there are some general principles which may seem obvious but nevertheless worth enumerating here.

Plans, and the regulatory actions in time of emergency, must be such that they will have the acceptance of the public as being reasonable under the circumstances; otherwise, they will be difficult if not impossible to carry out. The planning must be at once imaginative, since it is dealing with awful possibilities beyond any previous experience; and at the same time eminently practical, since the EHTR organization and operation will involve many government agencies and many people both in their employ and elsewhere. The EHTR plans must be highly flexible, to cope with what is likely to be an extremely fluid situation--and to meet unexpected difficulties that almost inevitable will arise, no matter how painstaking and skillful the planning. Even within the government agencies particularly involved in the EHTR responsibility--the highway and police departments--other emergency duties are lodged, and EHTR planning must be carefully coordinated with these other functions. It must also be coordinated with all other possibly related activities of Federal, State, and local civil defense agencies.

Planning areas

Specifically, planning for emergency highway traffic regulation at the State level must fully cover the areas described below and more fully discussed in the chapters that follow.

Authority - State and possibly local laws and regulations should be reviewed, and amended as necessary, to ensure that they provide adequate legal authority for the planned EHTR operations. Clear responsibility for organization and operation should be assigned by the State governor to a specific State agency (generally the State highway department has been so designated); and lines of authority, coordination, and cooperation should be clearly established. As detailed plans are developed they should be checked for complete compatibility with Federal emergency plans and with plans of other State agencies, particularly the State civil defense organization.

Organization and Staffing - The detailed EHTR plans should include provision for adequate safe office space, equipment and supplies, and staffing of a State emergency highway traffic regulation center and area and sub-area centers (districts and sectors in EHTR terminology). Provision must also be made for quickly setting up control posts wherever necessary on regulated highways. Adequate communication facilities are highly essential, for quick transmission of information between all the EHTR centers and posts and for communication with other emergency-operation agencies in the State and with EHTR centers in adjacent States. Radiological monitoring devices must be obtained and personnel trained to use them. Emergency signs and barricades and road-use permit forms must be prepared and stockpiled.

Operations - The detailed EHTR planning must include full arrangements for activating the State EHTR center and summoning key staff immediately following an enemy attack. Planning must thoroughly prepare for the subsequent operations, on whatever scale seems called for: first a quick necessarily rough estimate of the situation; activation of EHTR field centers where needed; and then, as communications are established and fuller information is received from various sources, designation of regulated routes and their operation by establishment of control posts and issuance of road-use permits for priority traffic movements. The EHTR planning for operations must also envision the problems of a constantly changing situation and the need to correspondingly expand or contract the areas served and the staff employed; and, of course, the need to terminate the operation entirely at the earliest practicable time.

Training - Personnel appointed to or recruited to the emergency highway traffic regulation organization will almost universally be fully occupied in other jobs during peacetime, either in government agencies or in the highway-user industry. Because their functions on the EHTR staff in an emergency will be different and difficult, and suddenly thrust upon them, it is important that they be adequately prepared; and yet, few of them will be able to devote extensive time to training. Thus, training arranged by the State must be carefully planned, and should involve short courses embodying lectures and discussions, supplemented by reading matter and by subsequent seminars and refresher sessions. Fundamentals will be appropriate course content for all EHTR participants, but training subject matter must be varied to suit the EHTR jobs of the trainees; e.g., whether at State or local level, administrative or operational, etc.

A further essential of training is the "trial run," through theoretical or actual field exercises, tied in where possible with other, broader exercises. In such exercises, some or all operations should be carried out, either simulated or in reality, including mobilization of personnel, opening of centers, assessment of damage, radiological monitoring, emergency sign and barricade placement, and issuance of permits and operation of road control posts. However, even in a thoroughgoing exercise, some of these operations will have to be at least partially simulated to avoid untoward alarming of the public and undue interference with normal road and street traffic.

EHTR terminology

While a certain amount of specialized terminology is probably necessary in emergency highway traffic regulation planning and operations, as in any undertaking of similar scope and complexity, it would be desirable to keep it to a minimum. Unfortunately, jargon and "shop talk" all too often get out of hand.

In EHTR operations, for example, it is appropriate and necessary to classify and designate the several types of route regulation. On the other hand, terms such as blocked route, detour, bypass, bottleneck, etc., are used liberally in this guide without specific definition; their meanings are commonly understood.

Specific "new" terminology should be created for EHTR operations only when it seems necessary to avoid misunderstandings in time of urgency. The adoption of an extensive new set of terms, possibly infringing on or conflicting with existing commonplace meanings, might well create confusion instead of avoiding it. Plain clear-cut English and universally used traditional engineering terms, should suffice for practically all EHTR needs.

Chapter VI.---PREPARATIONS

Much of the success of emergency highway traffic regulation, when the time comes for its application, will depend on the advance preparation not only planned but actually in effect. Such preparations include particularly the locating, establishing and equipping of operating centers, and the recruitment of an adequate staff for those centers and the preparation of the staff for the difficult activities into which they will be plunged in the postattack period This chapter is concerned with those subjects, and will help set the scene, so to speak, for the discussion of EHTR operations in the chapter that follows.

THE STATE EMERGENCY OPERATING CENTER

If and when a state of civil defense emergency is declared to exist by either the President or the Congress of the United States, all pertinent Federal emergency plans will at once come into operation. Certain Federal plans require individual, specific Presidential orders to become operative; but for the purposes of this guide it is assumed that all of the plans for and affecting emergency highway traffic regulation will be immediately effective in a civil defense emergency.

As soon as such a national emergency is declared, the Governor of each State presumably will at once order the full activation of his State emergency operating center. This center, planned and organized by the State civil defense agency, will thereafter be exactly what its name implies: a safeguarded center for emergency operation of the State government, at which will be assembled the governor and his advisors, the State civil defense director and his staff, and representatives of the regular and emergency State operating agencies. The latter presumably will include the heads or top-level representative of the emergency highway traffic regulation organization. Under prearranged emergency plans and assignments, the Governor probably will invite to the State emergency operating center representatives of those Federal civil and military agencies having emergency responsibilities, who will serve in liaison capacities between Federal and State operatings.

The State operating center will be the focal point for receiving and disseminating all kinds of information; for contact with the Federal Government; for communication with the general public; and for issuance of both specific and general directives to State agencies and local governments. Such directives will relate to specific emergency functions and responsibilities assigned by established emergency plans. The State operating center would determine when and which kinds of emergency procedures and activities should be undertaken; it would provide information to, and direction of aid and relief for, the State's surviving population. Most if not all such operations, including emergency highway traffic regulation, would be carried out by the previously designated responsible State agencies.

THE EHTR OPERATIONAL STRUCTURE

As will be evident in this guide, the overall plan for emergency highway traffic regulation is one of decentralized operation insofar as possible, with delegation of responsibility and action from the State EHTR headquarters center down through district and sector centers to the EHTR posts on regulated highways. Because coordination is so vital to the operation, cohesion must be supplied by close two-way communication linkage so that information, recommendations, and instructions may flow in all directions: downward from the State EHTR center to the district EHTR center to the sector EHTR center to the EHTR post, and back up, as well as laterally between posts, sectors, districts, and States, and between operating levels. The EHTR organization structure is illustrated in figure 2.

The State EHTR center

In most States, the State emergency operating center—headquarters of the State government--is unlikely to have space available for more than liaison representatives of such operating agencies as the emergency highway traffic regulation organization. The latter therefore must have a pre-established State EHTR center of its own at a different, but preferably nearby location. This will be the nerve and decision center for all emergency highway traffic regulation operations in the State.

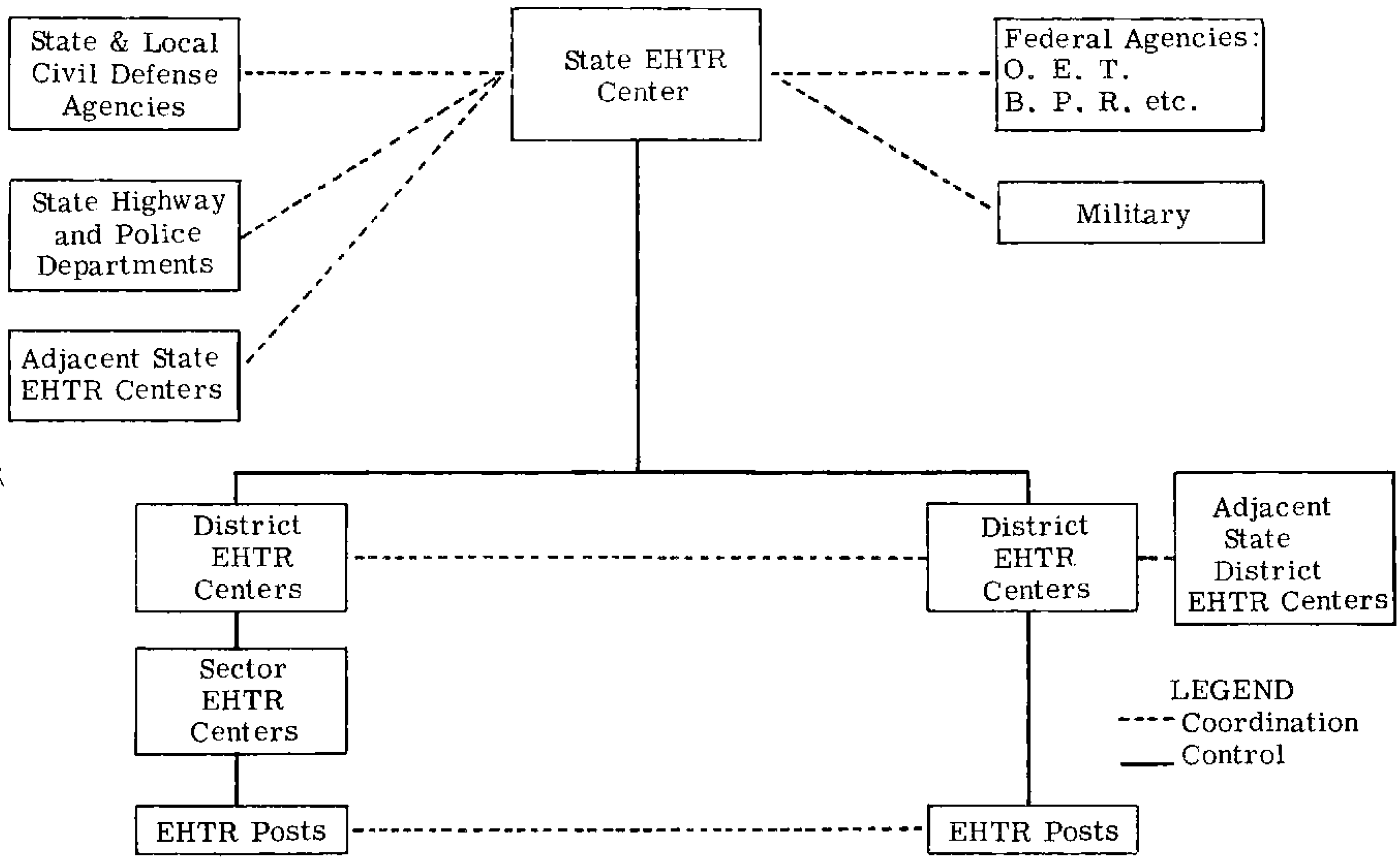


FIGURE 2-DIAGRAMATIC REPRESENTATION OF EHTR ORGANIZATION AND OPERATION

FIGURE 2-DIAGRAMATIC REPRESENTATION OF EHTR ORGANIZATION AND OPERATION

District EHTR centers

The State EHTR center must have ready means of accumulating information from throughout the State, of sizing up area and local situations, and of giving general direction to field operations. For these purposes, each State should have a number of district EHTR centers. In general, since in most States the State highway department has been assigned the EHTR responsibility (or will be working closely with any other agency assigned that responsibility), the logical subdivision for EHTR operation will be the State highway department district (in some States these are called divisions). These highway districts usually comprise several counties and are coextensive with county lines. Each has a district central office responsible for all or many of the normal State highway operations in the area, including road location, design, construction, maintenance and repair, traffic signing and signalization, and sometimes supervision of State aid to the counties and local governments.

Much like the main office of the State highway department, the district office is staffed with administrative, fiscal, and clerical personnel, highway, bridge, and traffic engineers, and other specialists. Usually the district office also has a force of equipment operators and mechanics; a fleet of automobiles, trucks, and road maintenance and repair equipment; and a substantial machine shop. Quite commonly, the district office and its mobile equipment are linked by two-way radio. Often, the highway districts are subdivided into working areas, each with a headquarters depot or garage for maintenance staff, equipment, and materials stockpiling. These depots usually have at least some office space.

Thus the highway districts, well staffed and equipped, and with intimate knowledge not only of State highways but probably of all roads and streets that lie within their teritories, are admirably suited for emergency duties related to highways, including emergency highway traffic regulation. Each State highway district office in the State should be prepared to act as a district EHTR center.

Sector EHTR centers

Where it appears likely to be necessary in time of emergency, EHTR planning should include subdivision of all or some EHTR districts into two or more smaller areas, called sectors. Each sector, which will have its own sector EHTR center, will cover a county, city, or some portion thereof, as seems appropriate for optimum operation. The sector EHTR centers should be arranged for in advance, and may be located in State highway department depots or garages, State police barracks, county or local highway or police department facilities, or some other preselected site which is available and suitable for the needs.

Metropolitan area EHTR sectors

Our metropolitan areas usually comprise a large and congested central city surrounded by populous suburbs and scattered exurban developments organized into larger or smaller political units as cities, villages, towns, etc. The conglomeration is very likely to be situated in several counties, and often in two States. A few have further political complexities since they lie on an international boundary. In such multi-structured metropolitan areas, each political jurisdiction is apt to have its own individual civil defense organization and emergency plans. To the extent that these plans affect highway transportation and regulation, there should be careful coordination on both sides.

In a large-scale enemy nuclear attack, many of the large metropolitan areas may be devastated by blast and fire and heavily contaminated by radiation. In such a situation, the function of emergency highway traffic regulation in relation to these areas, after initial rescue and evacuation operations, will be to arrange for safe and adequate bypasses of them.

Because of the size, both in area and population, of the metropolitan areas, and their political, economic, and traffic complexity, it will probably be wise to plan in advance for the division of each into several workable EHTR sectors. This will be a necessity when the metropolitan area is divided between two States. For management advantages, it would be best for all sectors covering the metropolitan area (within each State) to be under the jurisdiction of a single EHTR district; or for the area itself to be constituted as an EHTR district. Closely coordinated planning and operation between all agencies involved are obvious necessities.

EHTR posts

Finally, actual road regulation under the EHTR plan of operations will be conducted at EHTR posts established on the roadside at points of entry to regulated routes. These EHTR posts will usually be manned by State, or more likely, local police, perhaps with help from local highway department personnel. They should have means for close, continuous communication with the EHTR center, to which they are responsible; and to other posts on the route. This can be maintained through police or highway department mobile radio equipment.

ESTABLISHING THE EHTR CENTERS

The selection of locations for the emergency highway traffic regulation centers and their preparation is a matter of great importance, for once an emergency arises those centers that are needed must be activated without delay and immediately put into full operation.

State EHTR center needs

The most important and largest EHTR office, since it will be the nerve center of the entire operation, is the State EHTR center. It will be the first activated after an enemy attack, and, if there is an early warning, it may be activated in advance. The State EHTR center should be located as near as feasible to the State emergency operating center, which will be the focal point of all State activities. The State EHTR center preferably should be protected against blast and have a radiological protection factor of at least 100 (see appendix J).

Ideally, provisions should be made for continuing, 24-hour occupancy and operation. This requires adequate though spartan facilities for living, sleeping, and eating--and, of course, food preparation--sufficient for the maximum staff anticipated. Thus floor space is required both for office operations and for living quarters. The office operations will require furniture, typewriters and other office machines, paper and other office supplies, printed forms, and all the varied paraphernalia necessary for competent office operation. Adequate toilet and washroom facilities are required. For "live-in" accommodations, dormitory-type furniture and bedding are necessary. For feeding, cooking utensils, stove and refrigerator, china and cutlery, etc., are needed. And, of course, food itself, and above all, drinking water, are essentials.

Highly important in the State EHTR center is a full complement of communications equipment, linking the State center to each district EHTR center, to the State emergency operating center, to the State highway department and State police headquarters, and to the State EHTR centers in adjacent States. Two-way radio, teletype, and telephone communications are all desirable facilities to have for various purposes, and it would probably be best not to depend on any single system. Interlinkage with the established State highway department and State police radio networks, if such exist, will be extremely useful. Communications are so important to the EHTR operation that, if at all possible, these facilities should be installed in the State EHTR center and maintained on a standby basis.

An essential need in the EHTR center will be adequate, large-scale maps of the United States, showing major highways, and of the State (and adjacent States), showing all roads. Separate large-scale maps of the State's urban areas, showing all roads and streets, are also needed. These various maps should be mounted on the wall, in a suitable location and covered with sheets of clear acetate so that information may be posted, and revised as changes occur. Such maps, properly posted, will give a quick, current picture of both the overall situation and its details.

Since none of the personnel assigned to EHTR activities will be in uniform (except military liaison officers), suitable official identification is required for them. This can consist of a formal, wallet-size identification card which will serve as a pass, if needed. In addition, EHTR personnel should also probably be provided with a quick-identification device such as an armband or badge with a readily recognizable symbol and/or inscription.

It is highly desirable that the State EHTR center be physically established and equipped now. Ideally, it should be fully stocked with office furniture, equipment, and supplies, communications equipment, and living and feeding equipment and supplies--all in place and ready to use. Where this optimum situation is impossible to achieve at once, it may be accomplished gradually. In any event, every effort should be made to approach full operational readiness as nearly and as quickly as possible. For example, the State EHTR center may be physically established but only partially equipped and stocked, with the remaining needed equipment and materials stored at the State highway department headquarters or warehouse. Some of the equipment in use at the highway department may be earmarked for quick transfer to the State EHTR center when needed. In this case, lists of such items and their locations must be kept current, and adequate plans arranged for their quick transfer.

The administrative personnel of the State highway department who are responsible for the establishment and equipping of the EHTR center should have and maintain current, complete listings of equipment and supplies located in the center, those stockpiled elsewhere, and those in use which are to be moved to the center when needed.

Another important record to be kept by the EHTR administrative staff is a full, up-to-date roster of all personnel assigned to report to the center, including State highway and police officials, organized highway users, and military and civil defense liaison representatives. The listing should include names and both office and home addresses and telephone numbers. The State EHTR center's list should also include similar listings of the principal staff assigned to each district and sector EHTR center.

Associated with these personnel rosters should be a fully developed alerting system capable of summoning all or selected members of the EHTR staff to the center in rapid fashion. Prearrangements may also be made for the staff to report to the EHTR center even without notification, in a recognized emergency, or the staff may be instructed in advance to listen to radio broadcasts for general alerts or assignment messages.

At least one person assigned to the State EHTR center should be trained and equipped for radiological monitoring, and be responsible for the safety of the center itself and determining the radiation exposure of its occupants.

District and sector EHTR center needs

To the extent possible, all of the preattack arrangements described above in particular application to the EHTR center should also be made for each district EHTR center. If the State highway department's district headquarters itself cannot be made a properly protected site in which its own operations and those of the district EHTR center can be located, it would be desirable to plan, and if possible establish in advance a safe and adequate location for use in time of emergency by both the district highway office and the district EHTR center. Their emergency operations are closely related and they will function to best advantage if housed together. Specific arrangements should be made by and for each district EHTR center, adapted to its local situation and problems.

Similarly, preattack arrangements should be made for each sector EHTR center; again, adapted to the local situation. Sector centers may be located in State highway department area depots or garages, State police barracks, or county or local highway or police offices or stations.

In choosing locations for district or sector EHTR centers, consideration should be given to the convenience of those who must apply for road-use permits. However, procedures for issuance of such permits by telephone or from other more numerous and better located places are discussed in the chapter on operations.

The district and sector EHTR centers ideally will require all of the working and living furniture, equipment, and supplies described as needed for the State EHTR center, although probably in different proportions and scale. In addition, these centers, as the operational units in the emergency highway traffic regulation process, will have other needs which must be provided for in advance. Highway department personnel will do the required radiological monitoring of the highways, and equipment in sufficient quantity and ready for use for that purpose must be available. Road-use permit forms must be printed in advance and stored. The special-type signs and barricades for road closure and for use at the EHTR posts must be prepared and stockpiled.

EHTR post needs

The EHTR posts will be temporary roadside sites, and their locations cannot be determined in advance. As already noted, special signs and barricades for use at EHTR posts should be stockpiled at strategic and safeguarded locations. Other equipment and materials that might be needed at EHTR posts should also be available in reasonable quantities.

STAFFING THE CENTERS

As has already been noted, the staff for direction and operation of emergency highway traffic regulation will be drawn from the State and local highway and police departments and from the organized highway users. Highway user representatives may be recruited from the automotive, trucking, and related industries, with the cooperation and assistance of the State Highway Users Conferences in most States.

Staff assigned to or recruited for EHTR operation should be free to assume such responsibilities in time of national emergency; those with other commitments, such as members of the military reserves, should not be included.

It must be borne in mind that for both government and private-industry personnel, EHTR assignments are usually in addition to their normal, peace-time jobs, and their time and efforts in preparation for real EHTR activity should not be fruitlessly or frivolously used. Their training must be fully adequate but not protracted; and every possible means must be employed to arouse and sustain their awareness of the vital essentiality of emergency highway traffic regulation and to maintain their interest in and foster their dedication to it.

Every person assigned or recruited to the EHTR team should be informed specifically of the location of the center to which he or she is to report when summoned in time of emergency, and of the means by which the summons will be communicated. Desirably, all, or at least many, of the personnel--certainly all of the key officers--should visit the center to which they are assigned (when it is physically established), and have an opportunity to familiarize themselves with the location, operating facilities, and arrangements, as well as other personnel with whom they would be working in time of emergency.

All personnel involved in the EHTR operation should receive adequate initial training and sufficient refresher follow-up, and practice in exercises, geared to their particular duties in an emergency. Training is discussed more fully in a subsequent chapter in this guide.

State EHTR center staffing

Since the State EHTR center's function is to direct emergency highway traffic regulation as needed over the entire State, through the district and sector EHTR centers, its staff will not include operating personnel for field activities. The State EHTR center should have a staff comprising the following:

Administration - Administrative, secretarial and clerical staff.

Communications - Radio, teletype, and telephone operators, and technicians, and public information personnel.

Operations - State police, highway users, and State highway department personnel.

Liaison - Representatives from the military and State civil defense organizations.

Housekeeping - Maintenance staff; if live-in facilities are available or are to be arranged, housekeepers, cooks, etc., should be provided.

District and sector EHTR center staffing

Staff needs at the district and sector EHTR centers will be quite similar to those listed above for the State EHTR center. In addition, they will need a good-sized staff who are familiar with the roads and streets of the area and the normal traffic flow, and who are capable of making quick and reliable evaluations of traffic problems and situations.

The district and sector EHTR centers will have much of the responsibility for determining route capacities and the need for establishing regulated routes (in the three different classes), for locating and marking such routes, establishing and staffing EHTR posts where needed, and issuing road space permits to shippers who have obtained priority certifications for movements of goods or persons. Consequently, the district and sector EHTR centers must have available, on call, a large force for these activities. In the centers, engineers, police, and highway users will do much of the work. The engineers and police at the district centers will generally be State highway and police personnel; at the sector centers they will probably include or consist principally of personnel recruited from the county or local highway and police departments. The latter is desirable, in fact, since the sector EHTR centers will necessarily be maintaining close contact and collaboration, in an emergency, with county and municipal civil defense authorities and other agencies.

EHTR post staffing

The EHTR posts will be established on the roadside where and as needed, for the actual direction and regulation of traffic and to advise the traveling public about road conditions, detours, radiological hazards, etc. The EHTR posts should preferably be manned by police, from either State or local forces. The police are particularly suited for handling this assignment since it is related to their peacetime function, and because they are generally well equipped with motor vehicles, usually with emergency equipment and with two-way radio.

Staff size

Estimating the numbers and kinds of personnel required to man the State EHTR center and each district and sector EHTR center, as well as the EHTR posts, is an exceedingly difficult part of the planning for emergency highway traffic regulation. Since there are so many variations among pertinent factors from State to State, it is impossible to provide satisfactory guidelines on this subject. The State EHTR planners must endeavor to conceive in detail the variety and volume of operations to be performed, and estimate therefrom the size of staff in different categories that will be required. Planning must be for the worst possible situation, but it must include rational processes for a rapid evaluation of the situation and accordant call-up of the number of personnel that are needed at each individual center, and no more.

The hard fact must be faced that in a catastrophe such as a nuclear attack, an indeterminate number of assigned or recruited EHTR personnel may be killed, injured, or otherwise made unavailable for duty. Staffing plans must allow for such contingencies.

PREPARING THE PUBLIC

One of the great problems in emergency highway traffic regulation operations will be to gain the quick understanding, acceptance, and cooperation of the public--ranging from the individual private automobile driver to the large-scale commercial truck or bus fleet operator. It is certainly important that the EHTR organization do as much advance preparation of the public as possible, so that in a real emergency the EHTR operation will not face highway-user bewilderment and antagonism.

Several approaches toward educating the general public seem practicable. Leaflets, very briefly describing the State's EHTR plans, could be prepared and distributed to all motor-vehicle owners and/or licensed drivers, by the State motor-vehicle department, with vehicle license and driver permit issuances and renewals.

Short presentations, such as motion pictures or illustraded talks, could be prepared and offered for television or radio use or for service club luncheons and the like. These, or specially prepared material, could be included in school driver-education courses. News stories related to steps in the State's EHTR organization development and to practice exercises would probably find acceptance among the news media.

In these and any other means used to approach the general public, the reasons for, and the methods of, operating emergency highway traffic regulation should be made clear, with special stress on its effects on motorists normal freedom to travel where and when they wish, and how necessary travel can be arranged through the EHTR organization.

Informing the commercial operators and highway-user organizations of what to expect in an emergency would best be handled in a different fashion: first, because they can be reached through different means and more directly than the general public; second, because the commercial truck and bus operators will carry on a considerable proportion of priority-certified highway movement in an emergency, and hence have a greater need for knowledge about EHTR operations. In addition, the method of issuing road space permits to them may differ from that for the general public, as will be described later.

The obvious approach to commercial highway operators will be through their own associations and organizations, which should readily be reached by the organized highway-user members of the EHTR organization. In addition to the general concepts and plans for EHTR operation, the commercial vehicle operators need to be well acquainted, in advance, with the specific plans of the State's agencies involved in issuance of priorities for movement of persons and goods, and the State EHTR organization's plans for route regulation and issuance of road space permits. They also need to know what is expected of them in the way of furnishing information on planned and anticipated traffic movements to the EHTR staff during the emergency.

AUTHORITY

In the critical situation of a national emergency, highway traffic regulation and other emergency operations and activities should be conducted with full recognition that their purpose is to serve the Nation and its people. It may not be possible to observe entirely the niceties of peacetime traffic regulation, but the public, many of them confused and some terrified by a previously unimagined disaster, should be treated with individual consideration and understanding insofar as it is possible.

There is a motive in addition to altruism in this, for successful establishment of the EHTR operation will depend largely on the public's favorable response, acceptance, and confidence, rather than on any citation of law and regulation. Nevertheless, all emergency highway traffic regulation planning, organization, and actual operation should be with full sanction and direction of Federal, State, and local law and regulatory orders.

Responsibility for planning and carrying out all of the various aspects of emergency activities should be assigned specifically and officially to appropriate existing State agencies or to special agencies established for the purpose. Proper coordination and full collaboration among all of the regular and emergency agencies of the State should be assured.

A major requirement in the national and State EHTR plans is that, in time of emergency, the State highway department should have such authority over and responsibility for all roads and streets as it needs: it is emphasized, authority over <u>all</u> roads and streets in the State, regardless of their peacetime classification or jurisdiction. The need for this is obvious, since in an emergency it is highly probable that county and local road and street sections will have to be used, under EHTR operations direction, as detours, bypasses, supplements, or connecting links for main State highway routes.

In addition to the major sweep and concepts of the EHTR organization and operations plans, a great number of lesser details must be considered. The authority for closure of roads and institution of emergency road regulation, the validity and format of road-use permits, and the shapes and messages of road barricades and warning signs should be properly resolved in advance lest they be questioned. Inclusion of organized highway users in the EHTR organization may require formal sanction. Very important to EHTR field operation will be full recognition of the authority of the EHTR organization to request or command the services of other State and local agencies, particularly the highway and police departments--this, even though State highway and police personnel are an integral part of the EHTR team. These are but a few examples of the many subjects and situations, large and small, that should be scrutinized, during the planning stages.

Chapter VII.---OPERATIONS

So far, in this guide, an attempt has been made to explain the background and general purposes of emergency highway traffic regulation, and the planning of an organization necessary to make it effective in time of need. Far more planning is required than just for the establishment of the EHTR organization, its centers, and its staff, however. Plans in considerable detail must be made in advance for all of the manifold, interacting operational procedures that will have to be carried on rapidly and without hesitation in the urgent crises of reality.

Again, because the requirements and possibilities vary so greatly among the States, it is impracticable to present here a mass of details on operating procedures, with a full descriptive catalogue of enumerated and sequenced steps. Rather, this chapter will endeavor to describe the nature of the EHTR operation, once the process is activated in an emergency. From this framework, each State can develop the fully detailed procedures best suited to its individual situation. At the same time, cooperation in and review of such State planning by the Bureau of Public Roads, as the work progresses, should ensure that all State plans will be developed in effective, workable harmony.

ACTIVATION OF THE EHTR ORGANIZATION

In the event of a national emergency, such as an enemy nuclear attack, a state of civil defense emergency will immediately be declared by the Federal Government, with prompt activation of emergency plans. The State EHTR center will be activated at a very early time after the attack; or it may be activated beforehand if sufficient advance warning is received. By prearrangement, the EHTR officials may be authorized under cetain conditions to activate their organization on their own authority.

Key personnel should be summoned immediately to the State EHTR center, according to a predetermined plan. These will include the upper-level administrative officials; the technical staff--highway and traffic engineers, radiation experts, etc.--responsible for assessment and analysis of the general traffic situation; and some support personnel. Presumably a maximum-operations staff will not be needed immediately at the State EHTR center; but all assigned and recruited staff should be contacted at once. This will serve a dual purpose: it will put the entire staff on alert, either to come to the center or to stand by; and it will establish, at least for the moment, who is available and who is not. The staff, especially key personnel, should be forewarned to call the center on their own initiative if they have not been contacted in a reasonable time.

The initial check and call-up may show the need to summon to immediate duty some substitutes for key individuals who cannot be contacted or who are known to be dead or incapacitated. The center's roster should include substitutes for this purpose, and they should be trained to assume their principals' functions.

At the same time the EHTR center staff is being summoned, the previously developed plans for opening and making habitable and operable the center office should be put into effect. This will include transporting to the center any equipment and supplies stored, or in use elsewhere. Highly important will be the immediate activation and testing of all communications equipment. There is a great deal of petty detail involved in these operations, none of which can be overlooked (such as who has the key to the office.)

It would be natural to assume that the entire EHTR organization should immediately be activated, mobilized and put to work at choosing and operating regulated highway routes. But considered reflection will show that this would be fruitless and quite possibly, in the haste to "get going," only result in more confusion and congestion than no action at all. In the first hours--indeed, in all probability in the first few days--after a large-scale nuclear attack, all attention of government and the people will be dedicated to rescue, evacuation, and bare survival activities, and military operations; and there is not likely to be any need or capability to plan for much other organized highway traffic.

As soon as the situation begins to stabilize, the EHTR organization will take over all highway control and regulation operations. Hence the probability of the early developments recited above should not deter or delay the activation of the EHTR organization and its preparation for actual field operations.

SURVEYING THE SITUATION

Initial Information

The initial operation of the State EHTR center will be to size up the statewide situation with respect to highways. Information will be available very shortly after an enemy nuclear attack as to the locations, intensities, and nature of the bomb strikes within the State and the surrounding region. Such information, based on rapidly collected and perhaps sketchy facts, and interpreted by means of precalculated probabilities, should provide with fair reliability the locations of "ground zeros" (points of explosion) of each blast, the probable extent of the area affected by heavy destruction and fire damage, and the area exposed to varying degrees of radioactive fallout and contamination.

The blast areas may generally be assumed as circular; the fallout areas as long ovals, usually spread eastward by prevailing winds (see figure 1). However, topography may somewhat affect the patterns of the blast areas; and topography, wind, and other weather conditions combined will have a great deal to do with the patterns of the fallout areas--which, additionally, will change with time and changing weather. Only careful preplanning, detailed knowledge of topography and weather conditions in the target areas, and considerable training can develop the capability to make a quick reliable assessment of the general situation after an enemy nuclear attack.

As information is received in the State EHTR center, the "ground zero," area of destruction, and surrounding area of contamination of each blast should be plotted on the center's large-scale wall map. The information initially received may be meager, but should rapidly be improved in scope and reliability.

EHTR field activities

As soon as the State EHTR center has a general idea of the situation, it can begin moving into action. It may be evident that more personnel should be summoned to assist at the State center. Each district EHTR center whose area is or may later be affected by the attack and subsequent fallout should be called into operation. (As with the State center, prearrangements should be made for self-activation of district EHTR centers under specified circumstances.) Similarly, the affected districts may quickly call for activation of some or all of the sector EHTR centers under their command.

The first major assignment for the district and sector EHTR centers, as their staffs are assembled, will be to obtain more damage and fallout information in order to provide confirmation of the initially supplied facts and to fill in the local details of the situation picture. Highway department personnel who have such responsibilities will fan out into the field, either to pre-assigned or spot-assigned territories, to assess physical highway damage or blockage, to monitor radiation, and to observe the volumes of traffic already on the road (if any). By two-way mobile radio or telephone, these personnel will report all the information they have gathered to the EHTR organization.

The district EHTR centers, of course, will communicate all the information they receive to the State EHTR center as rapidly as it is available; similarly, the State EHTR center will provide all useful information to the district EHTR centers; particularly, this will include information from adjacent districts. As warranted, also, the district and sector centers will interchange information direct, among themselves, and with local civil defense and other government agencies. State EHTR centers in adjacent States will also need to establish intercommunication and information exchange. It is evident, again, that an ample and rapid communications system is essential to the entire EHTR operation.

Situation evaluation

The product of this interchange of information, occurring continuously during the first days after the attack, will be the detailing and updating of the highway situation map. It will be possible rather quickly to establish which roads and streets are physically impassable; which are too heavily contaminated by radiation to traverse at all; and which are contaminated but can be traveled under limiting conditions. Probably, also, it will quickly be established in the immediate postattack period, from the civil defense and military liaison officers in the EHTR centers, which specific road and street sections, or at least which general routes between indicated termini, are needed for urgent, large-scale movements, such as rescue, evacuation, or military movements.

Thus the State, district, and sector EHTR centers, working with almost continuous communication among themselves and with all other affected agencies, will quickly be able to map out those major routes that are wholly blocked; those requiring regulation as class A, (within radioactive hazard areas); and those requiring regulation as class B, (wholly reserved, at least during specified time periods, for large-scale civil defense or military traffic movements). Determination of the need for, and designation and operation of, class C routes, (regulated for limited traffic capacity reasons), will probably come somewhat later. Figure 1 illustrates what the situation may be when all three types of regulated routes are in operation. Each of the types will be discussed in turn in the text that follows, together with related operating procedures.

The ever-changing picture

It must be borne in mind that emergency highway traffic regulation will be far from a simple and static operation. Many of the situations and operations described in this guide are necessarily treated as individual subjects, but in practice many will be simultaneous, interacting, and sometimes in conflict.

Routes wholly reserved for essential movements (class B) and those operated on a priority permit basis (class C), may also be exposed to radiological hazard (class A). Class C routes may be operated as such only part time; or they may be reserved during certain periods for class B use. Postattack traffic needs will fluctuate; physical conditions will improve or worsen; radiation hazards will decay and shift; planned road repairs will be completed or deferred. It is thus evident that EHTR operations will be in an almost constant state of flux. Only by having full and current information posted on the maps at the State, district, and sector EHTR centers will it be possible to continuously assess the situation and plan and effect changes to accommodate anticipated traffic. Each regulated route, each barricade and sign installation, each roadside control post, each detour, each blocked route, each repair or reconstruction job (and its status), and every other pertinent detail that will aid in assessing the current situation and in planning ahead should be recorded in readily usable form at all of the EHTR centers. As a general principle, the EHTR operation should be as little encumbered by paperwork as possible. But details of the current situation are a prime essential; without them confusion could be extreme, and disastrous.

BLOCKED ROUTES

Routes which are found to be blocked by physical damage, such as destroyed pavement or demolished bridges, or which are impassable because of debris on the roadway, should be assessed promptly as to their repairability and restoration to full or partial service. Information on the priority ranking of work to be undertaken in debris removal, road and structure repair or replacement, construction of bypasses, and providing adequate detours should be obtained from the highway department.

Highway department decisions on a priority work schedule should be based on the developing postattack traffic needs and general route availability. The relative and absolute conditions at each location: the advantage to be gained for traffic movement; the local availability of construction equipment, manpower, and materials; and the speed and safety (e.g., from radiation hazard) in which the work can be done, should be taken into account.

Both the situation survey and the judgments involved in arriving at the reconstruction priority schedule should be handled as a collaborative effort of the EHTR staff and the State highway department, since the former will have the responsibility for traffic estimation and regulation while the latter will have the responsibility for doing the road repair work. Such collaboration can readily be preplanned, and readily effected in actual operation, since State highway department personnel will be a principal part of the EHTR organization, and in most States the State highway department itself has been given the primary responsibility for planning and organizing for emergency highway traffic regulation--that is, the highway department is the "parent" of the EHTR organization.

As has already been pointed out, in time of emergency the State highway department should have full authority over all roads and streets, not just the State highway system alone. With this authority, it can use its own forces to undertake needed work on local roads; it can take over jurisdiction and use local roads as detours for State routes; and it can requisition the help of the local highway departments.

An immediate need in connection with physically damaged or otherwise blocked highways will be to barricade the impassable sections. Probably the barricades should be placed at the nearest crossroad still open to traffic; and as soon as possible information signs prescribing available detours to various nearby destinations should be posted at the barricades. The barricades and signs will be placed by crews dispatched from the highway or police departments. As previously noted, barricades and signs of types that will be needed should be prepared and stockpiled in advance at convenient, safe locations.

CLASS A: CONTAMINATED ROUTES

Evaluation of radiological conditions

Determination of the need to designate a route as class A; that is, as radiologically contaminated, is dependent on technology and judgments that are quite strange to highway engineers. Past experiences in the aftermath of earthquake, hurricane, flood, and fire have strengthened and sharpened the highway engineers' capabilities to plan for and cope with the traffic problems that follow such catastrophes. But in these, the hazard and damage can not only be weighed against experience; they can be seen.

The hazards of radiation, in contrast, are beyond both experience and vision. Thus, while the State EHTR organization should endeavor to develop its own radiation hazard experts, particularly for the State center, it is probable that assistance will be needed in solving highly technical problems in complex situations. For that reason, the EHTR organization should establish a close working relationship with the experts in civil defense, public health, and military agencies. The process of collecting and analyzing information on radiological hazard and contamination, and posting it on maps, has already been described in general terms in the opening section of this chapter. (Appendix J contains a technical discussion of radiation detection and its effects, as related to highways.) It is worth emphasizing here again that the radiation situation is one of almost constant change, and must be assessed on an almost continuous basis.

Decision to control

Within each area tainted by radiation there will be an infinite range in the degree of danger to exposure, from slight health hazard at the periphery to perhaps high risk or certain death at the focal center (which usually will not be the geometric center of the area). The radiation experts, having mapped the current radiological situation, must next assess the feasibility of road usage within the contaminated area. This assessment will include the potential effects of exposure, taking into account radiation exposure criteria and the characteristics of travel.

The radiation intensity, distance of travel across the area, and anticipated sustained travel speed will determine the radiation exposure to which travelers will be subjected. Individual factors for each traveler may also be important: these include age, state of health, frequency of trip or accumulated previous radiation exposure, and kinds of radiation protection (if any). Some general criteria and empirical rules have been developed for such analyses and determinations, and are described in appendix J.

The basic question to be resolved for each contaminated route section is whether it is safe to use at all; and if so, under what conditions. Remembering that radiation is invisible, it is highly important that routes which would be dangerous or fatal to traverse, should be barricaded and posted as quickly as possible. Less dangerous but nevertheless hazardous routes should be operated under regulated conditions. The regulator control, based on relative risk, may vary from only a warning sign to pass through the area at a reasonable sustained speed, without stopping, to specification of minimum travel speed or traverse time, trip frequency limitation, or even recommendation to seek medical check-up or attention immediately after crossing the area. For the travelers' information, the distance from the control point to the radiation-free boundary on the other side of the contaminated area could be posted.

Where heavy radiation exists and health hazard is extremely high, the general rule will be to close the route completely. Alternative routes to various destinations should be plotted and posted, if possible; and they should be of sufficient capacity to handle anticipated traffic. Urgent needs, however, may force consideration of the use of a highly contaminated route for certain traffic movements under specified conditions; e.g., that the drivers travel at high (but safe) speed and make only one trip. (It is known that rather high radiation exposure can be tolerated for relatively short periods without serious or permanent health impairment.)

Radiation contamination and hazard will be in a continuous state of change. Normal rates of decay are known, so the decline of hazard can be predicted with some reliability. However, shifting winds, rain or snow, and other climatic conditions can bring about gradual or even sudden changes in radiation intensity, sometimes quickly reducing the danger in an area, sometimes just as quickly bringing danger to an area previously found hazard-free. Consequently, frequent field monitoring must be maintained, together with a constant weather watch, so that changes in the radiation situation can be anticipated or at least detected as rapidly as they occur.

Implementation of controls

Routes endangered by radiation will be regulated by manned roadside control posts if the EHTR organization can muster sufficient manpower. It seems unlikely, as a general probability, that there will be enough personnel available for this duty in all cases; their need will be greater on class B and C regulated routes--those wholly reserved or available only for priority traffic movements--and in other urgent activities.

In any event, as soon as the necessity of designating a route for class A regulation is determined on the basis of radiological monitoring and analysis, the district or sector EHTR center should immediately arrange for the placement of barricades and/or appropriate warning and information signs by the highway or police departments.

Manning of control posts on the roadside at the termini of class A regulated road sections should be arranged if possible. If only a limited number can be manned, it would be preferable to do so at locations where individual decisions are required. Routes that are completely closed to all travel and, at the other extreme, routes that may be traversed with only small risk, can be barricaded and signed, but not manned. Where intermediate hazard is involved, a manned post is desirable so that the risk circumstances of each traveler may quickly be assessed. The manning of such posts presumably will be by one or more police officers, through arrangement by the EHTR center. Such control officers should have previous instruction in radiological exposure problems, or at least be equipped with suitable guide material.

CLASS B: RESERVED ROUTES

Requirements for reserved routes

Need for designation of class B routes, reserved wholly for large-scale civil defense or military traffic movements, is apt to occur very quickly after the beginning of the emergency. In the initial postattack period, such movements are likely to be at a peak in frequency and volume. Later, civil defense and military traffic should stabilize or diminish.

The movement requirements that engender class B route designation may be characterized by the number of vehicles, their overall speed capability, the critical importance of a time schedule and of the materials or persons being transported, and the need for a unified or convoy type of movement. Initiation of request for a reserved route, which may be a specified highway or any route between two designated termini, will probably come to the EHTR center through the civil defense or military liaison officer serving on the center staff. In civil defense activity, a need may be for a large, controlled evacuation of the surviving population from a heavily damaged area; or for the quick transport of large quantities of food, bedding, etc., for the evacuees. Large-scale military movements may involve the transport of troops and equipment or the transport of essential material.

The need and importance of such movements, certified by civil defense or military authorities, will be accepted by the EHTR organization without question. However, there may be competing priority travel demands and limited route capacities. If so, it will then be the responsibility of the EHTR organization to resolve the competing requirements for road space according to their best judgment and ingenuity.

Among factors that require consideration in determining the need for selection of a class B reserved route are the size of the traffic movements, their timing, location, and frequency. Movements may range from a one-time operation to a multi-trip daily schedule. They may be trips that can be accommodated satisfactorily at night or it may be necessary to schedule them in the more crowded daylight hours. The entire movement may have to be held together in convoy, or it may be possible to divide it into smaller groups of vehicles.

The size of a single, indivisible movement needs some consideration, and it would be desirable to provide some size criterion for application on reserved routes. However, much depends on the overall speed of which the convoy is capable, and on the nature of the route itself: obviously a four-lane freeway can handle a situation better than a two-lane highway; an unobstructed, well-alined road better than one with existing bottlenecks or attack-damaged pavement and bridges. Thus, it hardly seems possible to generalize with respect to the size criterion for a reserved route.

It seems probable that in most areas, within a few days or so after an attack, the need for reserved routes will have stabilized or diminished. Time will be less of the essence, and the EHTR organization, as well as the civil defense and military agencies, will be better able to plan at least a day or two ahead.

In this situation it is quite probable that route sections will not have to be held wholly in reserve under class B regulation. Two possibilities are likely to offer themselves: either a reserved route may be maintained as such, but opened on an "as-available" basis during scheduled periods for other traffic movements; or the reserved route classification can be discontinued and convoy or other civil defense and military traffic can be accommodated preferentially at all times or during certain periods on class C routes.

It should be borne in mind that the unnecessary application of the full-time reservation of a route as class B may well place unwarranted restrictions on other essential traffic movements. Before a route is fully reserved for special use, therefore, all alternatives should be considered.

Control of reserved routes

As already noted, civil defense and military large-scale traffic movements will generally be convoy operations planned and controlled by their own organizations. While they will thus manage their own operations, the EHTR organization will provide approval, reserve the highway for use, and provide any coordination with other agencies that may be needed.

Problems of coordination that immediately come to mind are the possibility of demand for road space-time on the same route and at the same time by both a civil defense agency and the military; or the traffic conflict that would result if two convoys were scheduled to cross at an intersection at the same time. While urgent movements of this type should not be bogged down in procedural red tape, neither can they be sanctioned without examination of the situation simply because the request comes from the civil defense or military authorities.

CLASS C: ROUTES REGULATED FOR CAPACITY REASONS

The determination of blocked, contaminated (class A), and reserved (class B) routes by the EHTR organization, and activities in connection with them, are by no means simple functions. Regulation of class C routes, controlled for capacity reasons, will be even more difficult and complex, for it will deal with many imponderables and will rely much more heavily on widely scattered information sources and on quick but hopefully sound judgment. While highway and police personnel in the EHTR organization can handle problems of blocked and class A and B routes, class C route regulation will require much assistance and effort from the highway-user members of the EHTR team.

The probable need for class C type of route regulation is fairly evident: the capability of the highway network will be severely reduced by a nuclear attack. As the Nation recovers and transportation needs grow, highway capacity is unlikely to recover as fast as the demand; and in some locations, at least, essential demands along may equal or exceed the capacity of serviceable highways. Simply put, there will be times and places in the postattack period--perhaps for an extended time--when road space must be rationed.

Looking for the favorable side of the picture, it is probable that highway transportation will not suffer total paralysis; except in or close to bomb strike locations. Much of the route dislocation will be confined to localized problems or specific bottlenecks. Radioactive contamination will decay in time to safe levels, except in or close to the blast areas. Too, the need for large volumes of highway transport other than for urgent civil defense and military movements is unlikely to develop until at least some days after an attack, so there will be an interval during which the EHTR organization can get into high gear, so to speak, for class C route regulation, whose purpose is to fit together to best advantage the general and special traffic demands and the highways available to serve them.

How soon the operation will need to begin, how extensive it will have to be, and how long it must continue, are questions which are open to unlimited conjecture. But the EHTR organization should maintain as a basic, the premise that regulation ought to be restrained in scope, extent, and duration to a sensible necessary minimum. At the same time, the EHTR operation must seek to foresee and forestall highway overloading and the delays and interruptions to important traffic movements that would result.

It is the responsibility of the EHTR organization to evaluate both the demand and the capability for highway transportation and, once the decision to regulate has been made, it must regulate or ration road space, route by route and hour by hour, as necessary. Priorities for urgent and essential shipments will be issued by other agencies, who have been assigned that responsibility, but accommodation of these on the road, and of as much other traffic as possible, will be the EHTR organization's job.

Capacity of surviving highways

As described earlier, the EHTR organization, as one of its first operations, must have obtained sufficient information from all available sources to permit recording and plotting the road and street situation throughout the State. The result will be a visual representation, on a large-scale wall map of the road and street network, of those route sections that are impassable because of physical damage or radiation, and those under regulation as class A and class B (contaminated and reserved routes). The remaining roads and streets presumably are all usable; and from this base a workable transportation system must be patterned. The first concern will be to provide continuity in interrupted or bottlenecked primary and principal secondary routes. This can be accomplished by arranging for quick repair, bypasses, detours, or alternate connections by way of existing adjacent roads.

Intimate knowledge and available records of road geometrics and condition are prerequisites to this work of assessing the capacity of surviving highways, and planning for temporary system "patchwork." It will do no good, for example, to map a narrow, dirt road as an adequate detour for a damaged section of mainline highway. Road inventory information is generally available for all State highways; and State and local highway department staffs will be fully acquainted with the status of all roads and streets under their jurisdictions. As a consequence, the selection of detours, bypasses, etc., to provide needed route continuity can best be accomplished as a joint, cooperative effort of the EHTR centers at all three levels, with the collaboration of the State and local highway departments.

As indicated above, the relief section for a blocked route must be adequate for the job or it in turn will become a bottleneck. When full relief cannot be arranged, that is, if capacity adequate for all anticipated traffic demand is not going to be available, then class C route regulation, using road-use permits, must be instituted.

So it is evident that in mapping routes and systems for postattack highway transportation, in reaching decisions on the need for EHTR control of class C routes, and in operating those routes, the capacity of the surviving available highway network, especially the primary and principal secondary routes, must be determined. This will be done by the traffic engineers of the EHTR staff.

Highway capacity may be estimated, route section by route section, depending on foreknowledge and existing conditions. The geometrics, and, in fact, calculated and observed capacities, will be known and on record for State highways and many secondary roads. However, within affected areas, the suddenly created bottlenecks and the effects of necessary detours and emergency route connections will upset the normal characteristics of traffic flow and must be taken into account. There is a reasonable background of experience in such matters from situations occasioned by construction detours and the aftermath of natural disasters such as floods.

A possibly even more disruptive bottleneck in emergency route regulation may be the roadside control post itself. While trying to sort out permit-carrying vehicles from others, and expediting the former while turning back the latter, the control post may also create a major turbulence in the traffic flow along the regulated route. Operations planned and executed with extreme care may keep such turbulence at a minimum, but it cannot be expected that traffic will run smoothly past a control post at the capacity rate indicated by geometrics alone. This situation must be reckoned with in estimating route capacity under emergency conditions. There is little experience to use as precedent, although perhaps rough measures can be developed from operations at toll bridges, drive-in theaters, and paid parking lots at football stadiums, etc. Estimating the effect on traffic capacity of the roadside control post may amount to little more than skilled guesswork.

Highway capability may be expressed as vehicular capacity or tonnage capacity--that is, the average number of vehicles or number of tons of cargo that can be moved past a given point on the road in a specific time, usually per hour. Vehicular capacity is the normal measure among highway engineers; tonnage capacity is primarily a military usage. Methods of calculating these two types of highway capacity are covered, respectively, in the Highway Capacity Manual of the Highway Research Board and the Highway Capability Estimating Guide, Department of the Army Field Manual 55-54. Since the EHTR staff personnel engaged in capacity determinations presumably will be highway engineers, it is assumed that vehicular capacity will be the basis of EHTR calculations.

Demand determination: peacetime base

Estimating the capacity of usable highways in a time of emergency is not the simplest of tasks, but it should present no great difficulty to the engineers who will be responsible for that function. Estimating the traffic demand--the volume of traffic movements--under emergency conditions, however, is quite a different matter. In this task, the organized highway-user representatives recruited to the EHTR organization will play the principal role since they can best establish and maintain close contact with the highway users throughout the State and in the district or sector areas that they will serve.

Information on normal peacetime traffic demand is plentiful and well known to the highway departments, and thus readily available to the EHTR organization. On main highways and arterial streets, the seasonal, weekly, and hourly traffic volumes and fluctuations are on record. Information is also available in many cases of traffic composition (cars, busses, trucks, and combinations), trip lengths, origins and destinations, car occupancy, and cargo characteristics. Much less is normally available for secondary and local roads and streets, but, for all of these, there is an annual one-day traffic count and generalized knowledge of seasonal fluctuations.

On the basis of such peacetime information the EHTR staff engineers may be able to form judgments on probable traffic demands in an emergency. Of course, the whole picture, and certainly the local situation route by route, may be quite altered because of heavy losses and shortages or changed needs. System constrictions may shift or concentrate demands elsewhere than their normal channels. And there is no possible means for anticipating the public's reactions--and actions--in facing the crises of a large-scale emergency. As activity above bare survival develops in the postattack period, many of the conventional peacetime traffic demands will tend to reestablish themselves.

So, in trying to estimate the size, location, and nature of traffic demand in the postattack period, the EHTR organization's highway and police staff members will be doing their best to apply emergency adjustments to peacetime data. They will make full use of the EHTR field organization and the highway and police department field forces to constantly monitor and report on actual traffic volumes and compositions on the road.

Demand determination: the "push-pull" process

It is the highway user group on the EHTR center staff that will be expected to do the major job in estimating traffic demand. They will collect whatever information they can on probable traffic movements from all available sources and will play the principal part in forecasting route-by-route demand.

The needed traffic demand information can best be collected by the highway user members of the EHTR staff, to the extent possible, directly from all classes of highway users and traffic generators; and it will be a continuing, daily operation as long as there is a need for class C routes in the EHTR unit's jurisdictional area.

Information should be sought not only from the vehicle operators more commonly thought of, such as commercial truck and bus fleet owners, but also from all active and potential traffic generators and attractors. These will include, among others, manufacturing plants and other commercial enterprises employing or servicing large numbers of people, shopping centers, high schools and colleges, and any other establishments which continue or resume operation in the postattack period. It will be important to know, for example, that a temporarily shut-down plant is about to reopen and thus generate a flow of automobiles and trucks.

Collecting traffic information from vehicle operators and traffic generators should be developed as a two-way pattern, with the EHTR highway-user team members "pulling" and the road users "pushing." The "pulling" phase simply means that the highway user members of the EHTR staff will telephone all vehicle operating companies and organizations and traffic generators they know of--and because of their peacetime positions and activities they will be well acquainted with many of them--and ask what prospective road trips they expect to have, say, on the following day: how many vehicles and what kinds, what routes will be used, the time of trip; and also, what official priority or practical essentiality there may be for such trips. The "pushing" phase will simply be an information flow in the opposite direction: vehicle operators will telephone their friends who are the highway user members on the EHTR staff to inform them of pending or anticipated trips, and ask for advice.

Naturally, the more "pushing" that develops in this two-way pattern, the less "pulling" that will be necessary. For this reason the education now, in peacetime, of vehicle operators in the purposes and mechanics of emergency highway traffic regulation should prove of inestimable value in the eventuality that it has to be put into actual practice.

How often intercommunication between the highway user members of the EHTR staff and the vehicle operators and other traffic generators is needed will depend on the day-to-day situation with respect to traffic demand versus highway capacity. It will be especially needed shortly before a route section is expected to reach its operating capacity and class C regulation is being considered; and during the entire control period until it becomes evident that such control is no longer needed. During that entire time, it is vital to collect projected trip information in as much detail, and as far in advance, as is possible.

Theoretically, contact should be established and maintained between the EHTR organization and all vehicle operators and other traffic generators. The practical possibilities must be recognized, however, it is going to be much easier to contact and obtain information from operators of fleets of trucks and busses--and perhaps the larger, the easier--than it will be from operators of one or a few vehicles. Similarly, it is going to be easier to collect information from commercial operators than from private vehicle owners.

Demand determination: the private automobile

While the private automobile is by far the predominate vehicle on our roads and streets in peacetime, both in numbers and total vehicle mileage, it may be much less so in time of emergency, especially in relation to priority or essentiality of trip needs. Scarcity of gasoline and its rationing are likely to severely curtail nonessential automobile use. As national recovery progresses, after an enemy attack, legitimate private car trips may increase, for car-pools to work, etc.

But in any event it will clearly be beyond the capability of the EHTR staff to contact all automobile owners about their trip intentions and needs, either early or late in the postattack period; and there are no organizations that can speak for them on this subject, except perhaps in generalities. However, there are some possibilities that may develop into practical operations: for example, an industry important to the national economy or defense might obtain priorities for its car-pool traveling employees, and report en bloc on their daily trips to the EHTR center.

Essential traffic needs

Within the total traffic demand, no matter how estimates are compiled, consideration of essential needs will be highly important. When the total demand exceeds the capacity of a route, class C regulation must be instituted; but rather than a catch-as-catch-can operation, the EHTR organization must see to it that essential traffic movements are preferentially handled. In the emergency situation, and quite probably extending long into the post-attack and recovery periods, there will be an official priority system for expediting essential and urgent transportation movements. These priorities will be concerned not with specific vehicles or trips, but with movements of persons, foodstuffs, fuels, and other materials, machinery, etc. The issuance of such priorities, as noted earlier, is the responsibility of the transportation agencies charged with that function by the national emergency plan; and the priority certifications will be issued by them.

It is expected that the specific information needed for route regulation--numbers and types of vehicles, trip origins and destinations, route, and time of departure--will be collected from the shipper or vehicle operator by the highway user members of the EHTR organization, as described in the preceding section.

The EHTR organization is obligated to accept priority shipments without question, and accommodate them preferentially in its traffic regulation operations. In some cases this may be a critical factor in deciding to institute regulation on a particular route section. When priority demands alone exceed a route's capacity during a particular period, it will be the responsibility of the EHTR staff to effect solutions, such as arranging for changes of departure time or use of an alternate, less-congested route.

Admittedly, during periods of class C route regulation there will be representations of essentiality or urgency of trips by those who cannot obtain or do not have sufficient time to seek a formal priority certification. The EHTR operations, whenever possible, should give preferential consideration to bona fide cases of this type. They can best be taken care of at permit issuance "stations" or at roadside control posts, as will be discussed later.

Traffic classification

One form of traffic classification, in EHTR considerations, is according to need: that is, priority certified, essential (as commented on above), and nonessential. A second useful classification for EHTR planning and operation is that of trip length. Comparative terms commonly used are local, intermediate, and long-range (the exact words vary), and these are adaptable to EHTR use. However, their definitions for EHTR operation will be somewhat different than those generally understood in peacetime usage. The trip-length classification best suited to EHTR use, as will be seen later, is to designate as local trips those that lie entirely within an EHTR sector; as intermediate, those that lie entirely within an EHTR district; and as long-range, those that cross district lines.

The usefulness of thus defining local, intermediate, and long-range trips will depend to some extent on the area and nature of the EHTR sectors and districts, and of the State itself. What is entirely appropriate for the average-sized State may be ill-fitting at both extremes of geographic scale.

In this trip-length classification, more needs to be considered than just the origin and ultimate destination; for example, a single long trip by one vehicle may involve a number of pickup and delivery stops, or an overnight loading or rest stop, or even a lay-over of several days. Thus a "long-range" trip may actually turn out to be a connected but interrupted series of short trips.

Fitting the picture together, trip classification may be described as follows:

Civil defense - Civil defense transport needs will involve immediate postattack movements for rescue, fire-fighting, medical service, etc.; subsequent needs, when it becomes safe to leave shelters, will include mass movements of surviving population groups to safe areas, and provision of food, bedding, etc., for their temporary care until further, more permanent dispersal arrangements can be made. Both of these types of civil defense movements will come early in the postattack period, will be of large scale, and will have high official priority.

Military - Military transport will consist of convoy movements of troops, equipment, or supplies, which may come at any time in the postattack period, and will have high official priority. In addition, there will probably be greatly increased activity at military bases and other establishments, which will generate a large and varied volume of traffic, some official and organized, some personal and individual, some of priority importance and some non-essential.

Civilian - Civilian transport will, of course, comprise the bulk of traffic and the greatest variety, including the general and usual peacetime needs of industry, commerce, and agriculture and of the public as workers and individuals. In some areas, on some routes, at some times, there will be special demands for the handling of priority shipments, and specific, perhaps continuing, large-scale transport needs for certain movements such as petroleum or grain shipments of commuting to an industrial plant. With wide-ranging degree of essentiality, and sometimes with official priority, civilian trips may then be classified by length as:

1. Local trips involving short hauls, within the area of an EHTR sector often by vehicles making several or numerous daily trips to the same or varied local destinations. These may be truck, bus, or automobile trips; and quite possibly a good many of them could be diverted to available secondary and perhaps somewhat circuitous routes to free primary routes for priority travel. Among other advantages, the local drivers would have little or no difficulty in finding their way on secondary routes in the area.

2. Intermediate length trips, confined to the area of a single EHTR district; these will perhaps take several hours or up to a day to complete.

3. Long-range trips, which traverse more than a single EHTR district, and may be either intrastate or interstate in character.

As noted earlier, some of the supposedly intermediate or long-range trips may actually be a series of connected short trips.

The decision to regulate

The comparison of traffic capacity and traffic need--that is, supply versus demand--determined as described in the preceding text, will indicate for each route section studied whether and where trouble or potential trouble, in the form of congestion, exists or may soon develop. The EHTR chief, with the advice of his staff, must then make one of three decisions:

1. That no regulation is needed, because the trouble is not imminent enough or has a reasonable prospect of alleviating within a short time.

2. That some regulation is required, but need be operated only on a partial basis; as during specified hours or with the recognition that a considerable amount of non-priority traffic can be accommodated, some of it even during the controlled hours.

3. That full-scale, full-time control is required, with accommodation limited largely to priority traffic movements, at least during some time periods.

In some cases the decision to regulate may not come until after the congestion or other route difficulty has actually materialized; but it would be highly desirable to anticipate the need for and institute control reasonably well beforehand, so that serious congestion is averted. Many decisions will be difficult to make, for they will be concerned with "iffy" information and borderline situations. Two opposing forces will exist except in extreme cases: the losses incurred through congestion, if regulation is begun too late; and the inconvenience and wasted effort to shippers and the EHTR organization alike, if control measures are put into effect much too soon or in locations where anticipated congestion does not materialize. The EHTR chief must indeed thread a fine needle.

In the immediately preceding discussion, about reaching the decision whether or not to apply class C regulation to a route, no mention was made of operating level; that is, whether the decision is made by the State, district, or sector EHTR chief. An inflexible pattern of responsibility does not seem advisable; of overriding importance in an arrangement to ensure that each office knows they happen. As a general rule, it is logical for the EHTR office closest to the local situation to make, or at least initiate, decisions to control.

For example, a sector chief may decide that a particular route section will need class C regulation by the next day. If the situation is purely local, he should have authority to proceed with the arrangements, but be required to immediately inform his district chief, and adjacent sector chiefs, of his intent. If, however, route control need appears to span the entire sector, or extend to or across a sector boundary, then presumably the district EHTR chief should be responsible for the actual decision or for coordination between sectors. Similarly, a situation that extends to or beyond a district boundary should be the decision-making or coordinating responsibility of the State EHTR chief.

In every case, of course, it is imperative that each EHTR center--State, district, and sector--be promptly informed which route sections are going to be controlled, and when; which are operating under controls, and under what conditions; and which now under control are going to be released. Once again, it is evident that good communications are vital.

When and if the decision is made that class C regulation of a particular route is necessary, two considerations are required: one as to length of route to be put under regulation, and the other as to timing.

Length of regulated route

Individual decisions that class C regulation is required will usually be related to a specific location or limited area, and to a particular route, since in all probability the need will be occasioned by a bottleneck at a single spot or along a short stretch of road or street. Conceivably, control might be instituted on a route extending for many miles; perhaps across the entire State. But this seems less than likely to be a common need, based either on road capacity or traffic demand. In addition, control of a long route might well be difficult from an operational standpoint, and would involve considerable manpower and paperwork.

As a general principle, then, regulated route sections should be no longer than is necessary to ensure that congestion will not develop, because of the control operation itself, at the route section termini.

There may be situations where two route sections which require regulation are part of a continuous major route and are so close together that control as a single unit would function more efficiently. Also, control of one route section may create traffic problems on other nearby routes, particularly those crossing or closely paralleling it. Thus in preparing to make the decision to institute class C regulation on any individual route section, full consideration must be given to the consequent effects on other roads and streets in the vicinity.

The element of timing

The decision to institute class C regulation is, of course, concerned with a time period in the future. Regulation, whether partial or full scale, cannot effectively be applied at a moment's notice. Roadside traffic control posts must be spotted, equipped, and manned. Requests for road space must be solicited and received, and permits issued or authorized.

A logical and practical system of control operation is what might be called the "following-day" pattern (a plan commonly used by the military services), in which preparations are made each day for the following day's operations. In EHTR operation, information collected by the EHTR organization during the morning might indicate that traffic demand soon may exceed capacity on a particular route section. The decision to regulate might be reached by noon. During the afternoon, arrangements would be made for establishing and manning roadside control posts; requests for road space permits would be solicited and processed; and information would be disseminated to the general public on the situation. The actual regulation would begin on the road at a prescribed hour on the following day, probably at a very early hour.

A further consideration in timing is the duration of regulation on a particular route section. Sufficient information may be available, or careful judgment may indicate, that control should remain in force for several days, a week, or even a more extended period. This will be an initial decision, of course, subject to amendment as the situation develops from day to day. The extent of control on one route may also be affected by the situation on other nearby regulated routes.

Class C regulation may be needed only during certain hours of the day when congestion is likely to occur (for example, the peak-hour surges in and around urban areas) or it may be required for the full 24-hour period. Similarly, it may be required in one or both directions.

Operation of traffic control only during the day or even during just the few heavy-demand hours would greatly simplify the task, both as to manpower and paperwork. In addition, it would very well encourage many highway users to travel in off-peak, no-control periods, thereby actually reducing the peak-period demand.

One other point about timing has been mentioned earlier in the text. The beginning point for class C route regulation as a general type of EHTR operation cannot be defined. The needs for class A and class B route control will arise almost immediately after an enemy attack; but the needs for class C regulation are not likely to develop so quickly. Additionally, the EHTR organization may not be sufficiently activated and staffed for managing class C route regulation on any extended basis until at least several days after the attack.

OPERATING PROCEDURES

Once the decision is made to institute regulation on a route section, the EHTR activity moves from the survey, analysis, and planning stages into the sphere of actual operations on the road. These operations deal largely with class C routes. However, some of them are pertinent in greater or lesser degree to class A and class B route regulation. Additionally, on some occasions, routes reserved for civil defense or military movements (class B) and routes controlled for capacity reasons (class C) may also have to be operated under radiological hazard restrictions (class A); and at some times convoy movements may be accommodated on class C routes.

Allocation of road space

As previously described, the traffic demand of individual route sections is determined through the "push-pull" interchange between the highway user members of the EHTR staff and the commercial and private operators with whom they have made contact. Once the decision is made that class C regulation is necessary, then specific allocation of road space must be made to vehicle operators for specific vehicle trips which have received priority certification from the transportation agencies which issue them. These individual space allocations, made by the EHTR organization, will be validated by issuance of EHTR permits for display on the vehicles.

As an initial step, the hourly capacity of the route to be regulated should be rechecked, if there is any question about previously made capacity estimates. Next the total hourly capacity available will be divided among the State center and the district and sector centers involved, for allocation to vehicle operators. This tri-level division is necessary since the State center can best handle the allocation for long-range travel; the district center, for intermediate travel; and the sector center, for local travel.

Just how the total capacity of the route is divided will depend to a considerable extent on the route itself. As a generality, perhaps 10 percent is reasonable for State allocation, 20 percent for the district, and 70 percent for the sector; but the peacetime trip-length distribution of the route, and any other past or current indications, amy be used as criteria.

The mechanics of arranging the allocation probably are best handled in a descending order of EHTR level. The general routine of the operation is likely to begin with a tentative decision at an EHTR sector center that a particular route section ought to be regulated; this will be recommended upward through the EHTR organization structure. Confirmation, approval, or alteration of the tentative decision (for instance, the district may see the need to extend the controlled section into an adjacent sector) will be made first at the district center and then at the State center. In communicating the confirmed decision downward, the State first, and the district next, will specify the hourly allocation of road space each has reserved from the total capacity for its own anticipated needs in permit issuance.

Local and remote permit issuance

The reason for adopting the tri-level split-allocation method of handling individual trip allocations and road space permit issuance is fairly obvious. Local vehicle operators naturally will contact the local EHTR sector center for road space permits, particularly since they have already been in communication with that center, during the canvass of possible traffic demand, and will know from such contacts or from local news broadcasts that the particular route they want to use is now or shortly will be operated under regulation. (The actual issuance of permits for display on vehicles will be discussed later.)

The other extreme in the picture can best be described by example. A trucker at a distant point, say in Iowa, may have a priority-certified shipment involving several vehicles which, in the course of his long trip, must cross Ohio. Of course, only from the Ohio EHTR organization can he learn whether any part of the proposed trip route in Ohio is closed or under class C regulation. But it can hardly be expected that the shipper as an individual, away off in Iowa, should make direct contact with the Ohio EHTR organization, even if he knew how to do so. His logical and probable action will be to get in touch with the EHTR sector (or perhaps district) center in Iowa that is closest to him--one which undoubtedly he is already in contact with about local trips. From there, his request will be transmitted up to the Iowa State EHTR center and thence to the Ohio State EHTR center. (In this example, the State EHTR centers of the intervening States of Illinois and Indiana may act as intermediaries, especially since their own highways will be involved in the Iowa-Ohio trip.)

Information and authority for a road space permit will return to the Iowa shipper via the same communications channels, and the local EHTR center in Iowa will be able to give him fairly specific instructions. One of these will be where to pick up the actual permit for display on the vehicles. Presumably this will be the first roadside control post he reaches in Ohio. All this sounds involved, but radio or phone communication should make it possible to accomplish the entire transaction in a few hours.

On long-range trips of the type discussed above, it is probable that the vehicles involved will have to traverse several different class C regulated route sections within State but each in a different EHTR district or sector. The State EHTR center would be able to handle all of the allocations and permits for the separate route sections within a State. If the initial contact with the shipper was at the local level, the State EHTR center would instruct the EHTR sector center to issue the required permits.

As will be evident from the foregoing discussion, intermediate-length trips can be handled by the EHTR district center in the same manner that long-range trips are handled by the State center.

Special allocation problems

At each level--State, district, and sector--the staff members handling the allocations would know the number of vehicles for which they could issue road space permits, for each hour of controlled operation on each regulated route section. When it appears that the number of priority-certified vehicles seeking permits will exceed the quota, two alternatives are open.

One of these is to attempt to "borrow" space from the reserved block of another EHTR level; for example, the sector might query the district and State centers to ascertain whether either one could spare some of its originally allocated space. The other alternative is to attempt to get the shippers to rearrange their trip time schedules; thus, a shipper could be informed that a particular time slot is rapidly filling up, and that some earlier or later hour is available, which might serve him just (or almost) as well.

When a specific hour is already fully loaded by permit issuances, of course, further requests for that particular time will have to be refused. In urgent cases, however, it may be possible to get some shippers to relinquish their permits in exchange for others at a different hour. This sort of trip-time shifting or swapping can most readily be managed at the local level, where the highway users on the EHTR staff are well acquainted with many of the commercial vehicle operators.

There is a quite different type of situation which is likely to occur with some frequency. This will complicate the handling of allocations for road space unless it is anticipated and arranged for in advance. This involves the class C regulated route section that crosses EHTR unit lines; for example, a route that has one terminus in one EHTR sector and the other terminus in an adjacent EHTR sector. Depending on the individual situation, each of the two sectors involved could handle the allocation of road space for local traffic originating in that sector; that is, each sector center would be handling traffic in only one direction on the route. An alternative would be for the district EHTR center to handle both local and intermediate trip allocations.

The possibilities of variety in situations of this type are so manifold that it hardly seems practical to attempt to conceive of and plan for all of them in detail. Nevertheless, in actual operation, each time the decision to regulate a route section is about to be made, careful (but quick) consideration must be given to all possible unusual and complicating circumstances.

Recording allocations

It is obvious that some sort of records must be kept in each EHTR center, in this process of allocating regulated route section space; but they should be kept to a minimum. Putting it bluntly, records may be crude and casual, just so long as they are accurate. Even accuracy is relative, since over-issuance of trip permits by 10 or 12 on a road section with an hourly capacity of 800 vehicles, for example, is not going to create any great amount of congestion, if any.

In its barest essence, the road space allocation and permit issuance operation in any one EHTR center (especially at the local level) can largely be managed by a man with a telephone and a tally sheet.

In more specific terms, a sensible method of allocation control would be to post each day's operations on a single, large sheet of paper. At any one time, of course, it would probably be necessary to have available and work on separate sheets for the current day and three or four days ahead.

These work sheets might be mounted on a wall panel in the EHTR center, adjacent to the large-scale wall maps of the area. Here they would be available for all of the staff to see; and a number of EHTR staff members, engaged in contacting vehicle operators and issuing permits, could check the situation and post their records without unduly interfering with one another. If the operation is on a smaller scale, and one or two men can handle most of the contacts with vehicle operators, the posting sheets could be kept on a desk or table where the men are working.

Each sheet, for a single day's operation, would be divided into columns and lines; each column representing an hour of the day and each pair of lines a regulated route section. Figure 3 illustrates a part of such a posting sheet. The day and date are prominently displayed, and the center indicated (whether sector, district, or State). For each regulated route section, the control number assigned to the route section (and there should be a prearranged plan for this numbering), the Interstate, U.S., State, or County route number (as signed on the road), and the termini will be shown. Because two-directional travel is involved, each route is given two lines, one for each direction. The combination of route numbers, termini, and travel direction is proposed as a means of avoiding any misunderstandings about which route section is involved, both in talking to vehicle operators and in posting permit issuances.

As shown by the blown-up inset in the illustration, each block represents one hour of space in one travel direction. There will initially be posted in a small box in the upper left corner (perhaps in red pencil), four figures representing the route section capacity. The topmost figure is the capacity portion allocated to the State for permit issuance; the next, the capacity allocated to the district; the next, the allocated to the sector; and, at the bottom, the total. To avoid any confusion, the figure applicable to the allocating office should be heavily encircled. In the example illustrated, the posting sheet is that of an EHTR sector center, and the encircled figure 280 indicates the number of vehicles for which the sector can issue permits in the 12-1 a.m. period for eastbound trips on controlled section No. 1, on Thursday, December 2.

State of ___________ EHTR DAILY ROAD SPACE ALLOCATION SHEET

District: 3 Sector: Able County Day: Thursday 12/6/72

(If this is district or State center sheet, so indicate)

Regulated Route Identification					Hour of Operation									
Control No.	US or State Route No.	From	To	Direction of Travel	12-1 AM	1-2 AM	2-3 AM	3-4 AM	4-5 AM	5-6 AM				
1	U.S. 6	Smithville No. City line	JcT. SR 4	E										
				W										
2	SR 31	JcT. U.S. 13 near Billburg	JcT Co. RT 12	S										
				N										
3	U.S 42 + Co. 3	JcT. US 42A No. of Johnsville	JcT SR 23	S										
				NW										
4	S.R. 2 S.R-6 Co.-2			SE										
				NW										

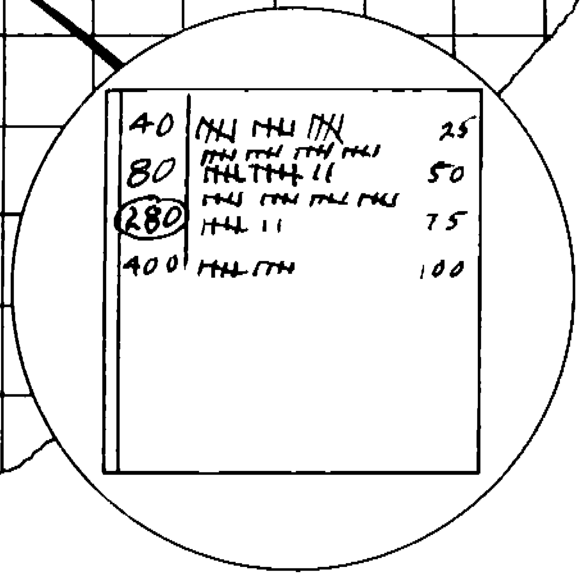


Figure 3.---EHTR daily road space allocation sheet, for posting permits issued or authorized

The tally of permits issued or authorized is kept in the simple, old-fashioned pencil stroke system, with every fifth count recorded as a cross-stroke. Since large numbers of tallies are likely to be recorded, it is recommended that a cumulative total of the tally in each box be noted on the right, as each line is completed; this is illustrated in the example.

It hardly seems necessary to keep any record of permit issuance other than that described here; even trying to make carbon copies of the daily sheets would be difficult because of their size and constant handling. At the end of each day, the day's sheet can be filed away, or for that matter, simply discarded. The records are worth saving only for possible analysis of successes and failures of the operation, at some long-distant future time. During the operation there will be no time for much analysis; and the day's work, insofar as it helped or hindered essential traffic movement, cannot be undone.

Permit format

As will be clear at this point, issuance by the EHTR organization of permits for road space is a major key to class C regulated route operation. It has to be fast-moving and unencumbered by formality or excessive paperwork.

The form of the permit is illustrated in the Bureau of Public Roads PPM 50-7 (see appendix D) and is reproduced here in figure 4. It is expected that the State EHTR organization, as a part of its planning and preparation for an emergency, will print and store supplies of these forms in large quantities. Since the permit form consists of a stub to be retained and a display portion to be issued for affixing on the vehicle, no carbons are necessary (or even desirable).

Individual permit use will be brief--normally, just for on day at most. Widespread advance distribution is desirable (as will be explained later) and as a consequence a considerable proportion of the total printed may never be used. For both of these reasons, the permits might well be printed on a relatively cheap paper, remembering, however, that they will be subjected to possibly rough handling and exposure to weather.

Figure 4.

No. A 0,000,001

Trip origin ______________________

Trip destination ______________________

Number and type of vehicle . ______________________

____

____

Owner ______________________

Commodity ______________________

Shipment priority ______________________

Regulated route number ______________________

Authorized time of entry ______________________

(and/or such other items of information as may be desired by issuing agency)

Issuing Agency ______________________

By ______________________

STUB TO BE RETAINED BY ISSUING AGENCY

- ← (Perforated line)

Number of vehicles authorized		Time of entry on to Regulated route
12	No. A 0,000,001	A.M. 12-1
		1-2
11	Highway directed Movement priority Permit for Regulated route number	2-3
		3-4
10		4-5
		5-6
9		6-7
		7-8
8	22	8-9
		9-10
7		10-11
		11-12
6		P.M. 12-1
		1-2
5		2-3
		3-4
4		4-5
		5-6
3		6-7
		7-8
2	Issuing Agency ______________	8-9
		9-10
1	By ______________	10-11
		11-12

Valid only on ______________________ 19__

ROAD SPACE PERMIT FORM TO BE ISSUED

STATEMENT OF PENALTY FOR MISUSE TO BE PRINTED ON BACK OF FORM:

This permit is the property of the United States Government. Its counterfeiting, alteration or misuse is a violation of 18 U.S.C., Section 499 (1948). Violators shall be fined not more than $2,000 or imprisoned not more than five years, or both.

The display portion of the permit is intended to be taped on the vehicle windshield, so it may quickly be scanned at the roadside control posts. As will be seen in the illustration, the route control number will be written in the center of the permit in large lettering, so it can be checked "on the fly." It is proposed also to make the date evident at a glance, simply by using a different color for the permit form, for each day of the week. The permits should be serially numbered, both on the stub and the display portion; the remaining details evident in the illustration are self-explanatory.

For reasons that will be clear shortly, the permit forms should be made up into pads or stapled into "books" each color being kept separate.

Permit issuance to major users

As a premise to further discussion of permit issuance, class C route regulation is instituted only when it appears that anticipated traffic will overload the route section, so that all traffic cannot be accommodated--at least, at the particular time each vehicle operator himself would choose. It follows, then, that some traffic must be turned back or delayed; conversely, that traffic involving priority shipments must be given preference over any other. Then, reduced to its simplest concept, permit issuance may be concerned only with shippers who have already received priority certification from one of the transportation agencies charged with that responsibility. (If this latter statement seems oft repeated, it is to ensure that EHTR participants constantly remember their own function is to accommodate official priority shipments, not to authorize them.)

Reducing the concept to this minimum position, then, it can be assumed that a large proportion of permit issuance is going to be accomplished by contact between the highway users of the EHTR staff and the commercial vehicle operators, particularly those with fleets of more than just a few vehicles. It is such operators, in all likelihood, who will be handling the types of highway movements that warrant priority certification: the hauling of critically needed foodstuffs and other goods, and the operation of bus transportation.

Actual permit issuance will be far more easily handled if these commercial vehicle operators are furnished with pads of permit forms, and instructed in their purpose and use, as a part of the EHTR organization's planning and preparatory work. If this advance distribution has not been accomplished, then it should be done quickly after the beginning of an emergency. It will be evident, of course, that handing out blank permit forms must be done with some discretion; and that they should be given only to trustworthy individuals in established and reliable concerns.

Assuming that the major vehicle operators have the blank forms in hand, the rest of the permit issuance operation is simplicity itself insofar as they are concerned. As soon as an operator has a specific shipment planned and has received a priority certification for it, he will telephone the nearest EHTR center to find out if a road space permit is needed, and to request its allocation. In all probability he will be talking by telephone with one of the highway user members of the EHTR staff with whom he has already had contacts, since the beginning of the emergency, and whom he knows through peacetime associations. The shipper will inform his EHTR contact of the trip origin and destination, number and types of vehicles, nature of shipment, and all the rest of the information called for on the permit form, including, of course, the desired travel route and time.

The EHTR staff man will check his map and his day's allocation sheet, and if the route has only a locally controlled class C regulated section, he will be able to issue permit authority then and there. If an intermediate or long-range trip is involved, with regulated sections controlled elsewhere, the EHTR sector center will have to make arrangements through the district center and possibly the State center. Interstate arrangement may have to be made, as described previously. In these situations beyond local control, as soon as it is known that road space on regulated route sections is available for the trip, the EHTR sector will advise the shipper accordingly.

For any allocations of road space within the State, the shipper will be told to fill in his own permits, on the blank forms he already has at hand. Necessary information will be interchanged; for example, the shipper will inform the EHTR contact of the serial numbers on the permits being used; the contact man will inform him of the route section control number. The EHTR man will tally the proper number of vehicles in the appropriate box on his day's allocation work sheet. The shipper will tape the display portions of the permits on his vehicle windshields; and they are ready to go--at the proper time, of course.

Interstate allocations and permit issuance will necessarily be somewhat more involved, although the problem is essentially one of communication. Arrangements will have to be made for the vehicle driver to pick up the actual permit somewhere within the State concerned; probably at the first control post in that State.

It is recognized that this procedure depends on the cooperation and integrity of the shippers involved, and it is possible that in isolated cases this confidence will be violated. But the alternative, to physically issue permits to major commercial vehicle operators only at EHTR centers or even at more numerous other locations, would inevitably result in inconvenience and delay to those handling the bulk of the priority shipments, and of course, delay to the shipments themselves.

Permit stations

While much of the priority-certified shipments may be handled by the larger concerns among the commercial vehicle operators, it will also be probable that priorities will be issued to commercial operators who own only one or a few vehicles, and to private automobile users--the businessman, doctor, or defense worker, or the family traveling to a new job and home.

To take care of these, permit-issuing stations can be established in fairly large numbers, well distributed for convenience throughout the area serviced. They can be located at police and fire stations, postoffice substations, and other government buildings, including libraries and schools. They might even be located at shopping centers, the entrances to major stores and factories, etc. About all that is needed for each permit station is the presence of a reasonably intelligent person who is going to be there anyhow and who is willing to cooperate in the simple process involved; a telephone, in order to be able to communicate with the nearest EHTR sector center; and a supply of permit forms. One additional simple requirement is a sizable cardboard sign that can be placed in the window or tacked to the door, to show that there is a road space permit station at the location.

The operation of permit issuance from such stations would not be essentially different from that described above, except that it would be done through an intermediary. The individual seeking a permit, or information as to whether he will need one for a planned trip, will present his priority certificate and/or request, in person, at the nearest permit station he can find. If possible, the locations of these stations should be announced by radio broadcast or in newspapers if they are being published. The person manning the station will call the EHTR sector center on the telephone and relay the request, with appropriate information. Quite possibly the request can be granted at once, and the station "agent" will make out the permit. If a delay is necessary, the permit seeker can be asked to return at a specified time to the same station, to complete the trip arrangements.

Permits for essential nonpriority traffic

Under some circumstances it will be anticipated, or found through experience after a few days' operation, that class C regulation is required on a route section because total traffic that would like to use it exceeds its capacity, yet the capacity is not nearly reached by the priority shipments. This situation may exist around the clock, or only during particular periods.

If the difference between priority shipment volume and total capacity is sizable enough and fairly steady, the EHTR organization may issue additional permits for what it considers essential trips which, for various reasons, have not been granted official priority. Such trips might be of an urgent nature, that cannot wait for formal priority action; or they may involve needs or purposes that are less important than those warranting priority but still, for economic or humane reasons, seem more essential than run-of-the-mill traffic. It is probable that the great majority of such trips will be local in character, and could almost wholly be processed by the EHTR sector center alone.

If permits of this category are to be issued, the daily road space allocation tally sheets should be modified accordingly. For each regulated route section to be operated in this manner, it will be necessary to allocate separately for priority trips and for essential nonpriority trips. Actual physical issuance of permit forms would be handled primarily at the stations described in the preceding section, and in the same manner.

In addition to nonpriority but essential trip permit issuance at EHTR centers and satellite stations, arrangement could be made for accommodation of such trips at the roadside control posts. This will be discussed further in connection with post operations.

Limited or partial regulation

It has already been said, but is worth repeating, that partial control should be used for routes under class C regulation, rather than full, round-the-clock control, whenever possible. It is highly likely that traffic demand will not exceed or even come close to capacity during the late nighttime hours; and in some locations there may be sizable lulls in off-peak morning and afternoon periods. If such situations exist, and appear to be fairly well stabilized, the route may have to be regulated only during the daytime or during specified hours during the day.

"Free" traffic--that without official priority or any demonstrable essentiality--should be encouraged to use these uncontrolled periods; the public can be made aware of them by local news broadcasts and other means. Special operating plans might be attempted, on trial, where it appears that partial control will be necessary for an extended time.

ROADSIDE CONTROL POSTS

As soon as the decision to institute class C regulation on a route section is reached, it will be necessary to choose locations for roadside control posts and provide for equipping and manning them. Making such arrangements is the responsibility of the EHTR organization, usually at the level controlling the regulation and the bulk of the permit issuance for the particular route section. Generally this will be the EHTR sector center; occasionally, the district.

The functions of a control post may vary from a simple task to a complex, large-scale operation, depending on the individual situation. For a comprehensive viewpoint, the large-scale operation is discussed in the text that follows; lesser situations will have lesser needs.

Choosing post locations

In the simplest kind of situation (regardless of traffic volume), involving a short route section which has no intermediate inlets or crossings, or at least none of traffic consequence, a control post at each terminus presumably will suffice for control needs. Longer route sections, with intermediate access points of traffic significance, may require additional control posts; certainly they will be needed at intersections along the route where any appreciable traffic may have to be fed onto and off (or barred from) the regulated route.

No arbitrary traffic-volume criteria can be suggested for this consideration, since it is a relative matter, depending on the possible inflow volume in relation to the total traffic volume anticipated on the regulated route, and to the proportion of that total which is operating with priority preference; in addition, the geometrics of the route and its intersections may have a bearing on the matter.

It will be realized from the above discussion that roads crossing or feeding into a regulated route section, if they carry any appreciable traffic, can create problems for the EHTR organization throughout the operation process. The crossing, entering, and leaving traffic has to be taken into account in attempting to estimate the total traffic capacity of the regulated route. It will also be a factor in total traffic demand; additionally, there may be some priority-certified traffic entering or leaving these intermediate points, and this will have to be reckoned with in allocating road space and issuing permits.

Wherever possible, each terminus and intermediate control post should be established close to a suitable road junction, so that traffic which must be barred from the regulated route may have an available alternate route open to them, even though it may be circuitous.

Almost inevitably, the control posts are going to create traffic bottlenecks just by their very existence. Vehicles traveling with priority will have to be stopped or slowed, even if only momentarily, to check their road space permits. Many others, arriving on the scene without permits, or even unaware of the existence of control on this route or anywhere else, may have to be given an individual (and hopefully brief) explanation of the situation. Some will want to take an alternate route to their destination. Some will want to turn around and head back. Others will want to wait and take their chances of getting a permit, or being allowed to slip into the traffic stream in a slack moment.

Because of these possibilities, control posts on routes with sizable traffic streams should be located where plenty of off-the-road parking is available to serve as a holding area. In fact, the post can hardly operate successfully without this. The space may only be a pasture; or, with luck, it may be the parking lot of a big shopping center, industrial plant, drive-in theater, or athletic field. In addition to space needs, the holding areas will require suitable entrances and exits, as will be evident a little later.

The shoulders along the regulated route, whether paved or not, cannot be used as a holding area. Their use for this purpose would seriously endanger moving traffic; they would not have adequate capacity within a reasonable distance; and vehicles stored on them could not satisfactorily be controlled or shifted.

Manning and equipping the posts

Control posts on regulated routes will be activated by the EHTR organization, but will be manned by State or local police by request of the responsible EHTR center. Highway department personnel may also be available. The police forces are best suited for the control post operation, of course, since they are trained and accustomed to the handling of traffic both in normal and in emergency circumstances, and in dealing with vehicle operators in unpleasant situations.

What size staff will be required at an individual control post will depend largely on the particular situation and traffic volume. On a relatively low-volume, rather short route section, only a few men will be needed. In a complex situation, with large volumes of traffic which must be screened and separated; and turned back, diverted, or held, a fairly large crew will be needed. To some extent, the staffing of posts will be dependent on the availability of manpower. But it will be evident that in such involved circumstances as those just described, a seriously undermanned control post could very well create more of a traffic bottleneck than no regulation enforcement at all. This could be equally true for a post which is adequately manned but poorly organized and directed.

A major equipment need at control posts will be communications facilities for continuing contact with the nearest EHTR center as well as with other control posts on the same regulated route section and with the State or local police and highway departments. Probably such communications will be available in the form of mobile two-way radio in police vehicles. In a large and extended control post, it is quite possible that internal communication is needed. This might be provided by field telephone or "walkie-talkie" sets.

Cars will be needed for transport of staff, patrolling the regulated route section, possible pursuit of law or permit-regulation violators, accident investigation and rescue, etc. It may be desirable, especially in connection with control posts on heavily traveled routes, to have available such equipment as tow trucks, wreckers or rescue vehicles and ambulances. Supplies such as gasoline, first-aid materials, fire extinguishers, drinking water, and food should be at hand. Shelter of some sort will be needed, at least in inclement weather; and sanitary facilities. Radiological monitoring equipment should be available and, of course, some of the post staff should have been trained in its use.

Barricades and signs will be needed at the control posts, their number and nature depending on the volume and complexity of the individual situation. Such materials should be prepared in advance and stockpiled for use. The basic signs required are represented in appendix K. However, additional signs for directing vehicles to alternate routes, to holding areas and out of them, etc., may be needed. Some of these may have to be prepared on the spot; materials should be available for the purpose.

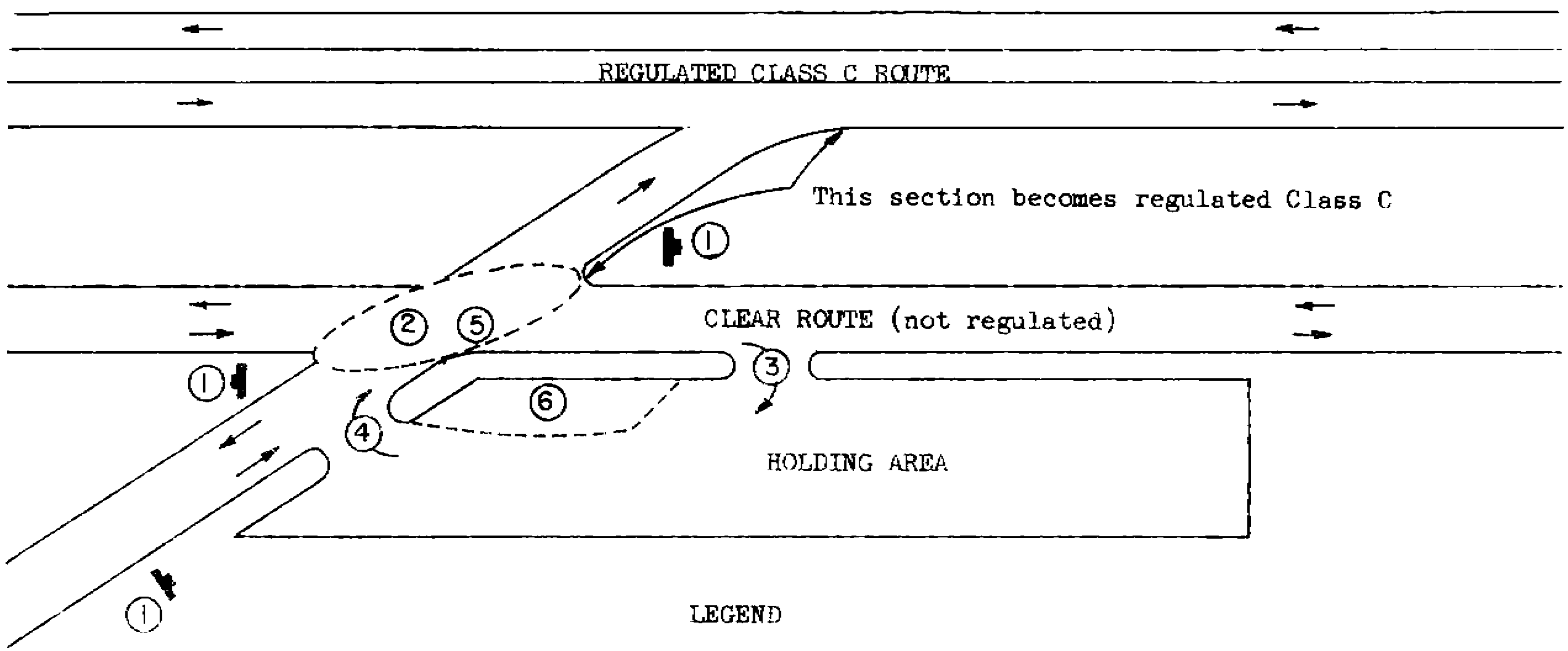
Control post operation

The nature of operations at a control post on a regulated route section will depend on the volume of traffic and complexity of the situation, and on the understanding and cooperation of the public. At many locations the problems discussed here may be of small scale or nonexistent; at others they will be full-blown, indeed. Figure 5, illustrating a large-scale control post operation, will be helpful in understanding the text that follows.

Essentially, the operation at the control post is to feed permit-bearing vehicles onto the road (or let them continue on it) and to turn others away; taking care of the latter, however, as road space allows. It is for this process that a suitable holding area of adequate size is required at or very near the control post.

As noted earlier, the display portion of the road space permit will be fastened to the vehicle windshield; its color and a large written-in number will show at a reasonable distance the day of the week and the specific regulated route section for which it was issued. Date and permit hour, also will appear on the permit, but will not be visible except in close-up examination.

A complete check of the permit on every vehicle would almost certainly result in a tremendous traffic bottleneck. For that reason it is proposed that vehicles bearing permits apparently proper for the day and the route section will be waved on without stopping. It must be remembered that a sizable proportion of the priority traffic may be heavily laden trucks and combinations which, once slowed or stopped, take considerable time and distance to accelerate to road speed. This leads to the further thought that control posts should preferably be located on level ground, and certainly not where an appreciable, sustained upgrade is involved.



LEGEND

1. Information signs

2. Control post check point; vehicles showing permits are waved on; those without permits are diverted into holding area or onto clear route

3. Entrance to holding area

4. Exit from holding area

5. Intersections where traffic direction will be necessary by police.

6. Shelter for post headquarters, first-aid, detention, sanitary facilities, etc.

Figure 5.---Roadside control post operation on a high-volume Regulated Class C Route.

While permits will thus be cursorily checked as the vehicles drive by, it would be desirable to pull an occasional vehicle out of the traffic stream, for a closer check. As with peacetime road-regulation checks, the "word" would probably get around pretty quickly.

Diverting non-permit vehicles

Those vehicles that do not have permits for the regulated route section will have to be pulled out of the traffic stream into the holding area without hesitation, regardless of whether they are going to stay there or not. It will be impossible to answer questions or give advice to drivers while they are on the road and thus blocking all traffic. And they cannot be permitted to stop at the entrance to the holding area, either, or the same problem would result. Hopefully, the use of advance warning and information signs, or of advance information posts, coupled with news broadcasts or other dissemination to the general public of information about regulated route sections in the area, will keep to reasonable proportions the number of vehicles that have to be diverted to the holding area.

General experience with the human race, however, indicates that regardless of such information devices, the holding area had better be of considerable size on a main route, particularly if there are no or only limited-capacity available "free" routes in the vicinity. Similarly, the work force operating in the holding area will have to be adequate for the task.

Several alternatives will be open to the vehicle operator who does not have a permit and who has been diverted to the holding area. One of these is to take an alternate route to his destination; and the staff working in the holding area should be prepared to give useful, up-to-the-minute detour and alternate route information. Coupled with this choice, if taken by the vehicle operator, is the need for suitable exits from the holding area, leading to the alternate routes without crossing or interfering with the mainline traffic any more than necessary. Where such crossings are necessary, a policeman should be stationed to direct traffic.

The second alternative open to a vehicle operator who has no permit will be to turn back toward his starting point; that is, give up the trip altogether for the time being. Again, there must be means for him to exit from the holding area and start his return trip. This may not be a simple operation, because the driver will have to cross the mainstream of traffic going in the direction he originally intended to follow. In addition, once he has crossed that traffic stream, he will want to enter the traffic stream going in the other direction; but this will be the traffic coming from the other end of the regulated route section and presumably already will be running at or near the capacity of the lane or lanes in that direction.

Thus, it will be seen that handling the non-permit, diverted traffic can be a very difficult task, and where traffic volumes are heavy it may require a very sizable, well-organized staff. Even in peacetime, and even then if all drivers were amiable and docile, the job would still be complicated; witness the traffic jams before and after big athletic or entertainment events. In an emergency, and dealing with anxious and distraught drivers, it is going to be perhaps the most taxing, both in planning and execution, of the EHTR operations. In addition to managing and directing traffic, there may occasionally be need for police action against recalcitrant drivers.

Accommodating non-permit vehicles

A third alternative may be open to the vehicle operator who has no permit: the possibility of obtaining a permit; or the chance of being "metered" from the holding area into the traffic stream on the regulated route section, if the route is being operated in such a way as to allow this, and if he chooses to take his chances and wait in the holding area. In the first instance, and in the second if the answer to both "ifs" is affirmative, the vehicle operator should be directed to a special part of the holding area, from which there is a suitable entrance to the regulated route.

Three levels or classes of consideration may exist for those vehicle operators who arrive at a control post without a permit, and nevertheless want to continue.

Among the three levels of non-permit-bearing vehicle classes, the first class to be considered would be those on an interstate trip for whom permit authority was arranged between the two State EHTR centers, and who had been instructed to pick up the actual permit at the first roadside control post they reached in the State. In some cases the control post staff will already have been advised of the arrangement and have a permit reserved; in others they may have to contact the EHTR center to verify it.

The second class would be those operators who are making a demonstrably essential trip, but have no road space permit. Such individuals may have been directed by telephone, by the EHTR center or one of its satellite stations, to go to the control post, because it is much closer to the trip origin; or the individual may not even be aware of the need for a permit. The control post staff will have to make quick decisions in these cases, using their own judgment and without any specific guidelines. Those vehicles accepted as being on essential trips would be fed into the traffic stream as soon as possible.

The third and lowest level or class of operators would be those who have neither priority nor essentiality to justify using space on the regulated route, but still have, in their own minds, at least, a strong reason or desire to make the trip. These, if there is a reasonable possibility of accommodating them, may be allowed to wait in the holding area and take their chances. If there is no reasonable chance of this, however, they should be shunted out of the holding area, either to an alternate route or to return to their origin.

Vehicles in all three of the classes described above, with those of the first and second level getting preference, can be lined up in the holding area close to the entrance to the regulated route--an entrance which necessarily must be at a location beyond the control post permit check point. As the control post staff assigned to this location sees that there is a reasonable gap in the traffic moving on the route, he will feed one or more vehicles from the holding area into the mainstream. In this manner, it will be possible to take care of all of the first two classes of non-permit-bearing vehicles, and a good many of the third class, over a reasonable period of time. The odds are strong that the mainstream traffic past the permit check point will be irregularly spaced and rather slow-moving.

Where regulated routes are operated under regulation only during certain hours, the non-permit vehicles can be kept in the holding area and released (without permits) when the controls are dropped.

Latecomers; overloading

The scheduling of road space on regulated routes will be on an hourly basis, and each permit issued will indicate for what hour it is applicable. Those who arrive early or late at the entering control post (and are detected), should be shunted into the holding area, but metered into the route as soon as clear space is available in the traffic stream.

There may be occasions when, through inadvertence, permits have been issued for more road space than is actually available on a regulated route during a particular hour; or the route capacity may unexpectedly and temporarily be decreased; or a sudden and urgent priority need may have arisen after all the space had been allocated. In such cases, the control post staff will have to make whatever adjustments they can, that seem reasonable and will accomplish the purpose. Any permit-bearing vehicles that have to be delayed, however, should be permitted to proceed as soon as possible; if necessary, by preempting part of the next hour and delaying vehicles scheduled for it.

Contaminated and reserved routes

The regulation of routes controlled solely because of radiological contamination or hazard (class A) has been discussed in an earlier section. As indicated there, control posts should be established on them if possible; and under certain circumstances this would be almost mandatory.

On class C regulated routes, controlled for capacity reasons, there may also exist a radiological hazard. If so, the control post staff should include personnel, properly equipped and trained, who can provide proper cautionary advice to the control post staff itself and to the vehicle operators traveling through the contaminated area.

PUBLIC INFORMATION

For emergency highway traffic regulation, as for every other aspect of an emergency situation, the better and more currently informed the public is, the easier it will be to conduct EHTR and all other emergency operations. With information, as with war, "too little and too late" can compound a disaster. Lack of information can lead to rumor and hysteria--and roads blocked with congestion. And information that is too meager, too vague, or too late will be little better than none at all.

The EHTR organization's prime "news" of public interest is going to be the current situation and short-range future prospects for traffic movement: which routes are open to use; which route sections are completely closed or wholly reserved; which route sections are under regulation; who can get permits to use them; where are the permit-issuing stations; and so on--all of the details that will let the commercial operator and the private citizen know whether he can make the trip from Avalon to Zion City today, or tommorrow, or not for some time.

Presumably it will not be the function or responsibility of the EHTR organization to carry on a full-scale public-information program during the emergency. It will feed whatever information it has that will be helpful to the public, to the State and local civil defense agencies for further dissemination. However, arrangements might be made with the civil defense authorities to feed the details of travel information, such as that indicated above, not only to them but also direct from the EHTR centers to any radio and television stations and newspapers that are in operation. Such information should also be channeled direct to major highway user concerns, and any user organizations that are still functioning.

As noted earlier, an advance public education program conducted as part of the EHTR organization's preparation efforts is highly desirable, so that the nature and mechanics of EHTR operations in an emergency will be understood beforehand.

Chapter VIII.---TRAINING PARTICIPANTS

In planning and preparing for emergency highway traffic regulation in the event of a national emergency, it is no more possible to predict the location, scale, and duration of the required EHTR operations than it is to predict with any reliability the timing and nature of a possible enemy nuclear attack. The situation may never eventuate, or it may be far less catastrophic than is often conjectured; but as a safe and conservative policy, EHTR planning must prepare for the worst possible situation.

It appears advisable that nationwide, approximately 100,000 persons should be trained in emergency highway traffic regulation. The number needed would be much smaller; and all those needed may not be occupied for the full duration and in every corner of the country. Nevertheless, anticipating the worst situation, an adequate corps must be recruited for the EHTR organization, and made acquainted with its purpose and the nature of its operations; and should be instructed fully in respective assignment. Uninformed, untrained personnel, no matter how willing, cannot be expected to perform well at unfamiliar tasks, particularly under the stress of emergency conditions.

The "cascade" training program

A large-scale training program is therefore an essential part of the preparatory work of the EHTR organization. Because each State is handling its own EHTR program, with the cooperation and involvement of several diverse groups, and because the training requirements of various jobs in the EHTR operation differ greatly, a "cascade" system of training seems best suited to the general need. Briefly, this would begin with the development of a national team of instructors, who will conduct regional courses attended by selected personnel from groups of States. These men in turn will become instructors in their respective States; and as the State instruction team they will train representatives who are or will be the staff leaders of the State, district, and sector EHTR centers. These in turn will train all of the EHTR personnel who will be working with them or under their direct or indirect guidance or command in time of emergency.

With this cascade form of training, instruction at each level and for each group can and should be tailored to specific need. Upper-level administrators, for instance, must know in considerable depth the mechanics of the whole EHTR operation but need have no technical knowledge of traffic estimating in an emergency. Those who have the latter assignment need not know the technical details of radiological monitoring. Those who man the control posts do not have to know how to make advance allocations of road space. Thus it is evident that all training courses should cover the EHTR purposes and operation methods, but in varying degree of depth and scope; and individual groups must learn in detail the mechanics and processes of specific aspects of the operation.

While the major concern of the training courses will be instruction in administrative and technical operations, appropriate indoctrination must not be neglected. It is difficult for the average individual to accept the real possibility of a nuclear attack and the extent of its consequences; or, having accepted that, to believe that the ensuing situation will be anything but hopeless. This attitude can be overcome and a genuine and keen interest developed in everyone engaged in the EHTR organization, if the instructors themselves are not only technically competent but are dedicated and skillful in their presentations as well.

Regional training courses

Plans have not yet come to fruition, but the plan is to launch a nationwide EHTR training program by first organizing a national instruction team, composed of representatives of Public Roads, the State highway departments, the State police, and the organized highway users. The team may also include as members, or at least as speakers on pertinent subjects, representatives from the Office of Emergency Transportation, the Office of Civil Defense, and the M.T.M.T.S.

This national team, traveling about the country, will hold training courses in each of the Bureau of Public Roads regions, to train representatives from that region who in turn will become instructors in their own States. The group from each State should include representation from the deveral agencies and organizations involved in the EHTR planning. For a typical State the group might include representatives of the State highway department, the State police agency, the organized highway users, and the Bureau of Public Roads division office, the State civil defense agency, and the military A typical State group would total 10 to 20 persons. Since Public Roads regions comprise four to nine States each, the regional classes might range in size from less than 75 to over 100. Depending on attendance commitments, two smaller regions might be combined for one course; two separate courses might be needed for a large region.

It is important that the individuals selected to attend these regional courses be chosen with care They should represent a cross-section of the groups comprising the EHTR team. They should be committed by their organizations to serving as instructors in their own States, with assurance of ample time to do so. They should be individuals who have a sincere interest in the subject; and they should be capable of becoming both competent and inspiring instructors.

State training courses

Each State group trained at the regional sessions will subsequently hold one or more training sessions in its own State for the selected administrative and technical personnel assigned to the State, district, and sector EHTR organizations. The number of such sessions will depend on the number of people involved and the size of the State

These State courses will probably follow the pattern of the regional training course, with adaptation to the individual situations in the State. Participants in these courses will be from county and local agencies and organizations as well as those of the State.

Finally, individuals or teams from among those trained in such courses by the State training team, with assistance from the latter at least in planning, will conduct training sessions for those who are going to work at the EHTR centers or under their direction or guidance. All persons involved in the organization in a local area may be gathered as a group for the general instruction on EHTR purposes, organization, and operations; but separate training sessions are desirable for each associated group or function: for example, administration and housekeeping; communications; traffic supply and demand estimating; radiological monitoring and interpretation; road space allocation and permit issuance; and control post operation.

Course planning and preparation

The regional "train-the-trainer" courses, because they will bring participants together from some distance, should be conducted in continuous sessions. Each will probably require full work-week of 40 hours of lectures, seminars, and discussions with supplementary reading and problem-solving. The courses to be given by the State training teams to groups in their own States might take somewhat less time to complete; perhaps 2 or 3 days. Depending on the convenience to personnel and on travel problems, these courses might be held on consecutive full days or be scheduled for one day a week, two hours a day, etc. The local specialized courses will probably require still less time; perhaps one or two full days, or a few hours a week for a month. Their timing as well as their content must be tailored to the advantage of the individual group being trained.

No instructor can handle his subject competently and in an organized fashion, and equally important, stay within his assigned time schadule, without careful preparation. For each course to be given, the instruction team should prepare a comprehensive outline, and each instructor should prepare detailed notes. This guide, together with the State's individual EHTR plans, will be helpful. A presentation made by Dr. Homer Rosenberger, former Chief of the Training Branch of the Bureau of Public Roads, at the Salem Conference is included as appendix L. This presentation contains a good many practical and helpful suggestions in instruction technique.

Outlines, guides, manuals and visual aids will also be needed for the more detailed instructions necessary in the technical phases of EHTR. These should be prepared to fit local situations and conditions.

Continuing training needs

What has been discussed so far in this chapter is the initial instruction of personnel who will be part of the EHTR organization. Further training needs must be considered. One that is evident is the training of individuals newly assigned to the EHTR organization and those who have been reassigned within the organization to a different function.

Another aspect of training is the need for periodic refresher courses. Refresher courses should be scheduled periodically to brush up memories and to introduce new, current concepts and procedures. The length and frequency of such courses are interrelated; but it would seem that a one-day session every six months might be better than a two-day annual session. The interval should not be too long; nor should the individual session be too short. Over-scrimping on time will, in effect, be wasting it.

Training exercises

Finally, as an essential part of training, there is need for exercises or practice sessions. They should be carefully planned, and executed with vigor and sincerity; and they should approximate a real situation as nearly as possible. To do otherwise would be a waste of time, and could well dampen any interest or enthusiasm for the operations that has been generated among the personnel engaged.

Exercises may involve specialized practice, such as an engineering group occasionally meeting to solve problems in estimating traffic demand and highway capacity supply, under pre-set theoretical conditions but for actual geographic locations. At the other extreme, they may involve a statewide or even regional exercise, which may range from a largely paperwork performance to an operation in which some or all of the EHTR organization staff are mobilized and called upon to carry on their assigned functions; again, under pre-set theoretical conditions.

Such exercises should test communications; collaboration among the highway departments, police, and highway users; coordination with civil defense and military agencies and with adjacent State EHTR organizations; and, indeed, all of the capabilities for real action. However, such exercises should not be so conducted as to alarm the public or cause any serious traffic disruption.

EHTR operations exercises, whether large or small, are invaluable both as practice and experience for the participants and as the basis for subsequent critiques. Careful, honest analysis of an exercise may reveal defects and gaps in plans that cannot always be detected by theoretical examination, no matter how thorough. It must be remembered by the participants that the purpose of a critique is a constructive one; negative criticism, defeatism, and nit-picking have no value and may well antagonize conscientious co-workers. Sins of commission and omission certainly should be pointed out, but with tact; and deserved commendations should be freely made.

Chapter IX.---THE PARTICIPANTS' ROLES

As is evident throughout the discussions of emergency highway traffic regulation presented in this guide, the EHTR planning and preparation, and actual operations, if they eventuate, are a collaborative effort requiring close cooperation on the part of the three partners involved--the highway and police agencies and the organized highway users--and requiring close coordination with other government agencies, particularly the civil defense, the military, and the transport regulatory authorities.

Just who does what in the EHTR organization and operation may vary somewhat among the States, according to specific plans developed to best suit their individual needs and situations; and many EHTR assignments and functions will be shared or jointly held. However, each participating organization has its principal roles and responsibilities, and it is the purpose of this chapter to present them individually. Since all of the subjects covered here have already been discussed at some length in previous chapters, they will be summarized only briefly here.

The highway departments

The State highway departments are charged with the responsibility for heading up the State EHTR organization and activities (except in some few States where another agency has the primary responsibility; but even in such cases the highway departments will have many of the functions described here). For this reason, the State highway department generally may be looked upon as the principal partner of the EHTR team, and therefore should assume leadership in promoting and developing the program and its plans and preparation. In providing such leadership, the State highway departments should seek the cooperation and be responsible for obtaining the collaboration of other agencies and organizations involved.

Since the State highway department has a very large work force with a variety of needed talents, it should expect to furnish all or most of the administrative and support personnel required to man the State and district EHTR centers Either State or local highway department personnel will serve in the sector centers. The highway departments will also provide the EHTR centers with the needed technical staffs whose function in an emergency will be to collect information, and, from it and recorded data, estimate and predict highway route capacity and traffic demand; map out detours, bypasses, and connecting links to provide an adequate highway network; and join in reaching the decisions on route regulation and planning for their operation. The highway departments should also have experts in radiological contamination analysis at the State and possibly the district centers, and their field personnel should be trained and equipped for radiological monitoring.

The State highway departments usually will provide the office facilities, equipment, supplies, and communications required for the State EHTR center, and will similarly provide or arrange for the district and sector centers Much of the special material needed for EHTR operations, such as permit forms, maps, tally sheets, and signs and barricades also presumably will be produced and stockpiled by the State highway departments.

The role of the highway department staff members of the EHTR organization in an emergency primarily will be that of administration, housekeeping, guaging traffic demand and supply, and reaching decisions on route regulation While the State and local highway department forces will be called upon extensively for emergency road maintenance and repair, this will be under the control of the highway departments themselves, rather than the EHTR organization. However, the two will necessarily work closely together, and should jointly determine the priorities of emergency road repair and reconstruction.

Highway department personnel will do most, if not all, of the field survey work in an emergency. This will include both survey for physical damage and radiological monitoring. In some cases, the highway departments will also be called upon to furnish men and equipment to help operate regulated route control posts.

The police

The role of the police in emergency highway traffic regulation will be primarily in field operations and route-regulation management and enforcement. Upper-level police agency personnel, probably in limited numbers, should be a part of the EHTR center staffs; those at the State and district centers presumably coming from the State police agency; and those at the sector center, from the county or local police departments. Representatives of the State police should participate fully in all EHTR planning and preparation, and the training work, particularly as it applies to their own personnel. The State police will form the principal link between the EHTR organization and county and local police forces.

Where needed, the police agencies may be able to provide facilities and equipment, and some support personnel, for district and sector EHTR centers. Since the State and local police generally have very extensive radio communications systems, the police agencies may play an important role in providing and operating the EHTR communications.

Police forces in the field may be called upon to assist in the collection of road and traffic information, and in radiological monitoring. But the principal police activity will be in manning, equipping, and operating the roadside control posts on regulated routes. This, in itself, may require large numbers of men and considerable equipment. Police will also patrol highways, particularly those under regulation, to enforce both normal and emergency regulations and to keep traffic moving.

The organized highway users

Representatives of the organized highway users should participate in the EHTR planning and preparation activities, since they are an integral part of the EHTR team and, in fact, are the public's spokesmen and representatives in the organization. Their knowledge of highway use and vehicle operations, and their well-established contacts with truckers and bus operators and with commercial highway-users and automobile-owner organizations, fit them particularly for their EHTR role.

The organized highway-user representatives in the EHTR organization should play a prominent part in educating highway users and the general public, now, in peacetime, on the purposes and mechanics of emergency highway traffic regulation.

In actual EHTR operations, the highway user representatives in the State, district, and sector centers will help the highway and police department representatives in analyzing information, forecasting taffic demand and capacity, and mapping usable routes. Their contacts with highway users will be a principal source of traffic demand information. They will help reach the decisions on route regulation When a route is put under class C regulation, the highway users in the EHTR centers will have the job of finding out what priority and other essential shipments need to be moved over it, making road space allocations, and issuing permits for the trips.

It is worth commenting that the position of the highway user representatives in the EHTR organization is an unusual and somewhat delicate one. They are usually recruited from private industry, but in EHTR they will be working with government employees. Because of different working backgrounds, the two groups may tend to approach and carry out EHTR activities with somewhat different attitudes. This is by no means intended to intimate that one style is "good" and the other "bad;" but it does point up the need for advance collaboration of the EHTR staff in planning for harmonious teamwork in time of emergency.

The individual highway user on the EHTR staff will also face the difficult circumstance of acting as an impartial collector and analyzer of traffic demand and making decisions with respect to it, and not as a representative of a particular phase of the transportation industry or of a particular company. If he represents anyone or anything on the EHTR team, it is all of the public and their transportation needs. But while he does need to be impartial in his EHTR service, he definitely does not need to be impersonal. In fact, one of his special values in the EHTR organization is his familiarity and close relationships with the people in the highway transportation industry in his area, and the nature of their daily operations.

The Bureau of Public Roads

As the agency designated by the Federal Government to manage highway problems in a national emergency, the Bureau of Public Roads is responsible for providing leadership, guidance, and coordination in the planning and organization of EHTR operations. Its function essentially is to plan a basic framework and assist the States in creating and developing their own EHTR organizations and operating plans. In this activity, Public Roads has sought to work jointly and cooperatively with the State highway departments, the police, and the highway users, through their national associations. As State plans are developed, it is Public Roads responsibility to see that they are harmoniously coordinated.

In an actual emergency, the Bureau of Public Roads would provide coordination between States, where needed, and conciliate problem-creating differences in emergency regulations or operating techniques.

Civil-defense agencies

The State and local civil defense agencies have overall responsibility for advance planning and for operation in an emergency. All emergency highway traffic regulation planning should therefore be coordinated with them, and civil defense representatives should be included as liaison officers on the EHTR staff.

In an emergency, the civil defense agencies will provide much of the radiological information to the

EHTR centers. The EHTR, in turn, will provide all useful information it collects to the civil defense headquarters. The civil defense authorities will be responsible for requesting the designation of class B routes for their own use.

During an emergency, the EHTR organization will look to the civil defense agencies for assistance in the dissemination of information to the public regarding highway conditions and route regulation.

The military establishment

It is Department of Defense policy to leave the operation of highways and their regulation in an emergency to civilian agencies; only in active theaters of operation would the military forces take control Nevertheless, representatives of the military should be consulted regularly in the course of EHTR planning; and, in an emergency, a military liaison officer should be stationed at the State EHTR center and as needed at district and sector centers.

The military will be responsible for requesting the designation of class B routes for their own use, such as convoy movements. In addition, the military may be asked to assist in the manning of control posts on class B routes reserved for military use.

Emergency transportation regulatory agencies

The Federal Office of Emergency Transportation is responsible for developing and coordinating policies and operation of a priority system for transportation in a national emergency. The OET and designated transportation agencies will issue priority certifications for the movement of persons and goods; but such priorities will be for shipments, not specific vehicles or trips. The producers, consumers, or shippers holding priorities must apply to the EHTR organization for road space permits. Because of this linkage in operation, the EHTR planning should be coordinated with the transportation agencies concerned.

APPENDIX A

May 6, 1963

Honorable George C. Wallace
Governor of Alabama
Montgomery, Alabama

Dear Governor Wallace:

Executive Order 10999 issued by the President February 16, 1962, assigned certain emergency preparedness functions to the Department of Commerce. The Bureau of Public Roads, of the Department of Commerce, has certain assigned responsibilities relating to highway traffic control problems during an emergency. In exercising these responsibilities, the Federal Highway Administrator has encouraged State highway departments to develop emergency highway traffic regulation plans as part of a national highway traffic regulation program. To be as effective as possible, this program requires teamwork between State highway departments, police, and certain emergency transportation organizations and organized groups of highway users.

Recently the Federal Highway Administrator enlisted the assistance of the National Highway Users Conference to aid in the development of emergency highway traffic regulation plans. The Conference, through its Alabama Highway Users Conference affiliate, stands ready to organize highway user groups to carry out their part of the work in cooperation with the State highway department and other State agencies concerned.

The Interstate Commerce Commission informs me that participation of the Alabama Highway Users Conference in assisting with highway traffic regulation would not be in conflict with the work to be done by the ICC Motor Carrier Board. I have been assured by the Office of Emergency Planning, of the Executive Office of the President, that the use of the membership of the National and State Highway Users Conferences would be consistent with the National Plan. Planning and organization such as in the subject field of highway traffic regulation is, in fact, an essential element of and contributory to the overall readiness planning effort by Federal and State authorities.

A representative of the Alabama Highway Users Conference will seek a conference with the Chief Administrative Officer of the State highway department in the near future to discuss this matter leading to the preparation of appropriate documentation for your signature should you agree to recognize the Alabama Highway Users Conference as the duly authorized agency of the State to perform the highway user group functions in this cooperative effort.

It is, of course, recognized that the Governor of each State decides which agency in the State should organize highway users, and that any agency assigned such responsibility must be duly authorized by him. However, the Federal Highway Administrator and I hope that you will find it advantageous to recognize user groups as the designated and duly authorized groups empowered to allocate road space as necessary to meet certain transportation priorities in the event of emergency.

In the event you recognize the Alabama Highway Users Conference as your duly authorized agency, it would have the responsibility of organizing highway users who would perform several functions. One function is to claim space on such highways as may have to be subjected to regulation. A second function is the issuance of permits, which would be consistent with and based on decisions by authorized Federal and/or State agencies as to transportation allocations and/or transportation priorities. A third function is to develop plans for utilization of space on regulated highways. These functions would be performed in cooperation with highway departments and police organizations. The user groups would be prepared to implement these plans in a national emergency.

Sincerely,

Clarence D. Martin, Jr.

Similar letters sent as per list attached with the exception Alaska, Hawaii, Florida and Puerto Rico.

Honorable George C. Wallace - Governor of Alabama
Honorable Paul Fannin - Governor of Arizona
Honorable Orval Faubus - Governor of Arkansas
Honorable Edmund G. Brown - Governor of California
Honorable John A. Love - Governor of Colorado
Honorable John N. Dempsey - Governor of Connecticut
Honorable Elbert N. Carvel - Governor of Delaware
~~Honorable Farris Bryant - Governor of Florida~~
Honorable Carl Sanders - Governor of Georgia
Honorable Robert E. Smylie - Governor of Idaho
Honorable Otto Kerner - Governor of Illinois
Honorable Matthew E. Welsh - Governor of Indiana
Honorable Harold E. Hughes - Governor of Iowa
Honorable John Anderson, Jr. - Governor of Kansas
Honorable Bert T. Combs - Governor of Kentucky
Honorable Jimmie H. Davis - Governor of Louisiana
Honorable John H. Reed - Governor of Maine
Honorable J. Millard Tawes - Governor of Maryland
Honorable Endicott Peabody - Governor of Massachusetts
Honorable George Romney - Governor of Michigan
Honorable Karl Rolvaag - Governor of Minnesota
Honorable Ross R. Barnett - Governor of Mississippi
Honorable John M. Dalton - Governor of Missouri
Honorable Tim M. Babcock - Governor of Montana
Honorable Frank B. Morrison - Governor of Nebraska
Honorable Grant Sawyer - Governor of Nevada
Honorable John W. King - Governor of New Hampshire
Honorable Richard J. Hughes - Governor of New Jersey
Honorable Jack M. Campbell - Governor of New Mexico
Honorable Nelson A. Rockefeller - Governor of New York
Honorable Terry Sanford - Governor of North Carolina
Honorable William L. Guy - Governor of North Dakota
Honorable James A. Rhodes - Governor of Ohio
Honorable Henry Bellmon - Governor of Oklahoma
Honorable Mark O. Hatfield - Governor of Oregon
Honorable William W. Scranton - Governor of Pennsylvania
Honorable John H. Chafee - Governor of Rhode Island
Honorable Donald Russell - Governor of South Carolina
Honorable Archie M. Gubbrud - Governor of South Dakota
Honorable Frank G. Clement - Governor of Tennessee
Honorable John Connally - Governor of Texas
Honorable George Dewey Clyde - Governor of Utah
Honorable Philip H. Hoff - Governor of Vermont
Honorable Albertis S. Harrison, Jr. - Governor of Virginia
Honorable Albert D. Rosellini - Governor of Washington
Honorable William W. Barron - Governor of West Virginia
Honorable John W. Reynolds - Governor of Wisconsin
Honorable Cliff Hansen - Governor of Wyoming

APPENDIX B

EXECUTIVE ORDER

10999

ASSIGNING EMERGENCY PREPAREDNESS FUNCTIONS TO THE SECRETARY OF COMMERCE

By virtue of the authority vested in me as President of the United States, including authority vested in me by Reorganization Plan No. 1 of 1958 (72 Stat. 1799), it is hereby ordered as follows:

Section 1. Scope. The Secretary of Commerce (hereinafter referred to as the Secretary) shall prepare national emergency plans and develop preparedness programs covering:

(a) Development and coordination of over-all policies, plans, and procedures for the provision of a centralized control of all modes of transportation in an emergency for the movement of passenger and freight traffic of all types, and the determination of the proper apportionment and allocation of the total civil transportation capacity, or any portion thereof, to meet over-all essential civil and military needs.

(b) Federal emergency operational responsibilities with respect to: highways, roads, streets, bridges, tunnels, and appurtenances; highway traffic regulation; allocation of air carrier aircraft for essential military and civilian operations; ships in coastal and intercoastal use and ocean shipping, ports and port facilities; and the Saint Lawrence Seaway; except those elements of each normally operated or controlled by the Department of Defense.

(c) The production and distribution of all materials, the use of all production facilities, the control of all construction materials, and the furnishing of basic industrial services except the following:

(1) Production and distribution of and use of facilities for petroleum, solid fuels, gas, and electric power;

(2) Production, processing, distribution and storage of food resources and the use of food resource facilities for such production, processing, distribution, and storage;

(3) Domestic distribution of farm equipment and fertilizer;

(4) Use of communications services and facilities, housing, and lodging facilities, and health and welfare facilities;

(5) Production, and related distribution, of minerals defined as all raw materials of mineral origin (except petroleum, gas, solid fuels, and source materials as defined in the Atomic Energy Act of 1954, as amended) obtained by mining and like operations and processed through the stages specified, and at the facilities designated in an agreement between the Secretary of Commerce and the Secretary of the Interior as being within the emergency preparedness responsibilities of the Secretary of the Interior, and the construction and use of facilities designated as within the responsibilities of the Secretary of the Interior;

(6) Distribution of items in the supply systems of, or controlled by the Department of Defense and the Atomic Energy Commission, and

(7) Construction and use of civil aviation facilities.

(d) Fallout forecasting based on current weather data.

(e) Collection and reporting of census data for emergency planning purposes.

These plans and programs shall be designed to develop a state of readiness in those areas with respect to all degrees of national emergency, including attack upon the United States.

Sec. 2. Transportation Planning and Coordination Function. The Secretary shall develop long range programs designed to integrate the mobilization requirements for movement of all forms of commerce with all forms of national and international transportation systems including air, ground, water, and pipelines, in an emergency; more particularly he shall:

(a) Resources and requirements. Obtain, assemble, analyze, and evaluate data on the requirements of all claimants for all types of civil transportation to meet the needs of the military and of the civil economy. Consolidate, evaluate, and interpret both current and projected resources and requirements data developed by all Federal agencies concerned with moving passengers or cargo by all modes of transportation for the purpose of initiating actions designed to stimulate government and industry actions to improve the peacetime structure of the transportation system for use in an emergency.

(b) Economic projections. Conduct a continuing analysis of transportation problems and facilities in relation to long range economic projections for the purpose of recommending incentive and/or regulatory programs designed to bring all modes of transportation in balance with each other, with current economic conditions, projected peacetime conditions, and with emergency conditions.

(c) Passenger and cargo movement. Develop plans and procedures which would provide for the central collection and analysis of passenger and cargo movement demands of both shipper and user agencies as they relate to the capabilities of various transport modes in existence at the time, control or delegate control of the priority of movement of passengers and cargo for all modes of transportation by mode or within a mode and develop policies, standards and procedures for emergency enforcement of controls through the use of means such as education, incentives, embargoes, permits, sanctions, claimancy policies, etc.

(d) Emergency transportation functions. In consonance with plans developed by other agencies assigned operational responsibilities in the transportation program, develop plans for and be prepared to provide the administrative facilities for performing emergency transportation functions when required by the President.

Sec. 3. Transportation Operations Planning Functions. The Secretary shall develop plans and procedures in consonance with international treaties and in cooperation with other Federal agencies, the States and their political subdivisions to:

(a) Highways and streets. Adapt and develop highway and street systems to meet emergency requirements and provide procedures for their repair, restoration, improvement, revision and use as an integral part of the transportation system in an emergency.

(b) Ocean shipping and ports. To plan for the operation and control of Federal activities concerned with:

(1) Shipping allocation. Allocation of merchant shipping to meet the national requirements including those for military, foreign assistance, and emergency procurement programs, and those essential to the civilian economy. The term "merchant shipping" and the term "ocean shipping" as used herein include all coastwise and intercoastal, and Great Lakes shipping except that solely engaged in the transportation of passenger and cargo between United States ports.

(2) Ship acquisition. Provision of ships for ocean shipping by purchase, charter, or requisition, by breakout from the national defense reserve fleet, and by construction.

(3) Operations. Operation of ocean shipping directly or indirectly.

(4) Traffic control. Provision for the control of traffic through port areas to assure an orderly and continuous flow of such traffic. The term "port area(s)" as used herein includes any zone contiguous to or associated in the traffic network of an ocean or Great Lakes port, or outport location, including beach loading sites, within which facilities exist for the transshipment of persons and property between domestic carriers and carriers engaged in coastal, intercoastal, and overseas transportation.

(5) Traffic priority. Administration of priorities for the movement of traffic through port areas.

(6) Port allocation. Allocation of available ports and port facilities to meet the needs of the Nation and our allies. The term "port facilities" as used herein includes all port facilities (including the Great Lakes), port equipment including harbor craft, and port services normally used in accomplishing the transfer or interchange of cargo and passengers between ocean-going vessels and other media of transportation or in connection therewith.

(7) Support activities. Performance of supporting activities needed to carry out the above functions, such as: ascertaining national requirements for ocean shipping including those for military and other Federal programs and those essential to the civilian economy; maintenance, repair, and arming of ships; recruitment, training, and assignment of officers and seamen; procurement, warehousing, and issuance of ships' stores, supplies, equipment, and spare parts; supervision of stevedoring and bunkering; management of terminals, shipyards, and other facilities; and maintenance, restoration, and provision of port facilities.

(c) Air carrier civil air transportation. Develop plans for a national program to utilize the air carrier civil air transportation capacity and equipment, both domestically and internationally, in a national emergency, particularly in the following areas concerned with:

(1) Requirements. Obtaining from the Department of Defense, Civil Aeronautics Board, or other agencies, and analyzing requirements for the services of air carrier aircraft for essential military and civilian use.

(2) Allocation. Allocation of air carrier aircraft to meet the needs of the Department of Defense for military operations and the Civil Aeronautics Board for essential civilian needs.

Sec. 4. Production Functions. Within the areas designated in section 1(c) hereof, the Secretary shall:

(a) Requirements. Periodically assemble, develop as appropriate, and evaluate estimated requirements for assigned resources and services taking into account the estimated needs for military, civilian, and foreign purposes. Such evaluation shall take into consideration geographical distribution of requirements in an emergency.

(b) Resources. Periodically assess assigned resources available from all sources in order to estimate availability under an emergency situation, analyze resource estimates in relation to estimated requirements in order to identify problem areas, and develop appropriate recommendations and programs including those necessary for the maintenance of an adequate mobilization base. Provide data and assistance before and after attack for national resource evaluation purposes of the Office of Emergency Planning.

(c) Priorities and allocations. Develop priorities, allocation, production, and distribution control systems, including provisions for other Federal departments and agencies, as appropriate, to serve as allotting agents for materials made available under such systems for construction and operation of facilities assigned to them.

(d) New construction. Develop procedures by which new production facility construction proposals will be reviewed for appropriate location in the light of such area factors as locational security, availability of labor, water, housing, and other requirements.

(e) Industry evaluation. Identify and rate those products and services, and their producing or supporting facilities, which are of exceptional importance to mobilization readiness, national defense, or post-attack survival and recovery.

(f) Production capability. Analyze potential effects of attack on actual production capability, taking into account the entire production complex including shortages of resources, and conduct studies as a basis for recommending pre-attack measures that would strengthen capabilities for post-attack production.

(g) Stockpiles. Assist the Office of Emergency Planning in formulating and carrying out plans for stockpiling of strategic and critical materials, and essential survival items.

(h) Essential activities. Maintain lists of activities essential to defense production and to minimum requirements of the civilian economy, such lists to be used in conjunction with lists of critical occupations.

(i) Financial aid. Develop plans and procedures for financial aids and incentives, including credit assistance to producers, processors, and distributors of those industries included in section 1(c) hereof, who might need such assistance in various mobilization conditions, particularly those resulting from attack.

(j) Salvage and rehabilitation. Develop plans for the salvage of stocks and rehabilitation of assigned products and facilities after attack.

Sec. 5. Economic Stabilization. The Secretary shall cooperate with the Office of Emergency Planning in the development of suitable economic stabilization measures providing continuing guidance to the States, their political subdivisions, manufacturers, processors, and the public on the use and conservation of essential commodities in an emergency including rationing.

Sec. 6. Cooperation with Department of Defense. In consonance with national civil defense plans, programs, and operations of the Department of Defense under Executive Order No. 10952, the Secretary shall:

(a) Facilities protection. Provide industry protection guidance materials adapted to the needs of assigned facilities and promote a national program to stimulate disaster preparedness and control in order to minimize the effects of overt or covert attack, and to maintain continuity of production and capacity to serve essential users in an emergency. Guidance shall include, but not be limited to, organizing and training facility personnel, personnel shelter, evacuation plans, records protection, continuty of management, emergency repair, deconcentration or dispersal of critical facilities, and industrial mutual aid associations for emergency.

(b) Public roads control. Develop plans for a national program, in cooperation with all Federal, State and local government units or other agencies concerned, for technical guidance to States and direction of Federal activities relating to highway traffic control problems which may be created during an emergency; and plans for barricading and/or marking streets and highways, leading into or out of restricted fallout areas, for the protection of the public by external containment of traffic through hazardous areas.

(c) Weather function. Prepare and issue currently, as well as in an emergency, forecasts and estimates of areas likely to be covered by fallout in event of attack and make this information available to the Federal, State, and local authorities for public dissemination.

(d) Monitoring. Provide for the detection, identification, monitoring, and reporting of chemical, biological and radiological agents at facilities operated or controlled by the Department of Commerce.

(e) Damage assessment. Maintain a capability to assess the effects of attack on assigned resource areas and departmental installations, both at national and field levels, and provide data to the Department of Defense.

Sec. 7. Claimancy. The Secretary shall prepare plans to claim supporting materials, manpower, equipment, supplies and services which would be needed to carry out assigned responsibilities and other essential functions of the Department from the appropriate agency and shall work with such agencies in developing programs to insure availability of such resources in an emergency.

Sec. 8. Census Data. The Secretary shall provide for the collection and reporting of census information on the status of human and economic resources including population, housing, agriculture, manufacture, mineral industries, business, transportation, foreign trade, construction, and governments, as required for emergency planning purposes.

Sec. 9. Research. Within the framework of Federal research objectives, the Secretary shall supervise or conduct research in areas directly concerned with carrying out his emergency preparedness responsibilities, designate representatives for necessary ad hoc or task force groups, and provide advice and assistance to other agencies in planning for research in areas involving the Department's interest.

Sec. 10. Functional Guidance. The Secretary, in carrying out the functions assigned in this order, shall be guided by the following:

(a) Interagency cooperation. The Secretary shall assume the initiative in developing joint plans for the coordination of transportation and production programs which involve other departments and agencies which have responsibilities for any segment of such activities. He shall utilize to the maximum those capabilities of other agencies qualified to perform or assist in the performance of assigned functions by contractual or other agreements.

(b) Presidential coordination. The Director of the Office of Emergency Planning shall advise and assist the President in determining policy for, and assist him in coordinating the performance of functions under this order with the total national preparedness program.

(c) Emergency planning. Emergency plans and programs, and emergency organization structure required thereby, shall be developed as an integral part of the continuing activities of the Department of Commerce on the basis that it will have the responsibility for carrying out such programs during an emergency. The Secretary shall be prepared to implement all appropriate plans developed under this order. Modifications and temporary organizational changes, based on emergency conditions, will be in accordance with policy determination by the President.

Sec. 11. Emergency Actions. Nothing in this order shall be construed as conferring authority under Title III of the Federal Civil Defense Act of 1950, as amended, or otherwise, to put into effect any emergency plan, procedure, policy, program, or course of action prepared or developed pursuant to this order. Such authority is reserved to the President.

Sec. 12. Redelegation. The Secretary is hereby authorized to redelegate within the Department of Commerce the functions hereinabove assigned to him.

Sec. 13. Prior Actions. To the extent of any inconsistency between the provisions of any prior order and the provisions of this order, the latter shall control. Emergency Preparedness Order No. 2 (heretofore issued by the Director, Office of Civil and Defense Mobilization) (26 F.R. 653-654), is hereby revoked.

JOHN F. KENNEDY

THE WHITE HOUSE,

February 16, 1962.

Title 32A—NATIONAL DEFENSE, APPENDIX

Chapter IX—Bureau of Public Roads, Department of Commerce

[BPR Order Thm-1]

HIGHWAY TRAFFIC REGULATION

A new Chapter IX, headed Bureau of Public Roads, Department of Commerce, is added to Title 32A to include BPR Order Thm-1—Highway Traffic Regulation, set forth below.

Sec.
1 Purpose.
2 Definitions.
3 Regulation of motor vehicle traffic on highways.
4 Establishing alternate highways.
5 Applicability.
6 Effective date.

AUTHORITY: Secs. 1 to 6 issued under sec. 401, 64 Stat. 1254, as amended; 50 U.S.C. App. 2253. Interpret or apply sec. 201, 64 Stat. 1248, as amended; 50 U.S.C. App. 2281, E.O. 10219, 16 F.R. 1983, 3 CFR 415; E.O. 10902, 26 F.R. 217; E.O. 10952, 26 F.R. 6577; E.O. 10999, 27 F.R. 1527.

Section 1. Purpose.

It is deemed necessary in the public interest and to promote the national safety and defense during the existence of a state of civil defense emergency to regulate, allocate, and promote the availability and use of all highways within the United States.

Sec. 2. Definitions.

The following terms when used in sections 1 to 6 have the following meanings:

(a) "Administrator" means the Federal Highway Administrator.

(b) "Civil defense emergency" means such emergency situations when proclaimed by the President of the United States or by concurrent resolution of the Congress, if the President in such proclamation, or the Congress in such resolution finds that an attack upon the United States has occurred or is anticipated.

(c) "Highways" includes all public roads, streets, bridges, tunnels, and appurtenances, including the entire area within the right of way.

Sec. 3. Regulation of motor vehicle traffic on highways.

(a) From and during the existence of a state of civil defense emergency, the Administrator, where he considers such action to be necessary, shall regulate motor vehicle traffic using the highways in such a manner as to facilitate the movement of priority motor vehicle transportation of persons and property, including motor carriers licensed or authorized to transport persons or property in over-the-road service.

(b) The regulation of motor vehicle traffic as provided for in paragraph (a) of this section may be administered by delegation through such agencies of the Federal, State and local governments as the Administrator may designate.

Sec. 4. Establishing alternate highways.

To assure availability of alternate highways to accommodate traffic, the regulation of which is provided under section 3, the Administrator shall utilize all available highways deemed safe for travel.

Sec. 5. Applicability.

The provisions of this regulation shall be applicable throughout the United States and the Commonwealth of Puerto Rico.

Sec. 6. Effective date.

This order is effective during the existence of a state of civil defense emergency proclaimed by the President of the United States or by concurrent resolution of the Congress and when so directed by or on behalf of the Administrator or in the absence of such specific direction immediately upon occurrence of a national emergency due to enemy attack.

Dated: March 14, 1962.

Recommended:

REX M. WHITTON,
Federal Highway Administrator.

Issued:

LUTHER H. HODGES,
Secretary of Commerce.

[F.R. Doc. 62-2755; Filed, Mar. 21, 1962; 8:43 a.m.]

U.S. DEPARTMENT OF COMMERCE — BUREAU OF PUBLIC ROADS

POLICY AND PROCEDURE MEMORANDUM

June 25, 1962

50-7

HIGHWAY TRAFFIC REGULATION

SUPERSEDED ISSUANCES

EPM 50-1 dated June 1, 1960, and IM 50-1-61 dated July 3, 1961

1. PURPOSE

The purpose of this memorandum is to set forth responsibilities, policies and procedures relating to highway traffic regulation in a national emergency.

2. AUTHORITY

a. Executive Order No. 10999 assigns to the Department of Commerce highway traffic regulation and control responsibilities during a national emergency.

b. Department Order No. 160 delegates to the Bureau of Public Roads all highway functions assigned to the Department of Commerce relating to civil defense and defense mobilization.

c. Annex 12 to the National Plan for Civil Defense and Defense Mobilization, entitled "Directed Movement," issued by Office of Civil and Defense Mobilization provides that the Bureau of Public Roads will direct and coordinate development and execution of the national directed movement program for highways in cooperation with all State and Federal Government units or other agencies concerned.

3. EFFECTIVE DATE

The operational aspects of Highway Traffic Regulation described in paragraphs 6, 7, and 8 are effective when so directed by or on behalf of the Federal Highway Administrator or in the absence of such specific instruction, immediately upon occurrence of a national emergency due to enemy attack.

4. SCOPE

a. Highway traffic regulation as used herein is a system which facilitates orderly flow of traffic under a national emergency situation including but not limited to evacuation, regulation of movement through dangerous areas and clearance of priority traffic over routes of limited capacity. It is a function requiring participation and teamwork of highway department and police working in close association with emergency transportation organizations and organized highway users. Highway traffic regulation centers, established at State and district levels and highway traffic sectors established at county, city, or metropolitan area levels, will determine how the highway network is to be operated, and allocate road space as necessary to meet movement priorities and precedence established by emergency transportation organizations.

b. Operational readiness requires establishment of a highway traffic regulation organization in peacetime to insure accomplishment of necessary plans and coordination that will permit, in time of national emergency, the completion of essential highway movements with maximum efficiency. The highway traffic regulation operations should be decentralized to the maximum extent consistent with the attainment of the overall objectives.

c. Implementation and direction of highway traffic regulation will be exercised on routes only where and so long as traffic demand exceeds traffic capacity and in restricted areas on routes where and so long as highway users must be protected from exposure to radiological or other hazards resulting from use of modern weapons.

d. Military assistance to civil authorities in a civil defense emergency will be rendered by the military departments and agencies of the Department of Defense when such assistance is requested or directed in accordance with Public Law 920, 81st Congress, and Executive Order 10346, April 10, 1952. Such assistance will not be undertaken by the military departments and agencies of the Department of Defense without the above-cited authority unless:

(1) The overruling demands of humanity compel immediate action to prevent starvation, extreme suffering, and property loss, or

(2) Local resources available to State and municipal authorities are clearly inadequate to cope with the situation.

e. Responsibilities for highway traffic regulation will extend into theatres of operation (areas in which active military operations are in progress) when such is the desire of the military commander.

5. ADVANCE PLANNING

Each State highway department should prepare a detailed plan for the implementation of highway traffic regulation which will conform to the general procedures set forth in this memorandum. Each such plan is to be submitted through channels to the Public Roads Washington office for approval, following which it should be incorporated into State emergency plans.

6. ORGANIZATION

a. Highway traffic regulation centers will be operating agencies staffed with personnel from highway and police departments and liaison representatives from emergency transportation organizations and organized highway users. Highway traffic regulation centers in turn will direct activities of highway traffic regulation sectors and highway traffic regulation posts along the highway network. (See recommended organizational framework, exhibit 1.) The organization is to be developed in such a manner that the identity of State agencies, e. g., State highway or police departments is maintained. Coordinated planning between adjoining States is essential.

b. In anticipation of highway traffic regulation activities extending over a period of many months following an attack, the State highway department should establish highway traffic regulation centers at State and State highway department district level and arrange for subordinate traffic regulation sectors at county, city, or metropolitan area level as required. Traffic regulation sectors should normally be staffed by county or city highway and police personnel.

c. Highway traffic regulation boundaries at district level should coincide with district boundaries of State highway departments to the extent practical in view of the postattack situation. Jurisdiction of a sector should be prescribed by the State highway department district engineer or official in charge of the district highway traffic regulation center.

d. Interstate problems should normally be resolved by cooperative action of highway traffic regulation centers of adjoining State at either district or State level. Special problems which cannot be so resolved should be referred to the Bureau of Public Roads.

e. When operating adjacent to an area under military jurisdiction, highway traffic regulation centers will coordinate operations with those of military highway traffic regulation units. Liaison will normally be effected through the staff transportation officer of the field commander having jurisdiction over the area.

f. For evacuation and postattack relocation purposes, a highway traffic regulation sector at metropolitan area level should be established.

7. PROCEDURES

a. <u>Inventory of highway network</u>

(1) In order to make most efficient use of the surviving highway network it will be necessary to identify and evaluate the availability and the capacity restrictions of the highway routes as a result of bomb blast and radioactive fallout or other hazards.

(2) State situation maps should be prepared at the State highway traffic regulation center showing radiation intensity on the principal highway routes as identified by the States in response to PPM 50-6.1. Likewise, district highway traffic regulation centers and

sector centers should prepare district, county or city situation maps showing radiation intensity on important routes within their jurisdictional areas. Points on these routes shall be identified as follows:

H+1 - 100 roentgens/hr. (safe for travel at D+1)
H+1 - 375 roentgens/hr. (safe for travel at D+30)
H+1 - 750 roentgens/hr. (safe for travel at D+90)

Physical damage to route sections not required to be closed because of radioactive fallout should also be identified.

b. Evaluation and selection of main supply routes

(1) Highway capacity and payload tonnage capability to support essential movements will be determined for the available highway network in each district highway traffic regulation center and sector center and emergency transportation organization will be kept fully informed on these matters.

(2) On uncongested routes where traffic does not need to be regulated, 24-hour highway capacity will be determined whenever needed by using the information shown in the Highway Capacity Manual. Payload tonnage capability for supply operation will be determined by breaking down the percentage of trucks by vehicle types and applying appropriate average payload factors.

(3) On congested routes, on routes required for crash movements or on routes that may have to accommodate trucks primarily over extended periods of time, 24-hour highway capacity and payload tonnage capability will be determined by the "Highway Capability Estimating Guide," Department of Army Field Manual 55-54, June 1959, developed jointly by a committee with representation from the Department of Defense, the Bureau of Public Roads and intelligence agencies.

(4) On the basis of the payload tonnage capabilities of the routes and the requirements of the user groups main and alternate supply routes will be designated to serve the large centers of traffic generation. If more than one route between centers is available one-way movement of traffic to and from the centers may result in the most efficient operation. Benefits of one-way operation of routes must be carefully weighed against the added requirement for administrative implementation.

(5) Priority for restoration and maintenance operations will be determined by the selection of main and alternate supply routes. In this respect highway traffic regulating centers will maintain liaison with the construction and maintenance forces.

(6) Periodic traffic counts will be made on the main supply routes to determine whether the traffic volume is approaching capacity of the route. As capacity is reached measures should be implemented to insure the movement of essential traffic. If such counts show that the traffic is not being effectively distributed over the 24-hour day the need for corrective action should be brought to the attention of the using groups.

(7) Route information for highways limited to essential movements of specific users and for highways in restricted areas will be disseminated to the highway users through various media including automobile associations, oil companies, press, radio, television and periodic condition maps.

c. Traffic regulation

(1) Standard traffic regulation measures used in peacetime will continue to be used in periods of emergency. Of necessity, certain modifications will have to be made and the requirement for enforcement will be greater than normal.

(2) Signing of routes through restricted and unrestricted areas will be in accordance with the Manual of Uniform Traffic Control Devices and the Bureau of Public Roads special sign standards for the emergency regulation of traffic.

(3) Maximum speeds will be prescribed in keeping with the local highway conditions and the development of maximum highway capacity. In some cases, minimum speeds will be

prescribed for radiological areas to reduce the radiation dosage to the driver and other occupants of the vehicle and to develop maximum capacity.

(4) The type of movement generally will be unscheduled except on routes so congested that only essential priority traffic can move. When convoy movements and special movements of high security cargo must be introduced into the traffic stream they will be scheduled at appropriate intervals to insure they have a minimum effect on the capacity of the route.

(5) When movement over a route must be limited to priority traffic special control of vehicles will be necessary. Road space will be allocated to using agencies within priorities established by emergency transportation agencies but care must be exercised to insure that capacity is not wasted. Users will normally retain responsibility for assigning priorities within their groups and will accomplish dispatching as necessary. Permits will be issued on basis of mission of the vehicle on a particular trip and not on the basis of ownership or general usage. Since convoys reduce the possible capacity of a route their use will be discouraged. Where convoys are necessary they should not exceed 15 vehicles in a single element. For adequate control and operation 4 to 8 vehicles are preferable.

(6) Close coordination between the State highway departments and the State and local police agencies will be maintained to insure the necessary patrol of routes, wrecker and escort service, direction of traffic and the required enforcement giving due regard to limitations in such activities because of radiation and other unusual hazards.

(7) Where traffic must move in or through contaminated areas State or district highway traffic regulation centers will select a minimum number of routes. Traffic will be carefully regulated on these routes. All other routes will be denied to traffic and will be posted and/or barricaded. The basic criteria in operating routes through radiologically contaminated restricted areas is that people in transit should be exposed to no more than an average of 0.4 roentgens per day over the first year. Highway traffic regulation post personnel stationed at the edge of restricted areas will inform vehicle occupants of the radiological dosage they will accumulate in transit. They will also arrange for prompt evacuation of any stranded motorists.

(8) Highway traffic regulation posts will be located at strategic locations on the networks in areas safe from radiological or other unusual hazards. Personnel at these posts will permit the passage of authorized traffic only, will check and report on status of movements, and will request instructions from the appropriate highway traffic regulation center for diversion of movements when congestion develops. Once the daily schedules for road space have been established it is the responsibility of the post personnel to see that the schedules are strictly followed by the using groups.

(9) Procedures for selection and operation of highway traffic regulation posts will be developed jointly by the State highway department and State police.

d. Highway traffic regulation priority permit

(1) Under provisions of OCDM Annex 12 to the National Plan for Civil Defense and Defense Mobilization, "Directed Movement," the Bureau of Public Roads is responsible for developing a uniform nationwide system for identifying and recognizing vehicles having priority missions on routes subject to highway traffic regulation.

(2) The form of a priority permit developed by the Bureau of Public Roads and now having formal concurrence of OEP and the Department of Defense is shown in exhibit 2.

(3) For road users making long trips involving travel over more than one regulated route, one permit will ordinarily be issued for each regulated route traversed. A regulated route is a section of a single highway or any combination of sections of different highways providing a continuous path of travel, the entire length of which has been made subject to highway traffic regulation. Each regulated route will be assigned an identifying number or letter (or both) at the time regulated

routes are established as the result of an emergency situation. Since most highway trips are short, road users will usually be issued single permits only. The route number appears as the most prominent item on the permit for possible use on the windshield in the kind of a situation where such display is desirable. The time of day and the number of vehicles (in case of convoy operation) appear at the edges of the form to permit use of punches, tearing off inapplicable portions, or simply marking out inapplicable portions. On the back of the form is printed the penalty for misuse. Permits are to be printed with serial numbers usually in book form with perforated top. The stub in the book carries the same serial number and includes spaces for recording data as desired by the issuing agency, such as trip origin and destination, number and type of vehicles, owner, commodity, shipment priority, regulated route number, authorized time of passage, etc.

(4) Public Roads and State highway departments should encourage the establishment of emergency transportation agencies at local level with a capability to serve as priority permit issuing agencies. Part V of Directed Movement, Annex 12 of the National Plan, provides that each State government will coordinate work of highway departments, police, and transportation user groups in the development and execution of its directed movement plan on a statewide basis, and that State governments will call upon transportation associations and agencies as necessary to develop and implement activities of the user groups. Also, Part V of Annex 12 provides that local governments, in developing and executing their own directed movement plans will seek the assistance of the transportation industry as necessary to develop and implement those portions of the directed movement plan involving civilian transportation user groups. In our opinion one function of transportation user groups in this three-way cooperative activity should be the issuance of the priority permits.

(5) The Department of Defense has already initiated action to develop a military organization structure which will enable representatives of the military services to function effectively as members of the emergency transportation agencies called for by the plan.

e. Cargo protection

(1) Security of classified or high-priority movements will be provided upon request by State and local police when such security cannot be provided by shippers or carriers. While the highway traffic regulation centers will not have a direct responsibility in this respect, any plan of highway traffic regulation must make allowance for the necessary protective measures.

(2) Liaison with respect to such matters should be maintained by the highway traffic regulation centers with the users and the local and State police agencies who will provide the necessary police protection.

(3) Adequate protection normally can be efficiently obtained by the use of convoys. Such convoys must have priority of movement and be carefully checked through highway traffic regulation posts.

(4) Suitable measures must be taken for adequate protection and security of explosive and/or flammable materials. Standard procedures now in force should be followed when applicable or can be modified to fit the local conditions or new requirements.

f. Size and weight restrictions

(1) Vehicle movements on the routes of the several road systems should not exceed the ability of the routes to provide for sustained movement of traffic. Due consideration must be given to structural capacity, maintenance capabilities, frequency of movement of heavy axle or gross loads and/or oversized loads and traffic volumes of such magnitude that the capacity would be seriously restricted by slow moving vehicles. In many cases roads having structures of limited load capacity can be made available for carrying necessary traffic by strengthening the structures either by temporary or permanent means.

(2) The issuance of special permits for oversized and/or overweight vehicles is a function of the State highway departments or other appropriate State agencies. Except

when there is an overriding civilian or military necessity, permits should be issued only where it is impracticable to transport the material on vehicles within the established weight limitations and the frequency of such loads will not result in damage to the highway facilities or result in excessive maintenance. Movements of oversized vehicles under special permit should have traffic escort where needed to provide for safety of movement and to prevent traffic congestion.

(3) Enforcement activities relating to compliance of traffic to the size and weight limitations are accomplished by the State and local police agencies. These activities should be coordinated as necessary by the State and district highway traffic regulation centers to assure the most efficient movement of essential vehicular traffic.

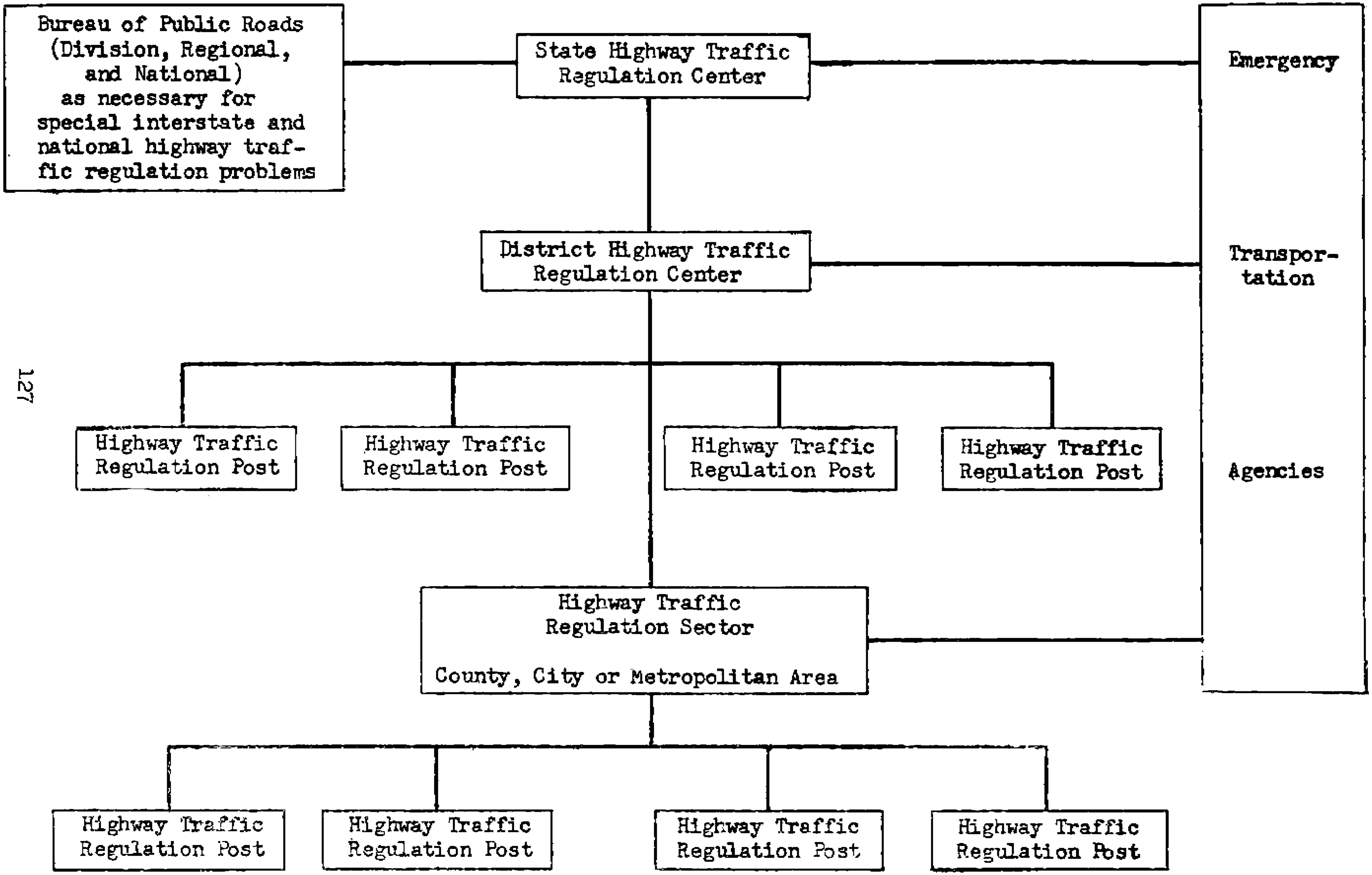
8. REPORTS

During the early period of a national emergency, division engineers of the Bureau of Public Roads will make narrative reports weekly to the regional engineer as to the extent of traffic regulation activities and problems in the State. The regional engineer will forward consolidated reports weekly to the national headquarters. Reports by State highway departments will, until further notice, be limited to those which they find necessary for coordination within the State civil defense organization.

Attachments

Rex M. Whitton
Federal Highway Administrator

RECOMMENDED ORGANIZATION FRAMEWORK



PPM 50-7,
June 25, 1962

No. A 0,000,001

Trip origin ____________________
Trip destination ____________________
Number and type of vehicle ____________________
____
____
Owner ____________________
Commodity ____________________
Shipment priority ____________________
Regulated route number ____________________
Authorized time of entry ____________________
(and/or such other items of information as may be desired by issuing agency)

Issuing Agency ____________________
By ____________________

STUB TO BE RETAINED BY ISSUING AGENCY

← (Perforated line)

Number of vehicles authorized		Time of entry on to Regulated route	
12	No. A 0,000,001	A.M.	12-1
11	Highway directed Movement priority Permit for Regulated route number		1-2
10			2-3
9			3-4
8	22		4-5
7			5-6
6			6-7
5			7-8
4			8-9
3			9-10
2	Issuing Agency ____________________		10-11
1	By ____________________		11-12
		P.M.	12-1
			1-2
			2-3
			3-4
			4-5
			5-6
			6-7
			7-8
			8-9
			9-10
			10-11
			11-12

Valid only on ____________________ 19__

PRIORITY PERMIT TO BE ISSUED

STATEMENT OF PENALTY FOR MISUSE TO BE PRINTED ON BACK OF FORM:

This permit is the property of the United States Government. Its counterfeiting, alteration or misuse is a violation of 18 U.S.C., Section 499 (1948). Violators shall be fined not more than $2,000 or imprisoned not more than five years, or both.

APPENDIX E

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

WASHINGTON D.C. 20235

September 25, 1963

INSTRUCTIONAL MEMORANDUM 50-4-63

32-70

Subject: Emergency Highway Traffic Regulation - Organization of highway users

This memorandum supplements Policy and Procedure Memorandum 50-7. Its purpose is to furnish guidance for organization of highway user groups.

This document is consistent with the guidance contained in applicable Executive Orders and the policies and procedures of the Office of Emergency Planning and has been coordinated with the Office of Emergency Transportation.

The National Highway Users Conference has agreed to assist the Bureau of Public Roads in organization of highway users for participation in highway traffic regulation.

The American Association of State Highway Officials advocates that each State highway department seek acceptance by its Governor of highway user groups organized through efforts of the National Highway Users Conference and its own State Highway Users Conference as the duly authorized user groups to work as partners with the State police and the State highway department in the performance of highway traffic regulation functions.

The Under Secretary of Commerce for Transportation, in whose office is located the Office of Emergency Transportation, has commended to Governors of the several States the services of the State Highway Users Conferences in this organizational effort.

The Bureau of Public Roads looks to the State highway department as the agency of the State having primary responsibility for highway traffic regulation. Activities of highway traffic regulation centers and sectors as described in PPM 50-7 should be under direction of the State highway department, including all activities of organized highway user groups.

Although Section 6 of PPM 50-7 indicates that staffing of State and district highway traffic regulation centers would include merely liaison representatives of organized highway users, recent studies of the problem indicate that there are considerable advantages to locating the entire organized highway user operation within the centers themselves. That same arrangement at sectors seems particularly appropriate.

Emergency highway traffic regulation must recognize and accommodate transportation priorities and allocations established by National and State transportation authorities, military movements, and special civil defense movements.

Highway users, whether organized by State Highway Users Conferences or otherwise, are concerned with handling road space requirements and allotments in such manner as to conform to priorities and allocations established by National and State transportation authorities whenever State highway departments determine that highway capacity is limited.

The Department of Defense has initiated action to develop a military organization to function effectively in presenting its requirements and obtaining necessary road space for military movements.

State civil defense agencies should be invited and encouraged by State highway departments to be represented at State and district highway traffic regulation centers or sectors and to function effectively in presenting requirements and obtaining necessary road space for special civil defense movements, such as removal of survivors from contaminated areas.

The overall organization of highway users for claiming, allotting, and issuing road use permits for space on regulated highways thus involves arranging adequate representation of all classes of users, as necessary, at highway traffic regulation centers and sectors.

Further details concerning highway traffic regulation operating procedures are being developed by the National Highway Users Conference to govern civilian user-group participation and by the Department of Defense to govern military and civil defense participation.

Regulated route designations

The two basic types of highway routes in an emergency are Clear Routes and Regulated Routes. Clear Routes are highway routes or sections without any restrictions or regulations and can be used the same as during normal times. Regulated Routes are selected highway routes which must be controlled by a highway traffic regulation (HTR) organization because of hazardous conditions, special uses or limited capacity. There are three separate classes of Regulated Routes depending upon the reason for their regulation and type of control exercised. Regulated Routes Class A are those highway sections that lie within a radioactive contaminated or other dangerous area and which must be identified and used with special precaution and practice. Regulated Routes Class B are highway sections which are temporarily reserved for a special purpose. This class most often refers to a route reserved specifically for Civil Defense movements and/or military movements. Regulated Routes Class C are highway sections which are determined to have or are expected to have critical capacity restrictions or volume demands and on which all traffic is rigidly controlled by official road use permit at specified times.

The designation of Clear Routes, or Regulated Routes Class A, B, or C will be made by the State highway department.

Such designation will ordinarily be made after consultation with the State police organization which is responsible for enforcement.

Activation of HTR centers and sectors

The State highway department will activate State HTR center upon declaration of a civil defense emergency, or on request of the Federal Highway Administrator, or upon its own finding of need to regulate traffic. As specific routes are designated by the State highway department as regulated routes, it will activate district HTR centers and HTR sectors as necessary. It will staff activated units with its own personnel as it deems appropriate, and arrange appropriate State police representation. It will call upon organized highway user groups to furnish their part of the staff at the State HTR center when activated. It will call upon organized highway user groups to furnish their part of the staff at those district HTR center and HTR sectors which regulate Class C routes.

Military and State civil defense representatives may be furnished as members of the overall organization of highway users at State HTR centers. One or both may constitute the entire highway user staff at HTR district centers or sectors which regulate Class B routes. One or both may be members of the overall highway user organization at HTR district centers or sectors which regulate Class C routes.

In cases where the State highway department elects to activate district HTR centers or sectors for regulation of Class A routes, it will seldom require any highway user representation on the staff, but will ordinarily establish liaison with each user group concerned.

As the changing situation permits regulated routes to revert to clear routes, HTR centers and HTR sectors will release organized highway user representatives no longer needed. HTR centers and sectors will be completely deactivated at the discretion of the State highway department.

Where the activity at a sector does not warrant full-time assignment of State highway department personnel or State police, the State highway department may elect to name one of the highway user representatives as chief of the sector to work under the direction of the Chief of the HTR center who should be a State highway department employee.

Dissemination of information

Dissemination of information to all highway users on the designation and use of regulated routes is important to the success of emergency highway traffic regulation. The State highway departments, State police, and State civil defense public information programs should be used for dissemination of such information, and highway user groups participating in the program should supplement such regular, public information channels. Each highway user participant should keep the group he represents fully informed on the nature of restrictions on use of highways, special practices that must be followed on regulated routes, and the advisability of using alternate routes.

Allotment of space on Regulated Route Class C

Once a Regulated Route Class C is established as prescribed above, the State highway department (normally after consultation with the State police) will first determine the amount and the rate of permissible travel on the route. This will be done at the State or a district HTR center. After the permissible amount of traffic has been determined and before any HTR unit allots use of the space, specific portions must be assigned to the State, district and sector HTR units that control the Class C Route. Travel on any highway route consists of local, intermediate and long distance movements, and the sector, district and State HTR centers are respectively responsible for each of these movements. Therefore, the space available is divided among these units to provide for each of their needs and to prevent excess allotments by any one unit, and overcommitments in total.

For example, on a given Regulated Class C Route it may be determined that 10 percent of the road space will be utilized for interstate and inter-district movements, 20 percent for intersector movements, and 70 percent for sector movements.

The space for long distance movements, interstate or between more than two districts will be controlled and allotted by the organized highway users in the State center. The division of permissible travel for intersector travel (20 percent in the example) or travel within a district or to an adjacent district but between more than two sectors will be allotted among claimants by the organized highway users in the district HTR center. All local traffic, within the immediate sector or to an adjacent sector will be similarly allotted at the sector within the limit of space made available to that sector.

If there is a surplus or shortage of road space at a given HTR unit, the unit may contact the next higher or lower center or sector to attempt to equalize this condition. Day-to-day adjustments will bring the division of space to the various HTR units to optimum levels.

At each HTR center or sector, the road space under its control will then be allotted to road users by the purposes of their trips, the urgency, the cargo, etc. These allotments will be made by the organized highway users at that center or sector and will be applied to all requests by road users.

When one center or sector receives a user request that concerns a Class C Route under the control responsibility of another center or sector, it will pass on this request to the appropriate center or sector.

User requests will normally originate at the local level, i.e. the HTR sector wherein the movement will begin. If it is for a local move or a move terminating in an adjacent sector the sector will handle direct. If the request concerns a longer movement, then it must be passed on to the district or State HTR center. For example, a move across several sectors will be received by the local sector but approved by the district HTR center. A movement across several districts will be received by the local sector but approved by the State HTR center. All requests for a particular class of road users (i.e. motor carrier, petroleum hauler, private automobile, civil defense, military, utility, bus, rural, etc.) will be sorted and summarized by the user representative at the sector serving as claimant for the particular class of user. The sorting operation includes a classification of the requests in accordance with echelon of HTR center or sector having jurisdiction. After agreement is reached by the highway user team operating at any echelon as to the allotment of space that should be made for a particular class of users, the user representatives serving that particular class of users are responsible for seeing that road use permits are properly issued within the approved allotment.

On Regulated Routes Class C all requests by potential users should be recorded on a standard form for uniform processing and to insure completeness of information. In addition, each HTR unit should maintain such records, means, and devices so as to readily have access to the status of their operation and their allotments of permits.

Enclosures - 3

F. C. Turner

F. C. Turner
Assistant Federal Highway Administrator
and Chief Engineer

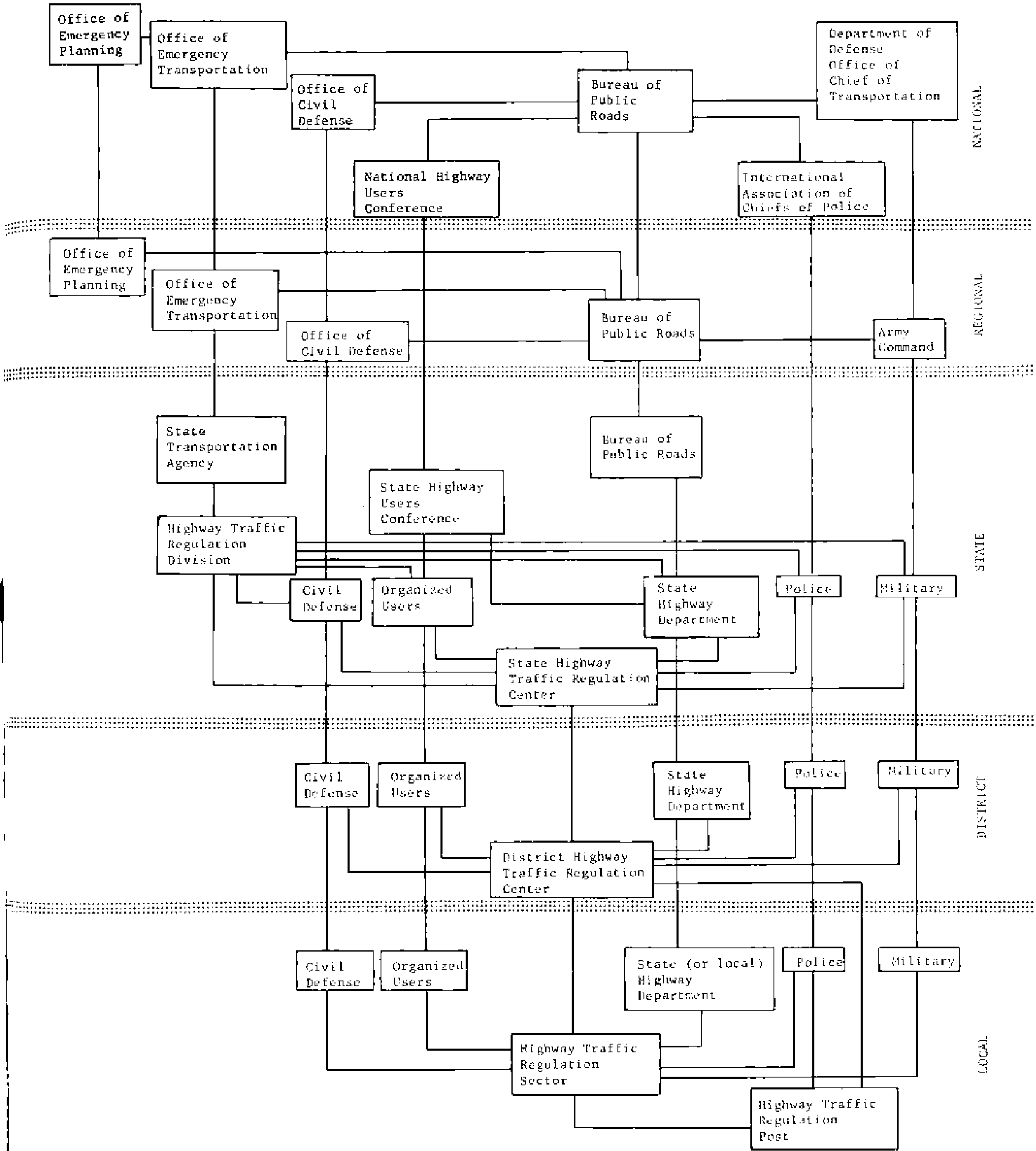
WHEN AND HOW AGENCIES AT STATE LEVEL
PARTICIPATE IN
HIGHWAY TRAFFIC REGULATION

ACTION	WHEN	ACTION AGENCY	AGENCIES CONCERNED	HOW PERFORMED
Activate State HTR Center	CD emergency declared or by direction of Federal Highway Administrator or SHD finds need	SHD	SHD Police OU MIL CD	SHD calls upon agencies to Staff State HTR Center and designates time to report for duty.
Designation of Regulated Routes Classes A, B, or C	Class A: Highly contaminated route open to use under regulation.	SHD	Class A: SHD Police	SHD designates Class A routes on basis of need and evaluation of risk to public and to SHD and Police.
	Class B: Route is reserved for military or CD use.		Class B: SHD Police MIL or CD	SHD designated Class B on basis of military or CD requirements for special movements.
	Class C: Traffic overtaxes capacity.		Class C: SHD Police OU MIL) As CD) necessary	SHD designates Class C routes on basis of need to assure movement of high priority traffic when highway capacity is inadequate to meet total demand.
Activate HTR Posts	Regulated Routes are designated	Police	Police SHD	Police man posts for enforcement and gain support of SHD for erection of signs, etc.
Activate District HTR Centers and Sectors	Operation of regulated routes is required	SHD	Class A: SHD Police Class B: SHD Police MIL or CD Class C: SHD Police OU MIL) As CD) necessary	SHD calls upon agencies to Staff District HTR Centers and designates time to report for duty.
Division of available space on regulated route amongst HTR Centers and sectors for allotment by them	Regulated Routes are first designated and periodically thereafter	SHD	SHD	SHD makes initial division on basis of best judgement of relative numbers of local, intermediate and long distance movements. SHD makes day to day adjustments in division of space as experience develops.
Claim and Allot Road Space	Operation of HTR Center or Sector is Required	OU MIL CD	Class A: Not applicable Class B: MIL or CD Class C: OU MIL) As CD) necessary	Organized users and participating military or CD representatives receive requests from groups they serve, classify such requests and agree upon allotments by classes.
Issue Road use Permits	Immediately following allotment of space	OU MIL CD	OU MIL CD	User representative serving each class of road user arranges for proper issuance of road use within approved allotment.
Deactivate HTR Centers or Sectors	No longer needed	SHD	All who have participated	SHD declares end of need and designates closing time.

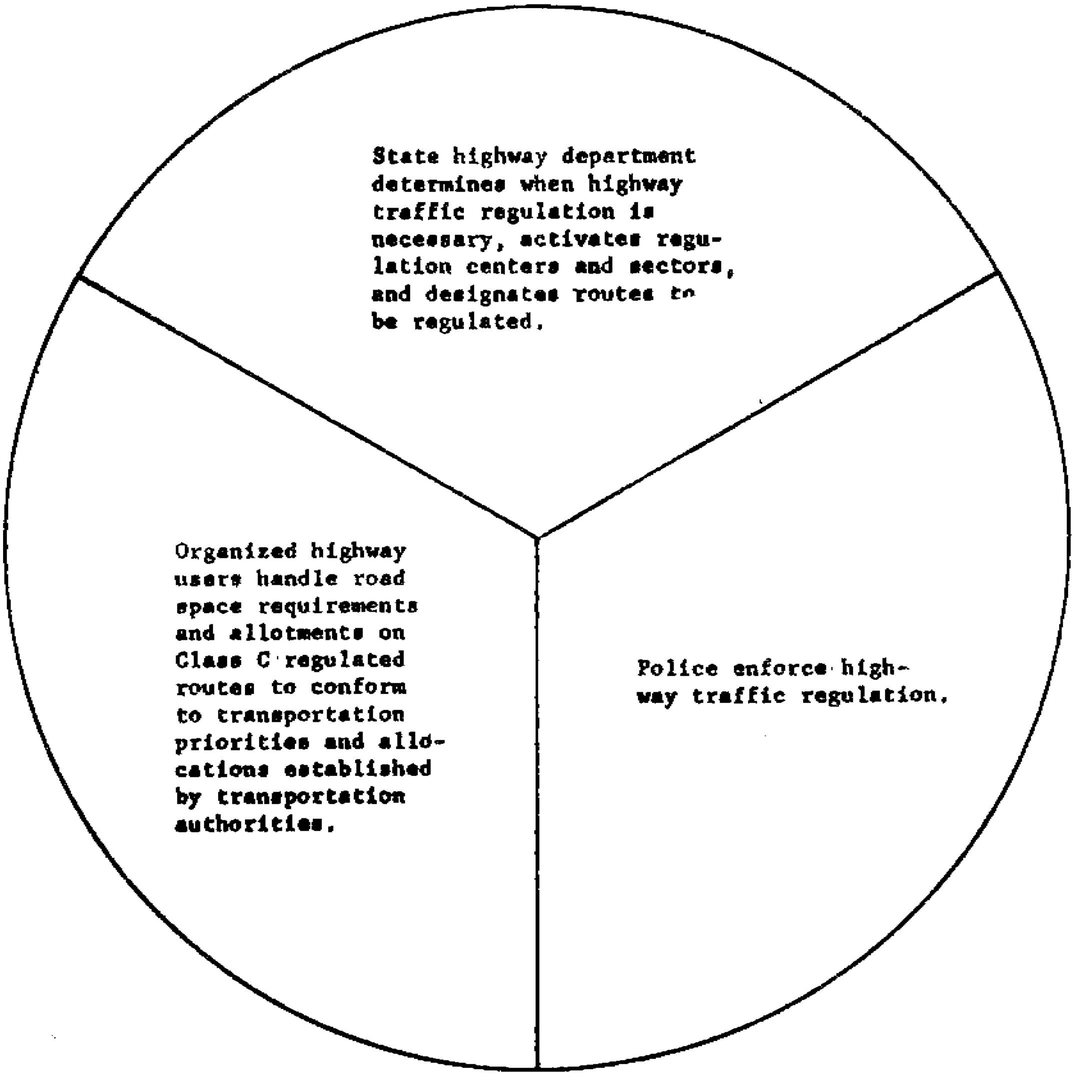
Legend

HTR - Highway Traffic Regulation
SHD - State Highway Department
OU - Organized Users
MIL - Military
CD - Civil Defense

CHANNELS OF COMMUNICATION BETWEEN AGENCIES
PARTICIPATING IN HIGHWAY TRAFFIC REGULATION



THE HIGHWAY TRAFFIC REGULATION TEAM



Attachment 1 to IM 50-4-63

FORM CD-121 (8-23-59)
(PRES. BY A.O. 300-10)

UNITED STATES GOVERNMENT

Memorandum

U.S. DEPARTMENT OF COMMERCE
OFFICE OF THE SECRETARY

TO : Executive Reservists
Office of Emergency Transportation

DATE: October 22, 1963

FROM : E. G. Plowman, Director
Office of Emergency Transportation

SUBJECT: Support of OET Executive Reservists in Development of Highway Traffic Regulation Plans

As you well know, planning by the Office of Emergency Transportation is directed at facilitating postattack movement of persons and cargoes, by all means of transport available. Clearly, a most important facility would be such movement over those highways remaining usable. In order to expedite priority movements over highways, protect the public, and avoid congestion, the Bureau of Public Roads has developed plans for highway traffic regulation in an emergency. (See item on this subject in the July number of the OET-NDER Bulletin)

These plans and procedures have been fully discussed with the Office of Emergency Transportation and have our complete concurrence and approval. There are enclosed two Public Roads documents (PPM 50-7 and IM 50-4-63) in which plans for highway traffic regulation are set forth in detail.

It is requested that you, as an OET Executive Reservist, familiarize yourself with these plans and, wherever possible, that you lend your support to their full implementation in the various States. Your cooperation in this respect will be greatly appreciated.

Enclosures
as

APPENDIX G

DEPARTMENT OF DEFENSE
OFFICE OF CIVIL DEFENSE
Washington, D. C. 20301

October 10, 1963

MEMORANDUM NO. 31-63 FOR ALL REGIONAL DIRECTORS

SUBJECT: Development of Operational Readiness, State Highway Departments

For several years the Bureau of Public Roads and the State highway departments have been working together to develop, in the highway field, a state of readiness to meet a national emergency. The wartime duties prescribed by Executive Order 10999, as well as those functions implied in the assigned duties, are the basis for a broad program which includes items of special Civil Defense significance such as highway traffic regulation in emergency, plans for barricading and marking streets and highways leading into fallout areas, and other measures concerning movement by highway.

In view of these responsibilities, it is desirable for the State highway departments to become fully informed of OCD-State Civil Defense programs. It is obviously equally desirable for State Civil Defense Directors to become aware of the programs being developed by the highway departments in cooperation with the Bureau of Public Roads. With this objective in mind, representatives of BPR and OCD have concluded that BPR, in its planning and programming with the State highway departments, should place a high priority on the following activities:

1. Shelter Marking and Stocking Program. BPR will urge the State highway departments to review Phase 2 printout data available in the State Civil Defense Office for the purpose of determining the capability of all highway department buildings to provide shelter protection for personnel, the public, and to determine their eligibility for participation in the National Stocking Program. In addition, as a result of the review of the Phase 2 information, highway departments will be urged to make analyses to identify qualified space available for highway department emergency operations, protection of communications operators, and the establishment of radiological monitoring stations.

2. Hardening of Communications Systems and Radiological Monitoring Stations. BPR will urge State highway departments to undertake programs to provide protection for staff, communications operators and radiological monitors by providing additional shielding of not less than 100 protection factor in facilities located in the review of Phase 2 summary information under Paragraph 1. This program may involve provision of additional

shielding when required in existing as well as new construction. OCD will match funds, generally, on such hardening. (State and local government facilities may be eligible for direct assistance in the event Congress authorizes the shelter development program.)

3. Federal Financial Assistance. BPR will make available to State highway departments available information regarding Federal financial assistance which may be obtained in furtherance of their readiness programs, (e.g., for shielding State and Area Highway Department emergency operating centers, Radef Monitoring Stations, Communications Centers, emergency highway traffic signs, etc.)

4. Radiological Monitoring Organizations and Systems. In addition to information and guidance already provided, BPR will provide further guidance and assistance, as necessary, to the State highway departments in order that they may complete their statewide radiological monitoring organizations and systems. BPR will also assist the State highway departments in developing operating procedures and reporting systems, as a part of the Statewide civil defense monitoring and reporting system.

5. State Highway Departments, including the highway maintenance and patrol services, will be urged strongly to establish fallout monitoring stations at all facilities controlled or operated by these services. A CD V-777 operational set of instruments will be made available to each highway facility through the State Director under the provisions of OCD Instruction 9667.1. This set of instruments will provide 'on-station' monitoring and will also support limited mobile operations. A second V-777 set will be made available to each of these facilities through the State Director beginning in calendar year 1964 to provide for further mobile support. Also, Regional Memorandum No. 26-63, dated July 29, 1963, provides authority for the issuance of additional individual survey meters and dosimeters to support surface mobile monitoring operations where additional instruments are required. OCD Instruction 9667.2 specifically provides for the grant of CD V-742 dosimeters to be issued to emergency workers such as highway personnel who will be required to perform high priority postattack operations in areas affected by fallout. Sufficient supplies of monitoring instruments should be maintained in good operable condition at each highway facility so that one survey meter (CD C-710, 715, or 720) and one dosimeter (CD V-740 or 742) can be issued postattack to each task force at the time it is given a specific mobile operational assignment. The OCD Regional Directors are requested to advise the State civil defense directors of these arrangements and to request the States to assign priority to the preparation and submission of the required OCD forms to requisition monitoring instruments as needed for the highway services.

6. Identifying Limits of Unrestricted Travel. BPR will provide continuing guidance and assistance to State highway departments on the identification of limits of unrestricted travel at the fringes of radiologically contaminated areas to protect the general public from unnecessary entry and exposure to radiological hazards. Guidance with respect to tolerable radiation exposure will be in accordance with the guidelines contained in the Federal Civil Defense Guide, Part E, Chapter 5, Appendix 1, Pages 5 - 10. Barricades and signs for protection of traveling public will be as set forth in the Manual on Uniform Traffic Control Devices for Streets and Highways.

7. Directed Movement. BPR will continue to develop, in cooperation with State highway departments, a system of emergency highway traffic regulations as provided in Executive Order 10999 and Annex 12 of the National Plan for Civil Defense and Defense Mobilization or as it may be revised in the National Plan for Emergency Preparedness.

8. Training. BPR, through its field organization, will provide a channel of communication with the State highway departments. It will urge them to support, by their active participation, the following OCD-State Civil Defense sponsored programs: Adult Education; Medical Self-Help; State and local government orientation conferences; Radiological Monitoring Instructor courses; Shelter Management Instructor courses; Radiological Officers (OCD Staff College). State Civil Defense Directors can supplement this information by providing local schedules for Adult Education and Medical Self-Help courses directly to the State highway departments.

9. It has been agreed between OCD and BPR that the above activities will be carried out at State level in close coordination with the State Civil Defense offices. In furtherance of this coordination, it is expected that BPR will instruct its Division (State level) offices to accompany a representative of the State highway department for discussions with the State Civil Defense office regarding the foregoing programs. In this way, the planning and readiness efforts of the State highway departments and BPR can be explained in all necessary detail to the State Civil Defense organization, with particular emphasis on those activities having Civil Defense significance.

John W. McConnell
Regional Coordinator

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE ADJUTANT GENERAL
WASHINGTON 25, D. C.

SUSPENSE
DATE 1 Jun 64

IN REPLY REFER TO
AGAM-P (26 Feb 64) TCADM-A

5 March 1964

SUBJECT: Highway Traffic Regulation in CONUS during National Emergencies

TO: Commanding General
U. S. Continental Army Command
Fort Monroe, Virginia

1. References:

a. Presidential Executive Order 10999, dated 16 February 1962.

b. Department of Defense Directive 4500.22, dated 18 October 1955, subject: Highways for National Defense Responsibilities.

c. AR 55-80, BUDOCKS INST 11210.1, AFR 75-88, dated 1 July 1955, subject: Highways for National Defense (currently under revision).

d. Department of Defense Directive 3025.10, dated 23 April 1963, subject: Military Support of Civil Defense - (partial authority for AR 500-70, dated 6 August 1963, subject: Emergency Employment of Army Resources - Civil Defense).

e. U. S. Department of Commerce, Bureau of Public Roads, Policy and Procedure Memorandum 50-7, dated 25 June 1962 (Inclosure 1).

f. U. S. Department of Commerce, Bureau of Public Roads, Instructional Memorandum 50-4-63, dated 25 September 1963 (Inclosure 2).

2. Reference 1a assigns to the Department of Commerce, U. S. Bureau of Public Roads, the national responsibility for highway traffic regulation during emergencies. Reference 1b assigns to the Department of the Army the Department of Defense's responsibility for--

a. Coordinating the defense transportation interest in public highways.

b. Maintaining liaison with State highway authorities in matters pertaining to the special defense utilization of public highways.

As a result of the Department of Defense Directive referenced in 1d and in accordance with AR 500-70, the Department of the Army has the primary responsibility to represent all Department of Defense agencies at various State highway traffic regulation centers in claiming road space and priorities of all essential military movements over public highways.

3. The purpose of this letter is to bring your headquarters up to date as to current planning pertinent to the subject and to insure that the Department of the Army's planning is in consonance with The National Plan developed by the U. S. Bureau of Public Roads. Some of the most significant actions already taken are as follows:

a. The National Highway Users Conference has agreed to assist the Bureau of Public Roads at the national level by obtaining the assistance of affiliated State Highway Users Conferences to represent highway users (except the Department of Defense and Civil Defense) at the traffic regulation centers at State and local levels. Civil Defense's requirements for road space will be made known by State and local civil defense personnel.

b. A test of a pilot operational plan to regulate highway traffic was conducted in Oklahoma, 24-26 September 1962, during Exercise SPADE FORK. The Oklahoma State Highway Users Conference, the various departments of the State of Oklahoma, and the Department of the Army, representing the Department of Defense, participated in the test.

c. The Under Secretary of Commerce, by letter dated 6 May 1963 (Inclosure 3), wrote to the Governor of Alabama recommending that the Alabama Highway Users Conference be the duly authorized authority to represent the various highway users in that State. Similar letters were subsequently sent by the Under Secretary of Commerce to all of the States.

4. The Bureau of Public Roads' publication (reference 1e), subject: Highway Traffic Regulation, is being used by the States to prepare detailed plans for the implementation of highway traffic regulation. As of this time, State plans are in various stages of completion.

5. The Bureau of Public Roads' publication (reference 1f), subject: Emergency Highway Traffic Regulation - Organization of Highway Users, supplements reference 1e by furnishing guidance to organize highway users groups.

6. Both the Bureau of Public Roads and the National Highway Users Conference have reviewed FM 55-31 and FM 25-10 and have adapted the principles of military highway regulation for civilian use.

7. The present Department of Defense concept of operation in the regulation of highway traffic during emergencies is to have the ZI Army Commander represent all services at the State traffic regulation center, and at such area traffic regulation centers, as deemed necessary, within his area of responsibility. This concept also includes the utilization of transportation engineering officers from both the Reserve and Regular services, wherever possible, to accomplish the objective. The Army representatives are to be assisted by Navy and Air Force personnel, based on the service density which varies within the Army areas. For example, in an area where the Navy has the highest population of Department of Defense personnel, the Army commander may wish to have Navy personnel predominantly represented in the area traffic regulation center.

8. It is visualized that plans will be developed in each Army area whereby all military installations will submit their road space requirements to the Army representative at the State central control point governing a specific area for those military highway movements to be made by military vehicles. It is also visualized that road space requirements for those military highway movements to be made by commercial carrier - bus or truck - will be submitted by the military installations to the Army representatives at the State central control point after determination of mode and carrier by the Defense Traffic Management Service in keeping with the Military Traffic Management Regulations.

9. In view of the above, it is desired that a study be made and plans formulated within each Army area, to include the following:

a. The location at which the various States intend to have their State, district, and sector centers located.

b. Based on the concept described and the location of these control points, the mobilization requirements for personnel - by identity - of all services to be representatives at these control centers. In the event that some officer spaces will be required as mobilization designees, it is desired that the number of spaces required be identified by grade and MOS.

c. The organizational structure required to insure appropriate service representation in order to obtain sufficient road space for all essential military movements.

Additional peacetime spaces for the conduct of this study cannot be provided.

10. As previously mentioned, State plans are in various stages of development and, therefore, difficulty can be expected in certain States in

coordinating military defense plans with State plans and in finalizing the study. It is most difficult to determine a date at which the study can be completed; however, an initial evaluation covering the current status of the study and an estimated completion date will be submitted by the Army area commander, through CONARC, to the Chief of Transportation, Department of the Army, Washington, D. C. 20315, by 1 June 1964.

11. Attached as Inclosure No. 4 is a list of Bureau of Public Roads' Regional Emergency Planning Officers who may be of assistance in contacting appropriate State highway officials.

12. If additional information on the above subject is required, inquiry should be made to the Chief, Highways for National Defense Branch, Office of the Chief of Transportation, Department of the Army.

13. Copies of the inclosures are attached for distribution to the Army area commanders.

By Order of the Secretary of the Army:

J. C. LAMBERT
Major General, USA
The Adjutant General

4 Incl
1. FPM 50-7, 25 Jun 62
2. TM 50-4-63, 25 Sep 63
3. Letter, 6 May 63
4. BPR Rgn Emerg Plng Off

Copies furnished:
Chairman, Joint Chiefs of Staff
Director
Defense Supply Agency
Commander
Defense Traffic Management Service
Chief of the Bureau of Yards and Docks
Director of Transportation, DAF
Chief of Transportation
Commander in Chief
US STRIKE Command
Commanding Generals
US Army Materiel Command
US Army Combat Developments Command
US Army Air Defense Command
Bureau of Public Roads
National Highway Users Conference

Chapter 6
TRANSPORTATION

This chapter is applicable to all forms of civil transportation of the United States, both domestic and international. It is equally applicable to all degrees of national emergency, including attack upon the United States.

(The Department of Defense and its military departments are responsible for developing appropriate plans and procedures for the management of transportation resources which they would control in a national emergency.)

DEFINITIONS

For the purposes of this chapter, the following definitions will apply:

Air Carrier Aircraft: All aircraft, both fixed and rotary wing, under the operational control of international and domestic scheduled and supplemental air carriers operating under the economic authority of the Civil Aeronautics Board; also, all other four-engine fixed-wing aircraft and all turbo-jet or turbo-prop fixed-wing aircraft over 12,500 pounds takeoff weight.

Civil Reserve Air Fleet (CRAF) : Those air carrier aircraft allocated by the Secretary of Commerce to the Department of Defense for military operations during an emergency.

Civil Transportation: The movement of persons, property, or mail by civil facilities and the resources (including storage except that for agricultural and petroleum products) necessary to accomplish the movement. (This definition excludes transportation operated or controlled by the military and petroleum and gas pipelines.*)

Interstate (Primary) Transportation Resources: Those civil transportation facilities, equipment, and services controlled or provided by operators generally engaged in interstate or international transportation; also, air carrier aircraft and their related facilities, equipment, and services.

Intrastate (Secondary) Transportation Resources: Those civil transportation facilities, equipment, and services provided or authorized for use primarily within a State, territory, or the District of Columbia, excluding air carrier aircraft and their related facilities, equipment, and services.

State and Regional Defense Airlift (SARDA): The program designed to provide for the use during an emergency of civil aircraft other than air carrier aircraft.

War Air Service Program (WASP): The program designed to provide for the maintenance of essential civil air routes and services and to provide for the distribution and redistribution of air carrier aircraft among civil air transport carriers after withdrawal of aircraft allocated to the Civil Reserve Air Fleet.

Transportation Operating Agencies: Those Federal agencies having responsibilities under national emergency conditions for the operational direction of one or more forms of transportation; they are also referred to as Federal Modal Agencies or Federal Transport Agencies.

Supporting Resources: Manpower, materials, equipment, and supplies needed to operate transportation systems.

In preparing this chapter the Office of Emergency Transportation (OET), Department of Commerce, was assisted by the Interstate Commerce Commission, Bureau of Public Roads, Civil Aeronautics Board, Federal Aviation Agency, Maritime Administration, Coast and Geodetic Survey, Department of the Interior, Tennessee Valley Authority, U.S. Army Corps of Engineers (Civil Works), and St. Lawrence Seaway Development Corporation.

*Pipelines are treated in Chapter 10, Fuel and Energy.

ORGANIZATION

Those Federal, State, and local government agencies with transportation responsibilities comprise the organizational structure for transportation mobilization. Their built-in readiness would be relied on to implement and enforce transportation procedures and control systems. Staffs of the Federal transport agencies would be augmented by members of the National Defense Executive Reserve.

Federal.

In response to the need for an overall control agency to fulfill the complex movement requirements of national emergency, an emergency transportation organization would be activated.* It would be composed of an augmented OET peacetime staff organized on a functional and modal basis, and would use capabilities of all other government agencies with transportation responsibilities.

Transportation operating and support agencies would provide emergency direction for the use of modes of civil transport and related services for which they are responsible.

The Transportation Allocations, Priorities, and Controls (TAPAC) Committee, a subcabinet level committee under the chairmanship of the Under Secretary of Commerce for Transportation, consists of representatives of the transportation service agencies and of agencies which would claim for transportation service.

An emergency transportation advisory committee would be established to advise and assist OET. It would be composed of selected experienced and recognized leaders from each segment of the transportation industry.

OET has eight regions. Each would be headed by a designated OET Regional Director who within his region would represent the Director, OET. In the event of isolation or a communications breakdown the OET Regional Director would act independently within the limits of his geographic jurisdiction subject to established national policy.

Regional representatives of the Federal transport operating agencies, as well as area transport boards or committees, would receive their transportation policy direction and guidance from the OET Regional Director, subject to policy direction and coordination of the OEP Regional Director.

State and Local.

State and local emergency transportation organizations would consist of transport agencies at those levels of government which have functional or modal responsibilities for water (including inland waterway), rail, motor carrier, or air transportation. These agencies would be organized as determined by appropriate State and local government officials and would be staffed by qualified representatives of industry and government.

Civil aircraft other than air carrier aircraft are organized under the FAA State and Regional Defense Airlift Plan for the continued use of these aircraft in the national economy during an emergency situation and for providing adequate support for direct survival operations.

Emergency highway traffic regulation would be primarily the responsibility of State highway departments, in coordination with State civil defense and police organizations and organized users of highways, operating under the general supervision and guidance of the Bureau of Public Roads (BPR).

*Elsewhere in this chapter, "The Office of Emergency Transportation" (or "OET") denotes that Federal office operating during peacetime or its emergency counterpart, the emergency transportation organization authorized to carry out emergency functions.

RESPONSIBILITIES

Federal.

The Office of Emergency Planning (OEP) advises and assists the President in determining policy for and coordinating the emergency plans and programs of Federal resource agencies.

Executive orders assign to certain agencies specific responsibilities for planning emergency transportation preparedness programs. They are:

- Department of Commerce, E.O. 10999.
- Interstate Commerce Commission, E.O. 11005.
- Civil Aeronautics Board, E.O. 11090.
- Federal Aviation Agency, E.O. 11003.
- Department of the Interior, E.O. 10997.
- Tennessee Valley Authority, E.O. 11095.

Under national defense emergency conditions, by direction of the President and subject to policy guidance from the Director of OEP or its successor agency, the Secretary of Commerce would implement control systems governing the use of all civil transportation and the allocation of its capacity to meet essential civil and military needs.* These responsibilities would be redelegated by the Secretary to the Director of the Office of Emergency Transportation (OET). The President would also order Federal transportation agencies to carry out their plans in consonance with overall policy direction of the Secretary of Commerce.

Department of Commerce. The Secretary of Commerce, through the Director, OET, would promulgate plans, policies, and procedures for control systems and would provide administrative facilities for the performance of emergency transportation functions.

Transportation Operating Agencies. In consonance with OET policy directives, transportation operating agencies would act in their respective areas as follows:

- *Interstate Commerce Commission (ICC)*—rail, motor, and inland water carriers.
- *Civil Aeronautics Board (CAB)*—domestic and international civil air transportation.
- *Federal Aviation Agency (FAA)*—National Airspace System, civil airports, civil aviation operating facilities, and civil aircraft other than air carrier aircraft.
- *Maritime Administration (MarAd)*—ocean and Great Lakes ports and ocean shipping.
- *Bureau of Public Roads (BPR)*—highway and street systems.
- *OET Air Carrier Division*—civil air carrier aircraft.

Support Agencies. Federal support agencies and their areas of responsibility are:

- *Tennessee Valley Authority (TVA)*—Tennessee River navigational system.
- *Coast and Geodetic Survey*—aeronautical and nautical data.
- *St. Lawrence Seaway Development Corporation*—sectional navigational systems of the St. Lawrence Seaway.
- *U.S. Army Corps of Engineers (Civil Works)*—waterway navigational facilities.
- *Department of the Interior*—petroleum and gas pipeline facilities.*

Advisory Committees. The TAPAC Committee would review policy and make recommendations on allocations, priorities, and controls for civil transportation. An emergency transportation advisory committee would advise the Director, OET, as required, on matters affecting the transportation industry. This committee would also facilitate industry coordination and understanding of emergency transportation policies and procedures.

Regional Offices. Federal policies and procedures would be disseminated and monitored in the field through regional offices of the respective transportation agencies in accordance with their own practices and organizational structure. Authority and responsibility would be delegated to them, subject to centralized coordination and policy direction.

In the event of isolation or a breakdown in communications, the primary responsibility for development, dissemination, and supervision of Federal transportation policies would shift to the OET regional representatives. Under such conditions, the regional offices would continue to assist State and local governments and military activities with transportation matters.

OET Regional Directors, subject to policy direction and coordination by appropriate OEP Regional Directors, would assume policy direction within their regions with respect to overall

*Essential civil and military needs include atomic energy and national aeronautical and space programs.

*See Chapter 16.

interstate civil transportation, except for air carrier aircraft, during postattack periods of communication breakdown with OET National Headquarters.

During such periods OET would receive information and assistance from appropriate OCD Regional Directors on the overall civil defense situation, together with recommendations about the civil defense needs of geographic areas within their jurisdiction.

At such times representatives of Federal agencies charged with operational responsibility for specific modes of transportation would assure that these modes comply with appropriate preparedness programs, including emergency transportation resource programs being carried out by States and localities. Actions of these representatives and of any modal board, committee, or group should be in consonance with Federal policies and coordinated through the appropriate OET regional representative.

State and Local.

State and local governments would be responsible for the emergency utilization of intrastate transportation resources, subject to Federal policies and national control systems.

State and local authorities would coordinate with officials in adjoining areas and States for joint use of intrastate transportation during emergencies. When, by use, such transport became interstate, coordination would be accomplished through the Regional Director of OET.

These State and local authorities, with assistance from the OET State representative, would also develop requirements for additional transportation and present claims to the appropriate OET Regional Director for such services.

State and local governments would comply with Federal control measures to provide assistance in assuring that essential interstate and foreign movements were not unduly interrupted.

Postattack, State and local officials would determine the remaining capability of all modes of intrastate transportation and apportion this capability among users so as to satisfy the essential requirements of both State and national recovery.

In the event of a breakdown in communications or area isolation, when the appropriate Federal representative responsible for the control system of a particular mode of transportation were not available, the State would assume responsibility for the control system of the affected mode within the boundaries of that State, exclusive of air carrier aircraft. As communications were restored and such representation became available, the control system of such transportation would revert to the responsible Federal representative.

Carriers and Users.

Transportation carriers would be responsible for operating their facilities so as to provide the maximum possible service within their capabilities to fulfill essential needs as specified by appropriate government authorities. This includes continuity of management, protecting personnel and facilities, conserving supplies, restoring damaged lines and terminals, rerouting, expanding or improving operations, and securing necessary manpower, materials, and services.

Users of transportation and shippers, including government agencies, would be responsible for their own internal transportation procedures and would arrange directly with carriers for the actual accomplishment of movements.

Federal agencies, acting as claimants for transportation, would inform the appropriate OET office of their estimated peak and time-phased future requirements for transportation services and of any specific claims which require special arrangement. OET would use broad requirements predictions as traffic forecasts in planning optimum distribution of transport resources and in determining specific allocations for transportation capacity.

Where shortages of transportation service existed, Federal claims would be submitted to the OET national or regional office, as conditions dictated. State and local claims would be submitted to the OET regional offices. Detailed procedures will be set forth in the Transportation Allocations, Priorities, and Controls Manual to be published by OET.

FEDERAL FUNCTIONS

Office of Emergency Transportation.

OET would develop and direct the transportation policies of the Federal Government so that all modes of civil transportation would be used to provide a unified system responsive to the national emergency. To do this, it would:

- Receive, assemble, and analyze requirements from all claimant agencies for movement of passenger and freight traffic of all types and integrate these requirements with all forms of national and international civil transportation systems.
- Determine the adequacy of the various modes to provide the required service.
- Allocate and apportion, by mode, the total civil transportation resources to meet overall essential civil and military needs.
- Establish and institute, as necessary, control systems—including allocations, priorities, permits, sanctions, and embargoes—to assure optimum use of civil transportation systems and their supporting intransit storage and warehousing facilities.
- Develop procedures designed to maximize the movement capabilities of the existing transportation equipment and facilities.
- Collate the individual attack effects assessments prepared by the modal agencies.
- Assemble and consolidate the resource claims of the several modal transportation agencies in support of the total transportation system; act as the Federal claimant agency for these agencies by presenting consolidated claims to the appropriate Federal resource agency; finally, when the resource allocations were made, suballocate these resources to the individual transportation agencies.
- Advise on proposed or existing emergency legislation affecting transportation and recommend additional emergency legislation as necessary or desirable.
- Provide, as required, the administrative facilities necessary for performing emergency transportation functions.

Transportation Operating Agencies.

Emergency transportation functions of the transportation operating agencies would be performed in consonance with the overall policy direction of the Director, OET.

Interstate Commerce Commission. Provide guidance to and consult with operators of railroad, motor carrier, inland water carrier, and public-storage industries and the States. This covers:

- For railroad use: reduction of vulnerability to enemy activity; maintenance during emergency periods and restoration after enemy action; operation during national emergencies.
- For motor carrier use: reduction of vulnerability to enemy activity; operational direction during national emergencies.
- For inland waterway equipment and shipping: reduction of vulnerability of water craft and terminal facilities; operational direction of the inland waterways terminal facilities and craft during national emergencies.

ICC would additionally:

- Assemble, develop, and evaluate, as appropriate, requirements for domestic surface transporation and storage in emergencies.
- Estimate availability of assigned resources, analyze resource estimates in relation to estimated supply-demand relationships, develop appropriate recommendations and programs following these analyses, and provide data and assistance for national resource evaluation purposes.
- Claim resources required to operate the domestic surface transportation network (except highways, highway facilities, and inland waterway navigational facilities).
- Allocate the use of domestic interstate surface transportation and storage to operators and users; administer priorities systems as necessary to assure the movement of essential freight and passengers.
- Coordinate and direct, with appropriate private transportation and storage organizations and associations, transportation and storage fa-

cilities for movement of passenger and freight traffic on interstate systems.

• Analyze the operational conditions and capabilities of the domestic surface transportation industry; help alleviate chemical, biological, and radiological (CBR) contamination; allay conflicts between major shippers and overcome bottlenecks; effect conservation of material and manpower facilities, equipment, and supplies; and regulate, as required, the operation of storage industries.

• Salvage and rehabilitate domestic surface transportation and storage equipment and facilities, including decontamination of terminals, rights of way (except highways, highway facilities, and inland waterway navigational facilities), equipment, and shops.

• Make maximum appropriate use of existing nonmilitary facilities, technical competence, and resources of Federal, State, local and nongovernmental organizations and systems engaged in domestic surface transportation and storage facilities, to promote the effective and safe use and maintenance of transportation facilities, equipment, and services.

• Assist in carrying out national plans for stockpiling strategic and critical materials and items vital to domestic surface transportation and storage capability.

• Cooperate in developing national economic stabilization policies as they affect domestic surface transportation and storage programs.

• Invoke plans and procedures for financial and credit assistance to domestic surface transportation and storage organizations in need of assistance.

• Coordinate joint actions of emergency domestic surface transportation and storage programs of agencies assigned responsibility for any segment of such activity.

Civil Aeronautics Board:

• Provide for emergency management and postattack use of air carrier aircraft in the maintenance of the War Air Service Program (WASP), including emergency management of the WASP Air Priorities System and administration of controls and priorities of passenger and cargo movements.

• Assist FAA and the Department of Defense, as appropriate, in assessing the effects of attack on air carrier aircraft.

• Assist FAA in determining resource requirements for WASP.

• Assist FAA in salvaging supplies and equipment for, and in restoring or replacing, essential civil air carrier aircraft and services after attack.

• Periodically assess assigned air transportation resources in order to plan for their use, make supply-requirements estimates and develop recommendations and programs following analysis, and provide data and assistance for national resource evaluation purposes.

• Investigate the facts, conditions, and circumstances surrounding accidents in civil air operations; determine probable causes; and recommend remedial actions.

Federal Aviation Agency:

• Maintain operating continuity of the National Airspace System.

• Detect, monitor, and report chemical, biological, and radiological hazards at all FAA operated and controlled facilities.

• Report and analyze the effects of attack on all aeronautical facilities, including civil aircraft, civil airports and landing areas, air carrier operations and maintenance bases, aircraft repair stations, communications stations, and other ground-support facilities.

• Provide for the emergency management and use of civil airports and of civil aviation operating and maintenance facilities; direct the SARDA program for the emergency management of civil aircraft other than air carrier aircraft.

• Determine requirements and claim supporting resources to maintain or restore its own operating continuity and that of the civil air transport system, including CRAF, WASP, and SARDA.

• In coordination with local authorities, direct Federal activities, as required, for the emergency clearance and restoration of essential civil airports in damaged areas.

Maritime Administration:

• Requisition or charter oceangoing vessels under the United States flag or vessels of foreign registry under effective or contractual United States control; operate oceangoing vessels under MarAd control; allocate shipping tonnage and accept allocations of tonnage from the NATO Shipping Pool for support of national or international shipping programs.

• Control forwarding of cargo to ocean port areas where MarAd maintains control of ocean shipping, coordinate convoy plans with naval authorities, and maintain statistical and intelligence data on vessel movements.

• Administer port traffic priorities and, in coordination with appropriate Federal agencies, control traffic through ocean and Great Lakes port areas.

• Allocate and, as necessary, reallocate ports and port facilities, equipment (including harbor service craft), and services.

• Assign maximum quota of cargo ocean lift for each port area.

• Determine need for port development; coordinate rehabilitation of substandard port facilities and development of alternative port and other water terminal facilities to meet essential requirements.

• Determine need for restoring damaged or destroyed ports and facilities or improvising new port facilities to maintain an adequate port capacity; direct, coordinate, and control the activities of Federal, State, local, and private agencies in such restoration or improvisation.

• Furnish current information on port conditions to the appropriate agency so it could approve and issue block releases for portbound traffic.

• Claim the supporting resources needed to carry out emergency responsibilities for ocean shipping and ports.

• Provide a means for administering the manpower and material needs of ocean shipping.

Bureau of Public Roads:

• Adapt all improvement programs to meet emergency requirements for all highway systems (and highways in the Federal domain), including emergency repair or restoration, and emergency provisions of highways, streets, bridges, and tunnels.

• Administer road programs for defense access, replacement, and maneuvers.

• Administer such foreign programs as justified in the emergency.

• Claim supporting resources required for all essential programs for public highway construction and maintenance, including urban streets, regardless of financing.

• Conduct continuous evaluation of highway needs based upon assessment of damage and coordinated with national recovery plans and programs.

• Conduct highway research of importance in an emergency.

• Arrange, in cooperation with appropriate Federal, State, and local government units or other agencies concerned, to safeguard and facilitate public highway travel. Such arrangements would include plans and procedures for emergency highway traffic regulation and for barricading or marking streets and highways leading into or out of restricted fallout areas.

• Provide, in cooperation with State or other highway agencies, for the detection, identification, monitoring, and reporting of radiological agents on highways and highway facilities.

• Maintain a capability in cooperation with State or other highway agencies to assess the effects of attack on highways and to report such assessments to the Department of Defense.

• Provide technical guidance to States and direct Federal activities relating to emergency operational responsibilities with respect to highways, roads, streets, bridges, tunnels, and appurtenances.

OET Air Carrier Division:

• Maintain an inventory of civil air carrier aircraft and their airlift capability.

- Evaluate emergency requirements for civil air carrier aircraft services.
- Recommend to the Director, OET, the allocation and reallocation of civil air carrier aircraft in accordance with established policies and procedures.
- Cooperate with CAB in distributing and redistributing civil aircraft in WASP among civil air carriers for optimum air carrier aircraft support of essential needs.
- Serve as the focal point for United States participation in activities of the NATO Board for Coordination of Civil Aviation (BOCCA).

Support Agencies.

Certain other Federal agencies have functions complementary to those identified with the transportation operating agencies. They, and their services, are:

Tennessee Valley Authority:

- Cooperate with ICC, the U.S. Army Corps of Engineers (Civil Works), and the U.S. Coast Guard in locating and removing river obstructions and in rebuilding or repairing channels, channel markings, and locking equipment on the Tennessee River and its navigable tributaries.
- Coordinate the use of terminal facilities along the Tennessee River waterway with terminal operators and shippers for optimum postattack use of the river.
- Assist in the diversion of Tennessee River shipments, as required, to land transport and vice versa for movement to final destination, in cooperation with ICC.
- Construct any necessary facilities to move goods and materials around inoperative locks.

Coast and Geodetic Survey:

- Provide nautical and aeronautical charts and related data on the United States, its territories, and possessions to meet military and civil navigation requirements (except for Great Lakes and inland waterways).
- Conduct hydrographic surveys to locate wrecks and other obstructions in ports and channels (except for Great Lakes and inland waterways).
- Establish emergency geodetic control for special-purpose surveys.
- Produce special charts for over-the-beach operations and emergency ports as required.
- Determine by survey methods the locations of emergency aids to air navigation.
- Conduct special geophysical and photogrammetric surveys and provide data as required for civil and military use.

Department of the Interior. The Department of the Interior has complete responsibility for preparedness planning and emergency control of construction, operation, and use of petroleum and gas pipelines. As the Federal resource agency responsible for petroleum and gas pipeline facilities and their use, it will provide OET with data on the capacity of such pipelines and the movement of petroleum and gas through them.

U.S. Army Corps of Engineers (Civil Works):

- Improve, restore or rehabilitate, operate, and maintain components of federally authorized river and harbor projects.
- Locate and remove obstructions to navigation; accomplish emergency dredging to clear and straighten navigation channels in harbors and navigable streams of the United States, its territories, and possessions.
- Conduct hydrographic surveys and provide nautical charts and related navigational material covering the Great Lakes system, Lake Champlain, New York canals, the Minnesota-Ontario border lakes and connecting waterways, and inland waterways generally.
- Collect, compile, and publish information on the physical characteristics and facilities of United States ports for the use and benefit of navigation.

St. Lawrence Seaway Development Corporation: Construct, maintain, and operate in United States territory the necessary deepwater navigation works in the appropriate area of the International Rapids section of the St. Lawrence Seaway.

Regional Offices.

The functions outlined above for the respective national organizations would be carried on at the regional level by their appropriate representatives in the field in the event of a break in communications and as otherwise required by their respective national headquarters.

Regional heads of Federal transportation claimant agencies would present claims for transportation services to the OET Regional Director in the event of a communications break.

Field offices of Federal transport agencies would consult directly with their counterparts at the national level or with other regional offices on appropriate matters.

In administering the emergency transportation program, transportation officials would be governed by the relative urgencies established by OEP.

CONTROL SYSTEMS

Principles.

Control systems in support of civil transportation would be initiated as necessary by the Federal Government in emergency. When effected, these systems in the form of traffic movement controls would be designed to assure movement of traffic responsive to the national emergency.

These control systems, if required, would be used only to the degree necessitated by the emergency situation.

Subject to such control systems, management of civil transportation would continue to be privately exercised, and the following basic principles of management would be recognized:

- Carrier management of operations.
- Direct shipper-carrier relationships.
- Traffic management by shippers and shipping agencies.

Policies and Procedures.

Requirements. Federal claimant agencies would be responsible for determining and claiming the transportation service requirements for the movement of that resource or function which they represent. These requirements would be in the form of time-phased traffic forecasts in an OET format and submitted to OET as an official statement of requirements.

These requirements would be analyzed by OET to identify potential conflicts, bottlenecks, and delays and thereby assist shippers and carriers in developing a balanced flow of essential traffic.

Capabilities Assessment. The Federal transportation operating agencies would assess the national transportation capability of interstate and international transportation systems. These data would be transmitted to OET, which would make a comparison of system capabilities with the total transportation requirements of shippers and travelers. Actions would be taken to eliminate or minimize any indicated shortages.

Detailed procedures for making rapid assessments of postattack capabilities of the transportation system would be developed by responsible Federal transportation agencies in coordination with OET.

Transportation would have high priority for restoration, including its requirements for manpower, materials, supplies, and equipment.

Federal transport agencies would be available to assist State and local governments in developing their capability for assessing residual intrastate and local transportation resources.

Allocations. OET would allocate civil transportation capacity to claimant agencies based upon the individual agency's traffic forecast of transportation movement requirements and the established competing claims. The essentiality of a claim would be based upon the overall national objectives.

Allocations of transportation capacity would be used to commit all or a portion of the available civil transportation in support of national defense. Adjustments of the traffic forecasts of some claimants might be necessary in those cases in which the allocation would be insufficient to satisfy the claim.

Allocations of transportation equipment and facilities would not be made unless overriding strategic or other considerations warranted such action. The recipient of such an allocation would have exclusive use of the equipment or facilities within the limits of the commitment and could suballocate such assets to subordinate elements as necessary.

Priorities. Overall national priorities would be established by OEP. Civil transportation priorities would be developed and controlled by OET, based upon and compatible with the overall national priorities. These priorities would be administered by ICC, CAB, and MarAd for the transport systems under their respective control.

Priority for the movement of transportation engaged solely in intrastate and local movements would be administered by the appropriate State transportation regulatory or control body or appointed transportation official.

Any person, agency, or organization initiating or making arrangements for movement of persons or goods by commercial carriers might claim a movement priority from the agency administering such controls. Any person, agency, or organization engaged in for-hire transportation must, when within its capacity to perform the service, accept persons or goods for transportation based upon a request when supported by a valid priority.

Detailed Procedures. Detailed procedures concerning transportation priorities, embargoes, sanctions, and permits will be provided in the OET "Manual of Transportation Allocations, Priorities, and Controls System."

DOMESTIC SURFACE TRANSPORTATION

Mobilization Procedures.

Emergency procedures are specified by a series of ICC "Transportation Mobilization Orders" (TM's) which would be implemented in an emergency by that agency. They are:

TM-1—Preference and Priority for the Transportation by Carrier for Hire of United States Military Personnel, Accredited Civil Defense Workers, and United States Mail. Requires that each passenger carrier for hire operating intercity shall give preference and priority over all other traffic to military and civil defense personnel and the United States mail.

TM-2—Rail Freight Embargo—Appointment of a Permit Agent. Requires specific action and the observation of permitting procedures by rail carriers after proclamation of a civil defense emergency.

TM-3—Motor Freight Embargo. Requires specific action by motor carriers after proclamation of a civil defense emergency.

TM-4—Inland Waterways Freight Embargo. Requires specific action by inland water carriers after proclamation of a civil defense emergency.

TM-5—Disposal by Carriers of Undeliverable Shipments. Provides direction to rail, motor, and inland water carriers when, by reason of enemy action, they would be unable to deliver commercial or military freight in their possession.

TM-6—Control of Railroad Tank Cars. Provides a central point for control of liquid tank cars and facilities.

TM-7—Rerouting of Rail Traffic. Provides direction to carriers to reroute or divert traffic over any available route when the rail system had been subjected to enemy action.

TM-8—Direction to Certain Over-the-Road Motor Carriers of Property Regarding Routes, Diversions, and Service to Certain Destinations. Provides direction to motor carriers of property relative to diversion and rerouting as a result of enemy action and increases operational area of carriers to or from any attacked area.

TM-9—Direction to Certain Intercity Common Carriers of Persons by Bus to Serve Certain Points. Provides direction to passenger motor carriers relative to diversions and rerouting as a result of enemy action and increases operational area of motor carriers of persons at attacked points.

TM-10—Control of Motor Transport Vehicles. Provides a central point for control of motor transport vehicles for operation in areas subjected to enemy action.

TM-11—Control of Freight Shipments to or within Port or Storage Areas. Requires carriers to observe specific conditions, places responsibility on the Commission to develop permititng procedures, and indicates certain exceptions. (The purpose of this order is to avoid congestion in port areas and to assure effective coordination of domestic surface transportation with ocean shipping in periods of national emergency.)

TM-12—Inventory and Disposition of Food and Medical Supplies Requisitioned by Government in Possession of Railroads and Motor Carriers. Provides for disposition of food and medical supplies in possession of carriers through the Department of Agriculture and the Department of Health, Education, and Welfare.

TM-13—Control of Liquid Transport Vessels. Provides a central point for the control of liquid transport vessels.

Highway Use.

The Federal Highway Administrator, BPR, has issued an order* effective during a civil defense emergency to regulate, allocate, and promote the availability and use of all highways within the United States. The order provides that the Administrator (or such agencies of the Federal, State, and local governments as he may designate) may as necessary regulate motor-vehicle traffic using highways and make use of all available highways deemed safe for travel.

Inland Waterways.

TVA, by means of its damage assessment system as well as communications with the National Resource Evaluation Center and the resource agencies concerned, would effect specific actions in order to make the Tennessee River system as navigable as possible.

The Saint Lawrence Seaway Development Corporation, by means of its damage assessment system as well as communications with the National Resource Evaluation Center and the resource agencies concerned, would act to make the United States-controlled sections of the St. Lawrence Seaway as navigable as possible.

The U.S. Army Corps of Engineers District Engineers would perform waterway rehabilitation and construction throughout the United States and (except for the Tennessee River System) supply damage assessment data for the National Resource Evaluation Center. Manpower, equipment, materials, and services needed for this work and for operation and maintenance of essential authorized projects serving navigation needs would be claimed by each District Engineer through the supervising Corps of Engineers Division Engineer, who would be claimant at the regional level. The Chief of Engineers would act as associated claimant to OET at the national level.

AIR TRANSPORTATION

Use of Civil Aircraft.

OET through its Air Carrier Division would allocate civil air carrier aircraft to meet the needs of the Department of Defense for military operations (CRAF) and to the Civil Aeronautics Board for essential civilian needs (WASP).

The Air Carrier Division (OET) would provide continuity between the NATO Board for Coordination of Civil Aviation (BOCCA) and OET.

At each level of government where air support were assigned a mission, provisions for obtaining flight priorities under existing air traffic rules and appropriate priorities and allocations for fuel, manpower, maintenance, and other supporting services must also be established in consonance with the OET policies controlling movements at that level.

Emergency Air Service Pattern.

CAB would implement an emergency air service pattern through WASP to provide transportation for maximum priority traffic.

Under WASP, provision has been made for the maintenance of essential civil air routes and services by distribution and redistribution of air carrier aircraft among civil air transport carriers after allocation of aircraft to CRAF.

CAB would issue orders to provide the air carriers, during the initial phases of an emergency, authorization and direction for the performance of essential air services.

During an emergency CAB would implement any further directives necessary to assure

*BPR-THM-1 (F.R. Doc. 62-2755, March 21, 1962).

the continuation of air service until such time as priority traffic requirements could be determined and a subsequent redistribution of aircraft could be made to implement a controlled emergency air service program.

WASP Air Priorities System.

The control and priority of passenger and cargo air movements operating under WASP would be implemented under national plans. These include the Interim Air Priorities System (OET–P–1) and the successor CAB plan for a worldwide air priorities system.

OET–P–1 would become effective upon declaration of a national emergency by the President and the issuance by OET of implementing directives. Such interim procedures for determining preference and priority of traffic moving by the civil air carriers during the initial emergency period would be administered by each carrier and would remain in effect until superseded.

The CAB plan for an air priorities system to assure the effective control and use of civil air transport resources of the Nation would be activated by CAB pursuant to appropriate OET directives.

Since the emergency air service pattern would be periodically adjusted to meet essential traffic requirements, CAB would maintain an air priority traffic survey to assure adequate control and maximum utilization of civil air transport resources. The survey would monitor the flow of priority traffic and provide data to assist in determining adjustments to the emergency air service pattern as needed to meet priority traffic demands.

Air Carrier Aircraft Management.

In an emergency CAB would be responsible for the management of air carrier aircraft allocated to it by the Department of Commerce under the WASP program. CAB directives would be issued to owners and operators of such aircraft to assure the development and maintenance of an air transportation program in accord with national emergency transportation policy.

CAB would use appropriate resources of the Federal and State governments and the air transport industry in developing WASP to meet priority traffic requirements under emergency conditions. The Board would, however, retain direct management of WASP resources in order to assure the maintenance of the emergency air service pattern required to meet the national claimancy requirement on a worldwide basis.

WASP Management. The air carriers would provide the actual operational management under the emergency air service pattern established by CAB. The primary responsibility of other Federal agencies having an assigned interest in civil air transportation would be to provide essential support as appropriate to maintain continuity of an emergency air service pattern under WASP. State and local governments would also provide a supporting role in maintaining both intrastate and interstate emergency air service under WASP.

Claims for Air Carrier Airlift Service. All claimants for transportation priorities provided under WASP in an emergency would conform to the regulations established by the CAB–WASP Air Priorities System. The peacetime carrier-shipper relationship would be maintained.

Requests for air transportation during the initial stages of an emergency would be directed to the air carriers under interim priority regulations set forth in CAB Order ATM–2. Upon activation of the formal CAB-administered air priorities system, requests for priority air transportation would be directed to the nearest Regional Air Priorities Control Office.

Resource Support for Air Carrier Airlift. CAB would assist FAA in the development of requirements for essential resources needed to support air carrier operations and would support their submission to appropriate resource management authorities.

Claimancy. Air carrier operations requirements for maintenance, repair, and operating supplies (MRO) are included in the Defense Materials System (DMS) arrangements for securing priorities and allocations.

Authority for delegation of priorities and allocations of controlled materials has been delegated by OEP to the Business and Defense Services Administration (BDSA), Department of Commerce. BDSA has redelegated part of its authority to DOD, which has in turn designated FAA as an "associated agency." This permits FAA to make allotments and to apply, or assign to others the right to apply, Defense Order (DO) ratings and allotments numbers for maintenance, repair, and operating supplies for domestic and foreign commerce airlines.

SCATER.

"The Plan for Security Control of Air Traffic and Electromagnetic Radiations"* requires FAA and appropriate military authorities to take specified joint action during an air defense emergency to effect security control of civil and nontactical military aircraft entering, departing, or moving within the United States or its coastal approaches. FAA would effect control of such air navigation aids and aeronautical communications as might be required.

Civil aircraft would be grounded upon the declaration of an air defense emergency in accordance with the SCATER Plan. As the situation permitted, air carrier operations would be resumed in accordance with priorities established in the plan. General aviation aircraft in the State and Regional Defense Airlift (SARDA) Plan would resume operations in support of essential priority activities under the direction of appropriate authorities as specified in the plan.

Additional details concerning the SCATER Plan may be found in the joint publication of the Department of Commerce and the Department of Defense, "Plan for Security Control of Air Traffic and Electromagnetic Radiations During an Air Defense Emergency," dated May 7, 1957.

SARDA Management.

SARDA would be activated by joint or unilateral action of FAA and State governors (or their designees) in accordance with existing arrangements in individual States. This plan may be implemented in whole or in part, as necessary, to fulfill national and State emergency requirements.

*The SCATER Plan is under revision and will be published under the name of SCATANA (Security Control of Air Traffic and Air Navigation Aids).

FAA would issue guidelines to provide for the use of State aviation organizations to manage other than air carrier aircraft resources. These organizations would function in primary control of these aviation resources under emergency conditions, subject to the general direction of FAA if required by overriding Federal needs.

The actual task of providing other than air carrier airlift support would be the responsibility of aircraft owners, operators, airmen, and airport managers who perform the actual operating functions.

Requests for other than air carrier airlift should be submitted to the emergency transportation authority at the State or local level.

Requirements for resources in bulk to support the essential airlift involving other than air carrier aircraft would be consolidated by FAA General Aviation District Offices and Airport District Offices for submission to appropriate management authorities at local, State, and regional levels as required.

Air Traffic Control.

FAA would authorize the use of airspace upon request, doing so under the direction of appropriate Air Defense Commanders. Dispatch of aircraft would be the responsibility of military commanders, air carrier officials, civil government officials, or private citizens performing essential wartime missions under legitimate authority. Policies and procedures for processing altitude reservation and other flight plans, including responsibilities currently assigned to the Central Altitude Reservation Facility (CARF) and to Air Route Traffic Control centers, would remain in effect unless modified by competent authority.

Rehabilitation of Civil Air Facilities.

Owners, operators, or managers would report damage to civil aviation resources, other than manufacturing plants, to the manager of the nearest surviving civil airport. Airport managers would consolidate such reports received and forward these to the nearest surviving FAA General Aviation District Office, as well as to any local or area transportation resource management body and to local civil defense authorities.

Two general plans determine the level of civil airport restoration operations. First in order of priority is the military plan to use certain civil airports during an emergency in support of military operations. Second in order of consideration is the civil plan to use certain airports in support of air carrier and other than air carrier aircraft.

Aeronautical Charts.

The Coast and Geodetic Survey would:

- Maintain at selected locations up-to-date files of selected aeronautical charts, chart reproducibles, and critical materials.
- Maintain contact with commercial printing plants for emergency production of charts.

OCEAN TRANSPORTATION

Shipping.

In an emergency, MarAd would take the following actions:

- Implement plans for assembling and analyzing data on ocean shipping requirements.
- Acquire ocean shipping through requisitioning, charter, reactivation of reserve fleet ships, or acceptance of NATO Shipping Pool allocations.
- Through the ships-warrant system obtain the use of the ships of neutral nations.
- Direct the operation of, and act to repair, provision, man, and bunker, oceangoing ships owned or acquired by the Government.
- Direct vessel movements and allocate tonnage to meet approved requirements.
- Exercise forwarding authority on cargo moving to port areas and destined for MarAd-controlled ships.

Ocean Ports.

Public Orders. In an emergency, MarAd would publish the following public orders:

- *General Order MA-TPM-1*—Restrictions Upon the Transfer, Change in Use, or Terms Governing Utilization of Port Facilities.
- *General Order MA-TPM-2*—Restrictions Upon the Use of Port Facilities Without a Ship Warrant.
- *General Order MA-TPM-3*—Removal of Export, Import, Coastwise, and Intercoastal Freight From Port Area.
- *Delegation Order MA-TPM-1*—Appointment of Federal Port Controllers and Acting Federal Port Controllers: Delegations of Authority.

Port Control Officer. To assure the free flow of traffic to, from, and within port areas in time of emergency, a local port control officer would be responsible for coordination and control of ocean and land transportation use of the facilities, equipment, and services of a port.

He would make appropriate disposition with respect to general restrictions to be placed upon the transfer, change in use, or terms governing the utilization of port facilities and would otherwise perform the duties and exercise the powers vested in the Maritime Administrator.

This officer represents the authority of the United States in the port and works in close coordination with Federal transport and shipping agencies, the Department of Defense, and the local port industry.

Other Emergency Procedures. With respect to United States port systems and facilities, MarAd would also:

- Establish systems for receiving field reports and for issuing port advisories on the status of port conditions, operations, and capabilities; disseminate a national damage assessment recapitulation and evaluation.
- Determine the necessity for and feasibility of the use of alternative ports and port facilities; coordinate and, as necessary, direct and control the use of usable ports and port facilities, damaged or undamaged; and direct the diversion of freight enroute to affected port areas to such alternative usable ports or to appropriate interior locations.
- Cooperate with local public officials and civil defense agencies in providing emergency berthing facilities and the use of commercial port-

operating equipment and port personnel for civil defense purposes.

Materials, Supplies, and Facilities.

In an emergency MarAd would:

- Procure supplies and equipment necessary for the reactivation and operation of reserve shipyards and for outfitting new shipyards.
- Activate a priorities organization and obtain adequate priority ratings or allocations for vessel materials and supplies.
- Cancel leases and permits for private occupancy of MarAd property.
- Suspend all disposal activities except scrapping and salvage.
- Contact manufacturers of marine components to determine capability for producing or furnishing essential supplies and equipment in acordance with production allocation regulations.
- Negotiate with contractors concerning claims under prime contracts and subcontracts for disposition of unacceptable repair parts, materials, and supplies and for provision of lists of scrap, salvage, and unrequired materials.

Manpower.

In an emergency MarAd would:

- Activate, in cooperation with the manpower agency, a recruitment and utilization program for manpower needed to meet the requirements of ocean shipping and for shoreside vessel operation.
- Administer a uniform deferment procedure to retain seamen aboard ships and to create and train a supply of former seamen and recruits to man vessels.
- Activate the National Defense Executive Reserve units to administer vessel operations and Federal control of United States ports.

Nautical Charts.

The Coast and Geodetic Survey would:

- Maintain at selected locations up-to-date files of selected nautical charts and chart reproducibles, except for the Great Lakes, as well as critical materials.
- Maintain contact with commercial printing plants for emergency production of charts.

The U.S. Army Corps of Engineers (Civil Works) would maintain essential records and provide nautical charts with respect to the United States Great Lakes channels and harbors.

Part VI

SIGNING FOR CIVIL DEFENSE

Section 6A–1 Civil Emergencies

The Office of Civil and Defense Mobilization has developed plans for the control of highway traffic under emergency conditions such as could result from accidental disaster or enemy attack. Particularly these plans are concerned with the possibilities of nuclear warfare.

For the prompt evacuation of threatened areas, the program contemplates the advance designation and marking of "Evacuation Routes." In the event of disaster there will be a closing of highways that cannot be used, a controlled operation of certain designated highways, the establishing of regulation posts for the expediting of essential traffic, and the provision of emergency centers for civilian aid.

To guide and control highway traffic in an emergency, special highway signs will be needed. The signs here specified have been approved by the Office of Civil and Defense Mobilization and are here prescribed as standard for use when and where applicable in the civil defense program.

These emergency signs will not permanently displace any of the standard signs that are normally applicable, and as conditions permit they should be replaced or augmented by standard signs.

6A–2 Design of Civil Defense Signs

For economy in stockpiling and in emergency fabrication all the special civil defense signs, with the exception of the Evacuation Route Marker, are designed for a single size of plate measuring 24 by 30 inches, and have a black legend and border on a white background. The background should be reflectorized.

In an emergency these signs may be needed in large numbers. Except for the Evacuation Route Markers, however, which may remain in service indefinitely, they are for essentially temporary use. Consideration should accordingly be given to their fabrication from any light and economical material that can serve through the emergency period.

Any of these signs may be accompanied by a standard triangular marker approved by the Office of Civil and Defense Mobilization for marking areas contaminated by biological and chemical warfare agents and radioactive fallout.

6A–3 Evacuation Route Marker (CD–1)

If advance warning of enemy attack can be given it is expected that the residents of urban targets will be evacuated into safer areas. To facilitate this movement "Evacuation Routes" will be selected in cooperation with local highway authorities and marked with a distinctive marker.

The Evacuation Route Marker shall be a circular sign, having a minimum outside diameter of 18 inches, carrying a directional arrow and the legend EVACUATION ROUTE. The standard Civil Defense Symbol, CD inscribed in a triangle within a ring, shall appear near the bottom of the sign, with a diameter of 3½ inches. The legend, arrow, symbol, and border shall be in white on a blue background. At least the arrow and border shall be reflectorized. The arrow designs shall include a straight vertical arrow pointing upward, a straight horizontal arrow pointing to left or right, and a bent arrow pointing to left or right for advance warning of a turn. The arrow may be a separate unit attached to the face of the sign.

The Evacuation Route Marker, with the appropriate arrow, shall be erected 150 to 300 feet in advance of, and at, any turn in an evacuation route, and elsewhere for straight-ahead confirmation where needed. In urban areas it shall be mounted at the right of the roadway, not less than 7 feet above the top of the curb, and at least 1 foot back from the face of the curb. In rural areas it shall be not less than 5 feet above the crown of the roadway and 6 to 10 feet to the right of the roadway edge.

Evacuation Route Markers shall not be placed where they will conflict with normal signs. Where conflict in placement would occur between the Evacuation Route Marker and a standard regulatory sign, the latter shall take precedence. In case of conflict with a standard informational sign the civil defense sign may take precedence.

Placement of Evacuation Route Markers should be made under the supervision of the officials having jurisdiction over the placement of normal traffic signs, but coordination and agreement between contiguous political entities will be necessary to assure continuity of routes.

6A–4 Area Closed Sign (CD–2)

The AREA CLOSED sign shall be used to close a roadway entering an area from which all traffic is excluded because of dangerous radiological or biological contamination. It shall be erected on the shoulder as near as practicable to the right-hand edge of the roadway, or preferably on a portable mounting or barricade partly or wholly in the roadway. For best visibility, particularly at night, its height should not normally exceed 4 feet to the bottom of the sign. Unless adequate advance warning signs are used, it should not be so placed as to create a complete and unavoidable blockade. Where feasible, the sign should be located at an intersection that provides a detour route.

CD–1
18" diameter (blue)

CD–2
30" x 24"

6A–5 Traffic Regulation Post Sign (CD–3)

The STOP—TRAFFIC REGULATION POST sign shall be used to designate a point where an official post has been set up to impose such controls as are necessary to limit congestion, expedite emergency traffic, exclude unauthorized vehicles, or protect the public. It shall be erected in the same manner as the Area Closed sign (sec. 6A–4) at the point where traffic must stop to be checked.

For emphasis the word STOP shall be in white letters on a black panel at the top of the sign, the remainder of the legend being black on a white background. The word STOP, like the white background, should be reflectorized.

CD–3
24" x 30"

CD–4
24" x 30"

6A–6 Emergency Speed Sign (CD–4)

The MAINTAIN TOP SAFE SPEED sign may be used on highways where radiological contamination is such as to limit the permissible exposure time for occupants of vehicles passing through the area. Since any speed zoning would be impractical under such emergency conditions, no minimum speed limit can be prescribed by the sign in numerical terms. Where traffic is supervised by a traffic regulation post, official instructions will usually be given verbally, and the sign will serve as an occasional reminder of the urgent need for all reasonable speed.

The sign should be erected at random intervals as needed, in the same manner as other standard speed signs. **In rural areas it shall be mounted on the right-hand side of the road with its lower edge not less than 5 feet above the crown of the roadway, 6 to 10 feet from the roadway edge. In urban areas the height shall be not less than 7 feet, and the nearest edge of the sign shall be not less than 1 foot back from the face of the curb.** Where an existing Speed Limit sign is in a suitable location, the Top Safe Speed sign may conveniently be mounted directly over the face of the older sign, which it supersedes.

6A–7 Priority Permit Sign (CD–5)

The PRIORITY PERMIT REQUIRED FOR THRU TRAFFIC sign is to be used at an intersection, at the entrance to a route on which a traffic regulation post is located. Its intent is to notify drivers of the presence of the post so that those who do not have priority permits issued by civil defense authorities can detour on another route, or turn back, without making a needless trip and without adding to the screening load at the post. Local traffic, without permits, may proceed as far as the regulation post. **The sign shall be erected in a manner similar to that of the Emergency Speed Sign (sec. 6A–6).**

CD–5
24" x 30"

CD–6
30" x 24"

6A–8 Emergency Aid Centers Signs (CD–6, etc.)

In the event of emergency, civil defense authorities will establish various centers for civilian relief, communication, medical service, and similar purposes. To guide the public to such centers a series of directional signs will be needed. **These signs shall carry the designation of the center and an arrow indicating the direction to the center. They shall be erected as needed, at intersections and elsewhere, on the right-hand side of the roadway, at a height in urban areas of at least 7 feet, and not less than 1 foot back from the face of the curb, and in rural areas at a height of 5 feet, 6 to 10 feet from the roadway edge.**

These signs shall carry one of the following legends, as appropriate, or others designating similar emergency facilities:

DECONTAMINATION CENTER	WELFARE CENTER
REGISTRATION CENTER	MEDICAL CENTER

APPENDIX K

THE SALEM CONFERENCE
ON HIGHWAY TRAFFIC REGULATION
IN EMERGENCY
AUGUST 5, 1964

TRAINING FOR HIGHWAY TRAFFIC REGULATION
BY
Dr. Homer T. Rosenberger, Chief
Training Branch

In order to train large numbers of adults, both employees and volunteers, quickly and with reasonable thoroughness it is necessary to organize, instruct, and test.

The organizing requires answers to such questions as the following: What shall the training include? Where and when shall it be given? Shall it be a concentrated week of 40 hours instruction, or a series of meetings over a period of several months? Who will instruct and how will the instructors be trained to do this particular job?

The instructing will require much ingenuity on the part of the instructor. He will need to find many ways to arouse the interest of his groups, and numerous ways to maintain that interest. He should discipline himself to follow his outline and the textbook on Highway Traffic Regulation in Emergency which you are preparing. Throughout most of his instruction and especially by the end of a course he should use various testing devices to see how accurately and how completely each group member understands the textbook and the many principles and examples which it will include.

The myth that a large majority of people who have been out of school for a dozen or more years learn slowly and the additional myth that one's learning curve, in spite of his own efforts, drops off drastically after age 25 have often created a feeling of defeat among employees and their supervisors.

When conducting a course for adults one can use to advantage many techniques of instruction because some people learn best by lecture, some best by reading, some best by use of case studies, some best by doing (participating) as part of a team, some best by doing individually, etc.

Any of us can avoid a flattening of our learning curve by taking on projects that are new to us and that cause us to stretch our stride a reasonable distance and reach above our daily routine.

Almost any employee and most volunteers have the capacity to learn if exposed to a variety of instructional techniques and if they feel the need to assimilate the instruction to which they are being exposed.

Perhaps most of you have fairly definite ideas as to how you will organize your respective training programs for highway traffic regulation. This morning I will focus on a few techniques of instruction that we in the Federal Government have found to be effective in the training of public employees. These techniques are presented here in the form of ten groups of suggestions as to how top quality instruction can be achieved. They are presented in the first person so that if you turn them over to one of your instructors he can pick them up with a minimum of transposing.

a. Use chalkboard

1. Use of the chalkboard forces you to put action into your instructing and gives the group an opportunity to see as well as hear.

2. Keep the chalkboard clean, or covered if you place material on it in advance that you will use later, rather than at the beginning of your session. In such case, cover it with a large sheet of wrapping paper or an improvised curtain until you are ready to use it. A chalky smudged board at the beginning of a session gives about the same impression as a littered floor. Nor will someone's hieroglyphics from yesterday be likely to improve your instructing. Erasing the chalkboard during your session is an unnecessary distraction unless you are asking for revisions or are moving from one full board of material to additional relevant material that should be placed on the board.

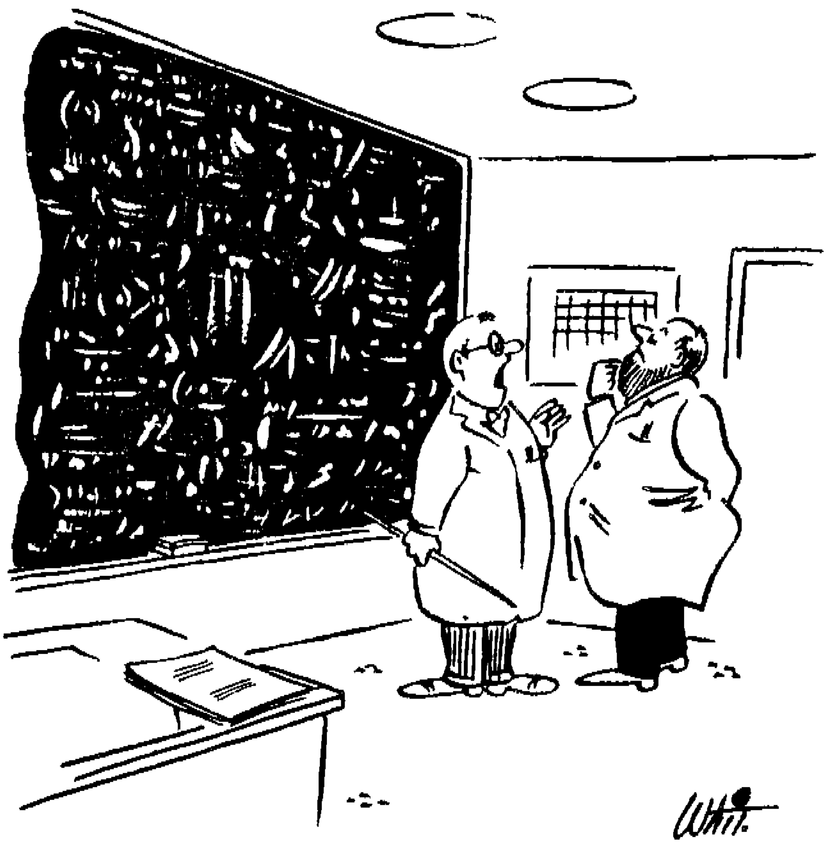
3. When you put a fact, an idea, a sketch or a step-by-step procedure on the chalkboard you alert the group immediately to the importance of this material.

4. Write legibly, and large enough to be seen readily by the entire group.

5. Use words, phrases, sketches, and numbers that are self-explanatory.

6. Use chalk in contrasting colors when color will clarify.

7. Keep the message fairly simple. It is better to drive one point home than try to cover many points in one chalkboard presentation.



"The biggest problem as I see it – is lack of blackboard space!"

Is it easier to find a mathematical formula for reaching the moon than to find the chalkboard space to jot it down?

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of Pan American World Airways

8. Stand aside rather than in front of the board. Frequently an instructor unknowingly obscures the material he wants his group to see. The use of a pointer enables him to discuss from the "sidelines" every phrase, digit, or sketch on the board.

9. Talk to the group, not to the chalkboard.

10. Advantages in placing material on the chalkboard in advance:

    (a) Can cover (hide) it and then exhibit at the strategic time.

    (b) Will avoid the awkward pause often caused when placing fairly detailed material on the board after group has assembled.

    (c) Gives opportunity to space the material well and draw sketches carefully.

11. If you want your story on the chalkboard to unfold gradually while speaking to the group, jot a few words, or a sketch, at a time, or build a chart, a step at a time, and maintain eye contact with your group, or have an assistant write and draw legibly while you talk.

12. If you write and sketch on the chalkboard while instructing, practice ahead of time so that you will use only keywords and phrases, summary statements, numbers, and simple sketches. Without a dry run you may find that you have twice as much material as chalkboard space.

13. If you are distributing materials to all members of the group it may be well to distribute them <u>after</u> you have discussed the material on the chalkboard, so that the chalkboard material will receive undivided attention.

14. Write or print one challenging statement on the chalkboard on a matter you want the group to ponder. This is especially effective if put on the chalkboard before the group enters the room or before it returns from an intermission in a long session. Here are a few examples relating to your area of training:

    WHO GETS A ROAD SPACE PERMIT?

    WHY HIGHWAY TRAFFIC REGULATION IN EMERGENCY?

REGULATED ROUTE -- WHAT IS IT?

SHOULD WE EVER SACRIFICE A DRIVER TO HEAVY RADIATION?

When timed and phrased well and legibly written a chalkboard statement "awaiting" the group will stimulate a considerable amount of thought on the subject to be presented. The statement will speak for itself.

15. When conducting a chalkboard discussion:

(a) Write on the chalkboard in the presence of the group, a concise statement or question to focus thinking during the discussion. Here are a few examples:

WHAT ARE THE STEPS AND CONSIDERATIONS IN PERMIT ISSUANCES?

FUNCTIONS OF TRAFFIC REGULATION CENTERS, SECTORS AND POSTS

WHEN SHOULD A ROUTE BE PLACED UNDER REGULATION?

(b) Sweep your eyes around the room so that you will SEE who is ready to speak.

(c) When a member of the group suggests a step, a function, a condition, etc., pertinent to the subject jot it on the chalkboard immediately, before the comment evaporates. You can erase, strikeout, or modify, but if you wait, you may lose the thought and not get it on the board. This immediate recording of a pertinent comment encourages most members of the group to speak up, with the probable result that the discussion will be active and the chalkboard will fill up with useful facts and ideas.

(d) Prevent out-of-hand discussion between members of the group, by monitoring. This can be done easily, and sometimes with a touch of humor, pointing to the chalkboard and reminding the group "this is what we are talking about," "these are the steps we are looking for," etc.

Through the use of the chalkboard in this type of guided discussion the group will see and learn.

16. A chalkboard that is small, wobbly and takes chalk poorly should be replaced at once.

17. The chalkboard is the most inexpensive tool at the command of an instructor, and one of the best. Do not underestimate its value. It adds variety, places emphasis, and, in a sense, puts action into instructing.

b. Use other visual aids

1. Frequently a technical matter can be explained better in a few minutes with the use of two or three carefully chosen slides than by a half hour lecture.

2. A well chosen cartoon can be mounted on cardboard and circulated to all members of the group to clinch an idea.

3. By circulating several 8" x 10" photographs you can pinpoint a pertinent fact.

4. An enlarged photograph can be used to discuss details.

5. You can clarify by placing a large design or plan of action in front of your group.

6. The reflecting transparent projector enables you to use 10" x 12" color transparencies and overlays.

7. The opaque projector enables you to project photographs, maps, and other similar opaque material.

c. Posture

1. When instructing a group look professional, look as though you mean business; give the appearance of being a professional man talking to intelligent people.

2. It is probably best to avoid posture extremes, statuelike austerity or slouched relaxation.

3. Posture which is "natural" for you and which helps to make others feel the urgency and importance of what you are saying is the right posture to use.

4. The effect your posture has on your audience is difficult to describe. Nevertheless, your posture does reflect very quickly your attitude toward the subject matter and the group. In turn your attitude usually shapes the group's attitude.

d. Avoid reading to groups unless you can do it skillfully

1. Each year the programs of hundreds of professional meetings in this country are filled with excellent papers that are mumbled to audiences having a pious intent to read the papers when published rather than struggle along with the mumbling.

2. Talk <u>to</u> your group. Keep in contact with your audience by sweeping your eyes around the room occasionally instead of fastening them continuously on a typescript.

3. If you feel it necessary to read a prepared paper because of highly technical subject matter, pause frequently, look at the group, and inject comments. Such pauses can be highly effective.

4. If you read a paper show enthusiasm when doing so.

5. If you have been accustomed to reading your remarks try to talk from any kind of outline that gives you what you need. The results will probably surprise you pleasantly, and quickly.

6. Now and then read and comment enthusiastically on a choice paragraph or two relevant to your subject. Occasional reading provides variety of presentation.

e. Voice modulation

1. The dictionary defines modulation as "The use of stress or pitch to convey meaning."

2. One who modulates his voice when instructing speaks with emphasis when making a point, and at times drops his voice momentarily to gain attention and provide change of pace. Put enthusiasm in your voice when teaching. Avoid monotone for it can quickly kill a well-outlined lecture.

3. Speaking in low voice is a good way to furnish change of pace but to talk only in a low voice can be a strain on the group and may eliminate modulation.

4. When modulating your voice with different kinds of expression and various amounts of volume you avoid monotone and the deadpan that usually accompanies it.

5. In a sense, rate of speaking is a modulation of voice. Speak rapidly when referring to material that is already familiar to the

group and slowly when discussing complex matters.

6. Above all, articulate clearly. Modulation without pronouncing words clearly is of no value.

7. Variety is the key to effective instructing - variety of teaching and testing techniques and variety (modulation) in voice. Variety is the purpose of voice modulation. The human voice is capable of great variety - volume, pitch, rate of speed.

8. To listen to an instructor who does not modulate his voice may almost amount to torture. To listen to an instructor who modulates effectively is to catch enthusiasm for his subject matter.

9. Through voice modulation, appropriate posture, and a general attitude of interest toward your subject and your group, you do put enthusiasm into your presentation.

f. Charts

1. The common defect of charts presented at professional meetings is that they include too much detail.

2. Use color, especially where it has meaning - to indicate reversible lanes, etc.

3. Charts can be made quickly with broad pens, small ink cans with felt wick, commercially available paste-on letters, etc.

4. Charts can readily be devised which unfold their story, gradually, one section being exposed, then a second, and then a third. Two of the sections can be covered temporarily with sheets of wrapping paper.

5. Use them. All too often when charts are supplied to an instructor, and placed at his side, he forgets to use them. If you spend time preparing your own charts you probably will use them.

6. An instructor nearly assures, and simplifies, the use of charts by making entries at various places in his outline indicating " refer to chart 1," "discuss chart 2," etc., and by placing the charts in the order in which they are to be used.

g. Use examples (actual cases, actions that have been taken)

A few illustrations:

1. A rather detailed description of how road space was rationed in World War II in England.

2. An explanation of highway signing that was used in England in World War II to regulate traffic at time of a reasonably successful evacuation.

3. An account showing how a bottleneck in traffic was broken in England or France to speed up delivery of vehicles carrying passengers or cargo of highest priority in World War II.

4. A quick recap of "Exercise Spade Fork" as described in Highway Highlights, October - November, 1962; and other published sources.

h. Maintain interest through audience participation (Use of questions - oral and written)

1. RESERVE MUCH TIME FOR QUESTIONS AND COMMENTS.

2. Two-way communication is a characteristic of effective instructing.

3. Use questions to determine how well you are communicating.

4. Build each question on a major point in your outline.

5. State the question so clearly, in relatively simple words, that all in the group can understand what you mean. A foggy question serves no useful purpose.

6. State the question, give all members of the group a few seconds to think about the question, then designate the person who is to answer. This practice keeps the entire group alert, as no one knows who will be called upon. If you designate the person and then state the question it is possible that half of the group will not even hear it.

7. Listen carefully to the answer and then revise or expand it as necessary so that the entire group knows the correct answer.

8. There is an art to asking questions, the kind which measure understanding, and stimulate, rather than humiliate.

9. The instructor who asks searching questions keeps an intelligent audience on its toes and receives intelligent responses.

10. Write out a dozen searching questions about such matters as who does what in time of a conflagration - the various roles of highway department officials, State police, representatives of highway user groups, State Civil Defense officials, and the military.

11. When a question is asked by a member of the group it may be well to ask someone else in the group to answer it. This increases audience participation.

12. See that the eager-beavers do not ask or answer all the questions. Use questions to draw out those who are not participating. When calling on one who hesitates to speak before the group because of feeling ill at ease be sure to ask a question that you know he can answer.

13. Bridle the man whose answer is turning into a speech or who is disgressing from the question.

14. Watch the facial expressions of your audience. When interest begins to wane throw in a question beginning with what, how, when, who, where, or why, so as to avoid a simple "yes" or "no" answer, or guessing.

15. Prepare and use a test consisting of approximately a dozen written questions in the form of statements that can be answered yes or no or about a dozen multiple choice statements. Immediately after the men have answered the test sheet, give the correct answers. Each man can grade his own test, with only he knowing his score. Everyone will leave the session with the correct answers.

16. Ask group to submit questions in writing a day in advance. Hold up one question before the group, state that it has been submitted by a member of the group, read the question, ask for a volunteer to answer the question, or have a board of experts sit in the front of the room to answer it. Proceed in the same way with a number of other questions that have been submitted by the group.

17. Other means, than use of questions, to maintain interest through audience participation:

    (a) Issue course agenda in advance. At the time of distributing the agenda ask those to whom the instruction is being provided to bring with them for solution a problem relevant to the course.

    (b) At time of issuing the course agenda send a problem and ask group members to bring in writing their solution to it (or submit it a week before the course begins, so that you can review the solutions before the group assembles.)

    (c) When the textbook on Highway Traffic Regulation in Emergency is available send it out in advance of the course, together with a reading assignment and an open book self-test on one chapter. Conduct an active question and comment session on that chapter and test at the first meeting of the group so as to set a pattern of active participation for the entire course.

(d) Distribute pertinent, summary material in advance of a particular session in the course and then at that session start a question and comment period based on the "handout."

(e) Request members of the group to do any of the following: define, compare, contrast, explain, outline, give examples of.

(f) Ask several men to each make a short talk on a segment of the subject and give them advance notice so they can prepare

(g) Have a panel of three to five men think about a subject for a week or two and then discuss it before the group.

(h) Select two or three men with oral facility to enact a skit of a likely typical event in highway traffic regulation in emergency.

(i) Write several solvable problems on the chalkboard. Divide the entire group into as many work groups as there are problems on the board. Five problems are a suitable number for a group of 40 to 50 persons. Assign one problem to each work group to solve. Disperse the groups (to separate rooms if available) and reconvene them into "Committee of the Whole" in 30 minutes or an hour or two, depending on how quickly the respective groups will be able to solve the problems. Select a chairman for each work group or have the work groups select their own chairman, to report orally the solution of the work group to the assembled work groups.

12. Have group prepare its own test of true and false or multiple choice statements and several essay questions and have them grade the test papers by asking each person to grade his own paper, or the paper of person on his right (or his left.)

I Rehearse

1. Review your outline to become familiar with it.

2. Judge your time - determine how much the outline should be lengthened or shortened in order to make good use of the allotted time.

3. Make a dry run:

   (a) To see if you have judged your time well.

   (b) To see if your outline includes all the main points, and

   (c) To see if you have included enough content and techniques to give "life" to the outline.

j. Make final check before presentation

1. See that you have the handouts that you plan to use, and in large enough quantity.

2. Arrange your materials in the order in which they are to be discussed, exhibited, or distributed.

3. See that the room is well ventilated and properly lighted. If you are responsible for physical arrangements, provide reasonably comfortable seating. If you can make coffee available at breaks, in or adjacent to the room where the group meets, time will be saved and the group will probably mix well and get down to business the first morning.

4. Be sure you have your outline, chalk, and any other necessary items so that you will not limp along.

5. As a final check, remind yourself that the group will probably judge you as much by your appearance and enthusiasm, or lack of it, as by what you say.

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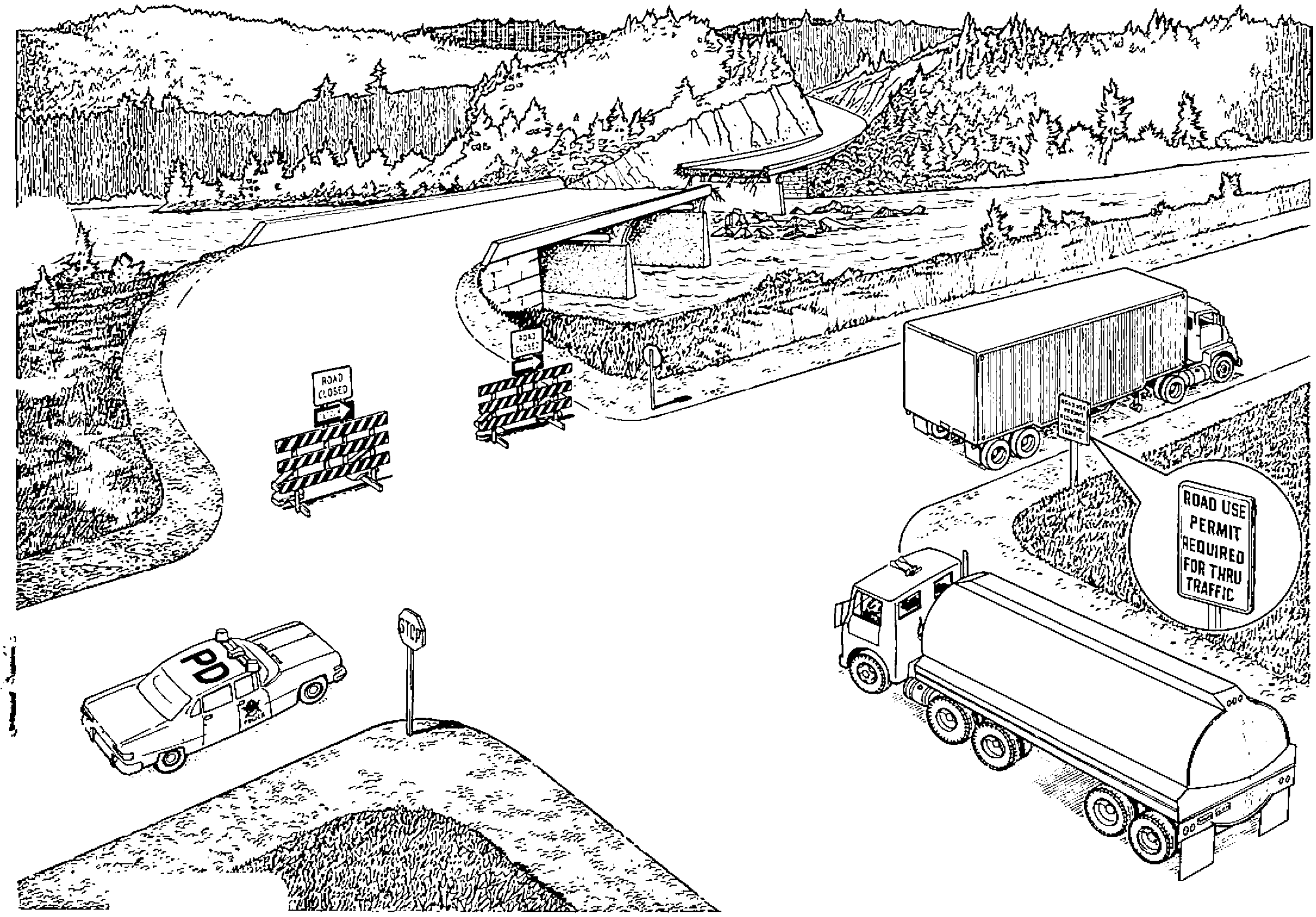
Homer T. Rosenberger
August 3, 1964

A GUIDE FOR HIGHWAY TRAFFIC REGULATION IN AN EMERGENCY



.S. DEPARTMENT OF TRANSPORTATION
ederal Highway Administration

A GUIDE FOR
HIGHWAY TRAFFIC REGULATION
IN AN EMERGENCY

1974

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
Office of Traffic Operations

PREFACE

This publication revises and supersedes emergency planning information previously issued. The information contained herein appeared in the following publications: A Guide for Highway Traffic Regulation in an Emergency, 1967 draft; The Police Function in Highway Regulation in an Emergency, 1967 draft; and Nuclear Radiation Hazards to Highway Transportation, May 1967 draft. This revised and updated Guide is incorporated by reference in paragraph 3b of FHWA Order 10–4.30, Emergency Standby Order, Establishment of Emergency Highway Traffic Regulation (EHTR), dated January 28, 1972, and is published with dated replaceable pages so as to simplify future revisions. This Standby Order has been incorporated in the Emergency Code of Federal Regulations as Document 22–40.

CONTENTS

APPENDIXES

List of Figures

GLOSSARY

"*Administrator*" means the Federal Highway Administrator.

"*Areas of unrestricted travel*" means those areas designated as being safe for travel. Traffic regulation (class "B" or class "C") may or may not be in effect.

"*Blocked routes*" means highways which are impassable as a result of physical damage or a radiation level so high that the highway is not usable as a class "A" route.

"*Clear routes*" means highways which are available to unrestricted use.

"*Defense Civil Preparedness Agency*" (formerly known as the "Office of Civil Defense") is the Agency at national level responsible under the Department of Defense, created May 5, 1972, for discharging the civil defense functions assigned to the Department of Defense under Executive Order 10952. This Agency is also responsible for providing natural disaster preparedness planning assistance to State and local governments.

"*District emergency highway traffic center*" means the centers designated by a State as subordinate to the State EHTR center and responsible for an appropriate part of the State supervised by the State EHTR center. The title of these centers varies from State to State depending on the State agency responsible for emergency highway traffic regulation.

"*Emergency highway traffic regulation*" means a system of traffic management and control devised to regulate the use of highways and to expedite and facilitate essential movements during a national defense emergency or a natural disaster.

"*Emergency highway traffic regulation boundaries*" means the boundaries of those areas falling within the primary jurisdiction of the State traffic regulation center, the district traffic regulation center, and the traffic regulation sector. The area of jurisdiction of the State center is the entire State. The area of the district center is explained in each State plan and differs from State to State. The area of jurisdiction of a sector center is that portion of an emergency highway traffic regulation district which is assigned to the sector by the highway department, or other State agency responsible for emergency highway traffic regulation.

"*Emergency highway traffic regulation sector center*" means the centers designated by the State as subordinate to the district EHTR center and responsible for an appropriate part of the State supervised by the district EHTR centers.

"*Emergency highway traffic regulation posts*" means control points at each end of or along regulated routes, for the purpose of controlling the flow of traffic onto or on the route, checking road-use permits, and advising occupants of vehicles of any danger from radioactive fallout.

"*Highways*" means all Federal, State, city, local, and other highways, roads, streets, bridges, tunnels, and appurtenant structures.

"*Highway Users representative*" means personnel from trucking associations, State public utility commissions or volunteers from any class of highway users acceptable to the State EHTR organization. This group will augment, as necessary, the personnel staffing State emergency highway traffic regulation centers, district centers and sector centers.

"*Liaison representatives*" means military and civil defense organization representatives at the State traffic regulation center, and at district and sector centers as necessary. They will consult with and submit claims to the highway department, or other State agency responsible for emergency highway traffic regulation, for highway space or for the temporary establishment of class "B" routes as required by their respective agencies.

"*National defense emergency*" means all adverse situations affecting the Nation's security so recognized by the President, the Congress, or other competent authority.

"*Natural disaster*" means any act of nature which is or threatens to be of such severity and magnitude as to cause extensive loss of life, personal injury and/or damage to/loss of property.

"*Police*" means any duly constituted peace officer engaged in law enforcement at the State, county, parish, or municipal level.

"*Regulated routes*" means highways which must be subjected to regulation because of hazardous conditions, special uses, or limited capacity in relation to demand.

"*Regulated routes—class "A"*" means highways which lie within an area contaminated by radioactivity that is hazardous to the life and health of highway users.

These roads may be used with special guidance precautions and practices.

"*Regulated routes—class "B"*" means highways which are temporarily reserved exclusively for a special purpose, such as military or civil defense movements.

"*Regulated routes—class "C"*" means highways which are determined to have, or which are expected to develop, critical traffic capacity restrictions, and on which travel is generally limited to holders of "road-use permits."

"*Road-use permit*" means a legal permit form issued to authorize specific travel over a designated regulated route during a specified time. (Some State plans use the synonymous term "road-space permit").

"*State emergency highway traffic regulation center*" means the center designated by a State as the agency responsible for overall supervision of emergency highway traffic regulation within the State.

"*State police*" means highway patrol, State highway police, and State troopers.

The sources of these definitions are listed below:

1. Glossary of Terms and Abbreviations for Use in Transportation Preparedness Planning, October 1971, Department of Transportation (DOT P 1945.1)
2. Example Plan for Highway Traffic Regulation in an Emergency—1968 Draft
3. A Guide for Highway Traffic Regulation in an Emergency—1967 Draft
4. The Police Function in Highway Traffic Regulation in an Emergency—1967 Draft

Part I GENERAL BACKGROUND OF EMERGENCY HIGHWAY TRAFFIC REGULATION (EHTR)

CHAPTER I—INTRODUCTION

Our nation is composed of people on wheels. For transportation, they are accustomed to using cars, trucks, or buses anytime they choose, traveling as far as they wish by whatever route they desire. As long as drivers conform to the rules of the road no one normally interferes with their movement nor challenges their right to be on the highway. These travelers accept certain restrictions in emergencies when it is necessary for police to block off local areas in the vicinity of accidents and fires, for example. They also tacitly accept detours established by highway authorities to guide them around road construction, washouts, and mountain slides. In brief, the highway traveler generally will accept control measures that are plainly and understandably presented for his benefit or safety, but he has no tolerance for any artificial restrictions to his freedom to go where or when he wants. Particularly repugnant would be any system imposed upon him which would require him to obtain a permit from government authorities to make any unusual highway trip.

These are the attitudes of Americans in peacetime. But what about a wartime or a natural disaster situation? Transportation assumes more critical proportions. Immediately the traveler thinks in terms of carpools, and gas and tire rationing which were endured in World War II. He reluctantly accepts the inevitability of a repetition of such control measures. There are other problems, however, which Americans did not have to face. The United States was not under attack and nuclear weapons and radiological hazards were not a problem. At Dunkirk, the British faced disaster when hordes of refugees clogged roads and immobilized troops. Transportation of essential material and personnel needed top priority. Out of necessity a system of traffic regulations was instituted and practiced during World War II by the British in North Africa and by the allies in Europe. The United States Army also, by necessity, devised a similar system called by the military "highway traffic regulation."

Defense officials foresaw a need for highway traffic regulation in the United States in the event of a national defense emergency, and requested the then Bureau of Public Roads (now the Federal Highway Administration) to devise a nationwide system of emergency highway traffic regulations for implementation by *civilian* authorities. Under this system the Bureau furnished guidance to the States in achieving a readiness to perform emergency highway traffic regulation, and to coordinate this function between the various States, including the planning for Interstate directed movements by highway. In the furtherance of this program, the Federal Highway Administration has entered into an agreement with each of the 50 States, the District of Columbia and Puerto Rico which, among other things, requires each of those governments to prepare emergency highway traffic regulation plans and to update them annually. Accordingly, emergency highway traffic regulation plans have been prepared following the procedures covered in this Guide.

Briefly, the State EHTR plans envision, in the post-attack period, a survey which would be conducted on the road and street network for both physical damage and radiation hazard. Barricades and warning signs would be placed where needed on those roads which were deemed to be hazardous. Following this, estimates would be made of potential traffic demands and the traffic-carrying capacities of facilities remaining available for use. If emergency highway traffic regulations were found necessary, road-use permits would be issued for traffic movements on routes which otherwise would be heavily congested. These activities would be conducted by the State EHTR organization. Regulation of traffic on the road would be accomplished at strategic checkpoints (posts) on each regulated route section.

It is a basic EHTR principle to allow as much as possible unregulated traffic to use existing facilities. Regulation would be instituted only where, and for as long as necessary. The State organization would necessarily continuously adapt and modify its operations to meet the constantly changing situation. For emergency situations, plans would have to be developed for an orderly movement of traffic. The emergency highway traffic regulation operation must involve a close-working, three-party team as follows:

I. State Highway Department—Assisted by county and/or city highway department personnel as needed, the highway organizations would assess damage and estimate traffic demand and traffic-carrying capacity of usable highways.

II. Highway User Organizations—This group could consist of personnel from the State's Public Utilities Commission (Commerce Commission, Public Service Commission, etc.) or from highway user organizations such as the various trucking associations, for example. For simplicity throughout the remainder of this Guide, this member of the three-party team will be referred to as the "highway users."

Their primary assignment would be to make periodic estimates of potential commercial traffic movements and, under the supervision of the EHTR center to which assigned, to issue road-use permits.

III. State Police—Assisted by local police organizations as needed, the police would actually control the regulated traffic movements that have been authorized by the State EHTR organization.

In close association with the three-party team would be liaison representatives of the local defense civil preparedness organization and of the military command. The Federal Highway Administration, identified hereafter as FHWA, while playing an important role in the development of emergency highway traffic regulation plans and preparedness, would have discretionary functions in the actual operation; probably only that of coordination among the States where and when needed. Executive Order 11490, Part 21, specifies that national emergency plans and preparedness programs be prepared by the Interstate Commerce Commission (ICC) under the coordinating authority of the Secretary of Transportation. The role of the ICC in relation to EHTR is described in the section "Operation of Regulated Routes" beginning on page II–24 and in Appendix "A". The Office of Emergency Transportation is an emergency planning organization in the Office of the Secretary of Transportation. Its functions are summarized on page I–8. The role of the military in EHTR is explained in Part III of this Guide.

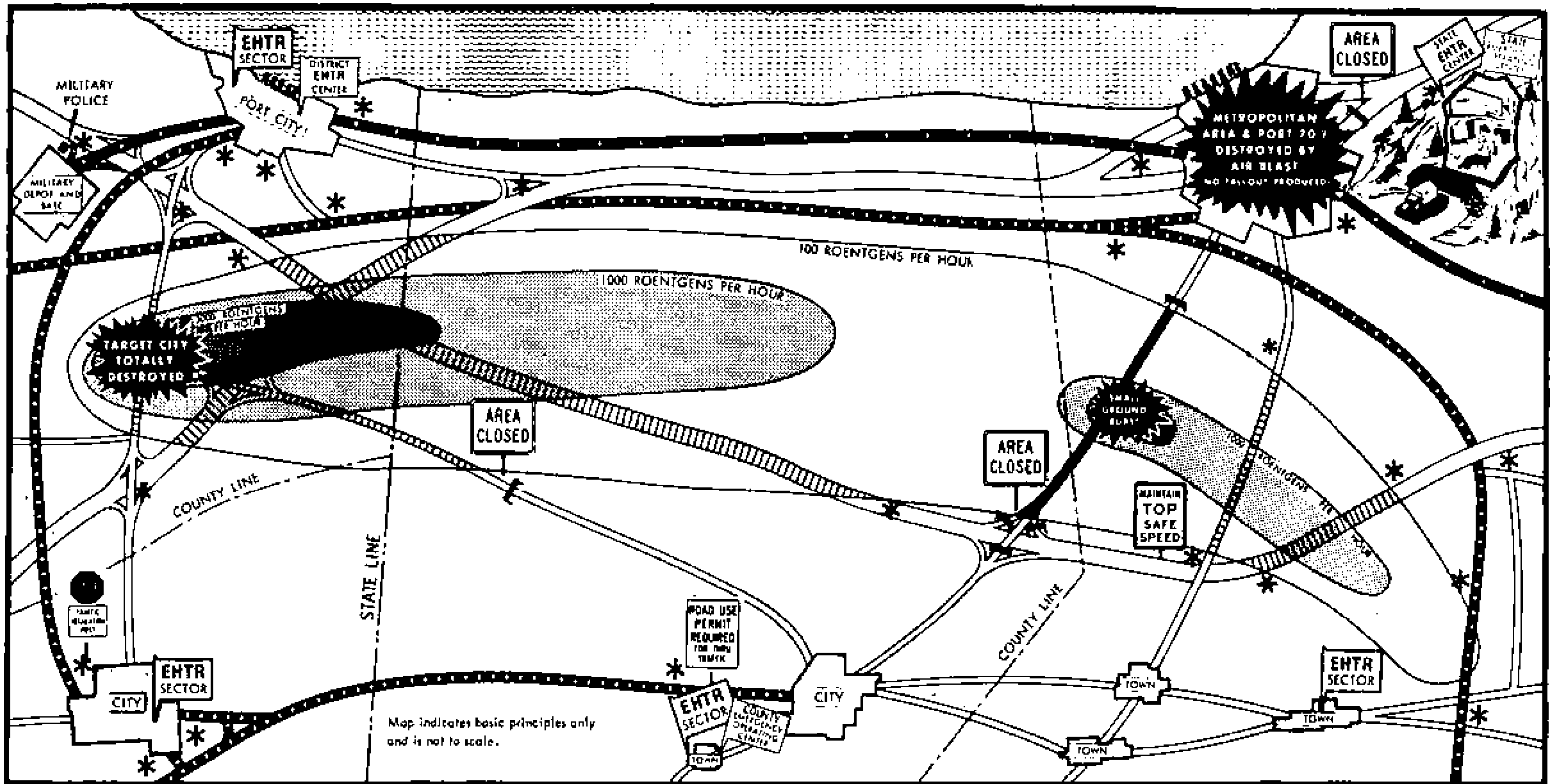
It is expected that for an extended period following an enemy attack, normally available highway traffic-carrying capacity may be greatly reduced in many areas. At the same time transport demand for essential needs may increase. Some routes could be blocked or closed. Some may be wholly reserved for defense civil preparedness or military operations. And, on some, rationing of road space will probably be required in order to give appropriate priority to traffic movements essential to sustenance of the population and to restoration and maintenance of industry and the national economy. Some indication of the effects of a nuclear attack on our highway network, and the regulation that would be required to meet traffic needs, is illustrated in figure 1.

Even from this brief introductory resume, it is evident that highway traffic regulation in a national defense emergency, in these United States, may indeed be a herculean undertaking. Under extreme conditions brought about by a massive nuclear attack, it is possible that as many as 100,000 persons might be engaged, during a considerable period of time, in the struggle to keep essential highway transportation from costly congestion and complete stagnation. The real eventuality, if it should come, may not attain the maximum possible anticipated scale but prudence dictates that planning, organization, preparation, and the recruitment and training of personnel for emergency highway traffic regulation must be rapidly undertaken and carried forward unremittingly until we have reached a full state of readiness. The only alternative is chaos.

The nature, scope, and operation of emergency highway traffic regulation is discussed at some length in this Guide. This publication has been coordinated with the Office of Preparedness of the General Services Administration, the Office of Emergency Transportation, the Department of the Army, the Emergency Preparedness Committee of the American Association of State Highway and Transportation Officials (AASHTO), formerly the American Association of State Highway Officials (AASHO), the Defense Civil Preparedness Agency and the International Association of Chiefs of Police.

The original draft edition of this Guide was designed to help the States prepare plans which would work effectively, individually and collectively. The function of this revised Guide is two-fold. First, since the Guide has been incorporated by reference in FHWA Order 10–4.30, it will, by the use of replaceable pages, serve as a tool to aid in the updating of the State's plan through the publication of changing national policies and programs. Secondly, this Guide, when used in conjunction with the State plans, will serve as a logical and effective aid for local level emergency highway traffic regulation training programs. It is obvious that in times of catastrophe, even more than in peacetime, the needs of the nation and its people know no political boundaries or highway jurisdictions. All available roads and streets must be used to best advantage as a continuous, coordinated transportation network. If highways are the arteries of our nation in time of peace, they are more so in time of war.

APPLICATION OF EMERGENCY HIGHWAY TRAFFIC REGULATION



CLEAR ROUTES

Roads, streets, and highways not regulated or restricted.

REGULATED ROUTES

CLASS A

Highways which lie within an area contaminated by radioactivity that is hazardous to the life and health of highway users. These roads may be used with special guidance precautions and practices.

CLASS B

Highways which are temporarily reserved exclusively for a special purpose, such as military or civil defense movements.

CLASS C

Highways which are determined to have, or which are expected to develop, critical capacity restrictions, and on which travel is generally limited to holders of "road use permits."

BLOCKED ROUTES

These highways are unusable because of intense radioactivity and/or total destruction.

EHTR POSTS

* Control points at each end of or along regulated routes for the purpose of controlling the flow of traffic, checking road use permits, and advising occupants of vehicles of any danger from radioactive fallout.

CONTAMINATED FALLOUT AREA

Radioactivity is invisible, intensity measured in roentgens per hour.

EMERGENCY HIGHWAY TRAFFIC REGULATION SIGNS

STOP — TRAFFIC REGULATION POST

DESIGNATES OFFICIAL EHTR POST. ALL VEHICLES MUST STOP TO BE CHECKED.

MAINTAIN TOP SAFE SPEED

EXPEDITES MOVEMENT THROUGH RADIOACTIVE AREAS.

AREA CLOSED

BARRICADE AND/OR SIGN CLOSES A HIGHWAY ENTERING A DANGEROUS AREA.

ROAD USE PERMIT REQUIRED FOR THRU TRAFFIC

NOTIFIES DRIVERS THAT ROUTE BEYOND IS REGULATED. A ROAD USE PERMIT IS REQUIRED TO PROCEED.

FIGURE 1

CHAPTER II—ORIGIN AND EVOLUTION

The emergency highway traffic regulation program as it is now conceived and developed is not a revolutionary but rather an evolutionary program. A brief account of its development is presented here as matter of interest.

Since its inception, the FHWA has recognized the strategic importance of our highways in relation to the national defense and in this regard has consistently worked closely with the military establishment. FHWA had also sought and obtained the full cooperation of all the State highway departments in helping to determine and meet the highway needs of the national defense. Included among the series of outstanding study reports published by the FHWA over the years are two which are especially noteworthy: *Highways for the National Defense* (1941) and *Highway Needs of the National Defense* (1949).

Consideration of highway needs of the national defense, however, was limited for many years to concern for provision of adequate routes for military use and war production service. Enemy invasion was considered almost inconceivable; air, sea, or sabotage attacks were visualized as possibly heavy but presumably localized. The vital importance of an organized program for highway traffic regulation in an emergency was forcibly brought home by the congestion on the refugee-choked roads of Europe in the early part of World War II. Subsequently, highway traffic regulation became a wartime commonplace.

After World War II, however, the subject was given low priority, even though emergency readiness planning in the thermonuclear age was authorized by the Congress in the Civil Defense Act of 1950, in which FHWA, by Presidential Order, was assigned an advisory role.

Interest picked up in 1957 when the American Association of State Highway and Transportation Officials (AASHTO) promised the cooperation of the State highway departments. In 1958, at the recommendation of the Secretary of Defense, FHWA was formally assigned responsibility for developing an emergency highway traffic regulation program. In 1962 AASHTO approved the participation of the highway users as members of the EHTR team and in 1964 the International Association of Chiefs of Police solicited the support and cooperation of police officers throughout the country.

The Federal Highway Administration position in emergency operations was formally reaffirmed in 1969. (Appendix "A") Executive Order 11490 assigning emergency preparedness functions to Federal departments and agencies, directed the Secretary of Transportation to ". . . develop a capability to carry out, the transportation operating responsibilities assigned to the Department, including but not limited to . . .

> (3) Emergency management of all Federal, State, city, local, and other highways, roads, streets, bridges, tunnels, and appurtenant structures, including:
>
> (a) the adaptation, development, construction, reconstruction, and maintenance of the Nation's highway and street systems to meet emergency requirements;
>
> (b) The protection of the traveling public by assisting State and local authorities in informing them of the dangers of travel through hazardous areas; and
>
> (c) The regulation of highway traffic in an emergency through a national program in cooperation with all Federal, State, and local governmental units or other agencies concerned."

The Secretary of Transportation delegated the above and other highway related emergency responsibilities to the FHWA. This Administration then formally stated its emergency highway traffic regulation responsibilities, with the approval of the Secretary, in a brief statement which appears in FHWA Order 10–4.30, dated January 28, 1972, Emergency Standby Order—Establishment of Emergency Highway Traffic Regulation (EHTR). (Appendix "H")

CHAPTER III—EMERGENCY HIGHWAY TRAFFIC REGULATION IN THE EMERGENCY PLANNING FIELD

The broad field of civil emergency planning includes, from the point of view of enemy attack, two major areas: defense civil preparedness (formerly civil defense) and emergency resource management.

The defense civil preparedness program includes warning, fallout shelters, radiological monitoring, damage assessment and post-attack survival activities such as fire fighting, rescue, debris removal, medical care, police services and related actions in damaged areas. State civil defense plans were prepared in accordance with guidelines issued by the then Office of Civil Defense of the Department of the Army.

Emergency resource management is concerned with the post-attack management of resources including communications, construction, housing, economic stablization, electric power, health, transportation and others. State resource management plans were prepared in accordance with guidelines issued by the former Office of Emergency Preparedness (now the Office of Preparedness General Services Administration), and these are separate and distinct from civil defense plans. *The EHTR program is identified as a resource management program in Chapter 6 of the National Plan for Emergency Preparedness* and is *not* a civil defense program. (Appendix "J")

An understanding of the time-frame relationship of civil defense (the term used at the local level for defense civil preparedness) and EHTR will be helpful in understanding where the latter fits in the emergency planning field. The EHTR program, as a post-attack program, will not be activated until radiation levels have decayed to the point where shelter emergence is feasible. As a resource-oriented program, the EHTR program will commence when the State emergency resource management plan becomes operative in support of the Office of Defense Resources.

In view of the above information and the agreement signed by the States to cooperate in emergency preparedness planning for the highway resources, virtually every State has prepared separately bound EHTR plans. There are, however, other reasons why it is desirable to have separate plans. Most of the reasons are related to the fact that the users of the plan will not be concerned with other portions of a larger resource management document but will have a specialized interest in the highway traffic regulation phase. Separate plans facilitate training and make for easier emergency use at relocation sites. Also, the activation of a separate plan is simpler than the activation of a separate part of a larger plan. A separate plan will facilitate the execution of FHWA Order 10–4.30, Emergency Standby Order, Establishment of Emergency Highway Traffic Regulation (EHTR), dated January 28, 1972. In addition, the existence of separate State EHTR plans will greatly assist the FHWA in the discharge of its responsibilities under Section 1303 of Executive Order 11490.

A copy of each State EHTR plan must be maintained at the national relocation site of the Federal Highway Administration for use in the event of a national defense emergency. Also, the Military Traffic Management and Terminal Service, Department of the Army, has directed that each Army commander develop a military EHTR plan and cooperate in the development of State EHTR plans. It is the responsibility of the FHWA, Washington Office, to furnish copies of all approved State EHTR plans to the Military Traffic Management and Terminal Service.

It is realized that in most of the States that resource management functions and the civil defense functions are administered by the same State office. This, of course, is the prerogative of the Governor and naturally no issue is taken with this arrangement. It follows, therefore, that the Federal Highway Administrator has no preference as to who performs these functions at State level; however, it is essential that the EHTR plans be so identified and bound separately for the reasons stated above.

CHAPTER IV—EMERGENCY HIGHWAY TRAFFIC REGULATION AND NATURAL DISASTERS

Emergency highway traffic regulation could likely be a necessity following natural disasters such as earthquakes, hurricanes, severe snowstorms, floods, etc. The degree of such regulation will depend, of course, on the magnitude and extent of the disaster. Each State plan should contain a provision for the use of EHTR during natural disasters and many do. For example, in the Illinois EHTR plan it is explained that each highway district has prepared a district "EHTR plan for a natural disaster." These district plans are voluminous and contain an alerting system, an SOP for alerting for various emergencies, names and addresses of key and field personnel for different areas of the district, map and listing of storage locations with material and equipment available at each, listing of mobile radios and call numbers by areas, location of stockpiles of signs and barricades, listing of news media, radios, television, for dissemeninating information to the public. These district plans were made in cooperation with the State police and the heads of the leading communities in the district.

The Louisiana EHTR plan also contains a section on emergency highway traffic regulation during natural disasters. This plan refers the reader to the Department of Highways Civil Defense Plan for the detailed procedures to be followed.

The Maryland Plan contains the following reference to natural disasters:

> "Following natural disasters such as floods, hurricanes, etc., an immediate survey of the road and street networks will be made to determine the extent of physical damage. Necessary signs and barricades will be erected to protect and reroute traffic.
>
> "Experience to date indicates that damage will probably be limited to an area assigned to a district engineer. The district engineer has the responsibility for survey of physical damage and the initiation of repairs to place the roads affected back into service. District highway personnel and equipment are available for the above action. This policy will continue in the future."

In the event that a large part of the State is stricken, the Maryland EHTR plan will be placed in effect to the degree felt necessary. The activation of the EHTR plan could vary from full implementation to partial (i.e., sector or district) activation. The extent and severity of the disaster will dictate to what degree the plan is implemented.

The 1972 tropical storm Agnes was the largest single disaster that has ever hit the United States in terms of damage and destruction to public and private property. It was greater than the combined total destruction of the 10 most devastating natural disasters of the past decade. The need for highway engineers for inspection of damaged bridges and highways was critical. In addition to 700 engineers from the affected State highway departments the FHWA furnished 260 engineers to assist in the damage inspection program. To illustrate the damage, a total of 718 bridges were either out of service or destroyed in Pennsylvania alone and a grand total of 1,170 were damaged or destroyed in the four States involved.

The FHWA was called upon by the Department of Housing and Urban Development to assist in the movement of 18,500 mobile homes over the highways to Pennsylvania and New York. A traffic regulation problem arose concerning State requirements and permit handling procedures which were hindering expeditious movement of these mobile homes. In view of the regional nature of this problem, the FHWA by working with the heads of the highway departments of the 37 States involved was able to expedite the movement of these emergency homes. Restrictions on load length and width of mobile homes, permissible hours for moving and requirements for escort vehicles and flagmen were eased. Permit handling was simplified and delays at State border crossings were minimized or eliminated.

Natural disaster EHTR in States as diverse as Alaska, Florida, North Dakota, and Pennsylvania will vary greatly. It is not feasible, therefore, to spell out detailed guidelines for this type of regulation in this publication. Because the size, topography, population, and highway system of each State varies so greatly, this type of regulation is better left to the individual State emergency highway traffic regulation planning officials.

CHAPTER V—ORGANIZATIONS INVOLVED IN EMERGENCY PLANNING

GENERAL SERVICES ADMINISTRATION (GSA)

Office of Preparedness

The General Services Administration is an independent agency which provides the Federal Government with an economical and efficient system for the management of its property and records. This agency has 10 regional offices scattered throughout the United States.

Executive Order 11725 (Appendix K) dated June 27, 1973, transferred the certain responsibilities of the former Office of Emergency Preparedness (OEP) to the Office of Preparedness, GSA as follows:

Section 1: Disaster assistance (under the Disaster Relief Act of 1970 as amended, and other authorities), including management of the President's Disaster Relief Fund and coordination of Federal agency efforts to the Secretary of Housing and Urban Development.

Section 2: Investigation of the effects of imports on national security (under Section 232) of the Trade Expansion Act of 1962, as amended, to the Secretary of the Treasury.

Section 3: Civil emergency preparedness (under all other authorities) including continuity of Government and emergency resource management to the Administrator of General Services. Included in this section are the functions under Executive Order 11490 "relating to the assignment of emergency preparedness functions to Federal departments and agencies."

Section 4: All rules, regulations, orders, determinations (including delegation of authority) and permits, etc., which have been issued by the OEP and are in effect at the time this order takes effect shall continue in effect until modified or terminated.

The National Plan for Emergency Preparedness, published by the former Office of Emergency Preparedness, contains the basic principles, policies, responsibilities, preparation and responses of civil government to meet any kind of national defense emergency and identifies the FHWA as a transportation operating agency. It describes the roles of the Federal Government, the States and their political subdivisions and, as appropriate, nongovernmental organizations and individual citizens. It brings together in one unclassified document an overview of individual emergency preparedness plans developed by Federal agencies in accordance with their responsibilities under the above-mentioned and other pertinent statutes and Executive Orders. Chapter 6 of this plan is attached as Appendix J. This chapter assigns to the FHWA the responsibility for the National Emergency Highway Traffic Regulation program.

DEFENSE CIVIL PREPAREDNESS AGENCY (DCPA)

This agency, in the Department of Defense, is engaged in a wide range of activities related to national civil preparedness. The primary thrust of the national program is to develop defense against the threat of enemy attack, including a shelter program, a national warning network, a radiological defense system, and other attack-oriented capabilities. The DCPA provides leadership, matching funds, and other assistance to State and local governments to develop civil preparedness. This includes on-site assistance in the local emergency planning and exercising, and related preparations, providing the ability to conduct coordinated lifesaving operations in emergencies.

Because most of the local capabilities needed for lifesaving operations under attack conditions are also applicable in major peacetime disasters or emergencies, DCPA's work with local governments aims at improving their ability to act swiftly and effectively to save life and protect property when the community is threatened or hit by *any* kind of disaster.

Working through their regional offices, DCPA would in time of emergency, house representatives of a number of Federal agencies in addition to the DCPA staff, and would be the focal points for communications to the States and for interchange of information necessary for effective operations.

Each State and many local governments maintain a civil preparedness, civil defense, or disaster office, with the name of the agency varying from area to area. These agencies are involved in preparing State and local government forces and departments for operations in major emergencies. Each State and many local communities have established and maintain an Emergency Operating Center (EOC), where the decision makers of a State or local government assemble in emergencies to direct, coordinate and control emergency actions. Liaison representatives provide close coordination with Federal civil and military agencies and activities.

THE OFFICE OF EMERGENCY TRANSPORTATION (OET)

The Office of Emergency Transportation in the Department of Transportation is solely dedicated to emergency preparedness. It is the primary staff element of DOT engaged in the development, coordination, and review of policies, plans and programs for attaining and maintaining a high state of emergency preparedness. With the active participation of appropriate Secretarial offices, operating administrations external agencies, and industry, OET oversees the effective discharge of the Secretary's responsibilities in emergencies. The OET ensures that emergency plans are developed and an acceptable state of readiness is achieved in each transportation operating and support agency.

Should a nuclear attack on our nation occur, the OET as a planning agency would probably be absorbed by the Department of Transportation Emergency Organization which would exercise Executive Management of the emergency functions of the Department, under the direction of the Secretary of Transportation.

THE FEDERAL HIGHWAY ADMINISTRATION (FHWA)

The first Federal agency concerned with highways, the Office of Road Inquiry, was established in 1893. However, the national influence of it and successor agencies was not fully developed until Congress passed the 1916 Federal-Aid Road Act. This statute, as amended, established the present pattern of Federal assistance to States for highway construction and improvement. The landmark impact of this Act was, however, the requirement that in order for each State to receive Federal-aid funds it must have a highway department with adequate powers, suitably equipped and organized to effectively carry out the duties required by this Act. This requirement generated a strong engineering skill capable of responding to the steadily expanding national highway program.

The Federal-aid program is a cooperative one. The States choose the systems of routes for development, select and plan the individual projects to be built each year, acquire the right-of-way, and award and supervise the construction contracts. The States pay for the work as it progresses and then claim reimbursement from the Federal Government for the Federal-aid share of the cost. The function of the FHWA is to administer this grant-in-aid program and furnish guidance, control and approval, with respect to the financial obligation of the Government, in each succeeding step of the progress.

The Federal-aid highway program operates on a pay-as-you-go basis and its cost is paid by highway users. Most of the Federal highway activities are financed from the Highway Trust Fund, supported entirely by Federal road-use taxes. The Federal tax on motor fuel, and certain other highway-related taxes, go into the Highway Trust Fund and provide the money for the Federal payments to the States. The annual amounts of Federal highway funds to be made available (authorized) to the States are set by Congress, and the funds so authorized are divided (apportioned) among the States according to methods prescribed by law.

The cooperative relationship between the States and the FHWA which has developed over the years is often cited as a model of Federal-State cooperation. This relationship is a logical basis for assigning the guidance and coordination of emergency highway traffic regulation to this Administration. In this spirit of cooperation, the responsibility for the direct emergency regulation of highway traffic has been accepted by the States and each State has prepared a detailed plan explaining how emergency highway traffic regulation will be administered. These State plans have been coordinated by the FHWA in accordance with national guidelines. This program is, therefore, decentralized and in the event of an attack on our nation the role of this Administration would consist of providing advice and assistance to the States as requested and coordination between the States as necessary, to provide for the smooth functioning of this program.

THE INTERNATIONAL ASSOCIATION OF CHIEFS OF POLICE (IACP)

The International Association of Chiefs of Police serves the law enforcement profession and the public interest by advancing the art of police service. Its staff of police management consultants, educators and trainers, highway safety consultants, researchers, and systems analysts develop and disseminate improved administrative, technical, and operational practices and promote their use in police work. Its aims are to foster police cooperation and the exchange of information and experience among police administrators throughout the world; to bring about recruitment and training of qualified persons; and to encourage adherence of all police officers to high professional standards of performance and conduct.

Traditionally in the forefront of efforts to improve and professionalize police service, the IACP has provided assistance and advice to a large number of police agencies, State criminal justice planning councils, congressional committees and presidential commissions. Because of its broad representation

EMERGENCY ORGANIZATION OF THE FEDERAL TRANSPORTATION COMMUNITY

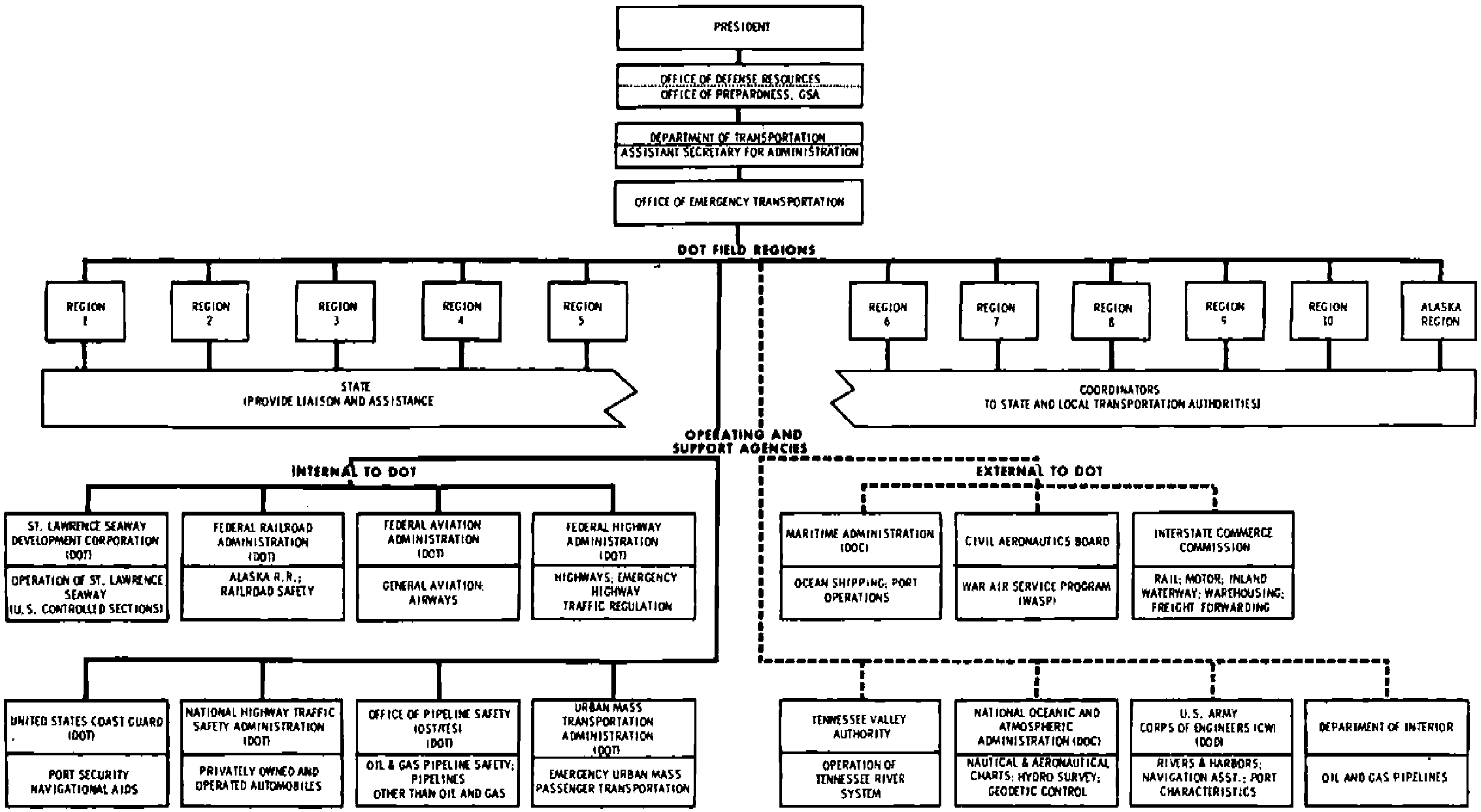


FIGURE 2

(approximately 8,000 members) this association was the logical group to be called upon for collaboration in developing concepts and general plans for emergency highway traffic regulation. The IACP prepared the original text of the section of this Guide which is concerned with the police function in emergency highway traffic regulation.

THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO is organized to foster the development, operation and maintenance of a nationwide integrated system of highways, and to cooperate with other appropriate agencies in considering matters of mutual interest with the other modes of transportation in serving the public need. To this end, the highway officers of all the States, Puerto Rico, the District of Columbia, and the FHWA have pledged their cooperation: to develop and improve methods of administration, planning, research, design, construction, maintenance and operation of highways to provide the efficient, safe and effective transportation of persons and goods in support of national goals and objectives; to study all problems connected with highway transport and its interaction with other modes of transportation; to counsel with Congress on highway legislation; to develop technical, administrative and highway operational standards and policies needed to carry out the highway program.

AASHTO has a special committee on emergency preparedness created by request of the FHWA. The committee is composed of one deputy chief administrative officer from one State highway department in each of the FHWA regions, and the Secretary is an FHWA official. It is the function of this committee to advise and assist the FHWA in the development of plans, procedures and training in the areas covered by the Emergency Standby Orders which appear in Appendixes D, E, F, G, H, and I.

CHAPTER VI—ORGANIZATIONS INVOLVED IN EHTR OPERATIONS

STATE HIGHWAY DEPARTMENTS

Every State has a highway department, although the name and nature of the agency vary among them to some degree. Because of their long experience in cooperating with the Federal Government, their broad operations and large corps of trained personnel, and their considerable managerial and technical capability, the State highway departments generally have been assigned responsibility by the Governors of their respective States for emergency highway traffic regulation. In some cases, however, another State agency such as the State police has been assigned this responsibility. (In this Guide, when "State highway department" is mentioned it is intended to refer to the State agency responsible for emergency highway traffic regulation, unless the context indicates otherwise). In preparing for and operating emergency highway traffic regulation, the State enlists the cooperation and assistance of county and local rural and urban highway departments as necessary.

With only a few exceptions, each State highway department has divided its State into working areas for purposes of administration and operation. In most of the States, these areas are identified as districts or divisions. (In this Guide they are called districts hereafter, but divisions should be understood where applicable).

These highway districts usually comprise several counties and many are coextensive with county lines. Each has a district central office responsible for all or many of the normal State highway operations in the area, including road location, design, construction, maintenance and repair, traffic signing and signalization. These districts are usually further divided into smaller administrative areas which are responsible for highway maintenance, etc. The logical subdivision, therefore, for EHTR operations is the State highway department district and subordinate offices.

DEPARTMENT OF THE ARMY

The Department of the Army represents the military services for the Department of the Defense in the development of the concepts and plans for emergency highway traffic regulation. The Army EHTR plans provide for the assignment of a team to each State EHTR center when activated. Upon activation of these centers, these teams will coordinate military movements, arrange for the establishment, when appropriate, of routes which will be reserved for the exclusive use of the military (for the duration of the movement) and/or effectuate the issuance of road-use permits for military movements. (See Part III below for a full explanation of the role of the military in EHTR.)

STATE AND LOCAL POLICE ORGANIZATIONS

The restoration and regulation of traffic in a national defense emergency is the responsibility of each State. Because the Governor has the prerogative of designating the agency having the authority to direct emergency traffic supervision, the police responsibility may vary from State to State, and the Governor will normally delegate the authority for statewide police emergency operations to the commanding officer of the State police agency. Since EHTR is but one of his many duties, the State police commander would usually designate another high-ranking State police officer to represent and direct police operations from the State EHTR center.

Whether police have full or only partial responsibility for enforcing emergency highway traffic regulation, the magnitude of the problems involved requires the full cooperation and coordinated efforts of many agencies and individuals.

Figure 3 illustrates the police "chain of command" for purpose of assigning responsibility, delegating authority and establishing lines of communication in the EHTR organization.

It is important to note the implications of the chain of command illustrated on Figure 3. Although it represents the most logical approach to performance of the police role, the success of the mission is solely dependent upon the complete devotion of all police agencies involved to a singular purpose. There must be a coordination and cooperation among State, county, and municipal police. Each must make his plans so as to mesh with the total effort. All officers need to be well and uniformly trained in highway traffic regulation during an emergency. Police have

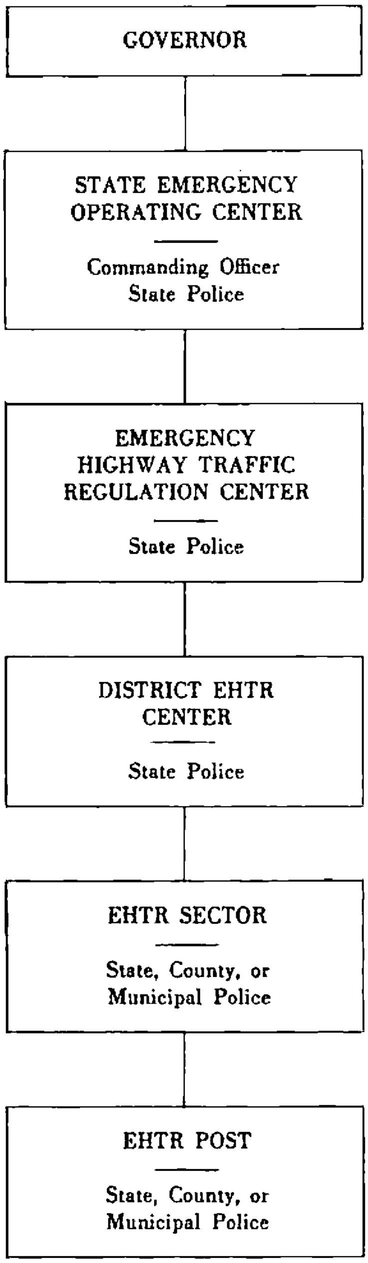


Figure 3.—Police "Chain of Command" for Emergency Highway Traffic Regulation

many responsibilities. A commanding officer must predetermine what portion of his force will be assigned to emergency highway traffic regulation duties and decide in conjunction with EHTR officials just what those duties are to be. A well-coordinated organizational, planning, training, and operating effort may be enhanced by using already existing groups such as State associations of chiefs of police or the enforcement committee of a State safety council.

The decentralized nature of State police operations, communications capability, proximity in some cases to State highway offices and garages, familiarity with routes throughout the State and their experience in handling areawide situations which frequently cross jurisdictional lines makes them the logical organization to assume responsibility for police highway traffic regulation command at the EHTR district level. Below this echelon, command responsibility may be assigned to State, county, or municipal police depending upon the availability of police manpower and the location of the EHTR sectors and posts. The police function at an EHTR sector established in or near a metropolitan area would normally be delegated to a county or municipal police officer. This will also be applicable to EHTR posts serving the sector area. This situation does not preclude the probability that State police or officers of other jurisdictions would be subordinate to such a command.

HIGHWAY USER OR REGULATORY COMMISSIONS

Historically the States have accepted the highway user representative as the third member of the EHTR team to work with the highway department and the police as staff members of the EHTR organization. Most State EHTR plans contain an explanation of how representatives of State highway user groups will function as part of the EHTR organization. As highway users, it is expected that the trucking industry will be more than willing to become an active participant in the EHTR organization and participate in peacetime training exercises designed to familiarize trainees with EHTR operations.

Within each State government is an organization which, among other things, regulates the intrastate trucking industry. The titles of these organizations vary from State to State among which are Public Service Commission, Department of Motor Transportation, Commerce Commission, and Public Utilities Commission. Some States are considering using these organizations to discharge the highway user function in the EHTR organization. This concept has the obvious merit of enlisting the support of an existing full-time organization of public employees.

It is important that each State EHTR plan provide for the highway user function and the States should assure themselves that the organization selected can be fully depended upon to participate should the need arise to activate the EHTR organization. This implies a willingness to furnish more than a token participation in peacetime training exercises.

Part II EMERGENCY HIGHWAY TRAFFIC REGULATION OPERATIONS

CHAPTER I—FUNCTIONS, EQUIPMENT AND PERSONNEL OF EMERGENCY HIGHWAY TRAFFIC REGULATION CENTERS AND POSTS

In case a national defense emergency is declared by either the President or the Congress of the United States, all pertinent Federal emergency plans would be implemented. Certain Federal plans require individual, specific Presidential orders to become operative; but for the purpose of this Guide it is assumed that State EHTR plans will become effective as required in a national defense emergency.

THE STATE EMERGENCY OPERATING CENTER

Introduction

Each State has an emergency operating center from which a minimum staff of key State officials would implement emergency plans and carry on essential governmental functions in the event of a national defense emergency.

Functions

As soon as a national defense emergency is declared, the Governor of each State presumably will order the full activation of his State emergency operating center. This center, planned and organized by the State civil preparedness agency, would thereafter be exactly what its name implies; a fallout protected center for emergency operation of the State government.

The State emergency operating center would be the focal point for receiving and disseminating all kinds of information; for contact with the Federal Government; for communication with the general public; and for issuance of directives relating to specific and general emergency functions and responsibilities assigned by established emergency plans. The State operating center would determine when and which kinds of emergency procedures and activities would be undertaken; it would provide information to, and direction of aid and relief for, the State's surviving population. Most, if not all such operations, including emergency highway traffic regulation, would be carried out by previously designated responsible State agencies.

Personnel

The State emergency operating center would be utilized by the Governor and his advisers, the State civil preparedness director and his staff, and representatives of the regular and emergency State operating agencies. The latter logically would include the heads or top-level representatives of the emergency highway traffic regulation organization. Under prearranged emergency plans and assignments, the Governor probably would invite to the State emergency operating center representatives from those Federal, civil and military agencies that have emergency responsibilities. These individuals would serve in liaison capacities between Federal and State operating centers.

Equipment

Each State has a fully equipped hardened emergency site. Many States are currently using these centers full-time for peacetime activities with the knowledge that, should a national defense emergency occur, the peacetime functions would terminate and emergency operations commence. The emergency operating center would be augmented as required and become the focal point for coordination of emergency operations. Whether or not the site is currently in use or not, each emergency operating center has facilities for full-time in-shelter period operations. All necessary sleeping, cooking, sanitary facilities, office equipment, food supplies, medical stores, water and fuel are stockpiled and rotated at predetermined intervals.

Communications

Without adequate communications it is obvious that an emergency operating center would be unable to effectively carry out its mission. Most such State centers have redundant communication facilities. These vary, of course, from State to State. Some centers, for example, have radio telegraph, radio teletype, landline teletype, voice radio, etc. In some cases, duplicate standby antennas are stockpiled for use in case a nuclear blast destroyed the existing antenna field. Other States may have comparable but less elaborate facilities. At any rate, it is abundantly clear that each State has recognized the need for and has provided an adequate long-range communication facility for use in both natural and nuclear disasters.

THE STATE EHTR CENTER

Introduction

Each State EHTR plan provides for a State EHTR center. The purpose of this center is to coordinate all EHTR operations within the State.

Functions

The most important and largest EHTR office, since it will be the nerve center of the entire operation, is the State EHTR center. It would be the first activated after an enemy attack, and, if there is an early warning, it may be activated in advance. The State EHTR center should be located as near as feasible to the State emergency operating center, which will be the focal point of all State activities. The State EHTR center preferably should be protected against blast and have an adequate radiological protection factor.

The initial operation of the State EHTR center would be to size up the statewide situation with respect to highways. Information would be available from the State emergency operating center after an enemy nuclear attack as to the locations, intensities, and nature of the bomb strikes within the State and the surrounding region. Such information, based on rapidly collected and perhaps sketchy facts, and interpreted by means of precalculated probabilities, should provide with fair reliability the locations of "ground zeros" of each blast. The probable extent of the area affected by heavy destruction and fire damage, and the area exposed to varying degrees of radioactive fallout and contamination would be determined.

The State EHTR center would make final determinations on all matters concerned with emergency highway traffic regulation. This center would direct and coordinate the activities of district and sector centers. The State EHTR center would affect all necessary coordination with adjoining States on matters of mutual concern, having recourse to the Federal Highway Administration for assistance in those instances where mutually satisfactory solutions cannot be developed.

Under the national emergency highway traffic regulation program each State has adapted the diagrammatic representation of a typical State EHTR organization illustrated in figure 4. The selection of locations for the EHTR centers is a matter of great importance, for once an emergency arises those centers that are needed must be activated without delay and immediately put into full operation.

One of the most difficult and yet most important functions to be performed by EHTR personnel is to acquire, assimilate, and appropriately disseminate the best information possible for public consumption as it relates to highway traffic. It is essential that the release of this information be coordinated with the State emergency operating center. The real test of a post-attack recovery ability is the effectiveness of communication with the surviving population. An effective public information capability will insure compliance with EHTR center policy and directives; facilitate the safe and efficient evacuation of goods and people as well as the prompt and orderly ingress to disaster areas. It will help lift the spirit of a shocked and terrified people and minimize further injury and loss of life and property. This important function of public information capability would best be performed at the State EHTR center which will be at the tip of a pyramid of information flowing to it from its subordinate centers and traffic regulation posts.

The State EHTR center, upon activation would:

(1) Identify and evaluate the availability and the traffic-carrying capacity of usable highways, roads and streets within the State, including all those within areas of unrestricted travel and those that can be opened to controlled use through contaminated areas.

(2) Develop and maintain, in cooperation with the State highway department, a State situation map showing damaged or destroyed highways and highway facilities, and the radiation intensity along highways, particularly those traversing contaminated areas. This map would identify points showing H+1 radiation levels and/or actual readings in accordance with Part IV of this Guide. Aerial radiological surveys may be requested through State or local emergency operating centers when sufficient data is not otherwise available.

(3) Make all information regarding radiation levels available to the State radiological defense organization, and to the public. The release of this information to the public should be coordinated with the State emergency operating center.

(4) Inform the public of highways closed by reason of damage or radiation.

(5) Estimate traffic demand for essential movements for the entire usable highway network.

(6) Determine the percentage of highway traffic capacity to be reserved at the State emergency highway traffic regulation center for Interstate traffic.

(7) With assistance from district and sector centers, make periodic traffic counts on main routes to determine whether the traffic volume is approaching the capacity of the route. As the volume

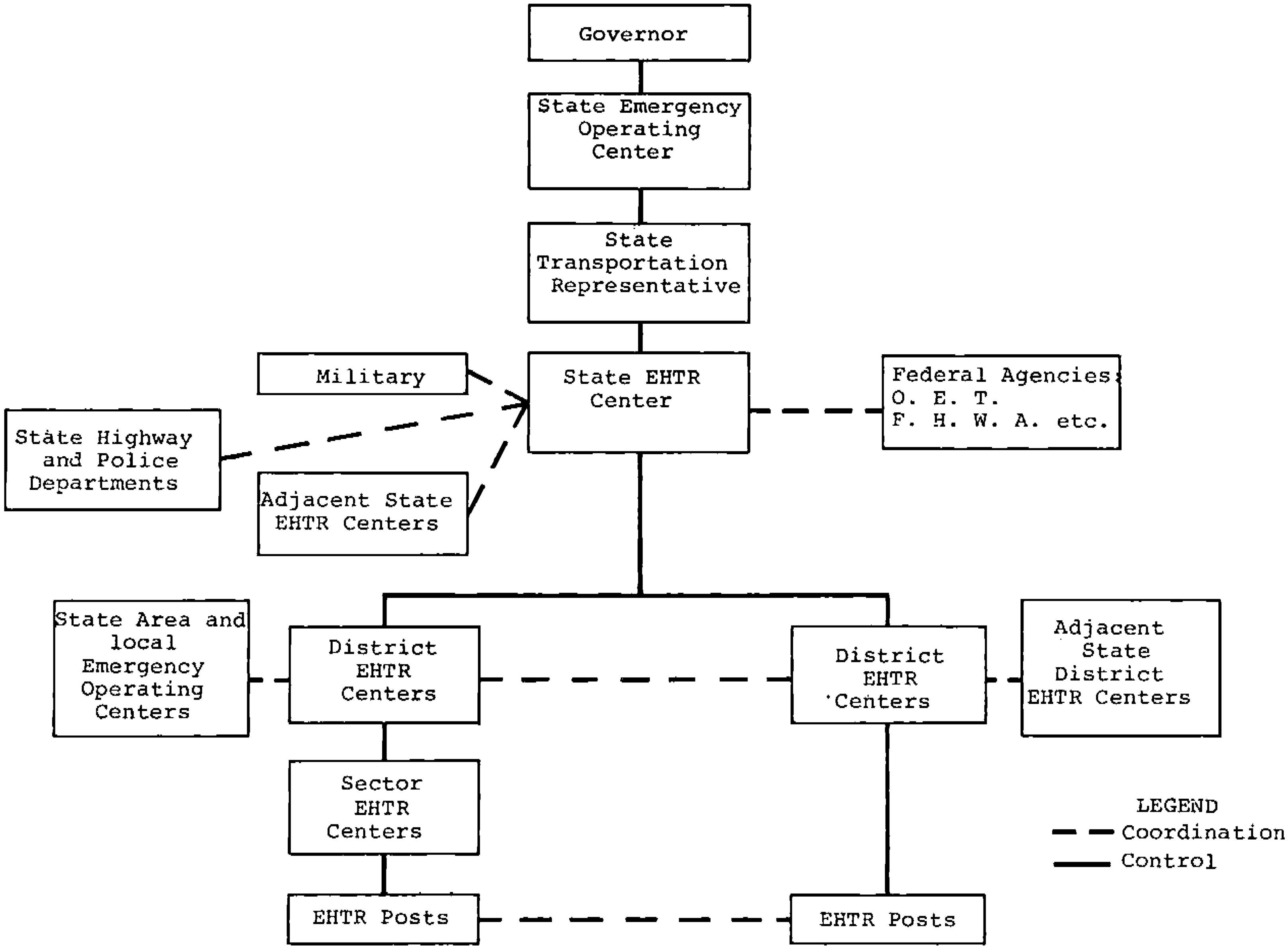


FIGURE 4-DIAGRAMMATIC REPRESENTATION OF A TYPICAL EHTR ORGANIZATION AND OPERATION

reaches the capacity of the route, take action to institute partial or complete traffic regulation of the route to insure the movement of essential traffic.

(8) Erect signs on routes through restricted and unrestricted areas in accordance with this chapter.

(9) Prescribe maximum and minimum speeds in keeping with local conditions. Minimum speeds would be prescribed for routes through radiological areas to reduce the radiation dosage to the driver and other occupants of the vehicle. It is realized that the higher the speed (above 30–35 m.p.h.) the lower the volume that can be handled.

(10) Issue road-use permits for the use of highway space on regulated routes and recognize permits issued in other States for single long trips involving use of highways within the State. Such travel will be allocated to that portion of reserved highway space as provided in paragraph (6) above. (For an explanation of road-use permits see below.)

(11) Assign to each regulated route, at the time it is established, an identifying number, letter, or name. The use of existing route numbers, letters, or names as shown on existing State highway road maps is strongly recommended. In urban and/or metropolitan areas street names may be more appropriate than route numbers. The use of well-known existing route numbers, letters, or street names, as modified by attack conditions, will lessen the confusion which would arise were new numbers or other identification suddenly presented to a public suffering from the inevitable shock and confusion following an enemy attack. These route identifications would appear on all road-use permits issued by State, district, and sector EHTR centers.

(12) Inform all district centers of the regulated routes within their boundaries and the number of road spaces allocated to such centers for issuance of road-use permits.

Personnel

Upon activation of the State EHTR center, key personnel should be summoned immediately, to this center, in accordance with the current State plan. These would include the upper-level administrative officials; the technical staff-highway and traffic engineers, radiation experts, etc.,—who are responsible for assessment and analysis of the general traffic situation and necessary support personnel. Presumably a maximum operations staff would not be needed immediately at the State EHTR center; but all assigned and recruited staff should be contacted at once. This will serve a dual purpose: it will put the entire staff on alert, either to come to the center or to standby; and it will establish, at least for the moment, who is available and who is not. The staff, especially key personnel, should be forewarned to contact the center on their own initiative if they have not been contacted in a reasonable time.

The initial check and call-up may show the need to summon to immediate duty some substitutes for key individuals who cannot be contacted or who are known to be dead or incapacitated. The center's roster should include substitutes or alternates for this purpose, and they should be trained to assume their principals' functions.

Personnel at the State EHTR center would be responsible for the administration of emergency highway traffic regulation within the State. Each State plan provides for this function and in most cases identifies this center as an emergency operating center staffed with personnel from the State highway department, the State police and, when feasible, representatives from the highway users.

Since only some of the personnel assigned to EHTR activities would be in uniform, suitable official identification is required for them. When available, the State emergency identification card should be used. In addition, EHTR personnel should probably be provided with a quick-identification device such as an armband or badge with a readily recognizable symbol and/or inscription.

An important record to be kept by the State agency responsible for EHTR is a full, up-to-date roster by job title, rather than name, of all personnel assigned to report to the center, including State highway and police officials, highway users, and military and civil defense liaison representatives. The State EHTR center's list should also include similar listings of the principal staff assigned to each district and sector EHTR center. Each State EHTR plan should contain these rosters.

An alerting system capable of summoning all or selected members of the EHTR staff to the center in rapid fashion should be developed in association with the personnel rosters. Arrangements may also be made for the staff to report to the EHTR center even without notification, in a recognized emergency, or the staff may be instructed in advance to listen to radio broadcasts for general alerts or assignment messages.

Equipment

It is desirable that the State EHTR center be physically established and equipped now. Ideally, it should be fully stocked with office furniture, equipment, and supplies, communications equipment, and living and feeding equipment and supplies—all in place and ready to use. Where this optimum situation is impossible to achieve at once, it may be accomplished gradually. In any event, every effort should be made to approach full operational readiness as quickly as possible. For example, the State EHTR center may be physically established but only partially equipped and stocked with the remaining needed equipment and materials stored at the State highway department headquarters or warehouse. Some of the equipment in use at the highway department may be earmarked for quick transfer to the State EHTR center when needed. In this case, lists of such items and their locations must be kept current, and adequate plans arranged for their ready identification and quick transfer.

An essential need in the EHTR center would be adequate, large-scale State maps as well as maps of the State's urban areas showing all roads and streets. These various maps should be mounted on the wall, in a suitable location and covered with sheets of clear acetate so that information may be posted, and revised as changes occur. Such maps, properly posted, would give a quick, current picture of both the overall situation and its details.

Ideally, provisions should be made for continuing, 24-hour occupancy and operation of the State EHTR center. This requires adequate though spartan facilities for living, sleeping, and eating—and, of course, food preparation—sufficient for the maximum staff anticipated. Thus, floor space is required both for office operations and for living quarters. The office operations would require furniture, typewriters, and other office machines, as well as paper and other office supplies, printed forms, and all the varied equipment necessary for competent office operations. Adequate toilet and washroom facilities are required. For "live-in" accommodations, dormitory-type furniture and bedding are necessary. For feeding, cooking utensils, stove and refrigerator, china and cutlery, etc., are needed. And, of course, food itself, and above all, drinking water, are essentials. In certain States, existing office facilities have been designated for use as the State EHTR center. Should an emergency occur the peacetime functions would cease and emergency operations would begin. In other States, an appropriate area has been designated for activation should the need arise.

Communications

Highly important in the State EHTR center is a full complement of communications equipment, linking the State center to each district EHTR center, to the State emergency operating center, to the State highway deparment and State police headquarters, and to the State EHTR centers in adjacent States. Two-way radio, teletype, and telephone communications are all desirable facilities to have, and it would probably be best not to depend on any single system. Interlinkage with the established State highway department and State police radio networks, if such exist, would be extremely useful. Communications are so important to the EHTR operation that, if at all possible, these facilities should be installed in the State EHTR center and maintained on a standby basis.

Each State highway department has an extensive communication capability which enables it to maintain contact with its subordinate units. If emergency communication with contiguous State highway departments has not been coordinated, this vital connection should be established as soon as possible. Each State plan should contain an explanation of its communication capability including its ability to contact the agency in the adjacent States which would be responsible for emergency highway traffic regulation.

DISTRICT EHTR CENTERS

Introduction

The State EHTR center must have ready means of accumulating information from throughout the State, of evaluating area and local situations, and of giving general direction to field operations. For these purposes, each State plan provides for EHTR districts to assist in this administration.

To the extent possible, all of the preattack arrangements described previously in particular application to the State EHTR center should also be made for each district EHTR center. If the State highway department's district headquarters itself cannot be located in a properly protected site in which its own operations and those of the district EHTR center can be situated, it would be desirable to plan, and if possible establish in advance a safe and adequate location for use in time of emergency by both the district highway office and the district EHTR center. The emergency operations of these centers are closely related and they will function to best advantage if housed together. Specific arrangements should be made by and for each district EHTR center, adapted to its local situation and problems.

Functions

The district EHTR center upon activation would:

(1) Receive from the State EHTR center all necessary information and guidance for its operation.

(2) Develop and maintain, with respect to the district a situation map showing damaged or destroyed highways and highway facilities in the district, available detours, and the radiation intensity on highways. On the situation map, identify points showing H+1 radiation levels and/or actual readings in accordance with Part IV of this Guide.

(3) Within limits assigned by the State EHTR center, issue road-use permits for trips originating in the district.

(4) Reserve a prescribed percentage of the highway traffic capacity of each regulated route for through traffic.

(5) With assistance from sector centers, make periodic traffic counts on main routes to determine whether the traffic volume is approaching the capacity of the route. As the volume reaches the capacity, institute partial or complete traffic regulation and notify State and sector emergency highway traffic regulation centers.

(6) Establish sector centers (county, city, or metropolitan area) as prescribed by the State EHTR center, and recommend to the State EHTR center such other sectors as should be established to facilitate the movement of essential traffic.

(7) Inform sector centers of regulated routes within the sector boundaries and the amount of space available to the sector against which it may issue road-use permits.

(8) Coordinate operations with the appropriate area emergency operating center.

Personnel

Much like the main office of the State highway department, the district office is staffed with administrative, fiscal, and clerical personnel, highway, bridge, traffic engineers, and other specialists. Usually the district office also has a force of equipment operators and mechanics; a fleet of automobiles, trucks, and road maintenance and repair equipment; and a substantial garage and repair shop. Often, the highway districts are subdivided into working areas, each with a headquarters depot or garage for maintenance staff, equipment, and materials stockpiling. These depots generally contain a small amount of office space.

Equipment

Each district EHTR center should have an appropriate amount and similar type equipment to that considered necessary for the operation of the State EHTR center. In those cases where the highway department district office will be the site for the district EHTR center, adequate equipment should be in place and ready for multipurpose use.

Communications

Each State highway department district (or division) office has as a minimum capability telephone and radio communication with its central office. Some highway departments have centrex telephone systems in operation. In addition, a few such departments are connected by teletype systems which provide for simultaneous messages to all district offices as well as individual communication. The district office radio capability also includes communication with mobile highway department units. It is expected that the district EHTR center will maintain communication with the appropriate emergency operating center.

SECTOR EHTR CENTERS

Introduction

The EHTR districts are further divided into EHTR sectors. In the State plans each EHTR sector covers a county or some logical portion of a county. These sector EHTR centers are usually located in State highway department or local highway or police department facilities or in some other preselected site which is available and suitable for the operation of such a center.

Functions

The EHTR sector centers (county, municipal, or metropolitan area) upon activation would:

(1) Maintain a situation map with respect to the sector, showing the information prescribed to be maintained at the district traffic regulation center with respect to the center.

(2) Make periodic checks on traffic volume and recommend to the District Center the institution of emergency highway traffic regulation as traffic volume on a highway reaches its traffic-carrying capacity.

(3) Within limits assigned by the district center issue road-use permits for trips originating in the sector.

(4) Requests for inter-sector movements which are received would be coordinated with the district headquarters.

Personnel

Similar to the district EHTR centers but to a lesser degree, the EHTR sector centers would be staffed with appropriate personnel in accordance with each State's EHTR plan and/ or as deemed appropriate by the State EHTR organization.

Equipment

The sector centers would require all of the working and living furniture, equipment, and supplies which are needed at the district center although probably in different proportions and scale. The need for equipment will be affected by the nature of the activity which will be used for the sector center. If it is a highway department maintenance office one type of equipment will be on hand. If a police department facility is selected by the State for a sector center a different type of equipment will, of course, be available.

Communications

Depending on the State plan, the sector centers may be located in highway department offices, police facilities, or some other logical location. Whatever communication facilities are available must be supplemented, if necessary, so that a constant communication may be maintained with the district EHTR headquarters and those EHTR posts under the control of the sectors as well as the appropriate emergency operating center. This plan provides a flow of information up from the sectors and posts through the districts to the State EHTR headquarters.

Metropolitan Area Sectors

Our metropolitan areas usually comprise a large and congested central city surrounded by populous suburbs and scattered suburban developments organized into larger or smaller political units as cities, villages, towns, etc. The conglomeration is very likely to be situated in several counties, and often in two States. A few have further political complexities since they lie on an international boundary. In such multi-structured metropolitan areas, each political jurisdiction is apt to have its own individual civil defense organization and emergency plans. To the extent that these plans affect highway transportation and regulation, there should be careful coordination on both sides.

In a large scale nuclear attack, many of the large metropolitan areas may be devastated by blast and fire and heavily contaminated by radiation. In such a situation, the function of EHTR in relation to these areas, after shelter emergence, would be to arrange for safe and adequate bypasses.

Because of the size, both in area and population, of the metropolitan areas, and their political, economic, and traffic complexity, it would be advantageous to plan for the division of each metropolitan area into several workable EHTR sectors. This will be a necessity when the metropolitan area is divided between two States. For management advantages, it would be best for all sectors covering the metropolitan area (within each State) to be under the jurisdiction of a single EHTR district; or for the area itself to be constructed as an EHTR district. Closely coordinated planning and operation between all agencies involved are obvious necessities. Many State EHTR plans reflect this planning.

EMERGENCY HIGHWAY TRAFFIC REGULATION POSTS

Definition

EHTR posts are control points at each end of or along regulated routes, for the purpose of controlling the flow of traffic onto or on the route, checking road-use permits, and advising occupants of vehicles of any danger from radioactive fallout or other hazard.

Introduction

The several levels of authority which exist above the EHTR posts are concerned primarily with planning, organizing, and administering the EHTR operation. It is at the EHTR posts themselves where this type of traffic regulation will occur. The police would have the responsibility for the operation and control of the EHTR posts and the traffic on the regulated routes. The detailed functions and operations of the posts are quite different from those of the EHTR headquarters, districts and sectors and for this reason are explained in considerable detail.

Functions

Choosing EHTR Post Locations—As soon as the decision to institute regulation on a route section is reached, it will be necessary to choose locations for roadside control posts and provide for equipping and manning them. Making such arrangements is the responsibility of the EHTR organization, usually at the level controlling the regulation and the bulk of the permit issuance for the particular route section. Generally this would be the EHTR sector center; occasionally, the district.

In the simplest kind of situation (regardless of traffic volume), involving a short route section which has no intermediate inlets or crossings, or at least none of traffic consequence, a control post at each terminus presumably will suffice for control needs. Longer route sections, with intermediate access points of traffic significance, may require additional control posts; certainly they would be needed at intersections along the route where any appreciable traffic may have to be fed onto and off (or barred from) the regulated route.

No arbitrary traffic-volume criteria can be suggested for this consideration, since it is a relative matter, depending on the possible inflow volume in relation to the total traffic volume anticipated on the regulated route, and to the proportion of that total which is operating with priority preference; in addition, the geometrics of the route and its intersections may have a bearing on the matter.

It can be realized from the above discussion that roads crossing or feeding into a regulated route section, if they carry any appreciable traffic, can create problems for the EHTR organization throughout the operation process. The crossing, entering, and leaving traffic has to be taken into account in attempting to estimate the total traffic-carrying capacity of the regulated route. It would also be a factor in total traffic demand; additionally, there may be some cargo priority-certified traffic entering or leaving these intermediate points, and this would have to be reckoned with in allocating road space and issuing road-use permits.

Wherever possible, each terminus and intermediate control post should be established close to a suitable road junction, so that traffic which must be barred from the regulated route may have an available alternate route open to them, even though it may be circuitous.

Almost inevitably, the control posts are going to create traffic bottlenecks just by their very existence. Vehicles would have to be stopped or slowed, even if only momentarily, to check their road-use permits. Many others, arriving on the scene without road-use permits or even unaware of the existence of control on this route or anywhere else, may have to be given an individual (and hopefully brief) explanation of the situation. Some might want to take an alternate route to their destination. Some may want to turn around and head back. Others may want to wait and take their chances of getting a permit, or being allowed to slip into the traffic stream in a slack moment.

Because of these possibilities, control posts on routes with sizable traffic streams should be located where plenty of off-the-road parking is available to serve as a holding area. In fact, the post can hardly operate successfully without this. The space may only be a pasture; or, with luck, it may be the parking lot of a big shopping center, industrial plant, drive-in theatre, or athletic field. In addition to space needs, the holding areas will require suitable entrances and exits, as will be evident a little later.

The shoulders along the regulated route, whether paved or not, cannot be used as a holding area. Their use for this purpose would seriously endanger moving traffic; they would not have adequate capacity within a reasonable distance; and vehicles stored on them could not satisfactorily be controlled or shifted.

Control Post Operation—The nature of operations at control posts on a regulated route section would depend on the volume of traffic and complexity of the situation, and on the understanding and cooperation of the public. At many locations the problems discussed here may be of small scale or nonexistent; at others they could be full-blown, indeed.

Essentially, the operation at the control post is to feed road-use permit-bearing vehicles onto the road (or let them continue on it) and to turn others away; taking care of the latter, however, as road space allows. It is for this process that a suitable holding area of adequate size is required at or very near the control post (see Figure 5).

If the display portion of the road-use permit were fastened to the vehicle windshield, its color and a large written-in number would show at a reasonable distance the day of the week and the specific regulated route section for which it was issued. Date and permit hour, also would appear on the permit, but will not be visible except in close-up examination.

A complete check of the road-use permit on every vehicle would almost certainly result in a tremendous traffic bottleneck. For that reason, it is proposed that vehicles bearing road-use permits apparently proper for the day and the route section will be waved on without stopping. It must be remembered that a sizable proportion of the priority traffic may be heavily laden trucks and combinations which, once slowed or stopped, take considerable time and distance to accelerate to road speed. This leads to the further thought that control posts should preferably be located on level ground, and certainly not where an appreciable, sustained upgrade is involved.

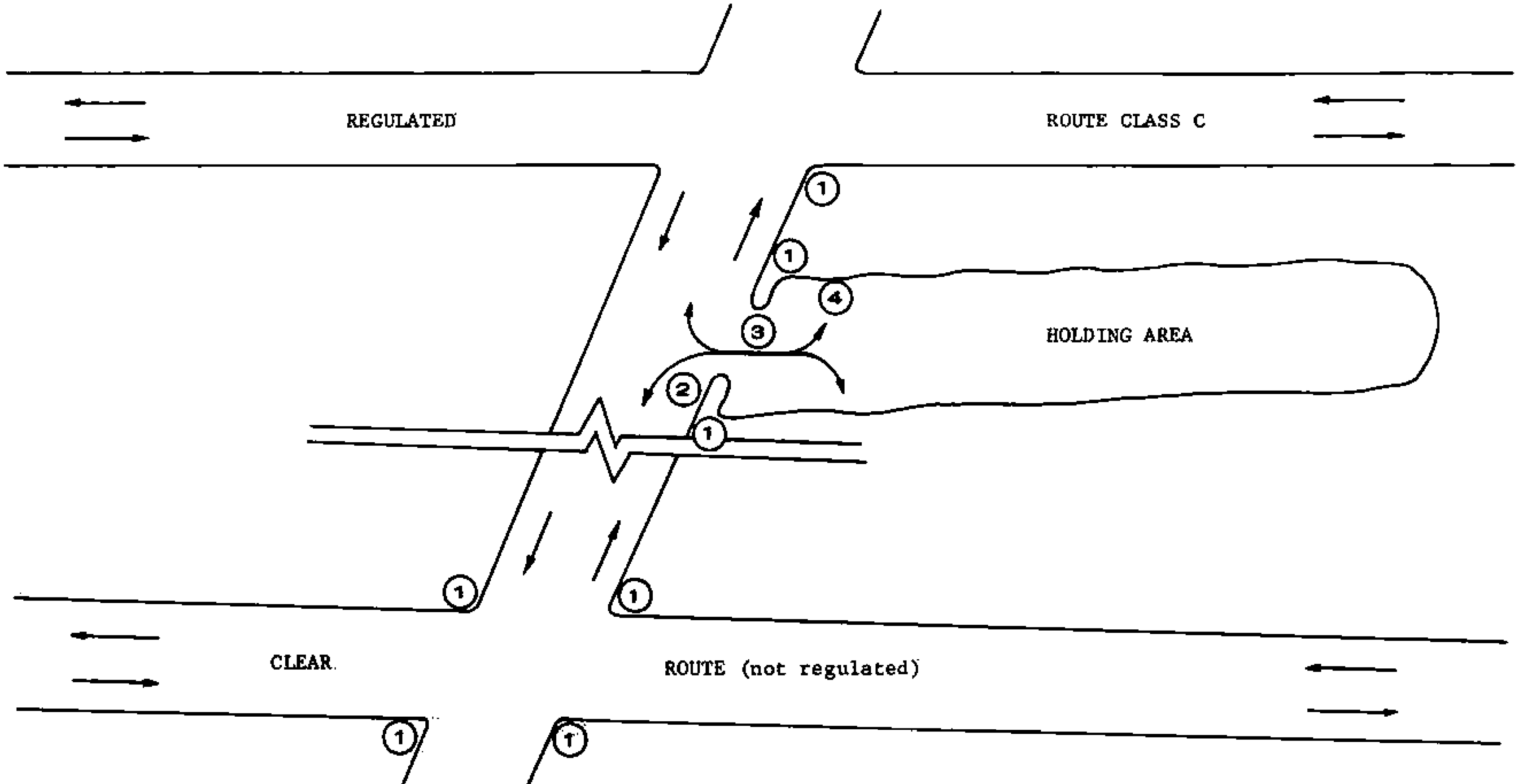
While road-use permits will thus be cursorily checked as the vehicles drive by, it would be desirable to pull an occasional vehicle out of the traffic stream, for a closer check. As with peacetime road-regulation checks, the "word" probably would get around pretty quickly.

Vehicles not Displaying Road-Use Permits—Those vehicles that do not have road-use permits for the regulated route section would have to be pulled out of the traffic stream into the holding area without hesitation, regardless of whether they are going to stay or not. It would be impossible to answer questions or give advice to drivers while they are on the road and thus blocking all traffic. And they cannot be permitted to stop at the entrance to the holding area, either, or the same problem would result. Hopefully, the use of advance warning and information signs, or of advance information posts, coupled with news broadcasts or other dissemination to the general public of information about regulated route sections in the area, would keep to reasonable proportions the number of vehicles that have to be diverted to the holding area.

General experience, however, indicates that regardless of such information devices, the holding area had better be of considerable size on a main route, particularly if there are no or only limited-capacity available "free" routes in the vicinity. Similarly, the work force operating in the holding area would have to be adequate for the task.

Several alternatives will be open to the vehicle operator who does not have a road-use permit and who has been diverted to the holding area. One of these is to take an alternate route to this destination; and the staff working in the holding area should be prepared to give useful, up-to-the-minute detour and alternate route information. Coupled with this choice, if taken by the vehicle operator, is the need for suitable exits from the holding area leading to the alternate routes without crossing or interfering with the mainline traffic any more than necessary. Where such crossings are necessary, a police officer should be stationed to direct traffic.

The second alternative open to a vehicle operator who has no road-use permit would be to turn back



LEGEND

1. Information signs
2. Control post check point; vehicles showing road-use permits are waved on; those without permits are diverted into holding areas or onto clear route
3. Entrance and exit to holding area
4. Shelter for post headquarters, first-aid, detention, sanitary facilities, etc.

Figure 5----Roadside EHTR control post operation on a high-volume Regulated Class C Route.

toward his starting point; that is, give up the trip altogether for the time being. Again, there must be means for him to exit from the holding area and start his return trip. This may not be a simple operation, because the driver would have to cross the mainstream of traffic going in the direction he originally intended to follow. In addition, once he has crossed that traffic stream, he would want to enter the traffic stream going in the other direction; but this would be the traffic coming from the other end of the regulated route section and presumably already would be running at or near the capacity of the lane or lanes in that direction.

Thus, it will be seen that handling the nonpermit, diverted traffic can be a very difficult task, and where traffic volumes are heavy it may require a very sizable, well-organized staff. Even in peacetime, and even then if all drivers were amiable and docile, the job would still be complicated; witness the traffic jams before and after big athletic or entertainment events. In an emergency, and dealing with anxious and distraught drivers, it is going to be perhaps the most taxing, both in planning and execution, of the EHTR operations. In addition to managing and directing traffic, there may occasionally be need for police action against recalcitrant drivers.

A third alternative may be open to the vehicle operator who has no road-use permit: the possibility of obtaining such a permit; or the chance of being "metered" from the holding area into the traffic stream on the regulated route section, if the route is being operated in such a way as to allow this; or his election to take his chances and wait in the holding area. In the first instance, and in the second if the answer to both "ifs" is affirmative, the vehicle operator should be directed to a special part of the holding area, from which there is a suitable entrance to the regulated route.

Three levels or classes of consideration may exist for those vehicle operators who arrive at a control post without a permit, and nevertheless want to continue.

Among the three levels of nonpermit-bearing vehicle classes, the first class to be considered would be those on an interstate trip for whom permit authority was arranged between the two State EHTR centers, and who had been instructed to pick up the actual permit at the first roadside control post they reached in the State. In some cases the control post staff would already have been advised of the arrangement and have a permit reserved; in others they may have to contact the EHTR center to verify it.

The second class would be those operators who are making a demonstrably essential trip, but have no road-use permit. Such individuals may have been directed by telephone, by the EHTR center or one of its satellite stations, to go to the control post, because it is much closer to the trip origin; or the individual may not even be aware of the need for a permit. The control post staff would have to make quick decisions in these cases, using their own judgment and without any specific guidelines. Those vehicles accepted as being on essential trips would be fed into the traffic stream as soon as possible.

The third and lowest level or class of operators would be those who have neither priority nor essentiality to justify using space on the regulated route, but still have, in their own mind, at least, a strong reason or desire to make the trip. These, if there is a reasonable possibility of accommodating them, may be allowed to wait in the holding area and take their chances. If there is no reasonable chance of this, however, they should be shunted out of the holding area, either to an alternate route or to return to their origin. It is expected that gasoline rationing or other restrictions on travel will reduce this class to a minimum.

Vehicles in all three of the classes described above, with those of the first and second level getting preference, may be lined up in the holding area close to the entrance to the regulated route. As the control post staff assigned to this location sees that there is a reasonable gap in the traffic moving on the route, he would feed one or more vehicles from the holding area into the mainstream. In this manner, it would be possible to take care of all of the first two classes of nonpermit-bearing vehicles, and a good many of the third class, over a reasonable period of time. The odds are strong that the mainstream traffic past the permit checkpoint would be irregularly spaced and rather slow-moving.

Where regulated routes are operated under regulation only during certain hours, the nonpermit vehicles may be kept in the holding area and released (without permits) when the controls are dropped.

Latecomers; Overloading—The scheduling of road space on regulated routes would be on an hourly basis, and each permit issued would indicate for what hour it is applicable. Those who arrive early or late at the entering control post (and are detected), should be shunted into the holding area, but metered into the route as soon as clear space is available in the traffic stream.

There may be occasions when, through inadvertence, road-use permits have been issued for more road space than is actually available on a regulated route during a particular hour; or the route capacity may unexpectedly and temporarily be decreased; or a sudden and urgent priority need may have arisen after all the space had been allocated. In such cases, the control post staff will have to make whatever adjustments they can, that seem reasonable and will accomplish the purpose. Any permit-bearing vehicles that have to be delayed, however, should be permitted to proceed as soon as possible; if necessary, by preempting part of the next hour and delaying vehicles scheduled for it.

Summary of EHTR Post Responsibilities—The following responsibilities for EHTR posts are taken from State plans or were developed at EHTR training sessions. They should be included as appropriate in the State plans.

(1) Restrict the use of regulated routes to those vehicles displaying road-use permits.

(2) Place and maintain as necessary appropriate traffic regulation signs and barricades.

(3) Maintain where feasible adequate lighting and personnel for 24-hour operation.

(4) Personnel assigned to control posts on class "A" routes should be sufficiently knowledeable of radiation hazards to enable them to warn vehicle operators of the dangers of travel through contaminated areas.

(5) Maintain a communication capability for liaison with the EHTR headquarters responsible for supervising the post.

(6) Through the exercise of sound judgment, meter into the traffic stream emergency vehicles such as ambulances, fire fighting equipment, vehicles bearing physicians, etc.

(7) Maintain a suitable off-the-road holding area for vehicles which do not have road-use permits.

(8) Procedure for handling nonemergency vehicles without road-use permits:

(a) Send to holding area for advice concerning availability of another appropriate route.

(b) As appropriate, retain in holding area with the possibility of metering such vehicles onto the route if light volume traffic develops.

(c) As necessary, detour to point of origin.

Personnel

Each State plan provides that the police would have the responsibility of manning the EHTR posts. Naturally, manpower would present a large problem. It is recognized that EHTR would be only one of the many post attack responsibilities which the police would receive.

It would be impossible through current planning to determine how many men will be necessary to serve at these posts. The number will vary with the traffic volume. A low volume post would require a few men to handle the traffic, whereas a complex post with a high-volume traffic would require a larger staff. It is anticipated that the police would receive assistance from the highway department, local civil defense personnel, and such other logical sources as the State may determine is appropriate.

Equipment

Certain obvious supplies will be needed at EHTR posts. These and others, as appropriate, should be listed in each State plan. Motor vehicles would be needed for the transport of staff, patrolling the regulated route section, or possible pursuit of vehicles not bearing road-use permits which attempt to slip through a busy post. It may be desirable, especially in connection with control posts on heavily traveled routes, to have available such equipment as tow trucks, wreckers, or rescue vehicles and ambulances. Additional supplies such as gasoline, first-aid materials, fire extinguishers, drinking water, and food for post personnel should be on hand. Shelter of some sort would be needed, at least in inclement weather; and sanitary facilities. A supply of road-use permits for emergency use should also be available. Radiological monitoring equipment should be available and, of course, some of the post staff should have been trained in its use.

Communications

Generally, police have the best existing emergency communication system. Therefore, with some modifications the system can be coordinated with the systems discussed above and used to maximum advantage for EHTR operations. Plans should be developed which will provide emergency adaption. The inventory of communications equipment, personnel, and facilities will reveal needs. Alternate communication plans should be drawn where possible. Plans should include emphasis on abbreviated or minimal messages and transmission discipline. Acquisition of pack sets and walkie-talkies is recommended. The great importance of emergency communications demands that greater impetus given now to increasing communications contact, particularly voice radio, between all police agencies.

CHAPTER II—REGULATED ROUTES, ROAD-USE PERMITS AND EHTR SIGNS

Introduction and Definitions

Following a nuclear attack or a natural disaster two main types of usable highways will remain: those that are clear and open without restriction for travel and those that must be regulated in some manner.

Regulated routes are of three types: Class "A," class "B" and class "C." Class "A" regulated routes are highways which lie within an area contaminated by radioactivity that is hazardous to the life and health of highway users. Class "A" routes may be used with special guidance and precautions. Class "B" regulated routes are highways which are temporarily reserved exclusively for a special purpose, such as military or civil defense and users of these routes will not need road-use permits. Class "C" regulated routes are highways which are determined to have or which are expected to develop critical traffic-carrying capacity restrictions and on which travel is generally limited to holders of "road-use permits."

CLASS "A" ROUTES

Establishment of Class "A" Routes

The hazard of radiation has its effect in many areas and on many things. In evaluating the radiation effects on highway personnel and highway operations, the Defense Civil Preparedness Agency principles and objectives are followed by the Federal Highway Administration. (See Part IV)

The Defense Civil Preparedness Agency says in effect—don't expose yourself to any radiation if you can avoid it, unless there is no alternative way of accomplishing your objectives.

This Agency also established the following wartime principles of limiting the exposure of people:

First: Protect them from radiation injury.

Second: Protect them from radiation injury severe enough to require medical care.

Third: Minimize the long-range effects of radiation.

The objective is to keep the exposure of the general public to the lowest possible level.

In the final analysis before a command decision to jeopardize lives in any operation is made, one must understand the consequences of radiation exposure. Consultation with radiological experts prior to such decisions is of utmost importance.

In addition to the effect on human life, fallout would have a detrimental effect on highway transportation, especially when one envisions that most of the country would be covered with radiological fallout if the attack was large and well planned.

The EHTR organization should have personnel trained in radiological defense so that an intelligent evaluation of radiological data can be made. In turn, this information can be used to develop the operational aspects of travel through fallout areas which is necessary for establishing class "A" routes. In this connection, it is recommended that the EHTR organization work in close coordination with the State radiological defense officer and obtain his assistance in this area.

We must keep in mind that highway department radiological monitors, even though they begin monitoring on D+1, will only have a minimum of radiological data; that is, the beginning of the danger zone. The State radiological defense officer would receive radiological data from a variety of sources including aerial monitoring data. His data would be received sooner, would be more inclusive and more complete. (Part IV of this Guide contains further information concerning radiation.)

Within each area contaminated by radiological fallout there would be an infinite range in the degree of danger to exposure, from a slight health hazard at the periphery to perhaps high risk or certain death at the focal center (which necessarily may *not* be the geometric center of the area.) The radiation experts, having mapped the current radiological situation, must next assess the feasibility of road usage within the contaminated area. This assessment would include the potential effects on exposure, taking into account radiation exposure criteria and the characteristics of travel.

The radiation intensity, distance of travel across the area, and anticipated sustained travel speed would determine the radiation exposure to which travelers would be subjected.

Before opening class "A" routes for travel, a number of things must be considered:

(1) The use of the road (for general public or for special purposes.)

(2) The radiation intensity.

(3) The distance of travel through the fallout area.

(4) The total radiation dose received by the traveler.

(5) The safe speed required for traveling through the area.

(6) Allowance for breakdowns within the fallout area.

(7) Frequency of trips.

The control of class "A" routes through fallout areas would vary. Where the radiation intensity is low, the posting of a sign warning of the hazard ahead would be sufficient. Where the route is long and/or the radiation intensity is high, a barricade with warning and detour signs would be posted. These routes should be completely closed. Intermediate routes would be opened for special purposes or for the general public, but controlled by EHTR personnel. Personnel operating control posts on a class "A" route should have sufficient knowledge in radiological effects to understand its dangers and provide advice to the traveler. The basic question to be resolved for each contaminated route section is whether it is safe to use at all; and if so, under what conditions. Remembering that radiation is invisible, it is highly important that routes which would be dangerous or fatal to traverse, should be barricaded and posted as quickly as possible. Less dangerous, but nevertheless hazardous routes would be operated under regulated conditions. The regulatory control, based on relative risk, may vary from only a warning sign to pass through the area at a reasonable sustained speed, without stopping, to specification of minimum travel speed or traverse time, trip frequency limitation, or even recommendation to seek medical check-up or attention immediately after crossing the area. For the travelers' information, the distance from the control point to the radiation-free boundary on the other side of the contaminated area should be posted.

Where heavy radiation exists and health hazard is extremely high, the general rule, as stated above, would be to close the route completely. Alternate routes to various destinations should be plotted and posted, if possible, and they should be of sufficient capacity to handle anticipated traffic. Urgent needs, however, may force consideration of the use of a highly contaminated route for certain traffic movements under specified conditions; e.g., that a particular driver travel at a high (but safe) speed and make only one trip. (It is known that rather high radiation exposure can be tolerated for relatively short periods without serious or permanent health impairment.)

Radiation contamination and hazard would be in a continuous state of change. Normal rates of decay are known, so the decline of hazard can be predicted with some reliability. However, shifting winds, rain or snow, and other climatic conditions can bring about gradual or even sudden changes in radiation intensity, sometimes quickly reducing the danger in an area, and sometimes just as quickly bringing danger to an area previously found hazard free. Consequently, frequent field monitoring must be maintained, together with a constant weather watch, so that changes in the radiation situation can be anticipated or at least detected as rapidly as they occur.

Routes endangered by radiation would be regulated by manned roadside control posts if the EHTR organization can muster sufficient manpower. It seems unlikely that there would be enough personnel available for this duty in all cases; their need would be greater on class "B" and "C" regulated routes—those wholly reserved or available only for priority traffic movements—and in other urgent activities.

In any event, as soon as the necessity of designating a route for class "A" regulation is determined on the basis of radiological monitoring and analysis, the District or Sector EHTR center should immediately arrange for the placement of barricades and/or appropriate warning and information signs by the highway or police departments.

Manning of control posts on the roadside at the termini of class "A" regulated road sections should be arranged if possible. If only a limited number can be manned, it would be preferable to do so at locations where individual decisions are required. Routes that are completely closed to all travel and, at the other extreme, routes that may be traversed with only small risk, can be barricaded and signed, but not manned. Where an intermediate hazard is involved, a manned post is desirable so that the risk circumstances of each traveler may quickly be assessed. The manning of such posts presumably would be by one or more police officers, through arrangement by the EHTR center. Such control officers should have previous instruction in radiological exposure problems, or at least be equipped with suitable guide material.

CLASS "B" ROUTES

Establishment of Class "B" Routes

Class "B" routes would usually be clear routes which means they are exposed to little or no radioactivity. It is conceivable, however, that a class "B" route may have to pass through a contaminated area. In this case, the portion which passes through the contaminated area will be identified as a class "A" route. The need for designation of class "B" routes is apt to occur quickly after the beginning of the emergency. In the initial post-attack period, such movements are likely to be at a peak in frequency and volume. Later, civil defense and military traffic should stabilize and diminish. Since class "B" routes are reserved exclusively for the use of the military and the civil defense, their organizations will not need road-use permits while using their routes.

The movement requirements that engender class "B" route designation may be characterized by the number of vehicles, their overall speed capability, the critical importance of a time schedule and of the materials or persons being transported, and the need for a unified or convoy type of movement. Initiation of a request for a reserved route, which may be a specified highway or any route between two designated termini, would probably come to the EHTR center through the civil defense or military liaison officer serving on the center staff.

The need and importance for class "B" movements, certified by civil defense or military authorities, would be accepted by the EHTR organization without question. However, there may be competing priority travel demands and limited route capacities. If so, it would then be the responsibility of the EHTR organization to resolve the competing requirements for road space according to their best judgment and ingenuity.

The size of a single, indivisible movement needs some consideration, and it would be desirable to provide some size criterion for application on reserved routes. However, much depends on the overall speed of which the convoy is capable, and on the nature of the route itself: Obviously, a four-lane freeway can handle a situation better than a two-lane highway; an unobstructed, well-aligned road better than one with existing bottlenecks or attack-damaged pavement and bridges. Thus, it hardly seems possible to generalize with respect to the size criterion for a reserved route.

It seems probable that in most areas, within a short time after an attack, the need for reserved routes would have stablized or diminished. Time would be less of a factor, and the EHTR organization, as well as the civil defense and military agencies, would be able to plan at least a day or two ahead.

In this situation it is quite probable that route sections would not have to be held wholly in reserve under class "B" regulation. Two possibilities are likely to offer themselves: Either a reserved route may be maintained as such, but opened on an "as-available" basis during scheduled periods for other traffic movements; or the reserved route classification can be discontinued and convoy or other civil defense and military traffic can be accommodated preferentially at all times or during certain periods on class "C" routes.

It should be borne in mind that the unnecessary application of the full-time reservation of a route as class "B" may well place unwarranted restrictions on other essential traffic movements. Before a route is fully reserved for special use, therefore, all alternatives should be considered.

It is expected that civil defense and military large-scale traffic movements would generally be convoy operations planned and controlled by their own organizations. While they would thus manage their own operations, the EHTR organization would provide approval, reserve the highway for use, and provide any coordination with other agencies that may be needed.

Problems of coordination that immediately come to mind are the possibility of demand for road-space time on the same route and at the same time by both a civil defense agency and the military; or the traffic conflict that would result if two convoys were scheduled to cross an intersection at the same time. While urgent movements of this type should not be bogged down in procedural red tape, neither can they be sanctioned without examination of the situation simply because the request comes from the civil defense or military authorities.

CLASS "C" ROUTES

Establishment of Class "C" Routes

The determination of contaminated (class "A"), and reserved (class "B") routes by the EHTR organization, and activities in connection with them, are by no means simple functions. Regulation of class "C" routes would be even more difficult and complex, for it would deal with many imponderables and would rely much more heavily on widely scattered information sources and on quick, but hopefully, sound judgment. While highway and police personnel in the EHTR organization can handle problems of blocked and class "A" and "B" routes, class "C" route regulation would require assistance and effort from the highway-user members of the EHTR team.

The probable need for class "C" type of route regulation is fairly evident: The capability of the highway network would be severly reduced by a nuclear attack. As the nation recovers and transportation needs grow, highway capacity is unlikely to recover as fast as the demand; and in some locations, at least, essential demands alone may equal or exceed the capacity of serviceable highways. Simply put, there would be times and places in the post-attack period—perhaps for an extended time—when road space must be rationed.

Looking for the favorable side of the picture, it is probable that highway transportation would not suffer total paralysis; except in or close to bomb strike locations, much of the route dislocation would be confined to localized problems or specific bottlenecks. Radioactive contamination would decay in time to safe levels, except in or close to the blast areas. Also, the need for large volumes of highway transport other than for urgent civil defense and military movements is unlikely to develop until at least some days after an attack. Therefore, there would be an interval during which the EHTR organization could get into high gear, for class "C" route regulation.

How soon the operation would need to begin, how extensive it would have to be, and how long it must continue, are questions which are open to conjecture. But the EHTR organization should maintain as a basic premise that regulation ought to be restrained in scope, extent, and duration to a necessary minimum. At the same time, the EHTR operation must seek to foresee and forestall highway overloading and the delays and interruptions to important traffic movements.

It is the responsibility of the EHTR organization to evaluate both the demand and the capability for highway transportation, and once the decision to regulate has been made, it must regulate or ration road space, route by route and hour by hour, as necessary. Priorities for urgent and essential shipments would be issued by other agencies as explained below.

Determining Demand

It is obvious that estimating the capacity of usable highways in a time of emergency is not the simplest of tasks, but it should present no great difficulty to the engineers who would be responsible for that function. Estimating the traffic demand—the volume of traffic movements—under emergency conditions, however, is quite a different matter. In this task, the organized highway-user representatives recruited to the EHTR organization could play the principal role since they can best establish and maintain close contact with the highway users throughout the State and in the district or sector areas that they would serve.

Information on normal peacetime traffic demand is plentiful and well known to the highway departments, and thus readily available to the EHTR organization. On main highways and arterial streets, the seasonal, weekly, and hourly traffic volumes and fluctuations are on record. Information is also available in many cases of traffic composition (cars, buses, trucks, and combinations), trip lengths, origins and destinations, car occupancy, and cargo characteristics. Much less is normally available for secondary and local roads and streets, but, for all of these, there is an annual 1-day traffic count and generalized knowledge of seasonal fluctuations.

On the basis of such peacetime information, the EHTR staff engineers may be able to form judgments on probable traffic demands in an emergency. Of course, the whole picture, and certainly the local situation route by route, may be altered because of heavy losses and shortages or changed needs. System constrictions may shift or concentrate demands elsewhere than their normal channels. Also there is no possible means for anticipating the public's reactions—and actions—in facing the crises of a large-scale emergency. In addition, of course, as activity above bare survival develops in the post-attack period, many of the conventional peacetime traffic demands would tend to reestablish themselves.

So, in trying to estimate the size, locations, and nature of traffic demand in the post-attack period, the EHTR organization's highway and police staff members would be doing their best to apply emergency adjustments to peacetime data. They would make full use of the EHTR field forces to constantly monitor and report on actual traffic volumes and compositions on the road.

It is the highway-user representative on the staff of the EHTR centers that would be expected to do the major job in estimating commercial traffic demand. They should collect whatever information they can on probable traffic movements from all available sources and play the principal part in forecasting route-by-route demand.

The needed traffic demand information can best be collected by the highway-user members of the EHTR staff, to the extent possible, directly from all classes of highway users and traffic generators; and it would be a continuing, daily operation as long as there is a need for class "C" routes in the EHTR unit's jurisdictional area.

Information should be sought not only from the vehicle operators more commonly thought of, such as commercial truck and bus fleet owners, but also from all active and potential traffic generators and attractors. These would include, among others, manufacturing plants and other commercial enterprises employing or servicing large numbers of people, shopping centers, high schools and colleges, and any other establishments which continue or resume operation in the post-attack period. It would be important to know, for example, that a temporarily shut-down plant is about to reopen and thus generate a flow of automobiles and trucks.

Collecting traffic information from vehicle operators and traffic generators should be developed as a two-way pattern, with the EHTR highway-user team members "pulling" and the road users "pushing." The "pulling" phase simply means that the highway-user members of the EHTR staff would telephone all vehicle-operating companies and organizations and traffic generators they know of—and because of their peacetime positions and activities they are well acquainted with many of them—and ask what prospective road trips they expect to have; e.g., on the following day: How many vehicles and what kinds; what routes will be used; the time of trip; and also, what official priority or practical essentiality there may be for such trips. The "pushing" phase would simply be an information flow in the opposite direction: Vehicle operators will telephone their friends who are the highway-user members on the EHTR staff to inform them of pending or anticipated trips, and asks for advice.

Naturally, the more "pushing" that develops in this two-way pattern, the less "pulling" that will be necessary. For this reason, the peacetime education of vehicle operators in the purposes and mechanics of EHTR should prove valuable in the eventuality that it has to be put into actual practice.

How often intercommunication between the highway-user members of the EHTR staff and the vehicle operators and other traffic generators is needed would depend on the day-to-day situation with respect to traffic demand versus highway traffic-carrying capacity. It would be especially needed shortly before a route section is expected to reach its operating capacity and class "C" regulation is being considered; and during the entire control period until it becomes evident that such control is no longer needed. During that entire time, it is vital to collect projected trip information in as much detail, and as far in advance, as is possible.

Theoretically, contact should be established and maintained between the EHTR organization and all vehicle operators and other traffic generators. However, a practical aspect must be recognized; e.g., it is going to be much easier to contact and obtain information from operators of fleets of trucks and buses —and perhaps the larger, the easier—than it will be from operators of one or a few vehicle. Similarly, it is going to be easier to collect information from commercial operators than from private vehicle owners.

While the private automobile is by far the predominate vehicle on our roads and streets in peacetime, both in numbers and total vehicle mileage, it may be much less so in time of emergency, especially in relation to priority or essentiality of trip needs. Scarcity of gasoline and its rationing are likely to severely curtail nonessential automobile use. As the national recovery progresses, legitimate private car trips may increase; e.g., for carpools to work, etc.

In any event, it will clearly be beyond the capability of the EHTR staff to contact all automobile owners about their trip intentions and needs, either early or late in the post-attck period; and there are no organizations that can speak for them on this subject, except perhaps in generalities. However, there are some possibilities that may develop into practical operations: For example, an industry important to the national economy or defense might obtain priorities for its carpool traveling employees, and report en bloc on their daily trips to the EHTR center.

Within the total traffic demand, no matter how estimates are compiled, consideration of essential needs would be highly important. When the total demand exceeds the capacity of a route, class "C" regulation must be instituted; but rather than a catch-as-catch-can operation, the EHTR organization must see to it that essential traffic movements are preferentially handled. In the emergency situation, and quite probably extending long into the post-attack and recovery periods, there would be an official cargo and personnel priority shipment system for expediting essential and urgent transportation movements.

Traffic-Carrying Capacity of Surviving Highways

It is basic that the EHTR organization, as one of its first operations, must have obtained sufficient information from all available sources to permit recording and plotting the road and street situation throughout the State. The result would be a visual representation, on a large-scale wall map of the road and street network, of those route sections that are impassible because of physical damage or radiation, and those under regulation as class "A" and class "B" (contaminated and reserved routes). The remaining roads and streets presumably are all usable; and from this base a workable transportation system must be patterned. The first concern would be to provide continuity in interrupted or bottlenecked primary and principal secondary routes. This can be accomplished by arranging for quick repair, bypasses, detours, or alternate connections by way of existing adjacent roads.

Intimate knowledge and available records of road geometrics and conditions are prerequisites to this work of assessing the capacity of surviving highways, and planning for temporary system "patchwork." It would do no good, for example, to map a narrow, dirt road as an adequate detour for a damaged section of mainline highway. Road inventory information is generally available for all State highways; and State and local highway department staffs would be fully acquainted with the status of all roads and streets under their jurisdictions. As a consequence, the selection of detours, bypasses, etc., to provide needed route continuity can best be accomplished as a joint, cooperative effort of the EHTR centers at all three levels, with the collaboration of the State and local highway departments.

It is obvious that the relief section for a blocked route must be adequate for the job or it in turn would become a bottleneck. When full relief cannot be arranged, that is, if traffic capacity adequate for all, anticipated traffic demand is not going to be available, then class "C" route regulation, using road-use permits, must be instituted.

So it is evident that in mapping routes and systems for post-attack highway transportation, in reaching decisions on the need for EHTR control of class "C" routes, and in operating those routes, the capacity of the surviving available highway network, especially the primary and principal secondary routes, must be determined. This would be done by the traffic engineers of the EHTR staff.

Traffic-carrying capacity may be estimated, route section by route section, depending on foreknowledge and existing conditions. The geometrics and, in fact the calculated traffic capacities, would be known and on record for most State highways and many secondary roads. However, within affected areas, the suddenly created bottlenecks and the effects of necessary detours and emergency route connections would upset the normal characteristics of traffic flow and must be taken into account. There is a reasonable background of experience in such matters from situations occasioned by construction detours and the aftermath of natural disasters such as floods.

A possibly even more disruptive bottleneck in emergency route regulation may be the roadside control post itself. While trying to sort out permit-carrying vehicles from others, and expediting the former while turning back the latter, the control post may also create a major turbulence in the traffic flow along the regulated route. Operations planned and executed with extreme care may keep such turbulence at a minimum, but it cannot be expected that traffic would run smoothly past a control post at a capacity rate indicated by geometrics alone. This situation must be reckoned with in estimating traffic-carrying capacity under emergency conditions. There is little experience to use as precedent, although perhaps route measures can be developed from operations at toll bridges, drive-in theatres, and paid parking lots at football stadiums, etc. Estimating the effect on traffic capacity of the roadside control post may amount to little more than skilled guess-work.

Highway capability may be expressed as vehicular capacity or tonnage capacity. Vehicular capacity relates to the maximum number of vehicles that can pass a given point on the road in a specified period of time under prevailing roadway and traffic conditions. Roadway characteristics that influence the vehicular capacity include: Type of highway or road, number of lanes, grades, horizontal curvatures, roadside clearances, and lane widths. The percentage of each type vehicle in the traffic stream and weather and visibility conditions also influence the traffic-carrying capacity.

While vehicular capacity is the capability analysis most familiar to the traffic engineer, the tonnage capacity of a roadway must be considered. For example, a "parkway" with a pavement structure designed for passenger-car use only might be under consideration as a heavy truck detour road to a vital industry. The "parkway" may be able to accommodate as much as 10,000 trucks a day if the roadbed is dry or frozen, but during a wet spring thaw after a few heavy truck passages, the roadbed might become impassible.

Tonnage capacity analyses are more familiar to the military. A short Section of the Department of the Army Field Manual 55–15 titled, HIGHWAY CAPABILITY ESTIMATES, is a good reference for aiding the traffic engineer in evaluating routes before and after the disaster, and a copy should be in each EHTR center. The reference for making vehicular capacity analyses is the Highway Capacity Manual, Special Report 87 of the Highway Research Board. A point to make here is that there will not be time to learn the details of the subject, but there should be a traffic engineer in each center capable of making highway capacity analyses and that at least the district and sector centers should have route logs and other records of the roadway pavement structure and geometrics available for his use.

The Decision to Regulate

The comparison of highway traffic capacity and traffic need—that is, supply versus demand—would indicate for each route section studied whether and where trouble or potential trouble, in the form of congestion, exists or may soon develop. The EHTR chief, with the advice of his staff, must then make one of three decisions:

(1) That no regulation is needed, because the trouble is not imminent enough or has a reasonable prospect of being alleviated within a short time.

(2) That some regulation is required, but need be operated only on a partial basis as during specified hours or with the recognition that a considerable amount of non-priority traffic can be accommodated, some of it even during the controlled hours.

(3) That full-scale, full-time control is required, with accommodation limited largely to priority traffic movements, at least during some time periods.

In some cases, the decision to regulate may not come until after the congestion or other route difficulty has actually materialized; but it would be highly desirable to anticipate the need for and institute control reasonably well beforehand, so that serious congestion is averted. Many decisions would be difficult to make, for they will be concerned with questionable information and borderline situations. Two opposing forces could exist in extreme cases: the losses incurred through congestion, if regulation is begun too late; and the inconvenience and wasted effort to shippers and the EHTR organization alike, if control measures are put into effect much too soon or in locations where anticipated congestion does not materialize. The EHTR chief must indeed thread a fine needle.

In the earlier discussion for determining demand for the use of class "C" routes, no mention was made of operating level; that is, whether the decision is made by the State, district, or sector EHTR chief. An inflexible pattern of responsibility does not seem advisable; of overriding importance is an arrangement to ensure that each office knows what the others are going to do, and that possible conflicts be eliminated before they happen. As a general rule, it is logical for the EHTR office closest to the local situation to make, or at least initiate, decisions to control.

For example, a sector chief may decide that a particular route section will need class "C" regulation by the next day. If the situation is purely local, he should have authority to proceed with the arrangements, but be required to immediately inform his district chief, and adjacent sector chiefs, of his intent. If, however, route control need appears to span the entire sector, or extend across a sector boundary, then presumably the district EHTR chief should be responsible for the actual decision or for coordination between sectors. Similarly, a situation that extends to or beyond a district boundary should be the decision-making or coordinating responsibility of the State EHTR chief.

In every case, of course, it is imperative that each EHTR center—State, district, and sector—be promptly informed which route sections are going to be controlled, and when; which are operating under controls, and under what conditions; and which now under control are going to be released. Once again, it is evident that good communications are vital.

When and if the decision is made that class "C" regulation of a particular route is necessary, two considerations are required: One as to length of route to be put under regulation, and the other as to timing.

Individual decision that class "C" regulation is required would usually be related to specific location or limited area, and to a particular route, since in all probability the need would be occasioned by a bottleneck at a single spot or along a short stretch of road or street. Conceivably, control might be instituted on a route extending for many miles; perhaps across the entire State. But this seems less than likely to be a common need, based either on road capacity or traffic demand. In addition, control of a long route might well be difficult from an operational standpoint, and would involve considerable manpower and paperwork.

As a general principle, then, regulated route sections should be no longer than is necessary to ensure that congestion will not develop, because of the control operation itself, at the route section termini.

There may be situations where two route sections which require regulation are part of a continuous major route and are so close together that control as a single unit would function more efficiently. Also, control of one route section may create traffic problems on other nearby routes, particularly those crossing or closely paralleling it. Thus in preparing to make the decision to institute class "C" regulation on any individual route section, full consideration must be given to the consequent effects on other roads and streets in the vicinity.

The decision to institute class "C" regulation is, of course, concerned with a time period in the future. Regulation, whether partial or full scale, cannot effectively be applied at a moment's notice. Roadside traffic control posts must be spotted, equipped, and manned. Requests for road space must be solicited and received, and permits issued or authorized.

A logical and practical system of control operation is what might be called the "following-day" pattern (a plan commonly used by the military services), in which preparations are made each day for the following day's operations. In EHTR operation, information collected by the EHTR organization during the morning might indicate that traffic demand may soon exceed capacity on a particular route section. The decision to regulate might be reached by noon. During the afternoon, arrangements would be made for establishing and manning roadside control posts; requests for road-use permits would be solicited and processed; and information would be disseminated to the general public on the situation. The actual regulation would begin on the road at a prescribed hour on the following day, probably at a very early hour.

A further consideration in timing is the duration of regulation on a particular route section. Sufficient information may be available, or careful judgment may indicate, that control should remain in force for several days, a week, or even a more extended period. This will be an initial decision, of course, subject to amendment as the situation develops from day to day. The extent of control on one route may also be affected by the situation on other nearby regulated routes.

Class "C" regulation may be needed only during certain hours of the day when congestion is likely to occur (for example, the peak-hour surges in an around urban areas) or it may be required for the full 24-hour period. Similarly, it may be required in one or both directions.

Instituting traffic control only during the day or even during just the few heavy-demand hours would greatly simplify the task, both as to manpower and paperwork. In addition, it would very well encourage many highway users to travel in off-peak, no-control periods, thereby actually reducing the peak-period demand.

One other point about timing should be emphasized. The beginning point for class "C" route regulation as a general type of EHTR operation cannot be defined. The needs for class "A" and class "B" route control would arise almost immediately after an enemy attack; but the needs for class "C" regulation are not likely to develop so quickly. Additionally, the EHTR organization may not be sufficiently activated and staffed for managing class "C" route regulation on any extended basis until at least several days after the attack.

Operation of Regulated Routes

It must be borne in mind that EHTR would be far from a simple and static operation. Many of the situations and operations described in this Guide are necessarily treated as individual subjects, but in practice many will be simultaneous, interacting, and sometimes in conflict with each other.

Routes wholly reserved for essential movements (class "B") and those operated on a road-use permit basis (class "C"), may also be exposed to radiological hazard. Class "C" routes may be operated as such only part time or they may be reserved during certain periods for class "B" use. Post-attack traffic needs will fluctuate; physical conditions will improve or worsen; radiation hazards will decay and shift; planned road repairs will be completed or deferred. It is thus evident that EHTR operations would be in almost constant state of flux. Only by having full and current information posted on the maps at the State, district, and sector EHTR centers would it be possible to continuously assess the situation and plan and effect changes to accommodate anticipated traffic. Each regulated route, each barricade and sign installation, each roadside control post, each detour, each blocked route, each repair or reconstruction job, and every other pertinent detail that would aid in assessing the current situation, and in planning ahead should be recorded in readily usable form at all the EHTR centers. As a general principle, the EHTR operation should be as little encumbered by paperwork as possible. But details of the current situation are a prime essential for without them confusion could be extreme and disastrous.

Routes which are found to be blocked by physical damage, such as destroyed pavement or demolished bridges, or which are impassible because of debris on the roadway, would be assessed as to their repairability and restoration to full or partial service. Information on the priority ranking of work to be undertaken in debris removal, road and structure repair or replacement, construction of bypasses, and providing adequate detours should be obtained from the highway department.

Highway department decisions on a priority work schedule should be based on the developing post-attack traffic needs and general route availability. The relative and absolute conditions at each location: The advantage to be gained for traffic movement; the local availability of construction equipment, manpower, and materials; and the speed and safety (e.g., from radiation hazard) in which the work can be done should be taken into account.

Both the situation survey and the judgments involved in arriving at the reconstruction priority schedule should be handled as a collaborative effort of the EHTR staff and the State highway department. This is important since the former would have the responsibility for traffic estimation and regulation while the latter would have responsibility for doing the road repair work. Such collaboration can readily be planned and readily effected in actual operation. This is true since State highway department personnel would be a principal part of the EHTR organization, and in most States, the State highway department itself has been given the primary responsibility for planning and organizing for emergency highway traffic regulation—that is, the highway department is the "parent" of the EHTR organization.

It should be remembered that in time of emergency the State highway department should have full authority over all roads and streets, not just the State highway system alone. With this authority, it can use its own forces to undertake needed work on local roads. It can also take over jurisdiction and use local roads as detours for State routes and it can requisition the help of the local highway departments.

An immediate need in connection with physically damaged or otherwise blocked highways would be to barricade the impassable sections. Probably the barricades should be placed at the nearest crossroad still open to traffic; and as soon as possible information signs prescribing available detours to various nearby destinations should be posted at the barricades. The barricades and signs would be placed by crews dispatched from the highway or police departments. As previously noted, barricades and signs of a type that would be needed should be prepared and stockpiled in advance at convenient, safe locations.

ROAD-USE PERMITS

Definition

The road-use permit is a legal form issued to authorize specific travel over a designated route during a specified time (see Figure 6.) The essential elements of this permit are: date, route number, time of entry, destination, number of vehicles, etc.

FIGURE 6

No. A 0,000,001

Trip origin ____________
Trip destination ____________
Number and type of vehicle ____________

Owner ____________
Commodity ____________
Shipment priority ____________
Regulated route number ____________
Authorized time of entry ____________
(and/or such other items of information as may be appropriate)

Issuing EHTR Center ____________
By ____________

STUB TO BE RETAINED BY ISSUING EHTR CENTER

(Perforated line)

Number of vehicles authorized: 12 11 10 9 8 7 6 5 4 3 2 1

Highway Road-use Permit for Regulated route number

22

Issuing EHTR Center ____________
By ____________

Time of entry on to regulated route
A.M.: 12-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12
P.M.: 12-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12

Valid only on ____________ 19__

ROAD-USE PERMIT TO BE ISSUED

STATEMENT OF PENALTY FOR MISUSE TO BE PRINTED ON BACK OF FORM:

This permit is the property of the United States Government. Its counterfeiting, alteration or misuse is a violation of 18 U.S.C., Section 499 (1948). Violators shall be fined not more than $2,000 or imprisoned not more than five years, or both.

Issuance and Record Keeping

The key to successful traffic regulation on class "C" regulated routes is the planned issuance of road-use permits. A revised form of this permit is reproduced in Figure 6. It is expected that State organizations responsible for emergency highway traffic regulation will stock a master copy of this permit form available for quick reproduction in the event the need for it arises. Each State plan should also contain a copy of this form.

The display portion of the permit is intended to be taped on the vehicle windshield, so it may be quickly scanned at the roadside control posts. As illustrated in Figure 6, the route control number would be written in the center of the permit in large lettering, so it can be checked "on the fly." It is proposed also to make the date evident at a glance, simply by using a different color for the permit form, for each day of the week. The permit should be serially numbered, both on the stub and the display portion; the remaining details evident in the illustration are self-explanatory.

As a premise to further discussion of permit issuance, class "C" route regulation is instituted only when it appears that anticipated traffic will overload the route section, so that all traffic cannot be accommodated—at least, at the particular time each vehicle operator himself would choose. It follows, then, that some traffic must be turned back or delayed; conversely, that traffic involving priority shipments must be given perference over any other. Then, reduced to its simplest concept, road-use permit issuance may be concerned only with shippers who have already received cargo priority certification from the transportation agency charged with that responsibility. (If this latter statement seems oft-repeated, it is to ensure that EHTR participants constantly remember their own function is to accommodate official cargo and personnel priority shipments, not to authorize them. See page II-24 for further information concerning cargo priorities.)

Reducing the concept to this basic position, then, it can be assumed that a large proportion of permit issuance would be accomplished by contact between the highway users of the EHTR staff and the commercial vehicle operators, particularly those with fleets of more than just a few vehicles. It is such operators, in all likelihood, who would be handling the types of highway movements that warrant cargo and personnel priority certification: i.e. The handling of critically needed foodstuffs and other goods, and the operation of bus transportation.

Actual permit issuance would be far more easily handled if these commercial and military vehicle operators are furnished with pads of permit forms, and instructed as to their purpose and use, as a part of the EHTR organization's planning and preparatory work. If this advance distribution has not been accomplished, then it should be done quickly after the beginning of an emergency. It is evident, of course, that handing out blank permit forms must be done with some discretion and that they should be given only to trustworthy individuals in established and reliable concerns.

Assuming that the major vehicle operators have the blank forms in hand, the rest of the permit issuance operation is simplicity itself insofar as they are concerned. As soon as an operator has a specific shipment planned and has received a cargo priority certification for it, he would telephone the nearest EHTR center to find out if a road-use permit is needed, and to request its allocation. In all probability he would be talking by telephone with one of the highway user members of the EHTR staff with whom he has already had contacts, since the beginning of the emergency, and whom he knows through peacetime associations. The shipper would inform his EHTR contact of the trip origin and destination, number, and types of vehicles, nature of shipment, and all the rest of the information called for on the road-use permit form, including, of course, the desired travel route and time.

The EHTR staff man would check his map and his day's allocation sheet, and if the route has only a locally controlled class "C" regulated section, he would be able to issue road-use permit authority then and there. If an intermediate or long-range trip is involved, with regulated sections controlled elsewhere, the EHTR Sector center would have to make arrangements through the District center and possibly the State center. Interstate arrangements may have to be made, as described previously. In these situations beyond local control, as soon as it is known that road space on regulated route sections is available for the trip, the EHTR Sector would advise the shipper accordingly.

For any allocations of road space within the State, the shipper would be told to fill in his own road-use permits, on the blank forms he already has at hand. Necessary information would be interchanged; for example, the shipper would inform the EHTR contact of the serial number on the permits being used; the contact man would inform him of the route section control number. The EHTR man would tally the proper number of vehicles in the appropriate box on his day's allocation work sheet. The shipper would tape the display portions of the permits on his vehicle windshields; and they are ready to go—at the proper time, of course.

It is recognized that this procedure depends on the cooperation and integrity of the shippers involved, and it is possible that in isolated cases this confidence would be violated. But the alternative, to physically issue permits to major commercial vehicle operators only at EHTR centers or even at more numerous other locations, would inevitably result in inconvenience and delay to those handling the bulk of the priority shipments and, of course, delay to the shipments themselves.

While much of the cargo priority-certified shipments may be handled by the larger concerns among the commercial vehicle operators, it would also be probable that cargo priorities would be issued to commercial operators who own only one or a few vehicles, and to private automobile users—the businessman, doctor, or defense worker, or the family traveling to a new job and home.

To take care of these, permit-issuing stations can be established in fairly large numbers, well distributed for convenience throughout the area serviced. They can be located at police and fire stations, post offices substations, and other government buildings, including libraries and schools. They might even be located at shopping centers, the entrances to major stores and factories, etc. Each could be manned by an appropriately instructed volunteer, who need not have had any previous experience but who is willing to cooperate in the simple process involved; a telephone would be required in order to communicate with the nearest EHTR sector center; and a supply of permit forms. One additional simple requirement is a sizable cardboard sign that can be placed in the window or tacked to the door, to show that there is a road-use permit station at the location.

The operation of a permit issuance from such stations would not be essentially different from that desribed above, except that it would be done through an intermediary. The individual seeking a permit, or information as to whether he would need one for a planned trip, would present his cargo priority certificate and/or request, in person, at the nearest permit station he can find. If possible, the location of these stations should be announced by radio broadcast or in newspapers if they are being published. The person manning the station would call the EHTR sector center on the telephone and relay the request, with appropriate information. Quite possibly the request can be granted at once, and the station "agent" would make out the permit. If a delay is necessary, the permit seeker can be asked to return at a specified time to the same station to complete the trip arrangements.

Under some circumstances, it would be anticipated, or found through experience after a few days' operation, that permit issuance is required on a route section because total traffic that would like to use it exceeds its capacity, yet the capacity is not nearly reached by the priority shipments. This situation may exist around the clock, or only during particular periods.

If the difference between cargo priority shipment volume and total capacity is sizable enough and fairly steady, the EHTR organization may issue additional road-use permits for what it considers essential trips which, for various reasons, have not been granted an official cargo priority. Such trips might be of an urgent nature, that cannot wait for formal cargo priority action; or they may involve needs or purposes that are less important than those warranting a cargo or personnel priority but still, for economic or humane reasons, seem more essential than run-of-the-mill traffic. It is probable that the great majority of such trips would be local in character, and could almost wholly be processed by the EHTR sector center alone.

If permits of this category are to be issued, the daily road-use allocation tally sheets should be modified accordingly. For each regulated route section to be operated in this manner, it would be necessary to allocate separately for priority trips and for essential nonpriority trips. Actual physical issuance of permit forms would be handled primarily at the stations described in the preceding section, and in the same manner.

In addition to nonpriority but essential road-use permit issuance at EHTR centers and satellite stations, arrangement could be made for accommodation of such trips at a roadside control post.

Just how the total traffic-carrying capacity of the route is divided for the purpose of permit issuance would depend to a considerable extent on the route itself. As a generality, perhaps 10 percent is reasonable for State allocation, 20 percent for the district, and 70 percent for the sector; but the peacetime trip-length distribution of the route, and any other past or current indications, may be used as criteria.

The mechanics for arranging the allocation probably are best handled in a descending order of EHTR level and should be explained in each State plan. The general routine of the operation is likely to begin with a tentative decision at an EHTR sector center that a particular route section ought to be regulated; this decision would be recommended upward through the EHTR organization structure. Confirmation, approval, or alteration of the tentative decision (for instance, the district may see the need to extend the controlled section into an adjacent sector) would be made first at the district center and then at the State center. In communicating the confirmed decision downward, the State first, and the district next, would specify the hourly allocation of road space that each has reserved from the total traffic-carrying capacity for its own anticipated needs in permit issuance.

The reason for adopting the tri-level split-allocation method of handling individual trip allocations and road-use permit issuance is fairly obvious. Local vehicle operators naturally would contact the local EHTR sector center for road-use permits, particularly since they have already been in communication with that center, during the canvass of possible traffic demand, and would know from such contacts or from local news broadcasts that the particular route they want to use is now or shortly will be operated under regulation.

The other extreme in the picture can best be described by the following example. A trucker at a distant point, say in Iowa, may have a priority-certified cargo involving several vehicles which, in the course of their long trip, must cross Ohio. Of course, only from the Ohio EHTR organization can he learn whether any part of the proposed trip route in Ohio is closed or under class "C" regulation. But it can hardly be expected that the shipper as an individual in Iowa should make direct contact with the Ohio EHTR organization, even if he knew how to do so. His logical and probable action would be to get in touch with the EHTR sector (or perhaps district) center in Iowa that is closest to him—one which undoubtedly he is already in contact with about local trips. From there, his request would be transmitted to the Iowa State EHTR center and thence to the Ohio State EHTR center. (In this example, the State EHTR centers of the intervening States of Illinois and Indiana may act as intermediaries, especially since their own highways would be involved in the Iowa-Ohio trip).

Information and authority for issuance of road-use permit would return to the Iowa shipper via the same communications channels, and the local EHTR center in Iowa would be able to give him fairly specific instructions. One of these would be to pick up the actual permit displayed on the vehicles. Presumably this would be the first roadside control post he reaches in Ohio. All this sounds involved, but radio or phone communications should make it possible to accomplish the entire transaction in a few hours.

On long-range trips of the type discussed above, it is probable that the vehicles involved would have to traverse several different class "C" regulated route sections within the States but each in a different EHTR district or sector. The State EHTR center would be able to handle all of the allocations and permits for the separate route sections within a State. If the initial contact with the shipper was at the local level, the State EHTR center would instruct the EHTR sector center to issue the required permits.

Concerning EHTR districts, intermediate-length trips can be handled by the EHTR district center in the same manner that long-range trips are handled by the State center.

At each level—State, district, and sector—the staff members handling the allocations would know the number of vehicles for which they could issue road-use permits, for each hour of controlled operation on each regulated route section. When it appears that the number of vehicles carrying priority-certified cargoes will exceed the quota, two alternatives are open.

One of these is to attempt to "borrow" space from the reserved block of another EHTR level; for example, the sector might query the district and State centers to ascertain whether either one could spare some of its originally allocated space. The other alternative is to attempt to get the shippers to rearrange their trip-time schedules; thus, a shipper could be informed that a particular time slot is rapidly filling up, and that some earlier or later hour is available, which might serve just (or almost) as well.

When a specific hour is already loaded by permit issuances, further reques' for that particular time will have to be refused. In urgent cases, however, it may be possible to get some shippers to relinquish their permits in exchange for others at a different hour. This sort of trip-time shifting or swapping can most readily be managed at the local level, where the highway users on the EHTR staff are well acquainted with many of the commercial vehicle operators.

There is a quite different type of situation which could occur with some frequency. This situation would complicate the handling of allocations for road space unless it is anticipated and arranged for in advance. This involves the class "C" regulated route section that crosses EHTR unit lines; for example, a route that has one terminus in one EHTR sector and the other terminus in an adjacent EHTR sector. Depending on the individual situation, each of the two sectors involved could handle the allocation of road space for local traffic originating in that sector; that is, each sector center would be handling traffic in only one direction on the route. An alternative would be for the district EHTR center to handle both local and intermediate trip allocations.

The possibilities of variety in situations of this type are so manifold that it hardly seems practical to attempt to conceive of and plan for all of them in detail. Nevertheless, in actual operation, each time the decision to regulate a route section is about to be made, careful (but quick) consideration must be given to all possible unusual and complicating circumstances.

It is obvious that some basic records of permit issuance must be kept in each EHTR center, in the process of allocating regulated route section space, but they should be kept to a minimum. It is suggested that these records may be crude in nature just so long as they are accurate. Even accuracy is relative, since over-issuance of trip permits by 10 or 12 on a road section with an hourly capacity of 800 vehicles is not going to create any great amount of congestion, if any.

In its barest essence, the road space allocation and road-use permit issuance operation in any one EHTR center (especially at the local level) can largely be managed by a man with a telephone and a tally sheet.

In more specific terms, a sensible method of allocation control would be to post each day's permit issuance on a single, large sheet of paper. At any one time, of course, it would probably be necessary to have available and work on separate sheets for the current day and three or four days ahead.

These work sheets might be mounted on a wall panel in the EHTR center, adjacent to the large-scale maps of the area. Here they would be available for all of the staff to see; and a number of EHTR staff members, engaged in contacting vehicle operators and issuing permits, could check the situation and post their records without unduly interfering with one another. If the operation is on a small scale, and one or two men can handle most of the contacts with vehicle operators, the posting sheets could be kept on a desk table where the men are working.

Each sheet, for a single day's operation, would be divided into columns and lines; each column representing an hour of the day and each pair of lines a regulated route section. Figure 7 illustrates a part of such a posting sheet. The day and date are prominently displayed, and the center indicated (whether sector, district, or State). For each regulated route section, the control number assigned to the route section (and there should be a prearranged plan for this numbering), the Interstate, U.S., State, or county route number (as signed on the road), and the termini should be shown. Because two-directional travel is involved, each route is given two lines, one for each direction. The combination of route numbers termini, and travel direction is proposed as a means of avoiding any misunderstandings about which route section is involved, both in talking to vehicle operators and in posting permit issuances.

As shown by the enlarged inset in the illustration, each block represents 1 hour of space in one travel direction. These would initially be posted in a small box in the upper left corner (perhaps in red pencil), four figures representing the route section capacity. The topmost figure is the capacity portion allocated to the State for permit issuance; the next, the capacity allocated to the district; the next, the capacity allocated to the sector; and, at the bottom, the total. To avoid any confusion, the figure applicable to the allocating office should be circled. As illustrated in Figure 7, the posting sheet is that of an EHTR sector center, and the circled figure 280 indicates the number of vehicles for which the sector can issue permits in the 12–1 a.m. period for eastbound trips on controlled section No. 1, on Thursday, December 6.

The tally of permits issued or authorized is kept in the simple, old-fashioned pencil stroke system, with every fifth count recorded as a cross-stroke. Since large numbers of tallies are likely to be recorded, it is recommended that a cumulative total of the tally in each box to be noted on the right, as each line is completed. This technique is illustrated in the example.

It hardly seems necessary to keep any record of permit issuance other than that described here; even trying to make carbon copies of the daily sheets would be difficult because of their size and constant handling. At the end of each day the day's sheet can be filed away, or for that matter simply discarded. The records are worth saving only for possible analysis of successes and failures of the operation, at some long-distant future time. During the operation there would be no time for much analysis; and the day's work, insofar as it helped or hindered essential traffic movement, cannot be undone.

It is important that each State consider the foregoing ideas for record keeping and incorporate in the State EHTR plan these or similar ideas whichever are best suited to the individual State.

OPERATION OF REGULATED ROUTES

Cargo Priorities

Each State EHTR plan should contain specific details as to how cargo and personnel priorities would be obtained by shippers subsequent to a nuclear attack. Clearly (see FHWA Order 10–4.30) it is not the function of the EHTR organization to issue these priorities. It is the function of this organization to ration road space as necessary by the issuance of road-use permits so that available traffic-carrying capacity may be efficiently utilized. The EHTR staff will make decisions of precedence of movement only when the number of equal-priority vehicles seeking road space at the same time exceeds the particular route capacity. Most State emergency management plans contain a provision for the post-attack creation of Federal-State Emergency Motor Transport Boards. The dual Interstate Commerce Commission (ICC)—State responsibility has been resolved by the formation, jointly by ICC, the States, and the District of Columbia of these boards to coordinate action concerning motor transportation. In most cases, each board is composed of a representative of the ICC, the State regulatory agency, and the motor transport industry. The ICC representative is responsible for ICC policies and procedures, the State representative is responsible for State policies and procedures, and the State motor carrier association

EHTR DAILY ROAD SPACE ALLOCATION SHEET

State of ____________

District: 3 Sector: ABLE COUNTY Day: Thursday 12/6/92

(If this is district or State center sheet, so indicate)

Regulated Route Identification					Hour of Operation									
Control No.	US or State Route No.	From	To	Direction of Travel	12-1 AM	1-2 AM	2-3 AM	3-4 AM	4-5 AM	5-6 AM				
1	U.S.6	Smithville No. City line	JCT. SR4	E										
				W										
2	S.R.31	JCT. U.S. 13 near Billburg	JCT Co. RT 12	S										
				N										
3	U.S.42 & CO.3	Jct U.S.42A No. of Johnsville	JCT SR 23	S										
				N.W.										
4	S.R.2 S.R.-6 Co. 2			S.E.										
				N.W.										

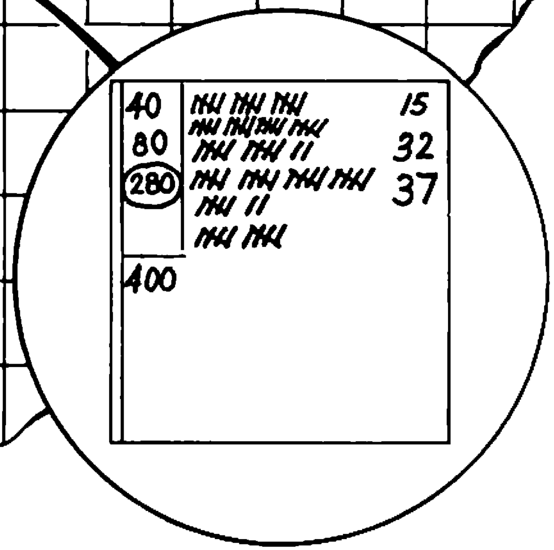


Figure 7 ---EHTR daily road-use allocation sheet, for posting road-use permits issued or authorized

FIGURE 7

manager or someone designated by him acts as the industry consultant or advisor to the board on motor transportation. In order to assure coordination, each board has a chairman. The chairman's function is one of coordination and central guidance to the board in order to assure unified actions. In an emergency the board would be activated and operate from the emergency headquarters as established by the State. Among the several responsibilities of these joint Federal-State boards would be the issuance of permits authorizing the shipment of resource commodities. The ICC will have no control over and would not participate as a member of the EHTR organization when the EHTR organization is activated. The ICC has the responsibility for the development of emergency preparedness plans and programs for the domestic surface transportation industries, and for guidance to States in the development of their transportation plans. This includes industry operational guidance, standby programs for reduction of vulnerability, maintenance, restoration and utilization of the capacity of domestic surface transportation in an emergency.

In order to better explain the procedures for motor freight shipment during a national defense emergency the steps required for a delivery after controls have been established are listed below.

(1) A shipper requests a priority for a load of critical material from the above-referenced ICC-State Emergency Motor Transport Board.

(2) The shipper either uses his usual carrier or requests from the ICC-State Emergency Motor Transport Board a carrier assignment; in which case a trucker having the required equipment would be assigned to make the delivery.

(3) If the State EHTR organization has concluded that highway regulation is unnecessary on the route which the trucker wishes to use, the trucker would deliver his load in a normal manner.

(4) If, however, the EHTR organization has instituted traffic regulation then the trucker must obtain a road-use permit from the nearest EHTR center which would be evidence that he has been cleared to use a particular regulated route.

Admittedly, during periods of class "C" route regulation, there will be representations of essentiality or urgency of trips by those who cannot obtain or do not have sufficient time to seek a formal cargo or personnel priority certification. The EHTR organization, whenever possible, should give preferential consideration to bona fide cases of this type. They can best be taken care of at road-use permit issuance "stations" or at roadside control posts, as will be discussed later.

The following information from Paragraph VIII, (c)(1) of the Louisiana EHTR Plan (October 1, 1971) exemplifies how a State plan should identify the organization which issues numerical priorities covering cargoes and personnel:

"(c) Priorities and allocation of road space

(1) Federal and State transportation agencies of a joint Federal-State Motor Transport Board will establish numerical priorities covering persons and goods to be transported and services to be rendered thus determining which should be given the preference in road space. Recognition of such priority by regulation centers in the issuance of road space permits will be based solely upon the priority classification assigned to the persons or goods for which road space permits are requested. The type of vehicle or the ownership thereof shall not be considered, nor does the possession of an Interstate Commerce Commission 'permit' to operate on all or certain routes during normal conditions, establish any form of priority or preference."

EMERGENCY HIGHWAY TRAFFIC REGULATION SIGNS

Under Section 102 of Executive Order 11490, in addition to preparing plans for a national emergency, as assigned to each department, the heads of departments and agencies shall "(c) . . . (3) be prepared to implement, in the event of an emergency, all appropriate plans developed under this order."

With respect to the responsibilities assigned to the Department of Transportation, Section 1303 of the Executive Order directs the Secretary of Transportation to "prepare emergency operational plans and programs for, and develop a capability to carry out, the transportation operating responsibilities assigned to the Department, including but not limited to:

(3) Emergency management of all Federal, State, city, local, and other highways, roads, streets, bridges, tunnels and appurtenant structures including:

(c) The regulation of highway traffic in an emergency through a national program in cooperation with all Federal, State, and local governmental units or other agencies concerned."

It appears from the foregoing requirements of the Executive Order that, in order to "develop a capability to carry out" the obligations of the Department of Transportation with respect to emergency signs, it is necessary to prepare the signs now for immediate installation when an emergency is declared and to stockpile the same for such use.

Under certain conditions, Federal-aid funds may be used to participate in the cost of purchasing and stockpiling emergency highway traffic regulation signing. It has been determined that no legal objection exists to the funding of such signs from funds otherwise available under 23, USC, 109(d), inasmuch as such signs, during a national emergency, "Will promote the safe and efficient utilization of the highways." However, since the funding of emergency signs appears to be also an obligation of the Defense Civil Preparedness Agency, in each instance in which Federal-aid funds are used, a State should first request assistance in the purchase of such signs from its State civil defense director. A denial of such funds by that office can be used as the basis for the determination of the eligibility for Federal-aid participation.

It is expected that all required signs will be initially purchased under one Federal-aid project and adequately warehoused so as to prevent undue deterioration.

Therefore, at the State's election, the project may be financed with either Federal-aid primary, secondary, or urban funds at the prevailing matching ratio. Interstate or special Federal-aid funds may not be used. The Federal Highway Administration should be contacted for specific instructions concerning the appropriate project and agreement number. It is expected that adoption of such simplified procedure will reduce administrative costs of these projects.

The Manual on Uniform Traffic Control Devices is the national standard to which all traffic control devices must conform. The standards contained therein apply to all classes of streets and highways that are open to public travel. A section of the Manual titled, "Signing for Civil Defense," includes signs for use during a national defense emergency. These signs should be available when needed in an emergency and provision should be made, therefore, for having these signs stockpiled and ready for use should the need arise. Reference should be made to the current booklet containing designs of Standard Highway Signs.

The following signs are identified below as having particular application to the emergency highway traffic regulation program since this program is a post-attack, post-shelter emergence program.

Area Closed Sign

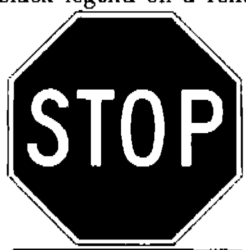
The AREA CLOSED sign shall be used to close a roadway entering an area from which all traffic is excluded because of dangerous radiological or biological contamination. It shall be erected on the shoulder as near as practicable to the right-hand edge of the roadway, or preferably on a portable mounting or barricade partly or wholly in the roadway. For best visibility, particularly at night, its height should not normally exceed 4 feet from the pavement to the bottom of the sign. Unless adequate advance warning signs are used, it should not be so placed as to create a complete and unavoidable blockade. Where feasible, the sign should be located at an intersection that provides a detour route.

Background white (refl.)
Border black
Letters black

Traffic Regulation Post Sign

The STOP TRAFFIC REGULATION POST sign shall be used to designate a point where an official post has been set up to impose such controls as are necessary to limit congestion, expedite emergency traffic, exclude unauthorized vehicles, or protect the public. It shall be erected in the same manner as the Area Closed sign at the point where traffic must stop to be checked.

The standard R-1 STOP sign shall be used for this mandatory stop restriction. The supplemental panel TRAFFIC REGULATION POST should be mounted directly below the STOP sign and shall consist of a black legend on a reflectorized white background.



Background Red (refl.)
Border white (refl.)
Letters white (refl.)

Background white (refl.)
Border black
Letters black

Background white (refl.)
Border black
Letters black

Emergency Speed Sign

The MAINTAIN TOP SAFE SPEED sign may be used on highways where radiological contamination is such as to limit the permissible exposure time for occupants of vehicles passing through the area. Since any speed zoning would be impractical under such emergency conditions, no minimum speed limit can be prescribed by the sign in numerical terms. Where traffic is supervised by a traffic regulation post, official instructions will usually be given verbally, and the sign will serve as an occasional reminder of the urgent need for all reasonable speed.

The sign should be erected at random intervals as needed, in the same manner as other standard speed signs. In rural areas, it shall be mounted on the right-hand side of the road with its lower edge not less than 5 feet about the crown of the roadway, 6-to-10 feet from the roadway edge. In urban areas, the height shall be not less than 7 feet, and the nearest edge of the sign shall be not less than 1 foot back from the face of the curb. Where an existing Speed Limit sign is in a suitable location, the Top Safe Speed sign may conveniently be mounted directly over the face of the older sign, which it supersedes.

Road-Use Permit Sign

The ROAD USE PERMIT REQUIRED FOR THRU TRAFFIC sign is to be used at an intersection, at the entrance to a route on which a traffic regulation post is located. Its intent is to notify drivers of the presence of the post so that those who do not have road-use permits issued by designated authorities can detour on another route, or turn back, without making a needless trip and without adding to the screening load at the post. Local traffic without permits may proceed as far as the regulation post. The sign shall be erected in a manner to that of the Emergency Speed sign.

Background white (refl.)
Border black
Letters black

Part III ROLE OF THE MILITARY

Beginning in the early days of the Federal-aid Highway Program, and continuing through the years, there has been a close link between American highways and national defense which has been of inestimable importance in strengthening the country's security.

As far back as 1922, the then Bureau of Public Roads, now the Federal Highway Administration, sought the advice of the War Department as to which roads should be considered of strategic importance in the event of war. As a result of this contact, the War Department supplied a map of the United States on which were marked highways of strategic value. This map, signed by General John J. Pershing, became known as the Pershing Map. The indicated roads have since been substantially improved as part of the Federal-aid System.

Subsequently, Congress, by the Federal-Aid Highway Act of 1944, created the National System of Interstate and Defense Highways, which initially authorized the designation of a network of 40,000 miles of limited access highways (subsequently raised to 42,500). This Act provided for a system "so located as to connect by routes as direct as practicable the principal metropolitan areas, cities, and industrial centers, to serve the national defense, and to connect at suitable border points with routes of continental importance in the Dominion of Canada and the Republic of Mexico."

The degree to which the national security is dependent on highway transportation cannot be overstated. Industrial plants producing military and defense supplies, as well as the military installations themselves, would be crippled without adequate highway facilities. In effect, highways have become an adjunct of industry's production line, taking a vital part in the conversion of raw materials to finished products. It is estimated that almost 4,000,000 persons are employed in defense-oriented industries, with most of them relying on motor vehicles to get to and from their jobs. The Department of Defense operates a substantial number of vehicles which require adequate highway capacity.

With this explanation, let us consider the role of the military in the field of emergency preparedness as background for emergency highway traffic regulation (EHTR) planning. The role of the military can, of course, be divided into two distinct categories: military actions in any theater of operations environment, and military support of civil defense—both of which will depend heavily upon the most efficient highway movement facilities and traffic flow patterns available at the time of any disaster. The latter especially requires effective emergency highway traffic regulation planning by civil highway authorities and military officials.

The Department of Defense (DOD) has designated the Department of the Army as the single manager of planning and operation of the military aspects of emergency highway traffic regulation. (At the national level, this program is administered by the Headquarters, Military Traffic Management and Terminal Service (MTMTS).) The Department of the Army has, in turn, passed this responsibility through Forces Command (FORSCOM) to the Army area commanders listed in this part. Each Army area commander has coordinated with the Navy and Air Force commanders in his area. It is expected that for some time in the post attack period the military will be the largest single highway user.

The Army concept of operation is to send a team to each State emergency highway traffic regulation center when activated. These teams will, in most cases, be jointly manned by all services, with the senior officer provided by the service with the highest density in the area. As an example, in Connecticut, with its many naval installations, the Navy would probably provide the chief of the team at the Connecticut State Highway Traffic Regulation Center, but each of the other services may also provide personnel, the number dependent on availability and the workload.

Following initial notification, the officer in charge will proceed to the traffic regulation centers to which he has been assigned and determine the military personnel and logistical support requirements. He will then notify the military installation commanders of these requirements. It is to be expected that the number of military personnel at any one traffic regulation center will vary from time to time as conditions change. All services will be instructed by the Military Traffic Management and Terminal Service—for those instances in which such procedures must be implemented—to curtail or eliminate, as much as possible, shipments into, out of, or through any affected areas.

There are several functional areas in which the military traffic regulation teams will perform. The principal function, of course, will be to receive requests from military users and obtain the necessary clearances in coordination with the other users staffing the emergency highway traffic regulation centers. Another principal function of the teams will be to request designation of class B routes whenever it is felt these routes will be required. It is the intent of the military to attempt to keep convoys to a minimum, although it is expected, particularly during the early phase of the operation, there will be a large number of emergency moves. Whenever possible, convoys will be consolidated and class B routes used to expedite moves through areas controlled by emergency highway traffic regulation.

Another function of the military teams will be to obtain information on road status and disseminate this to all military installations and activities. Conversely, these teams will obtain projections from military users and keep State traffic centers advised of projected moves. Military teams will assist civilian agencies in nondefense emergency highway traffic regulation movements, if requested, in accordance with public law, and if the military has the capability to provide this assistance.

It should be noted that these teams will not be granting clearances to the military. The military liaison officers will arrange for their vehicles to use road-use permits just as will any user. A distinctive difference, of course, will be the designation of class B routes for the use of the military. It is DOD policy to use commercial transportation whenever possible. In this case, the industry would obtain their own permits, with assistance from the military liaison officers if necessary. It should be stressed that the issuance of permits by the EHTR centers, referred to above, for road space allocation is a separate and distinct function from designating priorities of cargo movements. As stated in Part II, the EHTR organization is not responsible for the provision or allocation of motor vehicles to shippers, nor for designating priorities of cargo movements. These are the assigned functions of other emergency transportation agencies. The EHTR organization will accept the priority certificates of such agencies without question, and will have the responsibility in issuing road-use permits to accommodate all priority shipments.

Each Army area command has prepared a military EHTR plan which recognizes that the Federal Highway Administration has national responsibility for highway traffic regulation during national defense emergencies. By DOD directives and Joint Military Service regulation, the Secretary of the Army, through the Commander, MTMTS, is the officially designated representative of DOD in all public highway matters, and acts to assure that military plans for emergency highway traffic regulation are compatible with civil EHTR plans. These military plans recognize that each State is responsible for emergency highway traffic regulation in accordance with guidelines issued by the Federal Highway Administration. Accordingly, each State should coordinate and distribute its EHTR plan, and changes thereto, to the Army area commander within whose command the State lies. (Military addresses for distribution of EHTR plans are listed later in this part.)

No discussion of the military role in emergency highway traffic regulation would be complete without reference to the military role in support of the National Civil Defense Program, which follows.

The Department of Defense, in recognition of the essential interdependence of the civil and military defense efforts of our Nation in achieving the total posture of national security, has directed (DOD Directive 3025.10) that military support to civil authorities in civil defense operations is an emergency task within the mission of all Federal active duty and Reserve units of the military services and Defense agencies. Their mission is to be prepared to employ available resources which are not engaged in essential combat, combat support or self-survival operations, to assist civil authorities to restore order and civil control, return essential facilities to operation, prevent unnecessary loss of life, alleviate suffering, and take other actions, as directed, to insure national survival and a capability on the part of the Nation to continue the conflict. In such employment, established military organizational channels and prearranged plans will be followed when possible.

In the discharge of the mission, action will be taken to: (1) provide for coordination and control—both preattack and post-attack—of available military (active and reserve) capabilities and availble resources; (2) establishment, under CDR FORSCOM and the CONUS Army commanders, of State military headquarters to plan for and conduct operations in support of civil defense, utilizing the State adjutants general and the State headquarters and headquarters detachments; and (3) establishment of a State level system wherein the State adjutant general will be responsible for the preattack planning and emergency operations for such forces of all services as may be available within the State for civil defense support purposes.

The channel of command for all military support of civil defense planning and operations is from Headquarters, Department of the Army, through CDR FORSCOM to the CONUS Army Commander in whose installation or activity is located. This includes all preattack civil defense planning, the assignment of missions, and post-attack civil defense operations. It also applies to class II installation commanders and the available resources of the defense agencies placed under the planning and operational command of

CONUS Army commands for national defense emergencies.

When authorized by the President, under an appropriate Executive order to be issued during a national defense emergency, or during the prelude to such a situation, the State headquarters and headquarters detachments of the National Guard in each of the States, less elements required for conduct of selective service and State defense activities, will be ordered to active duty. These detachments will execute the CONUS Army commander's plan for control of military support within each respective State.

Upon order to active duty, the State level headquarters will continue close liaison with the State governors, the State civil defense director, and other appropriate State and local authorities. The State level commanders will assume command of such units and resources for military assistance to civil authorities as may be designated by CONUS Army commanders.

Requests for military support normally will be accepted no lower than the State military headquarters level from the appropriate State civil defense director.

Plans will be developed and maintained, as necessary, to assist civil authorities in times of emergency in restoring Federal, State, and local civil operations. Such interim emergency assistance will be in coordination with, and supplementary to, the capabilities of State and local governments and other nonmilitary organizations, and will be concerned with the specific categories of assistance as explained later in this part.

In planning for emergency operations, the comment is often heard that planning by civilian authorities is a useless exercise because, in a serious emergency, martial law would be declared and the military authorities would assume the functions of civil government. This, of course, is not planned, nor would it be possible. Following a nuclear attack, the Armed Forces simply would not have the manpower necessary to perform these civil functions, even if it were not needed for military operations. The military will expect the civilian EHTR program to control and regulate the usable highway road net. The military, however, will provide staffing at certain and, possibly, all of the EHTR centers, just as other users will provide staffing, to insure that appropriate road space allocations and assignments are made for those high priority military and other essential movements. The only occasion for the military to assume full control of highway traffic regulation would be in a theater of operations.

The following policy statement is the current guidance for emergency planning purposes:

"Nationwide martial law is not an acceptable planning assumption; martial law as a local measure is to be avoided wherever possible." Consequently, all civil emergency planning is based on the premise that the military services would assist but not replace civil government in carrying out its essential functions.

Additional information concerning the role of the military in emergency highway traffic regulation may be found in the following publications, copies of which may be obtained through the nearest military installation to the requester.

a. DOD Directives Number 3025.10, "Military Support of Civil Defense."

b. DOD Directive Number 5160.60, "Highways for National Defense."

c. Army Regulation 55–80, "Highways for National Defense."

d. Army Regulation 55–162, "Permits for Oversize, Overweight or Other Special Military Movements on Public Highways . . . ."

e. Army Regulation 55-355, "Military Traffic Management Regulation."

f. Army Regulation 500–70, "Emergency Employment of Army Resources."

Copies of these publications will be of interest to anyone concerned with emergency highway traffic regulation training, and they will be useful tools for State EHTR centers.

MILITARY ADDRESSES FOR DISTRIBUTION OF EHTR PLANS

Army Area

Region 1

Commanding General
First United States Army
Fort George G. Meade, Maryland 20755

Connecticut
Maine
Massachusetts
New Jersey
New Hampshire
New York
Rhode Island
Vermont

The FHWA Washington Office is responsible for distribution to the military of EHTR plans prepared by Puerto Rico.

Region 3

Commanding General
First United States Army
Fort George G. Meade, Maryland 20755

Delaware
District of Columbia
Maryland
Pennsylvania
Virginia
West Virginia

Maryland, Virginia and the District of Columbia should also transmit a copy to:

Commanding General
Military District of Washington
Fort Leslie J. McNair
Washington, D.C. 20315

Region 4

Commanding General
First United States Army
Fort George G. Meade, Maryland 20755

Alabama
Florida
Georgia
Kentucky
Mississippi
North Carolina
South Carolina
Tennessee

Region 5

Commanding General
Fifth United States Army
Fort Sam Houston, Texas 78234

Illinois
Indiana
Michigan
Minnesota
Wisconsin

Ohio should send a copy of its plan to:

Commanding General
First United States Army
Fort George G. Meade, Maryland 20755

Region 6

Commanding General
Fifth United States Army
Fort Sam Houston, Texas 78234

Arkansas
Louisiana
New Mexico
Oklahoma
Texas

Region 7

Commanding General
Fifth United States Army
Fort Sam Houston, Texas 78234

Iowa
Kansas
Missouri
Nebraska

Region 8

Commanding General
Sixth United States Army
Presidio of San Francisco, California 94129

Colorado
Montana
North Dakota
South Dakota
Utah
Wyoming

Region 9 and Region 10

Commanding General Sixth United States Army Presidio of San Francisco, California 94129	Arizona California Idaho	Nevada Oregon Washington

Hawaii should send a copy of its plan to:

Commanding General
United States Army Hawaii
APO San Francisco, California 96557

Region 10

Alaska should send a copy of its plan to:

Commanding General
United States Army
APO Seattle, Washington 98749

CATEGORIES OF ASSISTANCE BY THE MILITARY TO THE VARIOUS LOCAL AND STATE OFFICIALS FOR CIVIL DEFENSE PURPOSES

Restoration of facilities and utilities, including transportation, communications, power, fuel, water, and other essential services.

Emergency clearance of debris and rubble including explosive ordinance from streets, highways, rail centers, dock facilities, airports, shelters, and other areas. This will permit rescue or movement of people, access to and recovery of critical resources, emergency repair or reconstruction of facilities, and other emergency operations for lifesaving purposes.

Fire protection.

Rescue, evacuation, and emergency medical treatment or hospitalization of casualties, the recovery of critical medical supplies, and the safeguarding of public health. This may involve sorting and treating of casualties and preventive measures to control the incidence and spread of infectious diseases.

Recovery, identification, registration, and disposition of deceased personnel.

Radiation monitoring and decontamination to include identifying contaminated areas, and reporting information through the national warning system. Initial decontamination will, of necessity, be directed primarily at personnel and vital facilities.

Movement control, (not to be confused with EHTR) to include plans and procedures for essential movements.

Maintenance of law and order, to include—

- General police and law enforcement operations.
- Emergency highway traffic control and supervision.
- Security and protection of vital facilities and resources.
- Enforcement of economic stablization measures, as may be required in the immediate post-attack phase.

Issue of food, essential supplies, and material to include collection, safeguarding, and issue of critical items in the initial post-attack phase.

Emergency provision of food and facilities for food preparation should mass or community subsistence support be required.

Damage assessment.

Provision of interim communications using available mobile equipment to provide command and control.

Certain general policies and basic principles govern planning for military support of Civil Defense:

Military assistance will complement and not be a substitute for civilian participation in civil defense operations. Plans formulated by both military and civilian authorities must recognize that civilian resources will be the first to be used to meet civilian needs. Military resources will be used only when essential to supplement civilian resources.

Military support to civilian authorities in civil defense is an emergency task within the mission of all Federal active and reserve military units and defense agencies.

A military commander in making his resources available to civil authorities is subject to no authority other than that of his superior in the military chain of command.

Measures to insure continuity of operations, survival of troops and rehabilitation of essential military bases will take precedence over military support of civil defense.

Plans for military support of civil defense will be based on and will complement plans developed by civil authorities.

Military assistance to civil authorities is a temporary measure.

It will be terminated as soon as possible, in order to conserve military resources and to avoid infringement on the responsibility and authority of civil government agencies. This assistance is related to, but distinctly different from military operations.

Part IV NUCLEAR RADIATION HAZARDS TO HIGHWAY TRANSPORTATION

Background

Highway traffic regulation in an emergency may be instituted for several reasons. One of the reasons is the presence of radioactive fallout which would cover vast areas of the United States, including highways, in the event of all-out nuclear attack on this country.

Nuclear weapons can be exploded in three ways: In the air, called an air burst; on the ground, called a ground or surface burst; and below the ground or water level, called a sub-surface burst. The concern here is with the surface and sub-surface bursts because they produce radioactive fallout. For convenience, these two types will be referred to hereafter as ground bursts.

Radioactive fallout emits dangerous nuclear radiations, which cannot be detected by the five human senses, but can be injurious or fatal to all living things. Radiation emitted by fallout would be most dangerous within the first several hours after the explosion of a nuclear weapon. As time passes, the radioactivity becomes less intense and in time would be at a level low enough to permit normal movement in most areas although some areas (e.g. in the immediate area of the detonation) would be dangerous for human resettlement for many years.

Radioactive Fallout

When a nuclear weapon is exploded at or near the earth's surface, it would pulverize everything within a certain radius, suck up the pulverized material and form a hugh radioactive dust cloud. The cloud would then be pushed along by the wind dropping radioactive particles of dust (first the larger particles than the smaller ones) to the earth's surface as it moves. The dust cloud would move hundreds of miles in a downwind direction and the dust that falls from the cloud would cover thousands of square miles. Because of the wind, rain, terrain and difference in radiation intensity of dust particles, an irregular pattern of fallout of varying radiation intensities would be formed on the ground.

Fallout on Highways

Crisscrossing the United States are over 3 million miles of highways that are used by the drivers of more than 100 million cars, trucks, and buses. The fallout from a nuclear explosion would also fall on these highways and, highway users, being unaware of its presence could, unknowingly, expose themselves to lethal doses of radiation.

Even though traffic or changing weather conditions could blow or wash the fallout from the road surface, the radiation hazard could still be significant, since gamma rays given off by the fallout, along the side of the road can penetrate many feet of air without a great loss in energy.

Unless the highway user had specially designed instruments to detect the presence of radiation, he would not know whether a road was safe or unsafe for travel. Therefore, he must rely upon and be guided by those persons who are specifically trained and equipped to conduct radiological monitoring.

Areas of Unrestricted Travel

Figure 8 is a sketch which illustrates typical fallout patterns 1 hour after a nuclear explosion has occurred (H+1). While the sketch indicates varying rates of radioactivity within the fallout patterns, it also indicates other areas outside the patterns which are practically free of fallout. These areas are called "areas of unrestricted travel," and their boundaries should be established by placing barricades and signs at appropriate locations on highways. Unrestricted travel beyond these points would be prohibited because of the increasing levels of radiation.

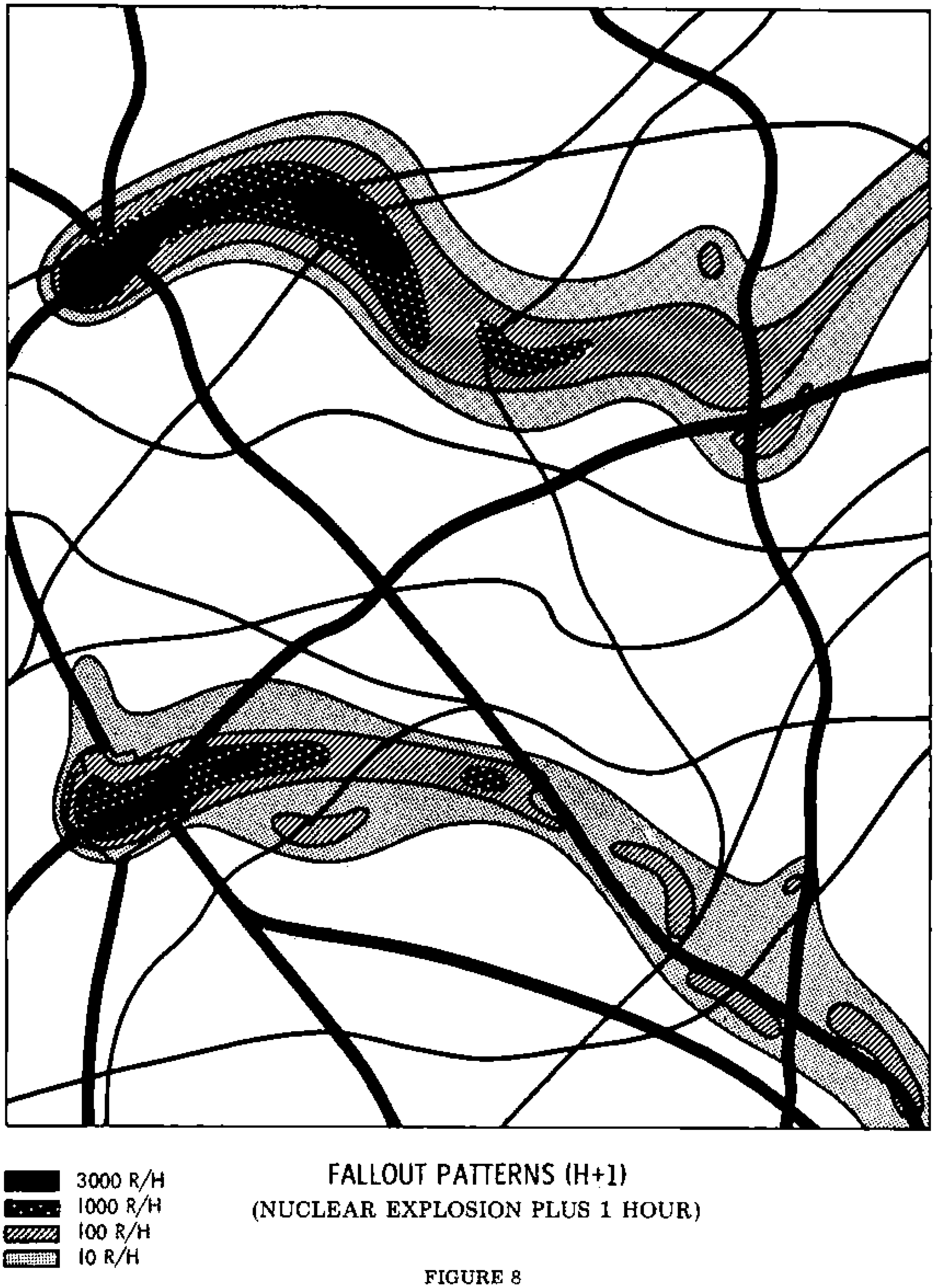
As time passes and radioactivity decay continues, barricades and signs should be moved forward thereby increasing the area of unrestricted travel and correspondingly reducing the area within which travel is restricted or prohibited.

The placement of barricades and signs to delimit areas of unrestricted travel should be consistent with established criteria for human exposure for human resettlement.

Travel Through Restricted Areas

Highway travel would be restricted in those areas in which the levels of radiation intensity would not permit permanent resettlement of people without subjecting them to serious biological consequences.

There may be many miles of highways covered by fallout within these areas, and travel would only be



FALLOUT PATTERNS (H+1)
(NUCLEAR EXPLOSION PLUS 1 HOUR)

FIGURE 8

permitted on certain regulated routes. Transportation benefits from the use of these routes would have to be balanced against the dangers of radiation exposure to drivers, policing personnel and highway maintenance personnel.

Certain routes extending into or through restricted areas would be open for emergency movement of equipment, supplies, manpower, or for postattack evacuation of people. Movements on such routes would be strictly regulated to keep radiation exposure of participating personnel to a practicable minimum.

Protecting the Traveling Public

Everyone may be exposed to some radiation hazard after a nuclear attack. Unless the general public was equipped with reliable dosimeters, it would be impossible to determine how much radiation was absorbed except through clinical studies of, and symptoms displayed by, those exposed.

It is known that radiation increases the chances of genetic damage and has other adverse long-term effects. In a national defense emergency, however, it is important, first, to minimize the number of deaths and, second, to keep to a minimum the number of people who may require medical care.

In considering highway travel in a national defense emergency, the following assumptions have been made:

(1) There may be millions of people in travel status after a nuclear attack.

(2) A large percentage of these travelers would be using the highway network.

(3) Thousands would be located in areas low in fallout contamination and would desire to return to their homes.

(4) The location of fallout, and its degree of hazard, may be unknown to the traveling public.

(5) The traveling public must be protected immediately after the attack and during the long-range recovery period.

(6) Flexible guidelines for limited exposure of the traveling public are necessary.

(7) Emergency missions will be required and the use of highways will play an important part in carrying out many of these missions.

Monitoring Adjustments

With a view to anticipating confusion and the probable lack of an orderly procedure in the early stages, State highway department personnel located in relatively uncontaminated areas should begin monitoring as soon as fallout has settled and coordinate their activities with the local emergency operating center.

Adjustments in monitoring operations and setting of barricades and signs may be necessary as measured radiological data are evaluated and interpreted by specialized technical personnel. The guidelines for setting barricades are based on the $t^{-1.2}$ theoretical decay scheme for a nuclear detonation of known time. In a real emergency, however, fallout from several weapons, which may be detonated at substantially different times, would result in a decay scheme other than that used in establishing the guidelines.

Limit of Unrestricted Travel

The general public, located in a relatively fallout-free area, must be protected as soon after the attack as possible by establishing the limits of unrestricted travel. Where possible, monitoring the highways with radiation detection instruments will begin 24 hours or 1 day (D+1) after the day of the attack or 1 day after the nuclear explosion, providing that all of the radioactive dust (fallout) has fallen to the ground. At D+1 the personnel doing the monitoring would determine the limit of unrestricted travel by locating the actual on-the-ground radiation dose rate of 2.2 roentgens per hour (R/hr) as determined with appropriate radiation detection and measuring instruments. This would indicate the area where the initial (H+1) radiation intensity was 100 R/hr. Likewise, at D+30, the actual boundary would be where the dose rate would be 0.14 R/hr. and at D+90 it would be 0.08 R/hr., thereby establishing the limits of unrestricted travel and indicating the areas where the initial (H+1) radiation intensities were 375 R/hr. and 750 R/hr., respectively.

General Exposure Criteria

The radiation exposure of the traveling public from relatively fallout-free areas will be limited by the area of unrestricted travel. The maximum dose that can be accumulated will be at the point where the highway has been barricaded.

If a person were to remain at this point, he would not accumulate more than 200 R of radiation from that time to the end of the year (D+365) which began on the day of the nuclear explosion.

Emergency Exposure Criteria

In emergency work, personnel performing monitoring and other highway work should not be exposed to more than 10 R in any single day nor more than a total of 50 R during the first week, 100 R during the first month and 50 R per month during the next 4 months.

Where an *extreme emergency* exists, such as the saving of many lives, saving an essential facility or retrieving medical supplies from a warehouse, for example, it may be necessary for a monitor or a construction or maintenance worker to accept an exposure of 150 R during a time interval ranging from 1 hour to less than 1 week. Anyone exposed to this amount of radiation during such a brief period of time should wait 30 days before being exposed again at which time the routine emergency exposure criteria will apply.

In no instance should radiation exposure of emergency mission personnel exceed a brief dose of 200 R.

Decision Making

After a nuclear attack, a major objective in the support of survival is maintenance of the economy and reconstruction. Prime elements in accomplishing this objective are the decisions made by officials in charge, regarding radiation exposure of individuals, in relation to all other elements of the situation.

Officials who have the responsibility for making command decisions which will expose persons to additional radiation must first understand the biological and medical consequences of exposure. Secondly, they must have essential materials readily available for reference in planning movements and/or controlling exposures. These materials mainly consist of exposure and dose rate charts published by the National Council on Radiation Protection, the Defense Civil Preparedness Agency, and other agencies.

The acceptance of any radiation exposure is warranted *only* when there is no practical or reasonable alternative way to achieve an overriding, essential goal.

APPENDIX A—EXECUTIVE ORDER 11490 ASSIGNING EMERGENCY PEPAREDNESS FUNCTIONS TO FEDERAL DEPARTMENTS AND AGENCIES

WHEREAS our national security is dependent upon our ability to assure continuity of government, at every level, in any national emergency type situation that might conceivably confront the nation; and

WHEREAS effective national preparedness planning to meet such an emergency, including a massive nuclear attack, is essential to our national survival; and

WHEREAS effective national preparedness planning requires the identification of functions that would have to be performed during such an emergency, the assignment of responsibility for developing plans for performing these functions, and the assignment of responsibility for developing the capability to implement those plans; and

WHEREAS the Congress has directed the development of such national emergency preparedness plans and has provided funds for the accomplishment thereof; and

WHEREAS this national emergency preparedness planning activity has been an established program of the United States Government for more than 20 years:

Now, therefore, by virtue of the authority vested in me as President of the United States, and pursuant to Reorganization Plan No. 1 of 1958 (72 Stat. 1799), the National Security Act of 1947, as amended, the Defense Production Act of 1950, as amended, and the Federal Civil Defense Act, as amended, it is hereby ordered as follows:

PART 1—PURPOSE AND SCOPE

Section 101. PURPOSE. This order consolidates the assignment of emergency preparedness functoins to various departments and agencies heretofore contained in the 21 Executive orders and 2 Defense Mobilization orders listed in Section 3015 of this order. Assignments have been adjusted to conform to changes in organization which have occurred subsequent to the issuance of those Executive orders and Defense Mobilization orders.

SECTION 102. SCOPE. (a) This order is concerned with the emergency national planning and preparedness functions of the several departments and agencies of the Federal Government which complement the military readiness planning responsibilities of the Department of Defense; together, these measures provide the basic foundation for our overall national preparedness posture, and are fundamental to our ability to survive.

(b) The departments and agencies of the Federal Government are hereby severally charged with the duty of assuring the continuity of the Federal Government in any national emergency type situation that might confront the nation. To this end, each department and agency with essential functions, whether expressly identified in this order or not, shall develop such plans and take such actions, including but not limited to those specified in this order, as may be necessary to assure that it will be able to perform its essential functions, and continue as a viable part of the Federal Government, during any emergency that might conceivably occur. These include plans for maintaining the continunity of essential functions of the departments or agency at the seat of government and elsewhere, through programs concerned with: (1) succession to office; (2) predelegation of emergency authority; (3) safekeeping of essential records; (4) emergency relocation sites supported by communications and required services; (5) emergency action steps; (6) alternate headquarters or command facilities; and (7) protection of Government resources, facilities, and personnel. The continuity of Government activities undertaken by the departments and agencies shall be in accordance with guidance provided by, and subject to evaluation by, the Director of the Office of Emergency Preparedness.

(c) In addition to the activities indicated above, the heads of departments and agencies described in Parts 2 through 29 of this order shall: (1) prepare national emergency plans, develop preparedness programs, and attain an appropriate state of readiness with respect to the functions assigned to them in this order for all conditions of national emergency; (2) give appropriate consideration to emergency preparedness factors in the conduct of the regular functions of their agencies, particularly those functions considered essential in time of emergency, and (3) be prepared to implement, in the event of an emergency, all appropriate plans developed under this order.

SECTION 103. PRESIDENTIAL ASSISTANCE. The Director of the Office of Emergency Preparedness, in accordance with the provisions of Executive Order No. 11051 of September 27, 1962, shall advise and assist the President in determining national preparedness goals and policies for the performance of functions under this order and in coordinating the performance of such functions with the total national preparedness program.

SECTION 104. GENERAL AND SPECIFIC FUNCTIONS. The functions assigned by Part 30, General Provisions, apply to all departments and agencies having emergency preparedness responsibilities. Specific functions are assigned to departments and agencies covered in Parts 2 through 29.

SECTION 105. CONSTRUCTION. The purpose and legal effect of the assignments contained in this order do not constitute authority to implement the emergency plans prepared pursuant to this order. Plans so developed may be effectuated only in the event that authority for such effectuation is provided by a law enacted by the Congress or by an order or directive issued by the President pursuant to statutes or the Constitution of the United States. (Parts 2 through 12, 14 through 20 and 22 through 29 are omitted since they are not considered relevent to EHTR).

PART 13—DEPARTMENT OF TRANSPORTATION

SECTION 1301. RESUME OF RESPONSIBILITIES. The Secretary of Transportation, in carrying out his responsibilities to exercise leadership in transportation matters affecting the national defense and those involving national or regional transportation emergencies, shall prepare emergency plans and develop preparedness programs covering:

(1) Preparation and promulgation of over-all national policies, plans, and procedures related to providing civil transportation of all forms—air, ground, water, and pipelines, including public storage and warehousing (except storage of petroleum and gas and agricultural food resources including cold storage): Provided that plans for the movement of petroleum and natural gas through pipelines shall be the responsibility of the Secretary of the Interior except to the extent that such plans are a part of functions vested in the Secretary of Transportation by law;

(2) Movement of passengers and materials of all types by all forms of civil transportation;

(3) Determination of the proper apportionment and allocation for control of the total civil transportation capacity, or any portion thereof, to meet over-all essential civil and military needs;

(4) Determination and identification of the transportation resources available and required to meet all degrees of national emergencies and regional transportation emergencies;

(5) Assistance to the various States, the local political subdivisions thereof, and non-governmental organizations and systems engaged in transportation activities in the preparation of emergency plans;

(6) Rehabilitation and recovery of the Nation's transportation systems; and

(7) Provisions for port security and safety, for aids to maritime navigation, and for search and rescue and law enforcement over, upon, and under the navigable waters of the United States and the high seas.

SECTION 1302. TRANSPORTATION PLANNING AND COORDINATION FUNCTIONS. In carrying out the provisions of Section 1301, the Secretary of Transportation, with assistance and support of other Federal, State and local governmental agencies, and the transport industries, as appropriate, shall:

(1) Obtain, assemble, analyze, and evaluate data on current and projected emergency requirements of all claimants for all forms of civil transportation to meet the needs of the military and of the civil economy, and on current and projected civil transportation resources—of all forms—available to the United States to move passengers or materials in an emergency.

(2) Develop plans and procedures to provide—under emergency conditions—for the collection and analysis of passenger and cargo movement demands as they relate to the capabilities of the various forms of transport, including the periodic assessment of over-all transport resources available to meet emergency requirements.

(3) Conduct a continuing analysis of transportation requirements and capabilities in relation to economic projections for the purpose of initiating actions and/or recommending incentive and/or regulatory programs designed to stimulate government and industry improvement of the structure of the transportation system for use in an emergency.

(4) Develop systems for the control of the movement of passengers and cargo by all forms of transportation, except for those resources owned by, controlled by, or under the jurisdiction of the Department of Defense, including allocation of resources and assignment of priorities, and develop policies, standards, and procedures for emergency enforcement of these controls.

SECTION 1303. DEPARTMENTAL EMERGENCY TRANSPORTATION PREPAREDNESS. Except for those resources owned by, controlled by, or under the jurisdiction of the Department of Defense, the Secretary of Transportation shall prepare emergency operational plans and programs for, and develop a capability to carry out, the transportation operating responsibilities assigned to the Department, including but not limited to:

(1) Allocating air carrier civil air transportation capacity and equipment to meet civil and military requirements.

(2) Emergency management, including construction, reconstruction, and maintenance of the Nation's civil airports, civil aviation operating facilities, civil aviation services, and civil aircraft (other than air carrier aircraft), except manufacturing facilities.

(3) Emergency management of all Federal, State, city, local, and other highways, roads, streets, bridges, tunnels, and appurtenant structures, including:

(a) The adaptation, development, construction, reconstruction, and maintenance of the Nation's highway and street systems to meet emergency requirements;

(b) The protection of the traveling public by assisting State and local authorities in informing them of the dangers of travel through hazardous areas; and

(c) The regulation of highway traffic in an emergency through a national program in cooperation with all Federal, State, and local governmental units or other agencies concerned.

(4) Emergency plans for urban mass transportation, including:

(a) Providing guidance to urban communities in their emergency mass transportation planning efforts, either directly or through State, regional, or metropolitan agencies;

(b) Coordinating all such emergency planning with the Department of Housing and Urban Development to assure compatibility with emergency plans for all other aspects of urban development;

(c) Maintaining an inventory of urban mass transportation systems.

(5) Maritime safety and law enforcement over, upon, and under the high seas and waters, subject to the jurisdiction of the United States, in the following specific programs:

(a) Safeguarding vessels, harbors, ports, and waterfront facilities from destruction, loss or injury, accidents, or other causes of a similar nature.

(b) Safe passage over, upon, and under the high seas and United States waters through effective and reliable systems of aids to navigation and ocean stations.

(c) Waterborne access to ice-bound locations in furtherance of national economic, scientific, defense, and consumer needs.

(d) Protection of lives, property, natural resources, and national interests through enforcement of Federal law and timely assistance.

(e) Safety of life and property through regulation of commercial vessels, their officers and crew, and administration of maritime safety law.

(f) Knowledge of the sea, its boundaries, and its resources through collection and analysis of data in support of the national interest.

(g) Operational readiness for essential wartime functions.

(6) Planning for the emergency management and operation of the Alaska Railroad, and for the continuity of railroad and petroleum pipeline safety programs.

(7) Planning for the emergency operation and maintenance of the United States—controlled sections of the Saint Lawrence Seaway.

PART 21—INTERSTATE COMMERCE COMMISSION

SECTION 2101. RESUME OF RESPONSIBILITIES. The Chairman of the Interstate Commission, *under the coordinating authority of the Secretary of Transportation*, shall prepare national emergency plans and develop preparedness programs covering railroad utilization, reduction of vulnerability, maintenance, restoration, and operation in an emergency (other than for the Alaska Railroad—see Section 1303(6); motor carrier utilization, reduction of vulnerability, and operation in an emergency; inland waterway utilization of equipment and shipping, reduction of vulnerability, and operation in an emergency; and also provide guidance and consultation to domestic surface transportation and storage industries, as defined below, regarding emergency preparedness measures, and to States regarding development of their transportation plans in assigned areas.

SECTION 2102. DEFINITIONS. As used in this part:

(1) "Domestic surface transportation and storage" means rail, motor, and inland water transportation facilities and services and public storage;

(2) "Public storage" includes warehouses and other places which are used for the storage of property belonging to persons other than the persons having the ownership or control of such premises;

(3) "Inland water transportation" includes shipping on all inland waterways and Great Lakes shipping engaged solely in the transportation of passengers or cargo between United States ports on the Great Lakes;

(4) Specifically excluded, for the purposes of this part, are pipelines, petroleum and gas storage, agricultural food resources storage, including the cold storage of food resources, the St. Lawrence Seaway, ocean ports and Great Lakes ports and port facilities, *highways, streets, roads, bridges, and related appurtenances,*[1]

[1] Italicized for emphasis.

maintenance of inland waterways, and any transportation owned by or pre-allocated to the military.

SECTION 2103. TRANSPORTATION FUNCTIONS. The Interstate Commerce Commission shall:

(1) *Operational control.* Develop plans with appropriate private transportation and storage organizations and associations for the coordination and direction of the use of domestic surface transportation and storage facilities for movement of passenger and freight traffic.

(2) *Emergency operations.* Develop and maintain necessary orders and regulations for the operation of domestic surface transport and storage industries in an emergency.

PART 30—GENERAL PROVISIONS

SECTION 3001. RESOURCE MANAGEMENT. In consonance with the national preparedness, security, and mobilization readiness plans, programs, and operations of the Office of Emergency Preparedness under Executive Order No. 11051 of September 27, 1962, and subject to the provisions of the preceding parts, the head of each department and agency shall:

(1) *Priorities and allocations.* Develop systems for the emergency application of priorities and allocations to the production, distribution and use of resources for which he has been assigned responsibility.

(2) *Requirements.* Assemble, develop as appropriate, and evaluate requirements for assigned resources, taking into account estimated needs for military, atomic energy, civilian, and foreign purposes. Such evaluation shall take into consideration geographical distribution of requirements under emergency conditions.

(3) *Evaluation.* Assess assigned resources in order to estimate availability from all sources under an emergency situation, analyze resource availabilities in relation to estimated requirements, and develop appropriate recommendations and programs, including those necessary for the maintenace of an adequate mobilization base. Provide data and assistance before and after attack for national resource analysis purposes of the Office of Emergency Preparedness.

(4) *Claimancy.* Prepare plans to claim from the appropriate agency supporting materials, manpower, equipment, supplies, and services which would be needed to carry out assigned responsibilities and other essential functions of his department or agency, and cooperate with other agencies in developing programs to insure availability of such resources in an emergency.

SECTION 3002. FACILITIES PROTECTION AND WARFARE EFFECTS MONITORING AND REPORTING. In consonance with the national preparedness, security, and mobilization readiness plans, programs, and operations of the Office of Emergency Preparedness under Executive Order No. 11051, and with the national civil defense plans, programs, and operations of the Department of Defense, under Executive Order No. 10952, the head of each department and agency shall:

(1) *Facilities protection.* Provide facilities protection guidance material adapted to the needs of the facilities and services concerned and promote a national program to stimulate disaster preparedness and control in order to minimize the effects of overt or covert attack on facilities or other resources for which he has management responsibility. Guidance shall include, but not be limited to, organization and training of facility employees, personnel shelter, evacuation plans, records protection, continuity of management, emergency repair, dispersal of facilities, and mutual aid associations for an emergency.

(2) *Warfare effects monitoring and reporting.* Maintain a capability, both at national and field levels, to estimate the effects of attack on assigned resources and to collaborate with and provide data to the Office of Emergency Preparedness, the Department of Defense, and other agencies, as appropriate, in verifying and updating estimates of resource status through exchanges of data and mutual assistance, and provide for the detection, identification, monitoring and reporting of such warfare effects at selected facilities under his operation or control.

(3) *Salvage and rehabilitation.* Develop plans for salvage, decontamination, and rehabilitation of facilities involving resources under his jurisdiction.

(4) *Shelter.* In conformity with national shelter policy, where authorized to engage in building construction, plan, design, and construct such buildings to protect the public to the maximum extent feasible against the hazards that could result from an attack upon the United States with nuclear weapons; and where empowered to extend Federal financial assistance, encourage recipients of such financial assistance to use standards for planning design and construction which will maximize protection for the public.

SECTION 3003. CRITICAL SKILLS AND OCCUPATIONS. (a) The Secretaries of Defense, Commerce, and Labor shall carry out the mandate of the National Security Council, dated February 15, 1968, to "maintain a continuing surveillance over the Nation's manpower needs and identify any particular occupation or skill that may warrant qualifying for deferment on a uniform national basis." In addition, the Secretaries of Defense, Commerce, Labor, and Health, Education, and Welfare shall carry out the mandate of the National Security Council to "maintain a continuing surveillance over the Nation's manpower and education needs to identify any area of graduate study that may warrant qualifying for deferment in the national interest." In carrying out these functions, the Secretaries concerned shall consult with the National Science Foundation with respect to scientific manpower requirements.

(b) The Secretaries of Commerce and Labor shall maintain and issue, as necessary, lists of all essential activities and critical occupations that may be required for emergency preparedness purposes.

SECTION 3004. RESEARCH. Within the framework of research policies and objectives established by the Office of Emergency Preparedness, the head of each department and agency shall supervise or conduct research in areas directly concerned with carrying out emergency preparedness responsibilities, designate representatives for necessary ad hoc or task force groups, and provide advice and assistance to other agencies in planning for research in areas involving each agency's interest.

SECTION 3005. STOCKPILES. The head of each department and agency, with appropriate emergency responsibilities, shall assist the Office of Emergency Preparedness in formulating and carrying out plans for stockpiling of strategic and critical materials, and survival items.

SECTION 3006. DIRECT ECONOMIC CONTROLS. The head of each department and agency shall cooperate with the Office of Emergency Preparedness and the Federal financial agencies in the development of emergency preparedness measures involving emergency financial and credit measures, as well as price, rent, wage and salary stabilization, and consumer rationing programs.

SECTION 3007. FINANCIAL AID. The head of each department and agency shall develop plans and procedures in cooperation with the Federal financial agencies for financial and credit assistance to those segments of the private sector for which he is responsible in the event such assistance is needed under emergency conditions.

SECTION 3008. FUNCTIONAL GUIDANCE. The head of each department and agency in carrying out the functions assigned to him by this order, shall be guided by the following:

(1) *National program guidance.* In consonance with the national preparedness, security, and mobilization readiness plans, programs, and operations of the Office of Emergency Preparedness under Executive Order No. 11051, and with the national civil defense plans, programs, and operations of the Department of Defense, technical guidance shall be provided to State and local governments and instrumentalities thereof, to the end that all planning concerned with functions assigned herein will be effectively coordinated. Relations with the appropriate segment of the private sector shall be maintained to foster mutual understanding of Federal emergency plans.

(2) *Interagency coordination.* Emergency preparedness functions shall be coordinated by the head of the department or agency having primary responsibility with all other departments and agencies having supporting functions related thereto.

(3) *Emergency preparedness.* Emergency plans, programs, and an appropriate state of readiness, including organizational readiness, shall be developed as an integral part of the continuing activities of each department or agency on the basis that that department or agency will have the responsibility for carrying out such plans and programs during an emergency. The head of each department or agency shall be prepared to implement all appropriate plans developed under this order. Modifications and temporary organizational changes, based on emergency conditions, shall be in accordance with policy determinations by the President.

(4) *Professional liaison.* Mutual understanding and support of emergency preparedness activities shall be fostered, and the National Defense Executive Reserve shall be promoted by maintaining relations with the appropriate non-Governmental sectors.

SECTION 3009. TRAINING. The head of each department and agency shall develop and direct training programs which incorporate emergency preparedness and civil defense training and information programs necessary to insure the optimum operational effectiveness of assigned resources, systems, and facilities.

SECTION 3010. EMERGENCY PUBLIC INFORMATION. In consonance with such emergency public information plans and central program decisions of the Office of Emergency Preparedness, and with plans, programs, and procedures established by the Department of Defense to provide continuity of programming for the Emergency Broadcast System, the head of each department and agency shall:

(1) Obtain and provide information as to the emergency functions or assignments of the individual department or agency for dissemination to the American people during the emergency, in accordance with arrangements made by the Office of Emergency Preparedness.

(2) Determine requirements and arrange for prerecordings to provide continuity of program service over the Emergency Broadcast System so that the American people can receive information, advice, and guidance pertaining to the implementation of the civil defense and emergency preparedness plans or assignments of each individual department or agency.

SECTION 3011. EMERGENCY ACTIONS. This order does not confer authority to put into effect any emergency plan, procedure, policy, program, or course of action prepared or developed pursuant to this order. Plans so developed may be effectuated only in the event that authority for such effectuation is provided by a law enacted by the Congress or by an order or directive issued by the President pursuant to statutes or the Constitution of the United States.

SECTION 3012. REDELEGATION. The head of each department and agency is hereby authorized to redelegate the functions assigned to him by this order, and to authorize successive redelegations to agencies or instrumentalities of the United States, and to officers and employees of the United States.

SECTION 3013. TRANSFER OF FUNCTIONS. Any emergency preparedness functions under this order, or parts thereof, may be transferred from one department or agency to another with the consent of the heads of the organizations involved and with the concurrence of the Director of the Office of Emergency Preparedness. Any new emergency preparedness function may be assigned to the head of a department or agency by the Director of the Office of Emergency Preparedness by mutual consent.

SECTION 3014. RETENTION OF EXISTING AUTHORITY. Except as provided in Section 3015, nothing in this order shall be deemed to derogate from any now existing assignment of functions to any department or agency or officer thereof made by statute, Executive order, or Presidential directives, including Memoranda.

SECTION 3015. REVOKED ORDERS. The following are hereby revoked:

(1) Defense Mobilization Order VI-2 of December 11, 1953.

(2) Defense Mobilization Order I-12 of October 5, 1954.

(3) Executive Order No. 10312 of December 10, 1951.

(4) Executive Order No. 10346 of April 17, 1952.

(5) Executive Order No. 10997 of February 16, 1962.

(6) Executive Order No. 10998 of February 16, 1962.

(7) Executive Order No. 10999 of February 16, 1962.

(8) Executive Order No. 11000 of February 16, 1962.

(9) Executive Order No. 11001 of February 16, 1962.

(10) Executive Order No. 11002 of February 16, 1962.

(11) Executive Order No. 11003 of February 16, 1962.

(12) Executive Order No. 11004 of February 16, 1962.

(13) Executive Order No. 11005 of February 16, 1962.

(14) Executive Order No. 11087 of February 26, 1963.

(15) Executive Order No. 11088 of February 26, 1963.

(16) Executive Order No. 11089 of February 26, 1963.

(17) Executive Order No. 11090 of February 26, 1963.

(18) Executive Order No. 11091 of February 26, 1963.

(19) Executive Order No. 11092 of February 26, 1963.

(20) Executive Order No. 11093 of February 26, 1963.

(21) Executive Order No. 11094 of February 26, 1963.

(22) Executive Order No. 11095 of February 26, 1963.

(23) Executive Order No. 11310 of October 11, 1966.

THE WHITE HOUSE
October 28, 1969.

(signed)
Richard Nixon

APPENDIX B—ARMY REGULATION 55-355 PARAGRAPH 109008 HIGHWAY TRAFFIC REGULATION

The Federal Highway Administration, under the Secretary of Transportation, is responsible for planning a highway traffic regulation system to facilitate the orderly flow of traffic under a national emergency situation. This planning function includes, but is not limited to, evacuation, regulation of movement through dangerous areas, and clearance of priority traffic over routes of limited capacity. Highway traffic regulation demands the participation and teamwork of highway and police officials working in close association with emergency transportation organizations and organized highway users. In an emergency, highway traffic regulation centers established at State and District levels, and highway traffic Sectors established at county, city, or metropolitan area levels, will determine how the highway network is to be operated, and will allocate road space, as necessary, to meet movement priorities and precedence established by other emergency transportation organizations. The emergency highway traffic regulation organization is not responsible for the provision or allocation of motor vehicles to shippers nor for designating priorities of movements. The control centers and sectors will operate highway traffic regulation posts, as necessary, to control access to and movements on various highways. All highway traffic regulation operations will be decentralized to the maximum extent possible consistent with the attainment of the overall objectives. Implementation and direction of highway traffic regulation will be exercised on routes only where and so long as traffic demand exceeds traffic capacity and, in restricted areas, on routes where and so long as highway users must be protected from exposure to radiological or other hazards. Priority permits will be required for a vehicle to traverse a regulated highway route. The carrier (or driver of the vehicle)will secure the necessary permit(s) by presenting the Government bill of lading, waybill, transportation request, or other transportation document to the appropriate control center, sector, or post. Normally, permit requests for interstate, intrastate, or local movements will be handled by control center, Sector or post personnel, respectively. When carriers are unable to secure permits for the movement of DOD personnel and freight, transportation officers, when requested by carriers, will assist to the extent possible in obtaining the necessary permits. When such assistance is unsuccessful, transportation officers may contact their MTMTS area commander for further support in accordance with the provisions of paragraph 104002. The necessity for any such movement must be clearly indicated.

APPENDIX C—ARMY REGULATION 55–80
CHAPTER 6
SPECIAL DEFENSE UTILIZATION OF PUBLIC HIGHWAYS

6–1. General. Special defense utilization of public highways is subject to the laws and regulations of the various States and political subdivisions, except in instances of overriding and urgent military necessity.

6–2. Special military movements. (a) Military movements over public highways which exceed any legal limitation on size or weight, or any other special military movement (i.e., one which subjects highway facilities or their users to unusual hazard) will comply with DOD policy cited in paragraph 1–4c.

(b) Procedures for requesting the issuance of permits for oversize, overweight, or other special military movements on public highways, and reporting on movements that cannot be accomplished, are published in AR 55–162/OPNAVINST 4600.11/AFR 75–24/NAVMC 2534. Individuals in each State who will be contacted for permits, together with officials within DOD authorized to request permits, are named in the directory cited in the foregoing regulation. The Commander, MTMTS, will prepare and publish the directory.

(c) It is the policy of the American Association of State Highway Officials that, during peacetime, DOD shall be the sole certifying agency for all movements by any agency declared essential to the national defense. During a national emergency, movements essential to national defense would be far greater in scope, and those not under direct control of the military departments or defense agencies would be certified by the appropriate emergency transportation authority.

(d) In cooperation with the American Association of State Highway Officials and the Federal Highway Administration, the Commander, MTMTS, will develop and coordinate policy and related procedures for special military movements on public highways.

6–3. Emergency Highway Traffic Regulation. (a) Under a national emergency situation, it may be necessary for civil authorities to regulate traffic on public highways to insure safe and expeditious movements of priority personnel and material. Circumstances may necessitate regulation of movements through dangerous areas or the clearance of priority traffic over routes of limited capacity. The purpose of such highway traffic regulation is to assure the highest degree of highway utilization under adverse conditions. Regulation will be exercised on routes only where, and so long as, traffic demand exceeds traffic capacity, and in restricted areas on routes where, and so long as, highway users must be protected from exposure to radiological or other hazards. The primary function of highway traffic regulation is to allocate available road space to satisfy movement priorities.

(b) Emergency highway traffic regulation requires close cooperation of four groups, the Federal Government; the State highway departments; State and local police; and highway users, including, among others, military users.

(1) The Federal Highway Administration, Department of Transportation, has been assigned the responsibility for developing a national program of effective emergency highway traffic regulation.

(2) The Commander, MTMTS, maintains liaison with the Federal Highway Administration to insure the integration of the operational requirements of the military departments into this national program. He will inform the Deputy Chief of Staff for Military Operations, Department of the Army, promptly of any actual or foreseen interference with military operational requirements.

(3) State authorities are responsible for developing plans for emergency regulation of highway traffic under their jurisdiction within the general guidelines of the national program. They will estimate highway capacities, provide information regarding the location and intensity of hazards, determine the availability of routes in their highway network, and provide for enforcement by police. Local plans implement and supplement the State's organization and plan.

(4) At State and local levels, highway users groups will issue authorizations, under previously established national priority guidelines, to users to operate over highways affected by regulation.

(5) Under the direction of the Commanding General, U.S. Continental Army Command, each CONUS army commander, or his designated representative, will correlate the interest of all Defense installations and activities within his area and will assist the Federal Highway Administration, State and local authorities, when requested, in the implementation of plans for emergency highway traffic regulation. Defense installation commanders will assist the CONUS army commander, as required.

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FHWA ORDER

10-1

February 14, 1972

EMERGENCY PREPAREDNESS

1. PURPOSE

To assign the responsibility for the development of a state of readiness within the Federal Highway Administration (FHWA) to meet any degree of national emergency including an attack on the United States.

2. AUTHORITIES

Executive Order Nos. 10480 and 11490; 49 U.S.C. 1657; 23 U.S.C. 315; 49 C.F.R. 1.4d.

3. POLICY

It is the policy of the FHWA to promote the development, throughout the highway and highway transportation field, of a state of readiness to meet any national emergency. By readiness is meant the capability to perform fully and effectively all the emergency duties which have been assigned by law, Executive Order, Department Order, regulation, delegation or otherwise, or which are implied therein.

4. SCOPE

National emergency preparedness plans and programs shall be developed as an integral part of the continuing activities of the FHWA. The offices of the Administration shall be prepared to carry out these plans and programs in a national emergency. The plans and programs shall be designed to develop a state of readiness to meet any degree of national emergency including an attack upon the United States.

5. COORDINATING COMMITTEE ON EMERGENCY PREPAREDNESS

a. A Coordinating Committee on emergency Preparedness is hereby established to provide advice and make recommendations to the Defense Plans and Operations Division, Office of Highway Operations, on matters concerned with national emergency preparedness within the FHWA.

b. The chief of the Defense Plans and Operations Division shall act as chairman of the Committee, appoint a vice chairman and secretary of the Committee, and provide support for the Committee.

c. Each Associate Administrator of the FHWA and each staff office director shall appoint a permanent and an alternate member of the Committee.

d. The Committee shall meet at the call of the chairman.

6. PROGRAM RESPONSIBILITIES

The Defense Plans and Operations Division of the Office of Highway Operations shall be responsible for the coordination of the emergency preparedness activities of the several offices of the FHWA and for the development of the integrated plans and programs necessary to assure an adequate FHWA emergency preparedness posture. The Administrator reserves to himself, however, the authority to approve and issue policies and substantive program requirements regarding overall FHWA emergency preparedness activities that involve commitments to higher authority or other agencies, commitments of substantial manpower, or the modification of the responsibilities assigned in this order. Specifically, the Defense Plans and Operations Division shall:

a. Develop, in cooperation with the various offices of the FHWA, the several State highway departments, and the highway transportation industry as appropriate, overall FHWA plans and programs to meet any degree of emergency including major disasters or enemy attacks upon the United States.

b. Monitor the development of detailed emergency operational plans by the offices of the FHWA and the development of a national, regional, division, and State capability to carry out those plans in a national emergency or disaster situation.

c. Develop and maintain an FHWA Headquarters emergency operating facility including all related services.

d. Establish and maintain an FHWA operating capability at the Special Facilities Division of the Office of Emergency Preparedness and at the Department of Transportation (DOT) Headquarters emergency operating facility.

e. Provide for the protection and survival of the FHWA Headquarters personnel.

f. Develop and maintain a nationwide capability to protect critical highway facilities from sabotage.

g. Establish and provide policy direction for the activities of an FHWA unit of the National Defense Executive Reserve.

h. Provide the FHWA defense coordinator (who shall be the Division Chief or his designee) required by DOT Order 1900.2 and represent the FHWA on the DOT Interagency Emergency Transportation Committee established by DOT Order 1120.36.

i. Represent the FHWA on matters concerned with national emergency preparedness.

7. SPECIFIC RESPONSIBILITIES

a. Associate Administrators

(1) The Associate Administrator for Planning shall be responsible for the development of a national, regional, division, and State capability to:

(a) Report and evaluate damage to highways and highway facilities including the partial or total interdiction thereof by fallout.

(b) Provide advice and guidance on the routing of important highway movements.

(c) Determine short-range highway needs.

(d) Determine long-range postattack highway needs in the light of destroyed population centers, population shifts, the development of new industrial centers, and other effects of the attack or disaster, and make appropriate revisions in the Federal-aid highway systems.

(e) Determine the postattack level of highway construction necessary to provide the maximum contribution to the recovery of the Nation.

(f) Continue normal activities necessary under postattack conditions.

(2) The Associate Administrator for Research and Development shall be responsible for the development of a national, regional, division, and State capability to:

(a) Provide advice and guidance on possible substitutes for highway construction and maintenance materials that are in short supply.

(b) Continue normal activities necessary under postattack conditions.

(3) The Associate Administrator for Right-of-Way and Environment shall be responsible for the development of a national, regional, division, and State capability to:

(a) Assist in the emergency acquisition of rights-of-way for the highway construction and reconstruction required by postattack conditions.

(b) Continue normal activities necessary under postattack conditions.

(4) The Associate Administrator for Engineering and Traffic Operations shall be responsible for the development of a national, regional, division, and State capability to:

(a) Review and evaluate existing and proposed Federal-aid and Federal highway and bridge construction to determine which contracts should be terminated, suspended, or expedited.

(b) Direct the emergency repair and reconstruction of damaged highway facilities.

(c) Direct the institution of, and coordinate the operation of, emergency highway traffic regulation.

(d) Direct the field operations necessary for the determination of the possibility of safe travel through fallout areas, the dissemination of information to the public concerning radiation hazards, and the placement of emergency signs to warn the public of hazardous conditions.

(e) Revise highway maintenance and construction programs to meet postattack conditions.

(f) Act as claimant for the materials, supplies, equipment, and manpower needed for the maintenance, repair, and construction of highways, streets, and bridges.

(g) Allocate available resources to essential highway construction and maintenance activities.

(h) Revise highway and bridge design and construction standards in view of postattack conditions.

(i) Continue normal activities necessary under postattack conditions.

(5) The Associate Administrator for Motor Carriers and Highway Safety shall be responsible for the development of a national, regional, and division capability to:

(a) Revise existing Bureau of Motor Carrier Safety regulations as necessary under the postattack conditions.

(b) Assist in emergency highway traffic regulation.

(c) Continue normal activities necessary under postattack conditions.

(6) The Associate Administrator for Administration shall be responsible for the development of a capability to:

(a) Carry out all housekeeping functions at the designated FHWA Headquarters emergency operating facility including housing, feeding, and the provision of medical services in the transattack and postattack periods.

(b) Perform all necessary administrative services including the maintenance of records and files, the provision of office supplies and equipment, printing, duplicating, and communications services at the FHWA Headquarters emergency operating facility.

(c) Perform all necessary personnel, security, and budgetary functions in accordance with emergency regulations, including processing the recruitment of National Defense Executive Reservists and the maintenance of appropriate personnel records relating to them.

(d) Carry out the duties outlined in (a) through (c) above at the regional and division levels during a period in which communications cannot be established with higher authority.

(e) Continue normal activities necessary under postattack conditions.

b. Staff Offices

(1) The Office of the Chief Counsel shall be responsible for the provision of legal advice and guidance on all matters including but not limited to the legal aspects of contract termination and suspension, land acquisition under postattack conditions, the preparation of legislative proposals found necessary under postattack conditions, and the continuation of present activities necessary under postattack conditions.

(2) The Office of Program Review and Investigations shall be responsible for the continuation of those present activities that are necessary under postattack conditions.

(3) The Office of Public Affairs shall be responsible for the preparation and dissemination of information to the public in regard to the postattack condition of the Nation's highway system and the continuation of those present activities that are necessary under postattack conditions.

(4) The Office of Civil Rights shall be responsible for the continuation of those present activities that are necessary under postattack conditions.

c. Regional Federal Highway Administrators

The responsibilities of the Regional Federal Highway Administrators shall include but not be limited to:

(1) Development and maintenance of an emergency operating facility for the regional office.

(2) Continuity of the Regional Federal Highway Administration as a functioning organization under national emergency conditions.

(3) Protection and survival of the regional employees of the FHWA.

(4) Establishment of Regional Coordinating Committees on Emergency Preparedness.

(5) Development of a regionwide capability to carry out the emergency plans and programs developed by the headquarters office of the FHWA.

d. Division Engineers

The responsibilities of the division engineers of the FHWA shall include but not be limited to:

(1) Development and maintenance of an emergency operating facility for the division office.

(2) Continuity of the division office as a functioning organization under national emergency conditions.

(3) Protection and survival of the division office employees.

(4) Development of a capability, under the overall supervision of the Regional Federal Highway Administrator, to carry out the emergency plans and programs developed by the headquarters office of the FHWA.

(5) Promotion and development of a State highway department capability to carry out emergency plans and programs including the obtaining and annual updating of an agreement covering the cooperation of the State (State highway department and/or other State agencies) in the performance of the emergency operations for which the FHWA is assigned the Federal responsibility. An example of such an agreement is shown in Attachment No. 1.

Attachment

F. C. Turner
Federal Highway Administrator

AGREEMENT
FOR THE DEVELOPMENT OF PLANS TO IMPLEMENT
NATIONAL EMERGENCY PREPAREDNESS PROGRAM
FOR HIGHWAY TRANSPORTATION

This agreement made and entered into this _____ day of _______________, 19__, by and between the Secretary of Transportation acting by and through the Federal Highway Administration and the State of _______________________, represented by the ___________________________, referred to herein as the State, witnesseth:

WHEREAS, effective national preparedness planning to meet any national emergency, including a massive nuclear attack, is essential to our survival; and

WHEREAS, effective national preparedness planning requires the identification of functions that would have to be performed during such an emergency, the assignment of responsibility for developing plans for performing these functions, and the assignment of responsibility for developing the capability to implement those plans; and

WHEREAS, the President of the United States by Executive Order No. 11490 has assigned emergency preparedness functions to Federal departments and agencies and has provided that the Department of Transportation shall be responsible for the nation's transportation systems; and

WHEREAS, the Federal Highway Administration has been assigned the responsibility for the preparation of emergency operational plans and programs for, and for the development of a capability to carry out such plans and programs concerning Federal, State, city, local and other highways, roads streets, bridges, tunnels and appurtenant structures in the event of a national emergency; and

WHEREAS, the Federal Highway Administration must have the assistance and cooperation of the various States if its responsibilities are to be successfully carried out; and

WHEREAS, the State of ______________________ has elected to cooperate with the Federal Highway Administration in the development of emergency preparedness plans and programs to be carried out within its jurisdiction in the event of a national emergency.

NOW THEREFORE, the parties hereto do mutually agree as follows:

Section I - Coordination of Efforts

The State and the Federal Highway Administration hereby agree to coordinate efforts with regard to the development and implementation of national emergency preparedness plans and programs concerning all highways, roads, streets, bridges, tunnels and appurtenant structures within the State.

Section II - State Emergency Preparedness Plans and Programs

A. The State hereby agrees to cooperate with the Federal Highway Administration in developing plans and programs for and in carrying out the following fuctions:

1. The protection of critical highway facilities from sabotage.
2. The evaluation of the effect of fallout on highway transportation.
3. The evaluation of the adequacy of the highway system after an attack.

4. The regulation of traffic in an emergency.
5. The reorientation of the on-going highway construction program to achieve changing objectives arising from a national emergency.
6. The determination of highway rehabilitation priorities.
7. The reconstruction of essential highway facilities.
8. The obtaining of adequate manpower, material, and equipment for the reconstruction and operation of the highway system.

B. Such plans and programs shall be amended from time to time to bring them into harmony with regional or national programs.

Section III - Federal Assistance

The Federal Highway Administration hereby agrees to provide such technical and financial assistance to the State in performing its obligations under this agreement as is possible under Federal legislation in effect at the time.

Section IV - Completion

It is mutually agreed that the development of plans and programs called for in Section II hereof shall be completed at the earliest date possible considering the availability of manpower and funds and shall be updated at least annually thereafter. After completion, they shall become the official emergency preparedness plans and programs to be carried out within the State in the event of a national emergency.

IN WITNESS WHEREOF the parties hereto have executed this Agreement as of ______________________________.

State of ______________________ FEDERAL HIGHWAY ADMINISTRATION

Department of ______________________

By ______________________ By ______________________.
Title Title

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FHWA ORDER

10-4

December 30, 1971

EMERGENCY STANDBY ORDERS (ESO's)

1. PURPOSE

To establish a series of Federal Highway Administration (FHWA) emergency standby orders designed to provide the Washington Headquarters, regional and division offices with uniform guidelines and procedures covering the additional operations for which the FHWA is responsible under emergency conditions and the authorities necessary to carry out these responsibilities.

2. AUTHORITIES

a. Title 23 (Highways), United States Code.

b. Department of Transportation Act, Section 9 (49 U.S.C. 1657).

c. Title 49 (Transportation), Code of Federal Regulations, Section 1.4(d).

d. Executive Order 11490, "Assigning Emergency Preparedness Functions to Federal Departments and Agencies".

e. Federal Emergency Action Plan, including Annex C (Resources), Section VII.

f. FHWA Order 10-1, "Emergency Preparedness".

3. EMERGENCY RESPONSIBILITIES

a. The Nation's highway authorities - the FHWA and the State, county, city and other local highway departments - are responsible in an emergency for the maintenance of a highway system adequate for the country's defense and rehabilitation and the movement of the essential materials, supplies and personnel necessary thereto. This responsibility includes, but is not limited to:

(1) The protection of critical highway facilities from sabotage.

(2) The survival of the Federal, State, county, city and other local highway departments.

(3) The evaluation of the effect of fallout on highway transportation after an attack.

(4) The evaluation of the adequacy of the highway system after an attack.

(5) The regulation of highway traffic in an emergency.

(6) The reorientation of the on-going highway construction program to achieve changing objectives arising from an emergency.

(7) The determination of highway rehabilitation priorities.

(8) The repair and reconstruction of essential highway facilities.

(9) The obtaining of adequate manpower, material, and equipment for the maintenance, repair, construction, reconstruotion, and operation of the highway system.

b. Executive Order 11490 also assigns to the FHWA the responsibility for coordinating the development of comprehensive State plans covering the functions listed above.

4. POLICY

The maintenance, reconstruction, and control of the use of the Nation's highway system in an emergency will be carried out to the extent possible by the Federal, State, and local highway departments responsible for such activities under normal conditions. Emergency authorities delegated to the Secretary of Transportation and the Federal Highway Administrator will be used only when absolutely necessary to augment the efforts of the State and local highway departments, i.e., the performance of essential activities that the State and local highway agencies cannot accomplish on their own. In addition, the FHWA will assist State, city, county and other local highway authorities in the development of plans for the direction and performance of those essential highway related emergency activities outlined in paragraph 3, above.

5. DOCUMENTATION OF SPECIAL EMERGENCY AUTHORITIES, PROCEDURES, AND GUIDELINES.

a. Format. The special authorities to be activated in the event of an emergency, along with appropriate procedures and guidelines, are to be documented in Emergency Standby Orders (ESO's). ESO's will be issued as sequentially numbered FHWA Orders in accordance with the listing contained in Attachment 1, and will include in the subject block the standard heading "Emergency Standby Order" followed by the indicated title.

b. Responsibilities. FHWA Staff Office Directors and Associate Administrators are responsible for developing individual ESO's, as set forth in Attachment 1 and any other ESO's required as a result of responsibilities for emergency functions assigned to those officials in FHWA Order 10-1.

c. Approval. All ESO's will be approved by the Federal Highway Administrator.

6. EXERCISE OF SPECIAL EMERGENCY AUTHORITIES

a. Federal Highway Administrator

The special emergency authorities referred to in paragraph 4, above, are available to the Federal Highway Administrator when he is so advised by higher authority. Selected authorities and related resources may be made effective at any time by direction of the Federal Highway Administrator pursuant to laws enacted by the Congress or orders issued by the President.

b. Regional Administrators and Division Engineers

(1) When communication exists between FHWA Washington Headquarters and a regional office, the Federal Highway Administrator may:

(a) retain final decisionmaking authorities and request recommendations from the regional office regarding implementation of the authorities included in the ESO's, or

(b) delegate final decisionmaking authorities to the appropriate Regional Administrator.

(2) When communications cannot be established with higher FHWA authority, the Regional Administrators and Division Engineers are delegated all the authorities of the Federal Highway Administrator (See FHWA Organization Manual, Part I (Delegations of Authority), Chapter 2 (Succession to Official FHWA Positions), paragraph 8b). In this situation, the Regional Administrators and Division Engineers may exercise such authorities as are necessary, when available information indicates that the President has issued pertinent instructions. A Division Engineer will exercise these authorities only when and for so long as he is unable to establish and maintain communication with his regional office or the FHWA Washington Headquarters. A Regional Administrator will exercise these authorities only when and for so long as he is unable to establish and maintain communication with the FHWA Washington Headquarters.

(3) In the event that communication cannot be established with higher FHWA authority, the Regional Administrators will be supplied broad general guidance regarding their emergency activities by either DOT regional offices activated pursuant to the DOT Preparedness Manual or the Regional Directors of the Office of Emergency Preparedness. Under similar circumstances, Division Engineers, cut off from their Regional Administrators, will attempt to obtain the same type of guidance from the sources listed above. If communication cannot be established with the aforementioned sources, the Regional Administrators and Division Engineers will carry out their assigned emergency responsibilities to the best of their ability based upon the general situation in their area.

R. R. Bartelsmeyer

R. R. Bartelsmeyer
Deputy Administrator

Attachment

TABLE OF FHWA EMERGENCY STANDBY ORDERS

NUMBER	TITLE	PURPOSE	RESPONSIBLE OFFICE
		GENERAL	
10-4.01	Protection of Critical Highway Facilities Against Sabotage	To outline the need for, and set forth recommended actions concerning the protection of critical highway facilities against sabotage.	Associate Administrator for Engineering and Traffic Operations
10-4.02	FHWA Situation Reporting	To establish uniform procedures for the reporting of the current operating capability of the Federal Highway Administration, the State highway departments and the highway system commencing with a DEFCON 1 and terminating in the early postattack time period.	Associate Administrator for Engineering and Traffic Operations
10-4.03 thru 10-4.19	RESERVED		
		ADMINISTRATION	
10-4.20	Emergency Personnel Management Activities	To provide procedures relative to FHWA personnel management activities under emergency conditions.	Associate Administrator for Administration
10-4.21	Emergency Financial Management Activities	To provide procedures relative to FHWA financial management activities under emergency conditions.	Associate Administrator for Administration

NUMBER	TITLE	PURPOSE	RESPONSIBLE OFFICE
10-4.22	Emergency Contracting and Procurement Activities	To provide procedures relative to FHWA contracting and procurement activities under emergency conditions.	Associate Administrator for Administration
10-4.23	Emergency Administrative Service Activities	To provide procedures relative to FHWA administrative service activities under emergency conditions.	Associate Administrator for Administration
10-4.24	Requisitioning of Private Property for Highway Purposes	To provide for the requisitioning of private property for highway purposes in a postattack situation and establish procedures for such action.	Associate Administrator for Administration
10-4.25 thru 10-4.29	RESERVED		
	TRAFFIC OPERATIONS		
10-4.30	Establishment of Emergency Highway Traffic Regulation (EHTR)	To outline the procedures to be used in the implementation of EHTR after an attack on the United States or subsequent to a major peacetime emergency.	Associate Administrator for Engineering and Traffic Operations
10-4.31 thru 10-4.39	RESERVED		
	CONSTRUCTION AND MAINTENANCE		

NUMBER	TITLE	PURPOSE	RESPONSIBLE OFFICE
10-4.40	Curtailment of Highway Construction	To establish the procedures for the suspension of work on all highway construction projects throughout the country, whether federally funded or not, that are already under way or about to be started.	Associate Administrator for Engineering and Traffic Operations
10-4.41	Highway Repair and Reconstruction in the Immediate Postattack Period	To establish the procedures for the repair or reconstruction, by any means possible, of highways, roads, streets, or bridges that are urgently needed for survival, retaliatory military operations, or the restoration of transportation services in disaster areas immediately following an attack on the United States.	Associate Administrator for Engineering and Traffic Operations
10-4.42	Termination or Resumption of Suspended Projects and Initiation of New Highway Projects	To outline the criteria for the evaluation of the essentiality of highway projects in light of national emergency conditions and recovery goals, and provide for the termination or resumption of suspended projects and the initiation of new projects deemed vital to national defense and recovery.	Associate Administrator for Engineering and Traffic Operations

NUMBER	TITLE	PURPOSE	RESPONSIBLE OFFICE
10-4.43	Preparation of Requirement Estimates (Materials, Supplies, Equipment and Manpower) for Highway Work	To provide procedures for the submission of estimates of resources (materials, supplies, equipment and manpower) needed for the construction, repair, maintenance, and operation of the Nation's highways, roads, streets, and bridges.	Associate Administrator for Engineering and Traffic Operations
10-4.44	Allocation of Resources for Essential Highway Work	To outline the procedures for the apportionment of the materials, equipment and manpower needed for the operation of the Nation's highway, road and street systems.	Associate Administrator for Engineering and Traffic Operations
10-4.45 thru 10-4.49	RESERVED		
	PLANNING		
10-4.50	Damage Assessment	To provide for the determination and reporting, with the assistance of State highway departments, of the extent of damage to a selected system of the Nation's highways, roads, streets and bridges. Reporting procedures include provisions for reporting the effects of debris and radiation on this selected system of highways.	Associate Administrator for Planning
10-4.51 thru 10-4.59	RESERVED		

Transmittal 109

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FHWA ORDER

10-4.01

January 28, 1972

EMERGENCY STANDBY ORDER - PROTECTION OF CRITICAL HIGHWAY FACILITIES AGAINST SABOTAGE

1. PURPOSE

This order outlines the need for, and sets forth recommended actions concerning the protection of critical highway facilities against sabotage.

2. AUTHORITY

Federal Highway Administration (FHWA) Order 10-4.

3. IMPLEMENTATION

This order is effective when:

a. There is a threat of a covert attack during a period of international tension.

b. There is a possibility of acts of sabotage being perpetrated by a dissident group or groups.

4. POLICY

a. Effective planning and policy formulation by the State highway departments will minimize the adverse effects of sabotage. It is the responsibility of the FHWA to encourage the States to develop plans for the protection of critical highway resources. The FHWA will also make every possible effort to provide the States with intelligence concerning possible covert action.

b. In addition, the FHWA will advise the State highway departments on procedures for selection of facilities to be protected and techniques to be used in protecting these facilities.

5. CRITICAL FACILITY DETERMINATION

a. Selected management representatives of the State highway departments should evaluate existing highway facilities within the State and identify those that are critical and those that are vulnerable. A facility is considered critical if its loss would seriously impair transportation in an important corridor. A facility is considered vulnerable if it is particularly susceptible to damage by a potential saboteur. Obviously facilities that are both critical and vulnerable should be given priority in any protection program.

b. Important factors for determining the criticality of a highway facility are:

(1) The average daily traffic count.

(2) The replacement factor, i.e., that period of time necessary to restore the facility if it were damaged or destroyed.

(3) The availability of alternate routes.

(4) The importance of the facility to defense production and/or military operations.

c. Important factors for determining the vulnerability of a highway facility are:

(1) The susceptibility of the facility involved to damage by an explosive charge.

(2) The susceptibility of the facility to damage by a planned traffic incident.

(3) The ease of access to an installation by outsiders.

(4) The inflammable nature of certain materials that are normally stored in areas such as equipment yards.

6. SECURITY MEASURES FOR HIGHWAY FACILITIES

a. The most critical and vulnerable highway facilities are bridges and tunnels. During a period of international tension, or as a result of threatened dissident action, there may come a point in time when a decision should be made to implement all available security measures in order to protect certain bridges and/or tunnels. Normally, the State highway departments cannot be expected to provide the personnel for around-the-clock guard forces. Therefore, it is recommended that the State highway departments (depending on the type of bridge and/or tunnel involved) make arrangements to obtain assistance as required from State or local law enforcement agencies, National Guard units, State militia units, or other military forces situated in the immediate vicinity. Guidelines for providing protective measures for bridges and/or tunnels are listed below:

(1) Guard forces can be either ambulatory or of the motor patrol variety (or both).

(2) Guards should be placed at each end of the bridge/tunnel and possibly at intervals along the span or inside the tunnel. This is not to imply that traffic should be stopped unless a specific situation necessitates a search of every vehicle traversing the route involved.

(3) Security forces should be armed. The controlling authority(ies) of these forces should provide a thorough indoctrination as to proper restraint in use of weapons.

(4) Flood lighting may be necessary to light tunnel entrances, abutments and piers at night.

(5) Patrol boats may be required to provide added surveillance for the substructure of certain bridges.

(6) Surveillance of the draw mechanism of drawbridges should be provided.

(7) The feasibility of closed-circuit TV systems should be explored.

b. Appropriate measures should be taken to protect other critical highway facilities when there is a threat of an attack or a distinct possibility of dissident action. Listed below is a summary of the more common measures employed for the protection of operating facilities, equipment yards, etc:

(1) Obtain assistance of law enforcement agencies, National Guard, State militia, etc.

(2) Establish a security organization.

(3) Erect perimeter fencing in order to deter potential intruders.

(4) Provide additional lighting for areas that are vulnerable to intrusion.

(5) Establish a system of identification and control of access to and egress from sensitive areas.

(6) Develop a fire prevention program in coordination with local fire officials and encourage the active participation of all employees.

(7) Develop a plan for alerting key officials and test the plan frequently.

(8) Develop an evacuation plan for operating facilities and test the plan frequently.

(9) Determine if there is a need to install an intrusion detection system(s) in specified areas of operating facilities.

(10) Develop an intelligence reporting system in the community which would include provisions for the reporting of any suspicious activities around critical highway installations by the local citizenry.

7. SUMMARY

There is no uniform concept of operations to prevent sabotage incidents which can be applied in all cases. The protective measures described in the preceding sections have proven invaluable to all types of organizations. It is recommended that they be seriously considered for implementation where appropriate by State highway officials when an attack on the United States is imminent or when there is a possibility of covert destructive actions by a dissident group or groups. Many of these security measures require an appreciable expenditure in terms of manpower and equipment. Management must weigh the outlay of these resources against what is to be gained in terms of an improved security posture.

F. C. Turner
Federal Highway Administrator

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FHWA ORDER

10–4.02

January 14, 1972

EMERGENCY STANDBY ORDER - FHWA SITUATION REPORTING

1. PURPOSE

To establish uniform procedures for the reporting of the current operating capability of the Federal Highway Administration (FHWA), the State highway departments and the highway system commencing with the declaration of a DEFCON 1 and terminating in the early post-attack time period.

2. AUTHORITY

FHWA Order 10-4.

3. POLICY

It is the policy of the FHWA to have its regional offices report at appropriate intervals during periods of increased international tension and during the initial phase of a national emergency the then current status of the Federal Highway Administration's division and regional offices, the State highway departments and the highway system. Division offices should report to their regional offices. Regional offices should prepare a consolidated report and forward it to the FHWA headquarters.

4. REPORT CONTENTS

a. Brief outline of major highway transpotation problems in each State.

b. Location at which the region is operating with telephone numbers and teletype addresses at that location.

c. Location at which each division is operating with telephone numbers and teletype addresses at those locations.

d. Location at which each State highway department is operating with telephone numbers and telegraph addresses at those locations.

e. Operational capability of the FHWA regional and division offices including an estimate of the number of personnel available for duty.

f. Operational capability of the State highway departments including an estimate of the personnel available for duty.

g. Other pertinent information.

5. REPORTING SCHEDULE

a. An initial report should be submitted upon the declaration of a DEFCON 1 or prior thereto upon the occurrence of an event having a significant effect on highway transportation.

b. Updated reports showing changes in the initial report should be submitted as such changes occur.

c. Updated reports should also be submitted following a nuclear attack or an act of sabotage against an important highway facility.

d. Updated reports should also be submitted during the early postattack period to reflect changes to earlier submissions by the regions.

6. REPORTING FORMAT

All reports should be structured in accordance with the format shown in section 4, above, using the same alphabetical designations for each essential element of information.

F C Turner

F. C. Turner
Federal Highway Administrator

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FHWA ORDER

10-4.30

January 28, 1972

EMERGENCY STANDBY ORDER - ESTABLISHMENT OF EMERGENCY HIGHWAY TRAFFIC REGULATION (EHTR)

1. PURPOSE

This order outlines policies, responsibilities and procedures relating to EHTR activities and provides for the implementation of such activities prior to and subsequent to an attack on the United States or a major peacetime disaster.

2. AUTHORITY

Federal Highway Administration (FHWA) Order 10-4.

3. GENERAL POLICY

a. Operational readiness requires the establishment of an emergency highway traffic regulation organization in peacetime. This organization shall be adequate to operate a system of traffic management and control which will regulate the use of highways and will facilitate urgent highway movements following a nuclear attack or a major peacetime disaster. This organization will be staffed by representatives of the State highway department, the police and, when appropriate, by the cooperating organized highway users. The functions of this organization are to be prepared to protect highway users from hazardous conditions and to ration road space for effective utilization of the highway system. The establishment of priorities for cargo or personnel movements is a function of the appropriate emergency transportation organizations and not of the EHTR organization.

b. Guidelines concerning the detailed operation of the EHTR program are contained in a Guide for Highway Traffic Regulation in an Emergency, published by the FHWA.

c. The EHTR program is a decentralized postattack program which will become operational when shelter emergence occurs. Each State shall have an EHTR plan which contains detailed procedures for the implementation and conduct of statewide EHTR operations. Since the highway system is comprised of key resource facilities, these plans will function as required during the postattack period or in a major peacetime emergency. EHTR will be implemented under the following conditions:

(1) When highway users must be protected from fallout resulting from a nuclear attack.

(2) When traffic demand exceeds highway capacity.

(3) When unauthorized traffic should be excluded from a specific area.

4. IMPLEMENTATION

When communications are available, the postattack provisions of this order will normally be made effective upon specific direction of the Federal Highway Administrator when deemed necessary in the light of conditions following an attack on the United States or during a major peacetime emergency. The following situations could arise:

a. The Federal Highway Administrator may make the order effective upon a specified date and delegate final decisionmaking authority to the Regional Federal Highway Administrator(s) with authority to redelegate (see Attachment No. 1).

b. In a postattack cutoff situation when communications are disrupted within the FHWA, this order is effective and all the authorities therein are available to the Regional Federal Highway Administrators as soon as there is reason to believe that the President has issued pertinent instructions.

c. If a major disaster such as a flood, hurricane, earthquake, etc., occurs, EHTR can be implemented by the chief executive of a State under the statutory authorities of that State.

5. RESPONSIBILITIES

a. Each State is responsible for the annual updating of its EHTR plan. These revisions will result from changing national policies, State laws and experience resulting from the use of State plans as EHTR training tools. State plans and changes in these plans should be submitted prior to publication through channels to the Washington Headquarters Office of Traffic Operations for approval.

b. The Federal Highway Administrator has the overall responsibility for administration of the EHTR program. The Regional Federal Highway Administrators have the responsibility for the development of an EHTR program in their respective States. The region and division offices will work with appropriate State agencies to develop records, displays, etc., upon which routes that are impassable due to radiation, blast damage or the resultant effects of a major peacetime emergency can be recorded. These offices will also be prepared to resolve problems of a multistate nature if State efforts to affect a workable solution have failed.

Attachment

F C Turner

F. C. Turner
Federal Highway Administrator

TELETYPE

TO: Administrators, FHWA Region(s) ______________________________

FHWA Order 10-4.30, "Establishment of Emergency Highway Traffic Regulation (EHTR)" is effective ______________________________.
Date

You are delegated the authority, with authority to redelegate, for the taking of all necessary actions required by this order.

____
Federal Highway Administrator

58415

Transmittal 130

U.S. DEPARTMENT OF TRANSPORTATION	FHWA ORDER
FEDERAL HIGHWAY ADMINISTRATION	10-4.50
EMERGENCY STANDBY ORDER - DAMAGE ASSESSMENT	August 18, 1972

Par. 1. Purpose
2. Authority
3. Responsibilities
4. Background
5. Procedures

1. PURPOSE

To provide for the determination and reporting, with the assistance of State highway departments, of the extent of damage from an enemy attack to a selected system of the Nation's highways, roads, streets, and bridges. Reporting procedures include provisions for reporting the amount of debris and radiation levels on this selected system of highways.

2. AUTHORITY

Federal Highway Administration (FHWA) Order 10-4.

3. RESPONSIBILITIES

In the event of a national emergency as a result of an enemy attack, the FHWA has the following responsibilities:

a. Collection and evaluation of reports of the extent of damage to a selected system of the Nation's highways, roads, streets and bridges, including reports of the partial or total interdiction of these facilities, or portions thereof, by radioactive fallout and/or debris.

b. Maintenance of the FHWA official map showing damage and denial of highways as reported.

c. Provision of advice and guidance on long-distance routing of important highway movements.

4. BACKGROUND

a. Two distinct damage assessments are contemplated. The first will be based on a computer analysis made by the Information Systems Division of the Office of Emergency Preparedness (OEP) during the transattack and early postattack periods. This analysis will be based on data previously furnished in accordance with PPM 50-6.1, "Highway Defense Bridges," and will require no further action on the part of the FHWA field offices or the State highway departments.

b. The second damage assessment will be performed by the State highway departments in cooperation with the FHWA as early as conditions permit after attack. It is this second assessment upon which this ESO is focused. The procedures for conducting this major activity are covered in paragraph 5.

5. Procedures

a. The postattack field assessment of damage to and/or denial of highways and highway facilities will be made primarily by the State highway departments with assistance where required from the FHWA. The instructions covered in the ensuing sub-paragraphs of this paragraph are based on the availability of any suitable communications media although the report format is primarily designed for teletype or facsimile transmission. These instructions are intended specifically for use in a national emergency resulting from an enemy attack.

b. The highway network on which damage is to be reported consists of those highways selected by the State highway departments in accordance with provisions of PPM 50-6.1. Identification of road sections and structures on this selected system is also based upon PPM 50-6.1. Current copies of these documents should be maintained at all relocation sites.

c. Normally the reports will be prepared at division level in cooperation with the State highway department(s) as soon as any definite information on highway damage or restrictions on the use of highways due to radiation is available. The report should be forwarded to the region. The region in turn will forward it to the FHWA Headquarters. If a division cannot communicate with its regional headquarters, the division should, if possible, submit the report directly to the FHWA Headquarters. Each division damage report should be numbered in sequence by the sender starting with the number 1. The region should number its damage reports serially and should indicate in the heading the source(s) of the report, e.g., Pennsylvania Division reports nos. 1 and 2. Regional reports may include reports from more than one division.

d. Reports should be submitted on those road sections damaged to the extent that the capacity is restricted and/or those that would be hazardous for essential traffic under controlled conditions from a radiological standpoint. The extent of structural damage, replacement or repair time, operational status, and the effects of radiation on a particular section should be reported in accordance with the instructions contained in Attachment 1.

e. The damage report column headings, codes, and descriptions are shown in Attachment 1. In those instances where the situation cannot be adequately covered by the codes furnished, brief narrative statements should be included as illustrated in the sample report in Attachment 2.

R. R. Bartelsmeyer

R. R. Bartelsmeyer
Acting Federal Highway Administrator

Attachments

DESCRIPTION OF DAMAGE REPORT HEADINGS AND CODES

Column I — Road section number - see PPM 50-6.1, Highway Defense Bridges — 5 spaces

Column II — Location of bridge damage, highway damage or highest radiation measurement in miles from the beginning of section (hundreths). For bridges, see PPM 50-6.1. Highway damage and radiation points would have to be recorded on a mileage indicator. — 5 spaces

Note: If reporting a section summary, show Z in fifth space of Column II.

Column III — Bridge description - see PPM 50-6.1, Highway Defense Bridges — 2 spaces

Note: If reporting (1) a section summary, (2) only highway damage, or (3) radiation restrictions, show Z in second space of Column III.

Column IV — Route number - see PPM 50-6.1, Highway Defense Bridges — 6 spaces

Column V — Length of section (tenths of a mile) - see PPM 50-6.1, Highway Defense Bridges — 4 spaces

Column VI — Length of structure (feet) - see PPM 50-6.1, Highway Defense Bridges — 6 spaces

Note: If reporting (1) a section summary, (2) only highway damage, or (3) radiation restrictions, show Z in sixth space of Column VI.

Column VII — Damage — 3 spaces

Note: If reporting only radiation restrictions, show 0 in space 3.

Space 1 Extent of Structural Damage

H= Highway damage--report H when there is damage to the highway surface or when there is sufficient debris to cause a road closure.

L= Light--the resultant structural damage does not prevent the immediate use of the facility (possibly with restrictions).

M= Moderate--moderate is defined as structural damage which does not extend beyond the point where repair is more costly than replacement.

S= Severe--damage to a facility is so great that it would be more economical to build anew than to repair the damage.

Space 2 Cause of Damage

Based on the best available information:

A= Nuclear weapon
S= Sabotage
U= Unknown

Space 3 Reliability of Report

X= High. A report resulting from a visual inspection by an engineer(s).

Y= Reasonable. A report resulting from a visual inspection by a competent source other than an engineer(s).

Z= Questionable. A report resulting from other than "X" or "Y" above.

Column VIII Time required to make: **3 spaces**

Note: If reporting only radiation restrictions, show 0 in space 3.

Space 1 Permanent Repairs

1= 1 week or less
2= 1 week - 1 month
3= 1 - 3 months
4= 3 - 6 months
5= 6 - 12 months
6= over 1 year

Space 2 Temporary Repairs

1= 1 week or less
2= 1 week - 1 month
3= 1 - 3 months
4= 3 - 6 months
5= 6 - 12 months
6= over 1 year

Space 3 Reliability of Estimate

X= High. (see column 7, space 3)
Y= Reliable. (see column 7, space 3)
Z= Questionable. (see column 7, space 3)

Column IX Operational status **3 spaces**

Space 1 Physical Restrictions

1= Open - no physical restrictions
2= Open - weight restrictions
3= Open - speed restrictions
4= Open - weight and speed restrictions
5= Closed - by-pass available in section
6= Closed - no by-pass available in section

Space 2 Radiation Restrictions

1= No radiation hazard
2= Open to controlled traffic
3= Closed

Space 3 Reliability

X= High. (see column 7, space 3)
Y= Reliable. (see column 7, space 3)
Z= Questionable. (see column 7, space 3)

Column X Radiation Intensity 11 spaces

Spaces 1 through 5 - roentgens per hour at either the location of a damaged bridge structure or highway damage. If neither of the two aforementioned situations exists, the reading indicated describes the worst radiation situation on that section. (This worst situation rule also applies to a section summary.)

Spaces 7 through 11 - spaces 7 and 8 = month and spaces 10 and 11 = day on which the inspection was made.

Based on the preceding instructions, the five most common types of entries required to complete the damage report are shown below:

(1) A damaged structure:

I	II	III	IV	V	VI	VII	VIII	IX	X
150	6.78	P1	S 1	27.3	34	SAY	53Y	63Z	23.5 10-23

(2) A section with highway damage and radiation restrictions but no bridge damage:

I	II	III	IV	V	VI	VII	VIII	IX	X
55	8.35	Z	US 2	17.2	Z	HAX	22Y	63Z	24.5 10-22

(3) A section with highway damage only:

I	II	III	IV	V	VI	VII	VIII	IX	X
305	8.70	Z	S 69	18.2	Z	HUY	21Y	51Y	0.0 10-24

(4) A section with radiation restrictions only:

I	II	III	IV	V	VI	VII	VIII	IX	X
50	1.30	Z	US 2	5.5	Z	0	0	13Z	26.0 10-22

(5) A summary line should be included at the beginning of each section containing one or more damaged structures showing the section number, route number, section length, maximum structural damage occurring in the section, maximum repair time for the most extensive damage in the section, the operational status reflecting the most extensive damage in the section and the maximum radiation existing in the section.

I	II	III	IV	V	VI	VII	VIII	IX	X
235	Z	Z	S 32	25.6	Z	SAY	63Z	63Z	21.0 10-24

SAMPLE REPORT

Region ________ Damage Report No. 3

Source___ Division Damage Report No. 1

I	II	III	IV	V	VI	VII	VIII	IX	X	
5	Z	Z	I 94	13.0	Z	SSX	64X	61X	0.0	10-15
5	4.52		I 94	13.0	1125	SSX	64X	61X	0.0	10-15
30	Z	Z	US 2	42.6	Z	SAY	22Y	53Z	15.0	10-22
30	24.21		US 2	42.6	30	SAY	22Y	53Z	12.0	10-22
35	Z	Z	US 2	12.3	Z	SAY	42Y	63Z	22.0	10-22
35	6.30		US 2	12.3	150	SAY	42Y	63Z	20.0	10-22
40	3.70	Z	US 2	4.2	Z	0	0	13Z	24.0	10-22
45	4.10	Z	US 2	6.0	Z	0	0	13Z	23.5	10-22
50	1.30	Z	US 2	5.5	Z	0	0	13Z	26.0	10-22
55	8.35	Z	US 2	17.2	Z	HAX	22Y	63Z	24.5	10-22
60	Z	Z	US 2	47.0	Z	SAZ	63Z	63Z	22.3	10-22
60	18.87		US 2	47.0	134	SAZ	63Z	63Z	20.5	10-22
105	Z	Z	US 83	37.6	Z	SAX	65Y	63Z	30.9	10-22
105	10.02		US 83	37.6	974	SAX	65Y	63Z	30.3	10-22
105	17.76		US 83	37.6	1003	SAX	65Y	63Z	30.0	10-22
150	Z	Z	S 1	27.3	Z	SAY	53Y	63Z	25.0	10-23
150	6.78	1	S 1	27.3	34	SAY	53Y	63Z	23.5	10-23
150	6.78	P1	S 1	27.3	34	SAY	53Y	63Z	23.5	10-23
155	Z	Z	S 1	24.0	Z	SAX	63Y	63Z	28.5	10-23
155	9.76		S 1	24.0	42	SAX	63Y	63Z	26.7	10-23
155	13.21		S 1	24.0	30	SAX	63Y	63Z	27.4	10-23
170	11.10	Z	S 5	22.7	Z	0	0	13Z	29.5	10-23
175	15.30	Z	S 5	20.5	Z	0	0	13Z	27.2	10-23
185	Z	Z	S 5	21.9	Z	SAY	53Y	63Z	29.5	10-23
185	2.22		S 5	21.9	53	SAY	42X	63Z	29.0	10-23
185	7.69		S 5	21.9	65	SAY	42X	63Z	26.5	10-23
185	15.25		S 5	21.9	84	MAY	53Y	63Z	28.0	10-23
185	18.67		S 5	21.9	32	MAY	53Y	63Z	25.9	10-23
230	Z	Z	S 5	27.0	Z	MAX	42Y	53Z	21.0	10-24
230	15.68		S 5	27.0	80	MAX	42Y	53Z	20.5	10-24
235	Z	Z	S 32	25.6	Z	SAY	63Z	63Z	21.0	10-24
235	1.11		S 32	25.6	63	SAX	53Z	63Z	16.0	10-24
235	4.52		S 32	25.6	27	SAX	53Z	63Z	15.0	10-24
235	4.52	P	S 32	25.6	27	SAX	53Z	63Z	15.5	10-24
235	6.71		S 32	25.6	60	SAX	53Z	63Z	17.5	10-24
235	8.89		S 32	25.6	70	MAX	53Y	63Z	21.0	10-24
235	11.12		S 32	25.6	68	SAX	53Y	63Z	20.5	10-24
235	14.72		S 32	25.6	26	SAY	63Y	63Z	19.0	10-24
235	18.76		S 32	25.6	34	SAY	63Y	63Z	14.0	10-24
305	8.70	Z	S 69	18.2	Z	HUY	21Y	51Y	0.0	10-24

Editor's Note: Executive Order 11725 dated June 27, 1973, specifies that the information in Appendix J will continue in effect until modified, terminated, superseded, set aside or revoked by appropriate authority. (See Section 4 of Appendix K.)

Chapter 6

TRANSPORTATION

This chapter is applicable to all forms of civil transportation of the United States, both domestic and international. It is equally applicable to all degrees of national emergency, including attack upon the United States.

(The Department of Defense and its military departments are responsible for developing appropriate plans and procedures for the management of transportation resources which they would control in a national emergency.)

DEFINITIONS

For the purposes of this chapter, the following definitions will apply:

Air Carrier Aircraft: All aircraft, both fixed and rotary wing, under the operational control of international and domestic scheduled and supplemental air carriers operating under the economic authority of the Civil Aeronautics Board; also, all other four-engine fixed-wing aircraft and all turbo-jet or turbo-prop fixed-wing aircraft over 12,500 pounds takeoff weight.

Civil Reserve Air Fleet (CRAF): Those air carrier aircraft allocated by the Secretary of Commerce to the Department of Defense for military operations during an emergency.

Civil Transportation: The movement of persons, property, or mail by civil facilities and the resources (including storage except that for agricultural and petroleum products) necessary to accomplish the movement. (This definition excludes transportation operated or controlled by the military and petroleum and gas pipelines.*)

Interstate (Primary) Transportation Resources: Those civil transportation facilities, equipment, and services controlled or provided by operators generally engaged in interstate or international transportation; also, air carrier aircraft and their related facilities, equipment, and services.

Intrastate (Secondary) Transportation Resources: Those civil transportation facilities, equipment, and services provided or authorized for use primarily within a State, territory, or the District of Columbia, excluding air carrier aircraft and their related facilities, equipment, and services.

State and Regional Defense Airlift (SARDA): The program designed to provide for the use during an emergency of civil aircraft other than air carrier aircraft.

War Air Service Program (WASP): The program designed to provide for the maintenance of essential civil air routes and services and to provide for the distribution and redistribution of air carrier aircraft among civil air transport carriers after withdrawal of aircraft allocated to the Civil Reserve Air Fleet.

Transportation Operating Agencies: Those Federal agencies having responsibilities under national emergency conditions for the operational direction of one or more forms of transportation; they are also referred to as Federal Modal Agencies or Federal Transport Agencies.

Supporting Resources: Manpower, materials, equipment, and supplies needed to operate transportation systems.

In preparing this chapter the Office of Emergency Transportation (OET), Department of Commerce, was assisted by the Interstate Commerce Commission, Bureau of Public Roads, Civil Aeronautics Board, Federal Aviation Agency, Maritime Administration, Coast and Geodetic Survey, Department of the Interior, Tennessee Valley Authority, U.S. Army Corps of Engineers (Civil Works), and St. Lawrence Seaway Development Corporation.

*Pipelines are treated in Chapter 10. Fuel and Energy.

December 1964

ORGANIZATION

Those Federal, State, and local government agencies with transportation responsibilities comprise the organizational structure for transportation mobilization. Their built-in readiness would be relied on to implement and enforce transportation procedures and control systems. Staffs of the Federal transport agencies would be augmented by members of the National Defense Executive Reserve.

Federal.

In response to the need for an overall control agency to fulfill the complex movement requirements of national emergency, an emergency transportation organization would be activated.* It would be composed of an augmented OET peacetime staff organized on a functional and modal basis, and would use capabilities of all other government agencies with transportation responsibilities.

Transportation operating and support agencies would provide emergency direction for the use of modes of civil transport and related services for which they are responsible.

The Transportation Allocations, Priorities, and Controls (TAPAC) Committee, a subcabinet level committee under the chairmanship of the Under Secretary of Commerce for Transportation, consists of representatives of the transportation service agencies and of agencies which would claim for transportation service.

An emergency transportation advisory committee would be established to advise and assist OET. It would be composed of selected experienced and recognized leaders from each segment of the transportation industry.

OET has eight regions. Each would be headed by a designated OET Regional Director who within his region would represent the Director, OET. In the event of isolation or a communications breakdown the OET Regional Director would act independently within the limits of his geographic jurisdiction subject to established national policy.

Regional representatives of the Federal transport operating agencies, as well as area transport boards or committees, would receive their transportation policy direction and guidance from the OET Regional Director, subject to policy direction and coordination of the OEP Regional Director.

State and Local.

State and local emergency transportation organizations would consist of transport agencies at those levels of government which have functional or modal responsibilities for water (including inland waterway), rail, motor carrier, or air transportation. These agencies would be organized as determined by appropriate State and local government officials and would be staffed by qualified representatives of industry and government.

Civil aircraft other than air carrier aircraft are organized under the FAA State and Regional Defense Airlift Plan for the continued use of these aircraft in the national economy during an emergency situation and for providing adequate support for direct survival operations.

Emergency highway traffic regulation would be primarily the responsibility of State highway departments, in coordination with State civil defense and police organizations and organized users of highways, operating under the general supervision and guidance of the Bureau of Public Roads (BPR).

*Elsewhere in this chapter, "The Office of Emergency Transportation" (or "OET") denotes that Federal office operating during peacetime or its emergency counterpart, the emergency transportation organization authorized to carry out emergency functions.

RESPONSIBILITIES

Federal.

The Office of Emergency Planning (OEP) advises and assists the President in determining policy for and coordinating the emergency plans and programs of Federal resource agencies.

Executive orders assign to certain agencies specific responsibilities for planning emergency transportation preparedness programs. They are:

- Department of Commerce, E.O. 10999.
- Interstate Commerce Commission, E.O. 11005.
- Civil Aeronautics Board, E.O. 11090.
- Federal Aviation Agency, E.O. 11003.
- Department of the Interior, E.O. 10997.
- Tennessee Valley Authority, E.O. 11095.

Under national defense emergency conditions, by direction of the President and subject to policy guidance from the Director of OEP or its successor agency, the Secretary of Commerce would implement control systems governing the use of all civil transportation and the allocation of its capacity to meet essential civil and military needs.* These responsibilities would be redelegated by the Secretary to the Director of the Office of Emergency Transportation (OET). The President would also order Federal transportation agencies to carry out their plans in consonance with overall policy direction of the Secretary of Commerce.

Department of Commerce. The Secretary of Commerce, through the Director, OET, would promulgate plans, policies, and procedures for control systems and would provide administrative facilities for the performance of emergency transportation functions.

Transportation Operating Agencies. In consonance with OET policy directives, transportation operating agencies would act in their respective areas as follows:

- *Interstate Commerce Commission (ICC)*—rail, motor, and inland water carriers.
- *Civil Aeronautics Board (CAB)*—domestic and international civil air transportation.
- *Federal Aviation Agency (FAA)*—National Airspace System, civil airports, civil aviation operating facilities, and civil aircraft other than air carrier aircraft.
- *Maritime Administration (MarAd)*—ocean and Great Lakes ports and ocean shipping.

*Essential civil and military needs include atomic energy and national aeronautical and space programs.

- *Bureau of Public Roads (BPR)*—highway and street systems.
- *OET Air Carrier Division*—civil air carrier aircraft.

Support Agencies. Federal support agencies and their areas of responsibility are:

- *Tennessee Valley Authority (TVA)*—Tennessee River navigational system.
- *Coast and Geodetic Survey*—aeronautical and nautical data.
- *St. Lawrence Seaway Development Corporation*—sectional navigational systems of the St. Lawrence Seaway.
- *U.S. Army Corps of Engineers (Civil Works)*—waterway navigational facilities.
- *Department of the Interior*—petroleum and gas pipeline facilities.*

Advisory Committees. The TAPAC Committee would review policy and make recommendations on allocations, priorities, and controls for civil transportation. An emergency transportation advisory committee would advise the Director, OET, as required, on matters affecting the transportation industry. This committee would also facilitate industry coordination and understanding of emergency transportation policies and procedures.

Regional Offices. Federal policies and procedures would be disseminated and monitored in the field through regional offices of the respective transportation agencies in accordance with their own practices and organizational structure. Authority and responsibility would be delegated to them, subject to centralized coordination and policy direction.

In the event of isolation or a breakdown in communications, the primary responsibility for development, dissemination, and supervision of Federal transportation policies would shift to the OET regional representatives. Under such conditions, the regional offices would continue to assist State and local governments and military activities with transportation matters.

OET Regional Directors, subject to policy direction and coordination by appropriate OEP Regional Directors, would assume policy direction within their regions with respect to overall

*See Chapter 10.

interstate civil transportation, except for air carrier aircraft, during postattack periods of communication breakdown with OET National Headquarters.

During such periods OET would receive information and assistance from appropriate OCD Regional Directors on the overall civil defense situation, together with recommendations about the civil defense needs of geographic areas within their jurisdiction.

At such times representatives of Federal agencies charged with operational responsibility for specific modes of transportation would assure that these modes comply with appropriate preparedness programs, including emergency transportation resource programs being carried out by States and localities. Actions of these representatives and of any modal board, committee, or group should be in consonance with Federal policies and coordinated through the appropriate OET regional representative.

State and Local.

State and local governments would be responsible for the emergency utilization of intrastate transportation resources, subject to Federal policies and national control systems.

State and local authorities would coordinate with officials in adjoining areas and States for joint use of intrastate transportation during emergencies. When, by use, such transport became interstate, coordination would be accomplished through the Regional Director of OET.

These State and local authorities, with assistance from the OET State representative, would also develop requirements for additional transportation and present claims to the appropriate OET Regional Director for such services.

State and local governments would comply with Federal control measures to provide assistance in assuring that essential interstate and foreign movements were not unduly interrupted.

Postattack, State and local officials would determine the remaining capability of all modes of intrastate transportation and apportion this capability among users so as to satisfy the essential requirements of both State and national recovery.

In the event of a breakdown in communications or area isolation, when the appropriate Federal representative responsible for the control system of a particular mode of transportation were not available, the State would assume responsibility for the control system of the affected mode within the boundaries of that State, exclusive of air carrier aircraft. As communications were restored and such representation became available, the control system of such transportation would revert to the responsible Federal representative.

Carriers and Users.

Transportation carriers would be responsible for operating their facilities so as to provide the maximum possible service within their capabilities to fulfill essential needs as specified by appropriate government authorities. This includes continuity of management, protecting personnel and facilities, conserving supplies, restoring damaged lines and terminals, rerouting, expanding or improving operations, and securing necessary manpower, materials, and services.

Users of transportation and shippers, including government agencies, would be responsible for their own internal transportation procedures and would arrange directly with carriers for the actual accomplishment of movements.

Federal agencies, acting as claimants for transportation, would inform the appropriate OET office of their estimated peak and time-phased future requirements for transportation services and of any specific claims which require special arrangement. OET would use broad requirements predictions as traffic forecasts in planning optimum distribution of transport resources and in determining specific allocations for transportation capacity.

Where shortages of transportation service existed, Federal claims would be submitted to the OET national or regional office, as conditions dictated. State and local claims would be submitted to the OET regional offices. Detailed procedures will be set forth in the Transportation Allocations, Priorities, and Controls Manual to be published by OET.

FEDERAL FUNCTIONS

Office of Emergency Transportation.

OET would develop and direct the transportation policies of the Federal Government so that all modes of civil transportation would be used to provide a unified system responsive to the national emergency. To do this, it would:

- Receive, assemble, and analyze requirements from all claimant agencies for movement of passenger and freight traffic of all types and integrate these requirements with all forms of national and international civil transportation systems.
- Determine the adequacy of the various modes to provide the required service.
- Allocate and apportion, by mode, the total civil transportation resources to meet overall essential civil and military needs.
- Establish and institute, as necessary, control systems—including allocations, priorities, permits, sanctions, and embargoes—to assure optimum use of civil transportation systems and their supporting intransit storage and warehousing facilities.
- Develop procedures designed to maximize the movement capabilities of the existing transportation equipment and facilities.
- Collate the individual attack effects assessments prepared by the modal agencies.
- Assemble and consolidate the resource claims of the several modal transportation agencies in support of the total transportation system; act as the Federal claimant agency for these agencies by presenting consolidated claims to the appropriate Federal resource agency; finally, when the resource allocations were made, suballocate these resources to the individual transportation agencies.
- Advise on proposed or existing emergency legislation affecting transportation and recommend additional emergency legislation as necessary or desirable.
- Provide, as required, the administrative facilities necessary for performing emergency transportation functions.

Transportation Operating Agencies.

Emergency transportation functions of the transportation operating agencies would be performed in consonance with the overall policy direction of the Director, OET.

Interstate Commerce Commission. Provide guidance to and consult with operators of railroad, motor carrier, inland water carrier, and public-storage industries and the States. This covers:

- For railroad use: reduction of vulnerability to enemy activity; maintenance during emergency periods and restoration after enemy action; operation during national emergencies.
- For motor carrier use: reduction of vulnerability to enemy activity; operational direction during national emergencies.
- For inland waterway equipment and shipping: reduction of vulnerability of water craft and terminal facilities; operational direction of the inland waterways terminal facilities and craft during national emergencies.

ICC would additionally:

- Assemble, develop, and evaluate, as appropriate, requirements for domestic surface transporation and storage in emergencies.
- Estimate availability of assigned resources, analyze resource estimates in relation to estimated supply-demand relationships, develop appropriate recommendations and programs following these analyses, and provide data and assistance for national resource evaluation purposes.
- Claim resources required to operate the domestic surface transportation network (except highways, highway facilities, and inland waterway navigational facilities).
- Allocate the use of domestic interstate surface transportation and storage to operators and users; administer priorities systems as necessary to assure the movement of essential freight and passengers.
- Coordinate and direct, with appropriate private transportation and storage organizations and associations, transportation and storage fa-

cilities for movement of passenger and freight traffic on interstate systems.

- Analyze the operational conditions and capabilities of the domestic surface transportation industry; help alleviate chemical, biological, and radiological (CBR) contamination; allay conflicts between major shippers and overcome bottlenecks; effect conservation of material and manpower facilities, equipment, and supplies; and regulate, as required, the operation of storage industries.
- Salvage and rehabilitate domestic surface transportation and storage equipment and facilities, including decontamination of terminals, rights of way (except highways, highway facilities, and inland waterway navigational facilities), equipment, and shops.
- Make maximum appropriate use of existing nonmilitary facilities, technical competence, and resources of Federal, State, local and nongovernmental organizations and systems engaged in domestic surface transportation and storage facilities, to promote the effective and safe use and maintenance of transportation facilities, equipment, and services.
- Assist in carrying out national plans for stockpiling strategic and critical materials and items vital to domestic surface transportation and storage capability.
- Cooperate in developing national economic stabilization policies as they affect domestic surface transportation and storage programs.
- Invoke plans and procedures for financial and credit assistance to domestic surface transportation and storage organizations in need of assistance.
- Coordinate joint actions of emergency domestic surface transportation and storage programs of agencies assigned responsibility for any segment of such activity.

Civil Aeronautics Board:

- Provide for emergency management and postattack use of air carrier aircraft in the maintenance of the War Air Service Program (WASP), including emergency management of the WASP Air Priorities System and administration of controls and priorities of passenger and cargo movements.
- Assist FAA and the Department of Defense, as appropriate, in assessing the effects of attack on air carrier aircraft.
- Assist FAA in determining resource requirements for WASP.
- Assist FAA in salvaging supplies and equipment for, and in restoring or replacing, essential civil air carrier aircraft and services after attack.
- Periodically assess assigned air transportation resources in order to plan for their use, make supply-requirements estimates and develop recommendations and programs following analysis, and provide data and assistance for national resource evaluation purposes.
- Investigate the facts, conditions, and circumstances surrounding accidents in civil air operations; determine probable causes; and recommend remedial actions.

Federal Aviation Agency:

- Maintain operating continuity of the National Airspace System.
- Detect, monitor, and report chemical, biological, and radiological hazards at all FAA operated and controlled facilities.
- Report and analyze the effects of attack on all aeronautical facilities, including civil aircraft, civil airports and landing areas, air carrier operations and maintenance bases, aircraft repair stations, communications stations, and other ground-support facilities.
- Provide for the emergency management and use of civil airports and of civil aviation operating and maintenance facilities; direct the SARDA program for the emergency management of civil aircraft other than air carrier aircraft.
- Determine requirements and claim supporting resources to maintain or restore its own operating continuity and that of the civil air transport system, including CRAF, WASP, and SARDA.
- In coordination with local authorities, direct Federal activities, as required, for the emer-

gency clearance and restoration of essential civil airports in damaged areas.

Maritime Administration:

- Requisition or charter oceangoing vessels under the United States flag or vessels of foreign registry under effective or contractual United States control; operate oceangoing vessels under MarAd control; allocate shipping tonnage and accept allocations of tonnage from the NATO Shipping Pool for support of national or international shipping programs.
- Control forwarding of cargo to ocean port areas where MarAd maintains control of ocean shipping, coordinate convoy plans with naval authorities, and maintain statistical and intelligence data on vessel movements.
- Administer port traffic priorities and, in coordination with appropriate Federal agencies, control traffic through ocean and Great Lakes port areas.
- Allocate and, as necessary, reallocate ports and port facilities, equipment (including harbor service craft), and services.
- Assign maximum quota of cargo ocean lift for each port area.
- Determine need for port development; coordinate rehabilitation of substandard port facilities and development of alternative port and other water terminal facilities to meet essential requirements.
- Determine need for restoring damaged or destroyed ports and facilities or improvising new port facilities to maintain an adequate port capacity; direct, coordinate, and control the activities of Federal, State, local, and private agencies in such restoration or improvisation.
- Furnish current information on port conditions to the appropriate agency so it could approve and issue block releases for portbound traffic.
- Claim the supporting resources needed to carry out emergency responsibilities for ocean shipping and ports.
- Provide a means for administering the manpower and material needs of ocean shipping.

Bureau of Public Roads:

- Adapt all improvement programs to meet emergency requirements for all highway systems (and highways in the Federal domain), including emergency repair or restoration, and emergency provisions of highways, streets, bridges, and tunnels.
- Administer road programs for defense access, replacement, and maneuvers.
- Administer such foreign programs as justified in the emergency.
- Claim supporting resources required for all essential programs for public highway construction and maintenance, including urban streets, regardless of financing.
- Conduct continuous evaluation of highway needs based upon assessment of damage and coordinated with national recovery plans and programs.
- Conduct highway research of importance in an emergency.
- Arrange, in cooperation with appropriate Federal, State, and local government units or other agencies concerned, to safeguard and facilitate public highway travel. Such arrangements would include plans and procedures for emergency highway traffic regulation and for barricading or marking streets and highways leading into or out of restricted fallout areas.
- Provide, in cooperation with State or other highway agencies, for the detection, identification, monitoring, and reporting of radiological agents on highways and highway facilities.
- Maintain a capability in cooperation with State or other highway agencies to assess the effects of attack on highways and to report such assessments to the Department of Defense.
- Provide technical guidance to States and direct Federal activities relating to emergency operational responsibilities with respect to highways, roads, streets, bridges, tunnels, and appurtenances.

OET Air Carrier Division:

- Maintain an inventory of civil air carrier aircraft and their airlift capability.

• Evaluate emergency requirements for civil air carrier aircraft services.

• Recommend to the Director, OET, the allocation and reallocation of civil air carrier aircraft in accordance with established policies and procedures.

• Cooperate with CAB in distributing and redistributing civil aircraft in WASP among civil air carriers for optimum air carrier aircraft support of essential needs.

• Serve as the focal point for United States participation in activities of the NATO Board for Coordination of Civil Aviation (BOCCA).

Support Agencies.

Certain other Federal agencies have functions complementary to those identified with the transportation operating agencies. They, and their services, are:

Tennessee Valley Authority:

• Cooperate with ICC, the U.S. Army Corps of Engineers (Civil Works), and the U.S. Coast Guard in locating and removing river obstructions and in rebuilding or repairing channels, channel markings, and locking equipment on the Tennessee River and its navigable tributaries.

• Coordinate the use of terminal facilities along the Tennessee River waterway with terminal operators and shippers for optimum postattack use of the river.

• Assist in the diversion of Tennessee River shipments, as required, to land transport and vice versa for movement to final destination, in cooperation with ICC.

• Construct any necessary facilities to move goods and materials around inoperative locks.

Coast and Geodetic Survey:

• Provide nautical and aeronautical charts and related data on the United States, its territories, and possessions to meet military and civil navigation requirements (except for Great Lakes and inland waterways).

• Conduct hydrographic surveys to locate wrecks and other obstructions in ports and channels (except for Great Lakes and inland waterways).

• Establish emergency geodetic control for special-purpose surveys.

• Produce special charts for over-the-beach operations and emergency ports as required.

• Determine by survey methods the locations of emergency aids to air navigation.

• Conduct special geophysical and photogrammetric surveys and provide data as required for civil and military use.

Department of the Interior. The Department of the Interior has complete responsibility for preparedness planning and emergency control of construction, operation, and use of petroleum and gas pipelines. As the Federal resource agency responsible for petroleum and gas pipeline facilities and their use, it will provide OET with data on the capacity of such pipelines and the movement of petroleum and gas through them.

U.S. Army Corps of Engineers (Civil Works):

• Improve, restore or rehabilitate, operate, and maintain components of federally authorized river and harbor projects.

• Locate and remove obstructions to navigation; accomplish emergency dredging to clear and straighten navigation channels in harbors and navigable streams of the United States, its territories, and possessions.

• Conduct hydrographic surveys and provide nautical charts and related navigational material covering the Great Lakes system, Lake Champlain, New York canals, the Minnesota-Ontario border lakes and connecting waterways, and inland waterways generally.

• Collect, compile, and publish information on the physical characteristics and facilities of United States ports for the use and benefit of navigation.

St. Lawrence Seaway Development Corporation: Construct, maintain, and operate in United States territory the necessary deep-water navigation works in the appropriate area of the International Rapids section of the St. Lawrence Seaway.

Regional Offices.

The functions outlined above for the respective national organizations would be carried on at the regional level by their appropriate representatives in the field in the event of a break in communications and as otherwise required by their respective national headquarters.

Regional heads of Federal transportation claimant agencies would present claims for transportation services to the OET Regional Director in the event of a communications break.

Field offices of Federal transport agencies would consult directly with their counterparts at the national level or with other regional offices on appropriate matters.

In administering the emergency transportation program, transportation officials would be governed by the relative urgencies established by OEP.

CONTROL SYSTEMS

Principles.

Control systems in support of civil transportation would be initiated as necessary by the Federal Government in emergency. When effected, these systems in the form of traffic movement controls would be designed to assure movement of traffic responsive to the national emergency.

These control systems, if required, would be used only to the degree necessitated by the emergency situation.

Subject to such control systems, management of civil transportation would continue to be privately exercised, and the following basic principles of management would be recognized:

- Carrier management of operations.
- Direct shipper-carrier relationships.
- Traffic management by shippers and shipping agencies.

Policies and Procedures.

Requirements. Federal claimant agencies would be responsible for determining and claiming the transportation service requirements for the movement of that resource or function which they represent. These requirements would be in the form of time-phased traffic forecasts in an OET format and submitted to OET as an official statement of requirements.

These requirements would be analyzed by OET to identify potential conflicts, bottlenecks, and delays and thereby assist shippers and carriers in developing a balanced flow of essential traffic.

Capabilities Assessment. The Federal transportation operating agencies would assess the national transportation capability of interstate and international transportation systems. These data would be transmitted to OET, which would make a comparison of system capabilities with the total transportation requirements of shippers and travelers. Actions would be taken to eliminate or minimize any indicated shortages.

Detailed procedures for making rapid assessments of postattack capabilities of the transportation system would be developed by responsible Federal transportation agencies in coordination with OET.

Transportation would have high priority for restoration, including its requirements for manpower, materials, supplies, and equipment.

Federal transport agencies would be available to assist State and local governments in developing their capability for assessing residual intrastate and local transportation resources.

Allocations. OET would allocate civil transportation capacity to claimant agencies based upon the individual agency's traffic forecast of transportation movement requirements and the established competing claims. The essentiality of a claim would be based upon the overall national objectives.

Allocations of transportation capacity would be used to commit all or a portion of the available civil transportation in support of national defense. Adjustments of the traffic forecasts of some claimants might be necessary in those cases in which the allocation would be insufficient to satisfy the claim.

Allocations of transportation equipment and facilities would not be made unless overriding strategic or other considerations warranted such action. The recipient of such an allocation would have exclusive use of the equipment or facilities within the limits of the commitment and could suballocate such assets to subordinate elements as necessary.

Priorities. Overall national priorities would be established by OEP. Civil transportation priorities would be developed and controlled by OET, based upon and compatible with the overall national priorities. These priorities would be administered by ICC, CAB, and MarAd for the transport systems under their respective control.

Priority for the movement of transportation engaged solely in intrastate and local movements would be administered by the appropriate State transportation regulatory or control body or appointed transportation official.

Any person, agency, or organization initiating or making arrangements for movement of persons or goods by commercial carriers might claim a movement priority from the agency administering such controls. Any person, agency, or organization engaged in for-hire transportation must, when within its capacity to perform the service, accept persons or goods for transportation based upon a request when supported by a valid priority.

Detailed Procedures. Detailed procedures concerning transportation priorities, embargoes, sanctions, and permits will be provided in the OET "Manual of Transportation Allocations, Priorities, and Controls System."

DOMESTIC SURFACE TRANSPORTATION

Mobilization Procedures.

Emergency procedures are specified by a series of ICC "Transportation Mobilization Orders" (TM's) which would be implemented in an emergency by that agency. They are:

TM–1—Preference and Priority for the Transportation by Carrier for Hire of United States Military Personnel, Accredited Civil Defense Workers, and United States Mail. Requires that each passenger carrier for hire operating intercity shall give preference and priority over all other traffic to military and civil defense personnel and the United States mail.

TM–2—Rail Freight Embargo—Appointment of a Permit Agent. Requires specific action and the observation of permitting procedures by rail carriers after proclamation of a civil defense emergency.

TM–3—Motor Freight Embargo. Requires specific action by motor carriers after proclamation of a civil defense emergency.

TM–4—Inland Waterways Freight Embargo. Requires specific action by inland water carriers after proclamation of a civil defense emergency.

TM–5—Disposal by Carriers of Undeliverable Shipments. Provides direction to rail, motor, and inland water carriers when, by reason of enemy action, they would be unable to deliver commercial or military freight in their possession.

TM–6—Control of Railroad Tank Cars. Provides a central point for control of liquid tank cars and facilities.

TM–7—Rerouting of Rail Traffic. Provides direction to carriers to reroute or divert traffic over any available route when the rail system had been subjected to enemy action.

TM–8—Direction to Certain Over-the-Road Motor Carriers of Property Regarding Routes, Diversions, and Service to Certain Destinations. Provides direction to motor carriers of property relative to diversion and rerouting as a result of enemy action and increases operational area of carriers to or from any attacked area.

TM–9—Direction to Certain Intercity Common Carriers of Persons by Bus to Serve Certain Points. Provides direction to passenger motor carriers relative to diversions and rerouting as a result of enemy action and increases operational area of motor carriers of persons at attacked points.

TM–10—Control of Motor Transport Vehicles. Provides a central point for control of motor transport vehicles for operation in areas subjected to enemy action.

TM–11—Control of Freight Shipments to or within Port or Storage Areas. Requires carriers to observe specific conditions, places responsibility on the Commission to develop permititng procedures, and indicates certain exceptions. (The purpose of this order is to avoid congestion in port areas and to assure effective coordination of domestic surface transportation with ocean shipping in periods of national emergency.)

TM-12—Inventory and Disposition of Food and Medical Supplies Requisitioned by Government in Possession of Railroads and Motor Carriers. Provides for disposition of food and medical supplies in possession of carriers through the Department of Agriculture and the Department of Health, Education, and Welfare.

TM-13—Control of Liquid Transport Vessels. Provides a central point for the control of liquid transport vessels.

Highway Use.

The Federal Highway Administrator, BPR, has issued an order* effective during a civil defense emergency to regulate, allocate, and promote the availability and use of all highways within the United States. The order provides that the Administrator (or such agencies of the Federal, State, and local governments as he may designate) may as necessary regulate motor-vehicle traffic using highways and make use of all available highways deemed safe for travel.

Inland Waterways.

TVA, by means of its damage assessment system as well as communications with the National Resource Evaluation Center and the resource agencies concerned, would effect specific actions in order to make the Tennessee River system as navigable as possible.

The Saint Lawrence Seaway Development Corporation, by means of its damage assessment system as well as communications with the National Resource Evaluation Center and the resource agencies concerned, would act to make the United States-controlled sections of the St. Lawrence Seaway as navigable as possible.

The U.S. Army Corps of Engineers District Engineers would perform waterway rehabilitation and construction throughout the United States and (except for the Tennessee River System) supply damage assessment data for the National Resource Evaluation Center. Manpower, equipment, materials, and services needed for this work and for operation and maintenance of essential authorized projects serving navigation needs would be claimed by each District Engineer through the supervising Corps of Engineers Division Engineer, who would be claimant at the regional level. The Chief of Engineers would act as associated claimant to OET at the national level.

AIR TRANSPORTATION

Use of Civil Aircraft.

OET through its Air Carrier Division would allocate civil air carrier aircraft to meet the needs of the Department of Defense for military operations (CRAF) and to the Civil Aeronautics Board for essential civilian needs (WASP).

The Air Carrier Division (OET) would provide continuity between the NATO Board for Coordination of Civil Aviation (BOCCA) and OET.

At each level of government where air support were assigned a mission, provisions for obtaining flight priorities under existing air traffic rules and appropriate priorities and allocations for fuel, manpower, maintenance, and other supporting services must also be established in consonance with the OET policies controlling movements at that level.

Emergency Air Service Pattern.

CAB would implement an emergency air service pattern through WASP to provide transportation for maximum priority traffic.

Under WASP, provision has been made for the maintenance of essential civil air routes and services by distribution and redistribution of air carrier aircraft among civil air transport carriers after allocation of aircraft to CRAF.

CAB would issue orders to provide the air carriers, during the initial phases of an emergency, authorization and direction for the performance of essential air services.

During an emergency CAB would implement any further directives necessary to assure

*BPR-THM-1 (F.R. Doc. 62-2755, March 21, 1962).

the continuation of air service until such time as priority traffic requirements could be determined and a subsequent redistribution of aircraft could be made to implement a controlled emergency air service program.

WASP Air Priorities System.

The control and priority of passenger and cargo air movements operating under WASP would be implemented under national plans. These include the Interim Air Priorities System (OET–P–1) and the successor CAB plan for a worldwide air priorities system.

OET–P–1 would become effective upon declaration of a national emergency by the President and the issuance by OET of implementing directives. Such interim procedures for determining preference and priority of traffic moving by the civil air carriers during the initial emergency period would be administered by each carrier and would remain in effect until superseded.

The CAB plan for an air priorities system to assure the effective control and use of civil air transport resources of the Nation would be activated by CAB pursuant to appropriate OET directives.

Since the emergency air service pattern would be periodically adjusted to meet essential traffic requirements, CAB would maintain an air priority traffic survey to assure adequate control and maximum utilization of civil air transport resources. The survey would monitor the flow of priority traffic and provide data to assist in determining adjustments to the emergency air service pattern as needed to meet priority traffic demands.

Air Carrier Aircraft Management.

In an emergency CAB would be responsible for the management of air carrier aircraft allocated to it by the Department of Commerce under the WASP program. CAB directives would be issued to owners and operators of such aircraft to assure the development and maintenance of an air transportation program in accord with national emergency transportation policy.

CAB would use appropriate resources of the Federal and State governments and the air transport industry in developing WASP to meet priority traffic requirements under emergency conditions. The Board would, however, retain direct management of WASP resources in order to assure the maintenance of the emergency air service pattern required to meet the national claimancy requirement on a worldwide basis.

WASP Management. The air carriers would provide the actual operational management under the emergency air service pattern established by CAB. The primary responsibility of other Federal agencies having an assigned interest in civil air transportation would be to provide essential support as appropriate to maintain continuity of an emergency air service pattern under WASP. State and local governments would also provide a supporting role in maintaining both intrastate and interstate emergency air service under WASP.

Claims for Air Carrier Airlift Service. All claimants for transportation priorities provided under WASP in an emergency would conform to the regulations established by the CAB–WASP Air Priorities System. The peacetime carrier-shipper relationship would be maintained.

Requests for air transportation during the initial stages of an emergency would be directed to the air carriers under interim priority regulations set forth in CAB Order ATM–2. Upon activation of the formal CAB-administered air priorities system, requests for priority air transportation would be directed to the nearest Regional Air Priorities Control Office.

Resource Support for Air Carrier Airlift. CAB would assist FAA in the development of requirements for essential resources needed to support air carrier operations and would support their submission to appropriate resource management authorities.

Claimancy. Air carrier operations requirements for maintenance, repair, and operating supplies (MRO) are included in the Defense Materials System (DMS) arrangements for securing priorities and allocations.

Authority for delegation of priorities and allocations of controlled materials has been delegated by OEP to the Business and Defense Services Administration (BDSA), Department of Commerce. BDSA has redelegated part of its authority to DOD, which has in turn designated FAA as an "associated agency." This permits FAA to make allotments and to apply, or assign to others the right to apply, Defense Order (DO) ratings and allotments numbers for maintenance, repair, and operating supplies for domestic and foreign commerce airlines.

SCATER.

"The Plan for Security Control of Air Traffic and Electromagnetic Radiations"* requires FAA and appropriate military authorities to take specified joint action during an air defense emergency to effect security control of civil and nontactical military aircraft entering, departing, or moving within the United States or its coastal approaches. FAA would effect control of such air navigation aids and aeronautical communications as might be required.

Civil aircraft would be grounded upon the declaration of an air defense emergency in accordance with the SCATER Plan. As the situation permitted, air carrier operations would be resumed in accordance with priorities established in the plan. General aviation aircraft in the State and Regional Defense Airlift (SARDA) Plan would resume operations in support of essential priority activities under the direction of appropriate authorities as specified in the plan.

Additional details concerning the SCATER Plan may be found in the joint publication of the Department of Commerce and the Department of Defense, "Plan for Security Control of Air Traffic and Electromagnetic Radiations During an Air Defense Emergency," dated May 7, 1957.

SARDA Management.

SARDA would be activated by joint or unilateral action of FAA and State governors (or their designees) in accordance with existing arrangements in individual States. This plan may be implemented in whole or in part, as necessary, to fulfill national and State emergency requirements.

*The SCATER Plan is under revision and will be published under the name of SCATANA (Security Control of Air Traffic and Air Navigation Aids).

FAA would issue guidelines to provide for the use of State aviation organizations to manage other than air carrier aircraft resources. These organizations would function in primary control of these aviation resources under emergency conditions, subject to the general direction of FAA if required by overriding Federal needs.

The actual task of providing other than air carrier airlift support would be the responsibility of aircraft owners, operators, airmen, and airport managers who perform the actual operating functions.

Requests for other than air carrier airlift should be submitted to the emergency transportation authority at the State or local level.

Requirements for resources in bulk to support the essential airlift involving other than air carrier aircraft would be consolidated by FAA General Aviation District Offices and Airport District Offices for submission to appropriate management authorities at local, State, and regional levels as required.

Air Traffic Control.

FAA would authorize the use of airspace upon request, doing so under the direction of appropriate Air Defense Commanders. Dispatch of aircraft would be the responsibility of military commanders, air carrier officials, civil government officials, or private citizens performing essential wartime missions under legitimate authority. Policies and procedures for processing altitude reservation and other flight plans, including responsibilities currently assigned to the Central Altitude Reservation Facility (CARF) and to Air Route Traffic Control centers, would remain in effect unless modified by competent authority.

Rehabilitation of Civil Air Facilities.

Owners, operators, or managers would report damage to civil aviation resources, other than manufacturing plants, to the manager of the nearest surviving civil airport. Airport managers would consolidate such reports received and forward these to the nearest surviving FAA General Aviation District Office, as well as to any local or area transportation resource management body and to local civil defense authorities.

Two general plans determine the level of civil airport restoration operations. First in order of priority is the military plan to use certain civil airports during an emergency in support of military operations. Second in order of consideration is the civil plan to use certain airports in support of air carrier and other than air carrier aircraft.

Aeronautical Charts.

The Coast and Geodetic Survey would:

- Maintain at selected locations up-to-date files of selected aeronautical charts, chart reproducibles, and critical materials.
- Maintain contact with commercial printing plants for emergency production of charts.

OCEAN TRANSPORTATION

Shipping.

In an emergency, MarAd would take the following actions:

- Implement plans for assembling and analyzing data on ocean shipping requirements.
- Acquire ocean shipping through requisitioning, charter, reactivation of reserve fleet ships, or acceptance of NATO Shipping Pool allocations.
- Through the ships-warrant system obtain the use of the ships of neutral nations.
- Direct the operation of, and act to repair, provision, man, and bunker, oceangoing ships owned or acquired by the Government.
- Direct vessel movements and allocate tonnage to meet approved requirements.
- Exercise forwarding authority on cargo moving to port areas and destined for MarAd-controlled ships.

Ocean Ports.

Public Orders. In an emergency, MarAd would publish the following public orders:

- *General Order MA-TPM-1*—Restrictions Upon the Transfer, Change in Use, or Terms Governing Utilization of Port Facilities.
- *General Order MA-TPM-2*—Restrictions Upon the Use of Port Facilities Without a Ship Warrant.
- *General Order MA-TPM-3*—Removal of Export, Import, Coastwise, and Intercoastal Freight From Port Area.
- *Delegation Order MA-TPM-1*—Appointment of Federal Port Controllers and Acting Federal Port Controllers: Delegations of Authority.

Port Control Officer. To assure the free flow of traffic to, from, and within port areas in time of emergency, a local port control officer would be responsible for coordination and control of ocean and land transportation use of the facilities, equipment, and services of a port.

He would make appropriate disposition with respect to general restrictions to be placed upon the transfer, change in use, or terms governing the utilization of port facilities and would otherwise perform the duties and exercise the powers vested in the Maritime Administrator.

This officer represents the authority of the United States in the port and works in close coordination with Federal transport and shipping agencies, the Department of Defense, and the local port industry.

Other Emergency Procedures. With respect to United States port systems and facilities, MarAd would also:

- Establish systems for receiving field reports and for issuing port advisories on the status of port conditions, operations, and capabilities; disseminate a national damage assessment recapitulation and evaluation.
- Determine the necessity for and feasibility of the use of alternative ports and port facilities; coordinate and, as necessary, direct and control the use of usable ports and port facilities, damaged or undamaged; and direct the diversion of freight enroute to affected port areas to such alternative usable ports or to appropriate interior locations.
- Cooperate with local public officials and civil defense agencies in providing emergency berthing facilities and the use of commercial port-

operating equipment and port personnel for civil defense purposes.

Materials, Supplies, and Facilities.

In an emergency MarAd would:

- Procure supplies and equipment necessary for the reactivation and operation of reserve shipyards and for outfitting new shipyards.
- Activate a priorities organization and obtain adequate priority ratings or allocations for vessel materials and supplies.
- Cancel leases and permits for private occupancy of MarAd property.
- Suspend all disposal activities except scrapping and salvage.
- Contact manufacturers of marine components to determine capability for producing or furnishing essential supplies and equipment in acordance with production allocation regulations.
- Negotiate with contractors concerning claims under prime contracts and subcontracts for disposition of unacceptable repair parts, materials, and supplies and for provision of lists of scrap, salvage, and unrequired materials.

Manpower.

In an emergency MarAd would:

- Activate, in cooperation with the manpower agency, a recruitment and utilization program for manpower needed to meet the requirements of ocean shipping and for shoreside vessel operation.
- Administer a uniform deferment procedure to retain seamen aboard ships and to create and train a supply of former seamen and recruits to man vessels.
- Activate the National Defense Executive Reserve units to administer vessel operations and Federal control of United States ports.

Nautical Charts.

The Coast and Geodetic Survey would:

- Maintain at selected locations up-to-date files of selected nautical charts and chart reproducibles, except for the Great Lakes, as well as critical materials.
- Maintain contact with commercial printing plants for emergency production of charts.

The U.S. Army Corps of Engineers (Civil Works) would maintain essential records and provide nautical charts with respect to the United States Great Lakes channels and harbors.

APPENDIX K—EXECUTIVE ORDER 11725
TRANSFER OF CERTAIN FUNCTIONS OF THE OFFICE OF EMERGENCY PREPAREDNESS

Under and by virtue of the authority vested in me by Reorganization Plan No. 1 of 1958, Reorganization Plan No. 1 of 1973, the Defense Production Act of 1950, as amended (50 U.S.C. App. 2061, et seq.), the Disaster Relief Act of 1970, as amended, (42 U.S.C. 4401, et seq.), and Section 301 of title 3 of the United States Code, and as President of the United States of America, it is hereby ordered as follows:

SECTION 1. The Secretary of Housing and Urban Development is designated and empowered to exercise, without the approval, ratification, or other action of the President:

(1) All authority vested in the President by the Disaster Relief Act of 1970, as amended, and assigned or delegated to the Director of the Office of Emergency Preparedness by Executive Order No. 11575 of December 31, 1970, as amended by Executive Order No. 11662 of March 29, 1972.

(2) All authority which was vested in the Office of Emergency Preparedness, or the Director thereof, by the Disaster Relief Act of 1970, as amended, and which was transferred to the President by Reorganization Plan No. 1 of 1973.

(3) All authority which was vested in the Director of the Office of Emergency Preparedness with respect to determining whether a major disaster has occurred within the meaning of (A) section 16 of the act of September 23, 1950, as amended, (20 U.S.C. 646), (B) section 7 of the act of September 30, 1950, as amended (20 U.S.C. 241–1), and (C) section 762(a) of the Higher Education Act of 1965 as added by section 161(a) of the Education Amendments of 1972, Public Law 92–318, 86 Stat. 288 at 299 (relating to the furnishing by the Commissioner of Education of disaster relief assistance for educational purposes), and which was transferred to the President by Reorganizational Plan No. 1 of 1973.

(4) All authority vested in the Office of Emergency Preparedness or the Director thereof, including serving as Chairman of the National Council on Federal Disaster Assistance, by Executive Order No. 11526 of April 22, 1970.

(5) All authority vested in the Director of the Office of Emergency Preparedness by Executive Order No. 11678 of August 16, 1972, relating the administration of certain temporary disaster relief provisions, and

(6) All other incidental authority relating to matters described in paragraphs (1) through (5) of this section that has been vested in the Office of Emergency Preparedness or the Director thereof by the President by Executive order, proclamation, letter, memorandum, or other form of directive, or otherwise.

SECTION 2. The Secretary of the Treasury is designated and empowered to exercise, without approval, ratification, or other action of the President, all authority which was vested in the Director of the Office of Emergency Preparedness by section 232 of the Trade Expansion Act of 1962, as amended (19 U.S.C. 1862), and which was transferred to the President by Reorganization Plan No. 1 of 1973.

SECTION 3. All authority vested in the Director of the Office of Emergency Preparedness as of June 30, 1973, by Executive order, proclamation, or other directive issued by or on behalf of the President or otherwise, other than that specified in section 1 (relating to disaster relief), and section 2 (relating to import investigations) of this order, is hereby transferred to the Administrator of General Services who shall exercise such authority in conformance with such guidance as may be provided by the National Security Council, and, with respect to the economic and disposal aspects of stockpiling of strategic and critical materials by the Council on Economic Policy. Those functions include, but are not limited to functions under—

(1) Executive Order No. 10242 of May 8, 1951, relating to employment of certain part-time and temporary advisory personnel under the Federal Civil Defense Act of 1950;

(2) Executive Order No. 10296 of October 2, 1951, as amended, relating to the designation of critical defense housing areas pursuant to section 101 of the Defense Housing and Community Facilities and Services Act of 1951, U.S.C. 1591;

(3) Executive Order No. 10421 of December 31, 1952, as amended, relating to the protection of facilities important to the national security;

(4) Executive Order No. 10480 of August 14, 1953, as amended, relating to the administration of the Defense Production Act of 1950, as amended;

(5) Executive Order No. 10494 of October 14, 1953, relating to the liquidation of the Economic Stabilization Agency created under the Defense Production Act of 1950 as amended;

(6) Executive Order No. 10601 of March 21, 1955 (section 3), relating to the designation of strategic materials to be acquired in return for surplus agricultural commodities (Supplemental Stockpile);

(7) Executive Order No. 10634 of August 25, 1955, relating to loans under the Defense Production Act of 1950 with respect to defense facilities damaged by a major disaster;

(8) Executive Order No. 10705 of April 17, 1957, relating to the radio stations during time of war (see Executive Order No. 11556 of September 4, 1970);

(9) Executive Order No. 10900 of January 5, 1961, relating to the Supplemental Stockpile;

(10) Executive Order No. 10952 of July 20, 1961, relating to civil defense functions;

(11) Executive Order No. 10958 of August 14, 1961, relating to civil defense functions;

(12) Executive Order No. 11051 of September 27, 1962 (except sections 404(a) and 405), relating to nonmilitary emergency preparedness planning, particularly under the National Security Act of 1947, as amended, and related functions under the Defense Production Act of 1950, the Strategic and Critical Materials Stockpiling Act, the Supplemental Stockpile and the Buy American Act;

(13) Executive Order No. 11179 of September 22, 1964, relating to the National Defense Executive Reserve;

(14) Executive Order No. 11415 of June 24, 1968, relating to the National Health Resources Advisory Committee;

(15) Executive Order No. 11490 of October 28, 1969, relating to the assignment of emergency preparedness functions to Federal departments and agencies;

(16) Executive Order No. 11556 of September 4, 1970, relating to telecommunications contingency planning;

(17) Section 203(n) of the Federal Property and Administration Services Act of 1949, as amended (40 U.S.C. 484(n), relating to the disposal of surplus property;

(18) All other incidental authority relating to matters described in paragraphs (1) through (17) of this section that has been vested in the Office of Emergency Preparedness or the Director thereof by the President by Executive order, proclamation, letter, memorandum, or other form of directive, or otherwise.

SECTION 4. All rules, regulations, orders, determinations, permits, contracts, certifications, licenses, and privileges (including all delegations of authority and delegations of authority to redelegate) which have been issued, made, granted, or allowed to become effective by the President, the Director of the Office of Emergency Preparedness, or the Office of Emergency Preparedness or any official thereof, in the performance of functions which are transferred by this order and which are in effect at the time this order takes effect, shall continue in effect according to their terms until modified, terminated, superseded, set aside, or revoked by the President, the Secretary of Housing and Urban Development, the Secretary of the Treasury, or the Administrator of General Services, as the case may be, or other authorized officials, or by operation of law.

SECTION 5. Pursuant to the authority vested in me by section 703 of the Defense Production Act of 1950 as amended (50 U.S.C. App. 2153), the Administrator is authorized to establish a subordinate agency within the General Services Administration to perform such of the functions under the Defense Production Act of 1950, as amended, as have been delegated to him under this order or any other Executive order, as the Administrator deems appropriate. The Administrator is authorized to appoint a head of that agency who shall be compensated at the rate now or hereafter established for level V of the Executive Schedule (5 U.S.C. 5316). That agency and its head shall perform such functions, in addition to functions under the Defense Production Act of 1950, as amended, as the Administor may, from time to time, prescribe.

SECTION 6. (a) The transfer of functions accomplished by this Executive order shall in no way be deemed to diminish the need for, or the scope or priority of, the performance of those functions.

(b) All Federal executive departments and agencies are directed to cooperate fully with officials exercising authorities transferred under this order.

SECTION 7. Sections 404(a) and 405 of Executive Order No. 11051, as amended, are hereby revoked.

SECTION 8. This order shall be effective as of July 1, 1973.

THE WHITE HOUSE
June 27, 1973

(signed)
Richard Nixon

P R O P O S E D   D R A F T

Guide for

The Protection of

STREET AND HIGHWAY TRANSPORTATION FACILITIES

From Sabotage and Enemy Attack.

This document is published as an
INTERIM GUIDE
for the protection of street and highway
facilities. While the text may be altered
in the final publication, the principles
stated herein shall remain the same.

DEFENSE TRANSPORT ADMINISTRATION
Washington 25, D. C.

DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
Washington 25, D. C.

August 2, 1954

PROPOSED DRAFT

PROPOSED DRAFT

ACKNOWLEDGMENT

This document was prepared by a Task Group consisting of representatives from Government and Industry with the assistance and advice of representatives of street and highway transportation industries, who have given their services in a spirit of cooperative helpfulness, clearly demonstrating their sense of responsibility to these matters.

Among the organizations contributing were the American Trucking Associations, Inc., the American Transit Association, the National Association of Motor Bus Operators, and the American Association of State Highway Officials.

PROPOSED DRAFT

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TABLE OF CONTENTS

PROPOSED DRAFT

PART V - PROTECTIVE MEASURES FOR HIGHWAY TRANSPORTATION SECURITY (Cont'd)

INTRODUCTION

Transportation service is essential to our national livelihood in peace and war. Foremost among the providers of highway service are the trucking firms, urban transit companies, intercity bus lines, and taxi fleets, collectively referred to as highway transportation industries.

This manual suggests procedures for the protection of these industries against espionage, sabotage and enemy attack. It is designed to assist the owners and operators of highway transportation services in determining what should be done in advance of a war emergency to protect their properties from damage and destruction. Steps to aid early restoration of damaged property are also indicated.

Both fixed and mobile facilities are considered. Fixed facilities discussed include terminals, garages, shops and storage yards as well as tracks, power systems, bridges and tunnels which may directly or indirectly affect one or more of the industries. Mobile facilities discussed include trucks, buses, trolley buses and automobiles which operate over highways, and streetcars which operate on rails. Procedures for the protection of subway and elevated rail services, being of a highly specialized nature, are not covered.

The protection of highway transportation facilities is the subject of special consideration because of the nature of the industry and its fundamental difference from the conventional industrial facility or factory. Because the industry provides a service rather than a manufactured product, the hazards to which it is subject and the measures taken to overcome them are essentially different from those of a production factory. Some of the characteristics which make it different are:

- Fleets are not usually concentrated. They are dispersed both night and day.
- There is never the concentration of machinery and products as exists in mass production plants.
- However, vehicles parked together or in temporary storage represent valuable concentrations of industrial property.
- Routes of the carriers, except street railways and trolley buses, are not fixed. If roads and streets are blocked, vehicles can detour.
- There is seldom any large concentration of employees, except for meetings and special events.

- Concentration of persons in passenger terminals makes threat of panic a danger.

- There are elements of danger in things moving not present in fixed facilities. Both passengers and loads in transit constitute special problems and obligations.

- Communications used in fleet dispatch are vitally important to the industry.

- A great degree of reliance must be placed on employees who operate vehicles away from direct supervision.

- If terminals, garages, or shops are destroyed other substitute or makeshift locations can usually be found.

- Both the fuels used and the products needed to maintain vehicles are often scarce and subject to restrictions in time of emergency.

PART I

SECURITY FOR HIGHWAY TRANSPORTATION INDUSTRIES

Our remoteness from enemy countries in past wars saved us from the necessary of testing the preparations made for our local protection. Now we can no longer rely on geographical distance to protect us. American industry should be keenly alert to the threat of a formidable and well-organized enemy within and without our borders. The defense of the nation no longer consists of military action alone. Today the continuation of full industrial production or service is an essential part of defense.

Transportation is one of the keystones on which the economy and productive ability of this country stand.. Highway transportation services form a very substantial and vital part of the facilities employed in the nation's commerce and business. They provide the distribution system between railroad, waterway and air terminals and factories, homes and offices. They provide a transportation system which under many conditions is more efficient and less costly than any other mode of transportation. These services possess a high degree of flexibility and adaptability.

The Time for Action is Now

An aggressive enemy can bring war to our doors. Such an attack may come without warning. No part of this country is immune. Transportation will be a prime target because its loss or disruption could mean the ruin of many dependent industries.

Direct invasion of our shores can disrupt transportation and reduce industrial production, but the most probable acts of an enemy are espionage and sabotage or attack by aircraft or guided missiles. In any emergency the demands on highway transportation will be increased considerably. The industry must be able to meet this increase, even in the face of partial loss of their means to provide it.

As countries can be at war without a declaration there is no way of defining the end of a "cold war" and the beginning of a "shooting war". Since it is not likely that any notice will be given as to when a "cold war" may become "hot" and include not only widespread acts of sabotage but actual enemy attacks, it is of prime importance that security plans for highway transportation industries be formulated in detail now, and that all employees who will be involved in these security measures fully understand their responsibilities so that no time will be lost when an emergency occurs.

In an emergency, it is likely that highway transport will be called upon to shoulder a disproportionate share of the burden of moving men and materials where they are needed most. The nature of the service provided by highway transportation--its versatility and dispersion--makes it particularly vital to the defense effort. These same characteristics tend to lessen its vulnerability; the normal dispersion of mobile equipment is itself a form of security. This does not, however, lessen the need for special protective measures.

The risks are real, not speculative. The stakes are large. The pay-off may be in terms of lives saved, a business preserved, a war won.

Responsibilities of Management

Private management in highway transportation, as in other industries, is expected to provide the necessary protection of its properties and operations to supplement the over-all protection provided by Government. Management and its employees, therefore, must play vital roles in the planning and operation of protection programs on their own properties, and, to a lesser degree, along their routes of travel.

It is not economically feasible for highway transportation managements to maintain full facility protection measures in effect during periods of international tension. Under these circumstances, planning must be flexible enough to provide for the initiation of protective measures by phases or degrees. Yet, when it appears that a full-scale war is imminent, the full facilities protection plan applicable to highway transportation, in all its phases, should be placed into effect immediately. Further, the effectiveness of the program should be reviewed often to determine what further measures are to be adopted.

Obviously, no method of protection can be established that would be capable of preventing or overcoming the effects of all disasters, any more than the best of safety programs can entirely eliminate accidents. But, with proper knowledge of protection principles, the highway transportation industries can apply some techniques and procedures which will materially protect terminals, shops, vehicles, and personnel, at reasonable cost, from many of the hazards both in peace and war.

Perhaps the most important duty of the owner or operator of a highway transportation service is the selection of those properties which if damaged or destroyed would seriously curtail or stop services. Maintenance shops and garages will probably be high on the selected list. Terminals and offices may also be high on the list, but the opportunity for full protection may be limited. Management must evaluate the degree of compromise required between security needs and operating efficiency. Analysis may disclose that some facilities should be given the highest degree of protection because their loss would cripple operation. Other facilities may be graded lower and some may be left unprotected on the theory that the security interest is so small that it may be assumed as a calculated risk. These are grave decisions to be based on the company's own interests and the necessity of the service to the public. All this will depend in large measure on the availability of time and the manpower, capital, and equipment which can be utilized to provide security while still meeting other necessary demands.

Management should also study available substitutes to its services in order to allow continued transportation of people and freight in the event certain vital resources are lost, are in short supply, or made subject to allocation. Consideration must be given to alternate sources of fuel and power, communications and utilities, water, materials, replacement parts, vital tools, maintenance equipment and machinery, etc. and to alternate communications systems. Such analysis should disclose criteria for future utilization of mobile equipment and the location and design of terminals.

Many basic facilities such as the streets, roadways and bridges used are of a public nature and not of primary responsibility to the individual fleet or transit operator. At the same time, the operator cannot neglect consideration of these facilities and the effect their loss or denial would have on his operation.

In conjunction with the plan adopted by management for the protection of its facilities, close contact should be maintained with community civil defense groups, and the advice of responsible government authority should be sought when needed. Federal agencies concerned with the field of internal security are listed in U. S. Government Organization Manual and the Handbook of Emergency Defense Activities, which can be obtained from the U. S. Government Printing Office, Washington 25, D. C.

PART II

HAZARDS TO HIGHWAY TRANSPORTATION INDUSTRIES

Management must appraise the probability of damage to facilities from hazards inherent in service operation; and from espionage, sabotage and enemy military attack. It should visualize what might occur and provide appropriate safeguards against its occurrence.

Hazards Inherent in Service Operation

Protection is not confined to meeting the most hazardous situations. Under a defense program, highway transportation is called upon to transport quantities of defense materials and to carry workers to and from defense facilities. With the increase in traffic volume, routine hazards are intensified. Hazards peculiar to the highway and street railway industries include:

- Damage and loss of freight due to mishandling, pilferage, theft, etc.
- Traffic accidents resulting in injury or death to passengers, damage or destruction to vehicles and cargoes.
- Shop mishaps incident to the maintenance, service, or repair of vehicles and equipment.
- Loss of fuel and other operating supplies through contamination, leakage, fire, etc.
- Possibility of panic and confusion in passenger terminals.
- Loss of control through disruption of communication facilities used in fleet dispatch.
- Disruption of street railways through loss of power, damage to bridges, tracks and switches.
- Dangers incident to the transportation of explosives.
- Operational delays and interruptions to schedules.

In combating these expanding hazards a transportation company must employ constant and increasing vigilance, and adjust its routine safety, employee welfare and other programs accordingly. The importance of such programs cannot be overemphasized because they are the foundation for a broader protection program.

Guidance and information concerning hazards such as fire, accidents, etc. can be obtained from underwriters, fire insurance companies, trade associations, and government agencies.

Espionage

Enemy action is often based on espionage. The information so collected contributes to an evaluation of the nation's war potential and may be used by the enemy in subversive activities and armed force attack. Freedom of speech makes espionage activities against us very fruitful. The highway transportation industries, by their very nature, cannot conceal many phases of their operations. However, by the use of discretion, much that might be useful to an enemy can be kept from him. Since it is reasonable to assume that the opening of the next war may be by unheralded attacks upon our cities, with transportation installations as prime targets, it follows that an enemy is now and will be continuously endeavoring to obtain complete data on these facilities.

Modern espionage is no longer of the "cloak and dagger" type. Of far greater importance is the continuous and painstaking accumulation of detailed information, which although developed piecemeal, finally fits together to complete a precise picture of, say, a transportation industry.

Espionage agents specifically seek information such as the following:

- Route of operations.
- Schedules.
- Location of major terminal facilities.
- Layout of each facility.
- Number of vehicles owned and types.
- Kinds of traffic or nature of freight carried.
- Volume of traffic.
- Operating habits and procedure.
- Information on number and attitude of employees.
- Anticipated shipments or movements.
- Detailed information on terminals and shops, shop

equipment, loading or unloading docks, relay points, layover points, gassing points, dispatchers' offices.

- Location of offices and confidential files.

- Measures in force for security, and to prevent sabotage.

Espionage agents may be expected to use great ingenuity in obtaining information by:

- Infiltration into the industry as drivers, mechanics, dispatchers, inspectors, or by other means.

- Stealing waybills and freight documents or information from records such as confidential letters, dispatchers' sheets, and from waste paper.

- Hitching rides on vehicles and inducing drivers to "talk shop".

- Listening to drivers' conversations at roadside stops or social gathering places of employees.

- Reporting from personal observations and studies made of the company's operations and practices, trips, loads, etc. while riding as a passenger or impersonating traffic or other officials.

- Using "fronts" such as commercial concerns, travel agencies, import-export associations, insurance agencies, businessmen's groups and other organizations to obtain pertinent information.

- Using threats, bribery, blackmail, and other means of inducing employer or employee to expose various valuable information.

In general, espionage may be rendered ineffective or made more difficult by the application of routine security measures and by the careful selection of employees.

Sabotage

Industrial sabotage is a method in which Communists have been well trained for years. Disruption of transportation is a key factor in effective sabotage. The results which may be accomplished by skillful sabotage, and the existence of substantial groups within this country willing to undertake such work make this hazard very great.

Compared with the far-reaching consequences to the transportation industry, an act of sabotage involves only negligible expenditure by the enemy. It is realistic, therefore, to assume that military attack may be preceded by a series of well planned sabotage efforts aimed at disrupting key transportation facilities.

Further, the enemy may attempt to create fear psychology by widely separated acts of sabotage. Such fear can cause panic and result in traffic tie-ups, stampedes and confusion in terminals, loss of the use of vehicles and drivers caught up in the panic, and increased demands for passenger transportation.

Panic may be a far greater threat than any other weapon. The most successful defense against it is awareness and alertness on the part of everyone. Employees must be told what dangers threaten, how they may be recognized, what protective measures are available and what defenses should be utilized.

The tools and methods of sabotage are limited only by the skill and ingenuity of the saboteur. The saboteur may or may not possess a high degree of technical knowledge. Hence, the device or agent utilized for sabotage may range from the crude to the scientific.

The highway transportation industries are well aware of inherent sabotage possibilities to their operations. A few examples of these are:-

- Mechanical damage to vehicles -- breakage, removal of parts, failure to lubricate, maintain or repair.

- Tampering with vehicle safety devices such as lights, brakes, mirrors so as to induce accident.

- Placing distractions or false traffic control devices on roadways so as to mislead driver or cause accidents.

- Deliberately induced traffic jams, bottlenecks and large-scale traffic tie-ups.

- Placing obstructions on roadways to damage tires and vehicles, delay or obstruct travel, or as part of planned highjacking.

- Blocking, jamming or otherwise obstructing street railway tracks and switches.

- Weakening or destroying bridges and tunnels so as to cut or reduce roadway capacity and thus prevent or delay travel.

- Contamination of fuel with chemicals so as to cause loss of power, explosion, or damage to mechanical parts.

- Slashing of tires so as to weaken and render them useless and irrepairable.

- Insertion of abrasives, sand and other foreign matter into shop equipment.

- Destruction of vehicles, shops, fueling facilities, etc. by explosives, electrically activated bombs, time bombs, etc.

- Ordinary means of arson and use of incendiary devices in starting fires in shops, terminals, garages, warehouses, etc.

- Interfering with or interrupting power, especially of electrically powered street railways.

- Jamming or cutting communications systems used in dispatch and fleet control.

- Damage, pollution or destruction of goods in transit.

- Theft of vehicles, parts, tools.

- Fomentation of unwarranted strikes, jurisdictional disputes, boycotts, unrest, personal animosities.

- Inducing inferior work, poor driving, causing "slow down" of shop operations.

- Provocation of fear or work stoppage by false alarms, character assassination.

Mechanical sabotage of vehicles should be guarded against by designing and instituting procedures in routine maintenance activities to detect and overcome it.

Frequent inspections of shop equipment, parts and tools, especially preoperation checks, will assist in the detection of sabotage effort before the damage is done.

Whenever indications of possible sabotage are noted on a company's routes, whether as misleading traffic control devices, weakened bridges, or other, they should be reported immediately to the proper authorities.

The same principle of reporting any suspicious or doubtful features where possible sabotage is indicated, applies to the company's own terminals, shops and other facilities. Personnel should be informed and alerted to these dangers at all times.

Manpower sabotage by psychological means is extremely difficult to detect. One disloyal employee engaged in psychological sabotage may influence others to unwittingly engage in activities resulting in loss of transportation services.

The saboteur is not necessarily a foreign national or of foreign parentage. He may be a driver, a mechanic, a dispatcher, or even a member of management. He may be anyone. His motives may be as varied as his personality. He may work for pay; for hatred; for sincere, though misguided, devotion to a cause; for revenge; to settle a real or imaginary grievance; or under threat of blackmail.

Psychological sabotage is essentially an inside job, and may require the assistance of someone inside. Hence, the principal protective measures must be designed to limit the entry or continued presence of saboteurs or their assistants.

Enemy Attack

When war begins, enemy attack on vital facilities can be expected. Obviously the responsibility for preventing or minimizing such attacks rests primarily with the Armed Forces. It is likely that the enemy may proceed along one or more of the following lines:

- Air attack (Bombs or guided missiles)

- Biological warfare

- Chemical attack

Practically all street and highway transport facilities are sufficiently dispersed so that they are unlikely to be selected as specific targets for direct individual attack. Nevertheless, they are likely to be affected to some degree by attacks on other targets. Also, after an attack, it is highly probable that the load on highway transportation will be greatly increased due to the damage or destruction of the more vulnerable transportation modes.

The highway transportation industries of a stricken community are almost certain to be called upon to perform such emergency tasks as evacuation of casualties, delivery of relief supplies from outside, assistance in clearing of debris, etc. It is also highly likely that the fleet communications systems, such as two-way radio, will be called into service. These emergency tasks may be in addition to normal services expected of highway transportation industries and necessary to sustain the community.

Utmost cooperation with local civil defense authorities is most essential.

PART III

SELECTION OF VITAL HIGHWAY TRANSPORTATION FACILITIES

Before adequate security measures can be taken it is necessary for highway transportation management to evaluate its systems and facilities and select those most vital and in need of protection. The protection afforded any particular facility depends on its critical importance and on its vulnerability.

A facility is considered critical if its loss would seriously impair the ability of the system to provide continuity of important service. A facility is considered vulnerable if it is particularly susceptible to damage or destruction by sabotage or enemy attack. A facility may be critical but not vulnerable; or it may be vulnerable but not critical. Facilities which are both highly critical and highly vulnerable should be given earliest consideration in protection programs.

In evaluating his own system, the individual fleet operator, manager of a transit firm, or highway official, should contact local civil defense authorities so as to determine his position in community security plans and the emergency service he may be called upon to perform. He should make criticality and vulnerability estimates of facilities such as key terminals and shops upon which the continuous operation of his service depends; fixed structures such as bridges, tunnels and tracks whose destruction would necessitate substitute routes or service; power and communications systems without which his system could not be operated as an integrated net; short supply fuels and lubricants; the garages and parking areas where his equipment is stored or maintained, loading and unloading points for passengers or freight; and important interconnections with other lines. Often comparatively small items are vital and should not be neglected.

In determining criticality the manager should consider the importance of the function provided by various facilities, and ask himself--could I operate without it? If not, could it be easily and quickly restored or replaced?

In determining vulnerability he must consider the possibilities of both sabotage and enemy attack. Since he will know more about his own system than any potential saboteur, he may, by placing himself in the position of the saboteur, best determine where and how the enemy might do him most harm. In determining vulnerability from attack, as well as sabotage, he must consider the possibilities of fire and explosion, and ask himself which facilities are most susceptible to these hazards.

System Analysis

An analysis of any highway transportation system, from the standpoint of determining its importance to the defense effort, should include consideration of broad factors of which the following are examples:

Size and composition of fleet.--A system may be vital due to its large size and the number of persons and vehicles employed. On the other hand, a small system, by the very nature of its operation, may be highly critical.

Type of carrier or vocational group served.--The criticality of the system may be directly related to the importance or criticality of the industry or activity it directly serves. The criticality of a carrier may depend on the large role it plays in the general defense effort.

Area served.--A rural service may be less vulnerable than an urban service; however, it is not necessarily less critical if it furnishes products essential to the health and welfare of the nation.

Method of operation or substitute service for which capable.--It is important to assure the continuation of scheduled services in time of disaster; however, if this becomes impossible, on-call services assume a high criticality as substitutes for scheduled services.

Listing of Facilities

To assure that every item within an industry is given consideration, it is desirable to make lists, first, of the facilities and equipment upon which operations depend; second, how easily each item might be damaged or destroyed, and what the effect might be. For example, a list of items on which highway transport depends, may include--but is not limited to--the following:

Bridges and Trestles

Tunnels, underpasses and defiles

Streets and highways

Tracks and switches

Shops

Garages

Terminals

General offices

Storage yards, carhouses and parking areas

Vehicles and Equipment

Parts

Tools

Fuel

Power

Communications

Facilities Appraisal

There are numerous considerations which should be kept in mind in determining the importance and vulnerability of various items on the list. For example:

What is the workload or capacity of the terminal, shop or storage area?

Where are terminals and shops located in relation to the system as a whole?

Does the size of vehicle parking areas allow for dispersal?

Can shop or mobile equipment be easily damaged?

How can equipment be quickly repaired or replaced?

What is the degree of dependence on fixed ways, power, communications and other established facilities?

What is the extent of limitations due to bottlenecks such as intersections, narrow lanes, bridges, tunnels, etc?

What are the capacities and capabilities of vehicles for transporting passengers or goods?

Is the facility likely to be an obvious target for enemy attack? If not, is it close enough to an obvious target to be subject to probable damage or destruction?

Can alternate routes be selected?

Can alternate or substitute service be provided?

Who is responsible for appraisal and for initiating protective measures?

The security effort cannot be spread over an entire route or system. It must be localized at particular installations in the system. For example, considering the first item on the list--bridges and trestles, if a company is operating a regular run using a bridge over a wide river, that bridge may be an important factor to the entire service, and its destruction may deprive an industrial area of the vital products delivered over it. If, however, there are several other bridges which could be used, the destruction of one might increase traffic congestion and delay, but the loss would be less serious.

Bridges can be damaged or destroyed by sabotage or aerial attack. Due to the great weight which must be supported, they can be rendered unserviceable by merely being weakened. If two bridges are close together they may be affected by the same raid and are therefore not suitable alternates. On the other hand, if an alternate bridge is too far away, detour routing may be impractical. Bridges can be replaced by ferries, or repaired, but either remedy may take considerable time.

Shops and garages, where a company services, stores or maintains its equipment, are of particular importance in assuring continued operation of the industry. Machine tools, equipment and replacement parts are highly vulnerable to sabotage. The shop itself may be vulnerable to attack if located within a highly concentrated industrial area. Management must give a high priority to protection of its shop facilities.

Vehicles are major items of highway transport equipment and, therefore, are of major importance. The only substitutes are additional vehicles, which may not be easy to secure in time of national emergency. Except when in terminals or storage yards, vehicles are generally dispersed and are, therefore, less vulnerable to either aerial attack or widespread sabotage. Yet they may be easily and seriously damaged when concentrated without proper protection. The responsibility for reasonable protection in this case falls on the company officials.

PART IV

ORGANIZING FOR HIGHWAY TRANSPORTATION SECURITY

The protective organization for a highway transportation industry will depend upon the size of the fleet, criticality and vulnerability of the system, the number of personnel, and the cost which may be wisely assumed.

Successful protection depends upon the interest and skill of those who devise and administer the program. It requires coordination between management and employees, and between the system and the community and government.

The Security Director

Most highway transportation industries, because of their layout and methods of operation, do not require an extensive organization for protection. Much of the protection is now being provided by the regular supervisory force as a normal function. Nevertheless, the complexity of the problems clearly points to the necessity for delegating to one individual the responsibility for protective operations. In many companies this responsibility lies with the Safety Director, and might continue under him unless expanded security duties make separation of the functions desirable. Other titles which might be applied to the individual charged with supervision of the security program are Security Director or Defense Coordinator. Whatever his title, his general duties should be to direct, plan, organize and coordinate all safety, security and defense activities. More specifically he should:

- Analyze the criticality and vulnerability of the system, both at terminals and along routes, to determine the extent of the hazards.

- Analyze existing safety, fire and other programs to determine the adequacy of these programs in the light of hazards involved. Revise and expand these where necessary.

- Coordinate plans for alternate emergency routes and schedules.

- Determine where fuel, oil, parts and operating supplies may be obtained in event present sources are cut off.

- Establish tentative agreements with other lines for exchanging, borrowing or lending equipment in event of emergency.

- Make provision for service and repair of equipment in event present facilities are damaged, destroyed or denied the company.

- Select alternate locations for passenger ticketing, loading and unloading points, parking and assembly areas, etc.

- Plan and provide for an emergency dispatching center by which company business may be continued without interruption in time of disaster.

- Instruct key personnel such as department heads, shop superintendents, chief dispatchers, etc. in protective functions so they may organize and direct employees under them.

- Provide for training of employees, especially drivers and mechanics, to observe protective regulations and to understand the reasons and purposes behind them.

- Establish working relationships with community civil defense organization.

- Direct emergency defense activities including fire fighting damage control, rescue, evacuation, medical aid services, and restoration of facilities.

Even under an expanded protection program, use should be made of the existing service departments. Their normal functions should be interfered with as little as possible, but they should be guided in all security aspects by the Company Security Director or Defense Coordinator, who takes full charge if an emergency occurs. In a large company, delegation of authority for various phases of the protection program is necessary. In a small company, top officials may do most of the work. Nevertheless, every employee, down to and including every driver and mechanic, is important to the program.

Protective Organization

Whether a company provides for its protective organization through the appointment of one or number of persons, there are certain protective activities the system may be required to perform. The scope of these activities may include, fire, warden, health and welfare, utility repair, guards, etc. Many of these activities are available from outside sources and small companies may not deem it necessary to include their full scope within the functions of their protective setups. Even in larger companies, having elaborate protective organizations, each activity may have to draw on the resources of the community for help.

In general, a civil defense protective system should be organized and trained to help prevent panic, extinguish fires, render first aid, repair utilities, direct and assist personnel in event of calamity.

The activities of those concerned with fire should be to direct measures necessary to detect fire hazards, guard against the occurrence of fire, and to fight fires when they do occur. They are responsible for the location, refill, and instructions in the use of fire extinguishers, whether in vehicles, shops or terminals.

The warden is concerned with safeguarding life and property in event of an enemy attack. This includes informing personnel of civil defense regulations, such as warning and shelter regulations, training personnel in self-protection measures, directing people to shelters, preventing panic and performing emergency rescue. It may also include assistance to others, such as police and fire when the occasion demands. When wardens are appointed they should cover the general offices, the maintenance and shops and garage layouts and important terminals.

Those concerned with medical assistance may, in emergency, have to work against great odds. The scarcity of professional medical people, present even under normal circumstances, will become more acute in an emergency. The medical staff of a large industry should be augmented by people trained in first aid, so as to be ready to meet major disasters. In small companies, first aid teams should be set up under properly qualified medical supervision. As a minimum, first aid personnel and equipment should be provided.

Most highway transportation industries will require only small guard forces or in many instances, no guard at all. Properly trained employees working in an area usually provide the required protection. However, in large garage or storage yards where vehicles are left unattended for long periods, guards are often essential. Guards may also be required to accompany vehicles carrying critical shipments.

Utilities repair, to be effective, should provide for the repair of buildings and utilities, restoration of damaged facilities and roads, and in a major disaster, should assist in demolition, decontamination, clearance and rescue activities.

Duties and Responsibilities of Individual Employees

Employees are in a favorable position to recognize and prevent sabotage. Their understanding and alert cooperation is the most effective single factor in the entire protection program. While management is primarily responsible for the safety of company property, employees have a vital and personal interest in protecting themselves from injury, loss of life, or loss of livelihood through the activities of subversives.

Supervisory personnel have an important responsibility for guarding against hazards, in alerting personnel to the dangers of hazards, and in training personnel in the methods to be employed in overcoming hazards when they occur.

Dispatchers and clerks who handle most of a company's records are in good positions to detect evidence of espionage and any sabotage effort directed at interfering with the company's schedules and movements.

Drivers of vehicles, especially line haul drivers who must operate their equipment for long periods away from direct supervision, must be depended upon to detect and report sabotage effort against the trucks or buses they operate and against facilities along their routes of travel.

Shop personnel and mechanics have a dual responsibility for finding and taking action against sabotage efforts directed at both the company's mobile equipment in for servicing and repair and against machinery and tools within the shop.

PART V

PROTECTIVE MEASURES FOR HIGHWAY TRANSPORTATION SECURITY

Protective measures include all actions employed to protect the personnel, services, equipment, premises and operations of highway transportation systems. Accordingly, protective programs should be designed to reduce lost time and damage occasioned by wartime as well as ordinary hazards such as fire, accident, and illness; to achieve security of information, to prevent sabotage, and reduction in service capability; and to permit quick restoration of service after an emergency or disaster.

The discussion of protective measures is organized as follows: General security measures; personnel security measures; protection of fixed facilities; and protection of mobile facilities.

A. GENERAL SECURITY MEASURES

General security measures applicable to the highway transportation industries provide a basis for planning and implementing over-all protective programs. They should be applied in varying degrees depending on the local conditions applicable to the particular facility or situation. Excessive protective measures should be avoided.

General Safety

The problem of safety -- prevention of accidents within garages, shops, loading docks and terminals, as well as on the road -- must not be neglected.

It has become common practice in the larger units of highway transportation to employ trained safety directors. In times of emergency, when transportation services are intensified, the safety problem becomes more acute. This means that the continuance of an adequate safety program should be a primary activity of each company, and the program made the basis of expanded protective measures.

Every fleet operator knows what accidents on the road can cost him in losses in equipment, personnel, freight, public good will and multiple losses of revenue. Because of this, driver incentive and training programs are geared to safety and skill in vehicle operation.

Safety in the shop, garage or storage yard must not be overlooked. Many an accident takes place when a terminal driver or mechanic shuttles a vehicle about a yard or in a garage. There is not the same urgency to be

PROPOSED DRAFT

careful, experienced by a driver on the road. Yet yard accidents can be costly; and mishaps within shops can be just as damaging to a company's tools and equipment as those on the road.

City, State and Federal safety regulations usually establish minimum requirements. Operators should endeavor to surpass the minimum requirements and strive for extra protection. Safety in all its aspects is essential to the protection program. Aid can be obtained through the numerous safety agencies and the Chief of Safety Section, Bureau of Motor Carriers, Interstate Commerce Commission, Washington 25, D. C.

Fire and Explosion

Fire is the favorite tool of the saboteur, and a constant hazard in an industry which relies on flammable fuels for its operation.

Most fires can be prevented through the elimination of fire causes. Protection against fires should include installation of suitable fire fighting equipment and the organization of fire fighting forces.

Fire prevention should cover vehicles as well as fixed facilities. Careful inspection of vehicles before they leave terminals or garages will insure that accessories such as fire extinguishers, axes if required, flares, etc. are in place. In buses the workability of emergency exits should be checked before departure.

The prevention of fires in shops and garages, and especially where vehicles are stored, is of paramount importance. Wooden floors are risks and tend to keep insurance rates up. Accumulations of waste -- used fuels, cartons, rags, etc. -- are hazards which should not be allowed to remain. The installation of automatic sprinkler systems and handy fire extinguishers is a good insurance against loss. Sabotage of such devices should be guarded against.

Wherever fire is a hazard, explosion is a possibility. This is especially true in closed areas where fuel vapors may accumulate, or wherever combustible materials are stored, loaded or unloaded, or transported. The Interstate Commerce Commission specifies certain rules to be observed in the transportation of explosives by motor vehicle.

Theft and Pilferage

In times of emergency, when vehicles and the loads they carry may become irreplacable, ordinary insurance against theft and damage is insufficient to protect a company and the property for which it is responsible.

The danger of pilferage or loss of freight in transit is increased if a company's records and shipping documents are inadequate or poorly prepared and authenticated. Companies should have procedures designed to place responsibility for its equipment and for goods in transit on specific individuals.

The greatest protective measure against theft and pilferage is to remove the opportunity for such acts, and establish procedures that will immediately detect theft or pilferage.

Enemy Attack

Measures to minimize the effects of enemy attack are set forth by civil defense organizations. Facilities of the highway transportation industry may be a target for such attack or may be affected by an attack directed at other targets. Measures for minimizing the effects of such attacks should be planned immediately.

Passive defense measures such as camouflage and blackouts may be imposed. Certain important routes may be restricted or denied. Personnel shelters may have to be provided in accordance with regulations of the civil defense authority.

Camouflage, which consists of protective coloring and concealment designed to blend facilities and equipment with surrounding natural terrain, is a highly specialized subject which should not be undertaken except by direction of governmental authority. However, management may wish to consider it when selecting the colors to be used on its vehicles and buildings.

The question of imposing blackouts or dim-outs will be decided by civil defense or military authorities. The immediate effect of such restrictions will be the slowing down of vehicle operations at night. Special lighting may have to be provided for vehicles, and drivers may have to be given special instructions for driving under such conditions.

Restrictions may be imposed on the use of certain routes. It is expected that the highway transportation industry, because of the importance of its service to the community, will be given a relatively high priority in the use of restricted routes. This will vary with the nature of the service provided. For example, companies performing emergency evacuation and relief will obviously be given higher priority for use of routes than those engaged in normal transportation activities.

Some defense plans include measures for highway traffic regulation in which the highway transportation industry itself may be given some authority as to priority for its own movements. Local civil defense organizations should be contacted as to the degree of restriction to be imposed and the amount of assistance expected of the local industry.

Bomb shelters, especially at larger terminals, may be required. The utilization of existing basements, underground parking areas, etc. should be studied before consideration is given to new structures. This subject is discussed more fully under passenger terminals.

Inspections and Reports

Management should require frequent inspections of all vehicles, equipment, and fixed facilities to assure itself of the sufficiency of its security program. If the transportation service performed is of a highly important and critical nature, it may be necessary for authorized governmental agencies to make a security inspection.

Suspicious actions or subversive information should be reported by employees to their supervisors, and if deemed of sufficient importance, it should be reported immediately to the nearest field office of the Federal Bureau of Investigation. The nearest FBI office is listed on Page 1 of most telephone directories.

Security check lists for the highway transportation industry are included in the appendix.

B. PERSONNEL SECURITY MEASURES

Personnel constitute the company's chief defense against many hazards. However, they themselves may cause hazards. They may engage in theft and pilferage, disrupt service through carelessness, cause accidents resulting in injury and damage to property, or engage in subversive activities and sabotage. However, if properly screened and selected they constitute one of the main elements of security protection.

Screening Applicants

Loyalty to one's country is important in both peacetime and war. In a different sense or degree loyalty to one's firm is also important. The Federal Bureau of Investigation is charged with the responsibility for investigation of disloyal and subversive persons on a national level, but it must not be assumed that the FBI will inform management of subversives within a particular industry.

In the highway transportation industry loyalty of operations and maintenance personnel must be very high, because of the dependence placed on them.

The screening and investigation of applicants for employment should be assigned to a responsible management official and designed to get complete and reliable information. Statements of the applicant as to his qualifications should not be the deciding factor in employment. Former employers, friends and acquaintances should be contacted for verification of applicant's claims and the character of the applicant. References should be checked. Consideration should be given to accomplishing personnel investigation by arrangement with private investigation organizations.

In reviewing the final application, check for discrepancies between various reports and for unfavorable information. Use fair, common sense judgment and analyze all relevant information in making a decision on the security clearance.

Employee-Management Cooperation

The cooperation of employees is a requisite to any successful security program. An Employee-Management Committee can be of great help in all employment and personnel matters.

Supervision and Training

Effective cooperation of employees cannot be expected or securied without education and training in the problems involved. Education in security should cover:-

- Acceptance of the unpleasant fact that employees may be inconvenienced by the rules and regulations designed to trap or thwart subversives.

- The dangers of talking business while on the road, in roadside eating places, and whenever away from the job.

- The dangers of spreading important information about the company, especially about persons or goods to be transported.

- The dangers of spreading unconfirmed rumors.

- The detection and reporting of all evidences of sabotage whether in shops and terminals, or noted while on the road.

- Observance of suspicious characters and their actions and the detection of trespassers on company property.

- Avoidance of association with dubious characters everywhere. (Never pick up hitchhikers or other doubtful characters who may solicit rides.)

- Especially noting and reporting vehicle failures and accidents.

- Familiarity with tactics of saboteurs against the highway transportation industry.

To be effective, educational work of this character must be continuous. Furthermore, it must be sufficiently appealing to capture the interest of the employee. Experience indicates that the most effective form of education is the informal, on-the-job instruction conducted by the employee's immediate supervisor. Here it is possible to use actual, everyday examples to illustrate principles, thus fixing the problems and responsibilities more firmly in the mind of the employee.

C. PROTECTION OF FIXED FACILITIES AND THEIR OPERATIONS

This section considers the protection of facilities normally located at a company's terminals and those along routes which are essential to operation of the industry. For convenience, those operating procedures connected with a facility are discussed under that facility.

The streets and highways themselves are important facilities upon which continuous fleet operations depend. And although the normal planning, upkeep and protection of these are done by government, their adequacy and condition cannot be overlooked by the industry. If routes are thought to be inadequate, dangerous, or in need of repair this should be brought to the attention of proper authorities. Routes leading into and out of the terminals or facilities of a company may have to be provided for and maintained by the company. These should be paved, provided with adequate drainage, properly marked and signed with standard devices, and kept free of pot holes and obstructions. Insofar as possible dead-end roads should be avoided or adequate turn arounds provided. Possible expansion of the company's activities in an emergency should be considered in evaluating the adequacy of ingress and egress routes.

Terminal Areas in General

As used herein the terminal area is the entire area or areas comprising a company's offices, freight loading docks, carhouses, garages, shops, fueling facilities and parking areas.

Management of a trucking or transit firm should consider the extent to which its terminals should be restricted to outside entry and made subject to internal restriction and control. The following basic security measures may be considered:

- Fencing and other perimeter barriers.

- A personnel identification and control system.

- Guard protection.

- Protective lighting.

- Protective alarm systems.

Fencing. In providing fencing or other barrier for a terminal area, location of main entrance and exit gates is a primary consideration. They should be planned with the view toward facilitating the flow of traffic through the terminal. Guard booths should afford a good view of both entrance and exit gates. Separate gates for employee entrance and for emergency use should be provided as required, but gates and doors should be limited to number necessary for efficient and safe operation. Employees' parking area normally should be outside the grounds of the terminal area and may be separately fenced. Fences meeting the following specifications should be considered:

- Be of chain link design of not larger than 2-inch square mesh of No. 9 gage or heavier wire with twisted and barbed selvage top and bottom.

- Eight feet high, topped with strands of barbed wire one foot high, making a total of nine feet.

- Be built as straight as possible, drawn taut and securely fastened to rigid metal posts set in concrete with additional bracing as necessary at corners and gates.

- Be extended to within two inches of firm ground, depending on the nature of the soil or reinforcement available.

If windows serve as barriers, they should be protected by securely fastened bars and grills.

Access Control. The problem of admission of persons into a terminal area, or sub-areas within a terminal, requires some study to assure that the inspection is conducted rapidly and efficiently. Where the work shift is small the area can be controlled by personal recognition. Where the

PROPOSED DRAFT

area is large, a personnel identification system, such as "tamper proof" passes, badges, or other devices, is necessary. All personnel, including employees and visitors, should be required to show identification or pass at a check-in gate.

Management should further consider establishing a definite system for the control and examination of suspicious parcels entering and leaving the terminal. Such control is desirable as a means of minimizing property loss, reducing theft and pilferage, and preventing possible sabotage and espionage.

Guards. Most transportation services will require only small guard forces or in many instances no guard at all. Properly trained employees working in an area usually provide the required protection services. A gate guard during normal operational periods and a shop and yard watchman during periods of reduced activity are considered the normal requisites.

Lighting. Floodlighting a terminal area serves the dual purpose of protection and of facilitating night operations within the terminal. Adequate protective lighting is needed most in areas where vehicles are stored, especially in outdoor storage areas whether or not areas are surrounded by a fence.

The determination as to the necessity for protective lighting depends on such considerations as: The military policy as to blackouts and dim-outs; the economies which may result from a reduction of the number of guards required; the advantages protective lighting affords in unguarded, isolated facilities by providing for observation by law enforcement officials and the general public; and the availability of protective lighting materials.

Control of lighting should be given every consideration. Lights should be installed in well protected and well guarded locations.

Alarm Systems. If a community air raid warning system is adequate, a company warning system may not be needed, but an alarm system may be required to guard against local sabotage. It is not likely that the terminal will require anything more elaborate than a local alarm system in which the protective circuits are connected to a visual and/or audible signal element which is located at or in the immediate vicinity of the component of the terminal to which it applies and which is responded to by guard personnel or designated employees.

Passenger Terminals

Passenger terminals are necessarily open to the general public and during rush hours constitute a critical location due to the concentration of people and vehicles. Normal safety features are of utmost importance here, and provision for emergency first aid, warning, bomb shelter, etc. may be found desirable. Most passenger terminals have facilities available for meeting routine emergencies, and planning for defense becomes a matter of evaluating the extent or degree of protective measures to which these facilities should be expanded or added to in event of major disaster.

Access Routes. Many passenger terminals are so restricted as to access streets and maneuvering area for buses that selection of alternate routes or terminals is highly desirable in security planning. Whatever decisions are made along these lines should be coordinated with local authorities.

Bomb Shelters. Suitable shelter areas should be provided in the terminal or in other areas near the terminal. In the utilization of existing structures as bomb shelters, the following should be considered:-

- The number of persons probably required to be sheltered.
- Readily accessible entrances and exits.
- Sanitary accommodations.
- Heat, light, and water.
- First aid equipment.

The following risks should be avoided insofar as possible:

- Excessive overhead loads of machinery or equipment.
- Presence of large water and gas mains, sewage systems, and steam pipes.
- Nearby storage of flammable liquids.

Offices and Related Facilities

The terminal manager or other executive in charge should make sure that in his absence a responsible person is left in charge to assume responsibility in case of emergency.

Important office files should be properly secured and locked when not in use. If management possesses vital records which are difficult to replace, consideration should be given to the storing of duplicate copies or microfilm at other locations. Much of the information accumulated as to routes, schedules, etc. becomes public knowledge. However, special moves, such as troop movements, movements of explosives and critical materials, and statistics concerning important military and industrial installations if classified must be guarded as such. Duplication of records should be confined only to the material needed to expedite the rehabilitation of the operation.

Other offices where company's accounts and business activities are attended to should be restricted to authorized persons.

Loitering in rest rooms or locker rooms should be prohibited. During emergencies lockers should be inspected frequently for packages, stolen or lost articles, evidences of sabotage, etc.

The dispatching office should be restricted to designated personnel. Smooth operation of the dispatch office is essential to fleet control. The probability of increased work under emergency conditions should be considered in evaluating the adequacy of dispatch facilities. See also Communication Centers and Equipment below.

Communication Centers and Equipment

The communication center and allied communication equipment which is essential to the operation of the facility and control of the fleet should be adequately protected to prevent sabotage and tampering. The telephone exchange, the teletype, radio transmitter site and such other control centers as the dispatcher's office should be designated restricted areas.

Communications systems intended for the transmission of messages between departments within the facility or terminal, can be utilized advantageously in a protection program. Public address systems are particularly useful and may be used in warning of imminent danger.

In general, the following communications system would provide ample coverage for a large transportation installation:

- At least two systems of communication with outside sources, one of which should be radio with an independent emergency source of power.

- At least two systems of communication within the facility covering all important fixed areas, of which one system should have an independent power source.

- A system of radio communication with and between all necessary motor patrols with each fixed and portable ground station provided with an independent emergency source of power.

Management should conduct frequent and regular inspections and tests of all communication equipment.

Two-way fleet radio communications. Rapid progress has been made in the last few years in equipping highway transportation vehicles with two-way radio communications. In addition, there is increasing use of radio receivers in urban streetcars and buses. These installations are valuable in emergencies and are highly important. They merit special measures of protection which are described in government and other publications.

Centralized control room. As a center of its dispatch or communications activity a company should use a strategically located and protected control center.

If at all possible, the control room should be established in a shelter area, preferably below ground level, and it should be protected against sabotage. It should contain system and facility maps and charts so that damaged areas can be readily identified and marked. There should be an alternate location for an emergency control center to function in the event of serious damage to the regular control center.

Freight Terminals

Protective measures for truck freight terminals have been generally described under Terminal Areas. In addition, the degree to which freight is handled, held in transit, or stored will have an effect on protective programs, and if the accumulation is large, principles of good warehousing apply.

Freight loading docks. Freight loading docks should be provided with suitable fire fighting equipment. Materials handling equipment -- lift trucks, draglines, pallets, etc. -- should be kept in operating condition or removed from the dock. Freight should move freely across the dock and "hold" items should never be allowed to accumulate in work lanes. Over-short-and-damaged items should be stored in the basements or other protected area. Electric and gas control and metering centers should be in an enclosed or restricted area. Stand-by power should be available and ready for emergency use. Dock personnel -- fork lift operators, checkers, strippers, etc. should be previously cleared for trustworthiness and loitering should not be permitted. Evidence of pilferage should be reported immediately by persons finding it.

Storage areas. Places where over-short-and-damaged items, refrigerated cargo, or other goods are stored or held while awaiting further movement should be accessible only to designated personnel.

Maintenance Shops and Facilities

Personnel employed in maintenance shops should be thoroughly screened. The opportunity for sabotage is perhaps greatest in the shops. Not only are valuable tools and equipment within the shops subject to tampering and damage, but vehicles moving through the shops may suffer damage which may not be noted until much later when out on runs. An antisabotage check of vehicles should be a standard part of inspection procedure, and no vehicle should be released until a thorough investigation has been made if evidence of sabotage on it is noted. Mechanics should be held responsible for tools and machinery they use. Accidents and mistakes resulting from carelessness can be as harmful as deliberate sabotage.

Grease rack, pit or mechanical lift. Fire fighting equipment should be accessible to this equipment. This is a fertile field for saboteurs and special precautions should be taken in inspecting and protecting lift equipment.

Preventive maintenance lines or stalls. Care should be taken that no one station or stall within the preventive maintenance system is allowed to delay movement of equipment through the line or shop. Evidence indicating that such delays may be deliberate slowdowns is justification for prompt investigation.

Replacement parts crib or storeroom. The crib should be fenced in and access to storeroom or crib should be limited to authorized personnel. A strict accounting of parts is necessary and used items likely to be in short supply should be retained for possible salvage.

Paint Shop. The paint shop should preferably be of fireproof construction and detached from other facilities. Paints and spray equipment should be stored in fire-resistant closets when not in use.

Tire shop. Tires are a favorite object of sabotage both for the ease with which they may be damaged and the crippling effect their loss may have on vehicle operations. Tires should be checked carefully for unusual abuse or sabotage. Revulcanizing equipment should be checked often for condition and fitness. Tire storage areas should be especially protected against fire and other hazards.

Vehicle Servicing and Fueling Facilities

Water, fuel, and lubricants are highly susceptible to contamination. Sabotage efforts may be directed at them. Gasoline is always an important item. Arrangements should be made in advance with gasoline dealers for emergency fueling in case of disaster.

Water tanks and pumps. Water supplies and equipment essential to the operation of the facility should be afforded adequate protection to prevent curtailment, contamination, and damage. Insofar as feasible, the areas in which they are situated should be restricted.

Gasoline pumps. Fuel pumps are usually vulnerable and to some extent critical. Each pump should be locked except during periods of use. Outlets to gasoline storage tanks (underground) should be locked and tamper-proofed. Portable auxiliary fuel pumps capable of manual operation or with self-contained power units should be available.

Fuel storage. Outside fuel tanks should be surrounded with appropriate barriers to access and for the containment of fire. Special fire protection in the form of foam extinguishers and foam flooding devices are desirable for larger facilities of this type.

Power and Utilities

All buildings or rooms housing power, heat or other utilities should be equipped and safeguarded in accordance with safety codes in effect. When unattended, utility rooms should be kept locked and the keys held by the plant maintenance supervisor, terminal manager or other designated person.

Outside areas containing power generating, transmission and conversion facilities should be fenced and only authorized personnel should be permitted access thereto. Pole mounted switching equipment should be mounted as high as practicable and locked if enclosed. For more detailed information relative to the measures for the protection of facilities in this category refer to the appropriate security manual on electric power.

Portable auxiliary power units should be available for the operation of fuel pumps, compressors, etc. in event of power failure.

Carhouses and Garages

Buildings in which vehicles are parked, stored or repaired should, insofar as possible, be of fireproof construction and detached from other buildings and activities. Preferably they should be without basements and only one story high. When this is not practicable special features -- building supports, fire escapes, sprinkler systems, etc. -- have an added importance.

At least two exits should be available. These exits should be at opposite ends or sides of the building and should be so located that they are not habitually blocked by equipment or activities within the building. Exit doors not of the overhead or sliding type should open outward, and internal doors should open in the direction of flow of vehicles or equipment through the facility. If electrically operated doors are used, an alternate means of operation should be provided. Ramps and passageways should be kept clear and marked as to directions of low and exits.

Vehicle Parking Areas

Vehicle parking areas within the terminal facility should be segregated according to types and uses made of the vehicles. Vehicles should be properly dispersed within the limits of the area, and should not be parked too close to buildings, stores, fences, etc. They should be so placed as to permit rapid removal. When practicable, employees and visitors should be required to park their automobiles within designated areas outside the main terminal facility.

Tracks, Switches and Overhead

Urban transit industries provide whatever protective measures are possible for their tracks, switches and overhead as a routine part of their operations. Due to the high vulnerability of these facilities protection becomes a public matter and fullest cooperation of local authorities and the public should be solicited, especially in time of emergency.

New Construction

The defense measures which should be considered by management include those precautions taken in connection with the proposed construction, design, and layout of new buildings which will afford protection to personnel and equipment against sabotage and destructive forces such as blasts, fragmentation, radiation and other effects of enemy air attack. These measures include dispersion, camouflage, personnel shelters, underground construction and similar measures designed to minimize casualties and damage to equipment.

D. PROTECTION OF MOBILE FACILITIES

This section considers the protection of a company's trucks, trailers, buses, streetcars, trolley coaches, automobiles and service vehicles. The normal dispersion of mobile equipment in the operation of highway transpotation industries is in itself a normal procedure as well as a practical security measure. Day and night service scatters many fleets, eliminates concentration, and reduces the danger of large-scale destruction. Where there are concentrations at any time which might contribute to the loss of a substantial portion of a fleet, efforts should be made to disperse the vehicles by the use of more storage yards. Vehicles should be so parked that, in case of fire or other damage to some, the others will not be immobilized.

Automotive Vehicles in General

Before a motor vehicle is put into operation it should have a regular security inspection in which safety features of the vehicle and any evidences of tampering or abuse are to be noted. Particular attention should be given to those features, which if not properly functioning, might lead to serious mishap or mechanical damage later, and to those features particularly susceptible to sabotage: Wiring, fuel lines, carburetor, distributor, wheels and tires, lights and safety devices, brakes, and emergency equipment. Major engine accessories should be checked for evidences of tampering or breakage. Fuel features should be observed for evidence of puncture or loose connections causing leakage. Engine oil and gasoline should be checked for possible contamination or drainage. Electrical features should be checked for evidences of cutting, shorting, or the attachment of sabotage devices. The cooling system should be checked for loose hoses, puncture of radiator, etc. Condition of tires and tightness of wheel lugs should be checked. Brakes and steering equipment should be in good working condition. Fire extinguishers should be filled with the proper ingredient and sealed. (If seal is broken it should be reinspected for proper contents.) All emergency equipment should be in its proper place. Lights, mirrors and other safety features should be functioning properly. Proper security of the load should be assured before dispatch of the vehicle.

A vehicle security check list, which may be incorporated in a fleet's regular preventive maintenance check of equipment, is appended hereto. (See Appendix C.)

Trucks, Truck Tractors and Trailers

Protection of cargo hauling transport involves procedures for securing, checking, proper loading and skilled driving.

While it may be impractical for some fleets to place locks on gas tanks, cab doors, and hoods, it is usually desirable, as a minimum, to provide locks on truck ignitions. Small fleets may find it practicable to provide fullest protection by a complete system of locks, and by strict accounting for vehicle keys.

In all truck transportation proper loading and security of the load are essential. Drivers should be held responsible for the condition of loads in transit. If critical loads are carried it may be desirable to have the vehicle accompanied by guards either riding in the vehicle or following it in another vehicle.

...ers should be checked as to condition of brakes, electrical and brake connections, fifth wheel plate, and general condition of body prior to use. Body seals should also be checked to see if load is secured and that seal is intact.

Taxis, Limousines and "Drive Yourself" Cars

Automobiles require special attention in the matter of safety and comfort of passengers, and security from theft and vandalism.

Taxis and limousines normally should not be left unattended during operating periods. When they have to be parked, even for short periods, they should be locked.

The taxi driver can be of great benefit to his country in detecting espionage activities. Suspicious acts of passengers or suspicious conversations overheard should be reported to the FBI.

The two-way radio and mobile dispatch systems of many taxi fleets may be especially useful in times of emergency and may often be called upon to assist in civil defense operations.

Buses

Passenger buses require special protective measures in regard to the hazards inherent in transporting large groups of people at one time.

Overloading of buses is unavoidable in time of emergency. The degree of overloading should be left to the operator, bearing in mind that safety is the primary consideration. In no case should passengers be allowed to crowd the driver or obscure his vision.

Drivers should be thoroughly trained in what to do in event of an air raid or other warning.

Streetcars and Trolley Buses

Most of the protective measures prescribed for buses and other vehicles are equally applicable to streetcars and trolley buses. Special measures necessary for the protection of streetcars and trolley buses evolve from the fact that these vehicles depend on fixed way facilities for their operation.

Sabotage of tracks, switches, power lines, and power sources are serious hazards to the urban transit industry and to the successful operation of its equipment. Frequent and careful inspections to prevent plugging of switches and rails, and loosening of rail joints, etc. and prompt response to repair calls are essential protective measures.

Power failure in time of disaster may necessitate the abandonment of these vehicles and the substitution of self-powered equipment. When loss of use of streetcars and buses would create a severe shortage of needed transit service, plans should be made for the use of vehicles of other firms.

Service Vehicles

A company's service vehicles should be kept in good operating condition at all times. They should be located in easily accessible positions for emergency use. Wreckers, fire fighting vehicles, sand spreaders, snow fighting equipment, and utility repair vehicles should be prepared for heavy emergency use in event of disaster.

PART VI

RESTORATION OF HIGHWAY TRANSPORTATION SERVICE

In a large-scale enemy attack it must be anticipated that there will be substantial destruction and damage. In such an event the problems of restoring service will be complicated by such conditions as panic, road and street blocks, contaminated areas, extensive fires and lack of fuel and electric current. It is essential that plans be developed to cover such conditions.

In the case of the street and highway transportation services the greatest need will be for vehicles and the personnel to operate them. An inventory of equipment, its location and its condition is of first importance. Finding enough operating personnel to man the vehicles is the next consideration. Alternate operating routes and alternate schedules should be ready in case the regular ones are blocked by fires, contamination and debris or their use is denied. Constant contact with civil defense officials will help determine the routes available.

Provision should be made for the transfer of administrative and operating headquarters to alternate locations in case of the possibility of destruction of normal facilities. Such alternate headquarters should be carefully selected after due consideration of loading, unloading and operational and repair conditions. The risks of access routes being jammed by refugees and military movements should also be considered.

To provide additional operating help, the past records of all employees should be reviewed to ascertain who has had driving experience. As far as practicable, nonoperating personnel should be trained in good operating practices so that they can assist in emergencies.

Close cooperation should be maintained between similar highway transportation industries in a locality or in nearby cities so that, in an emergency, transfers of equipment, substitutions of service, or other arrangements for mutual assistance and benefit may be made.

P R O P O S E D   D R A F T

____________________ Company   Appendix A

Security Status Report

Transportation System or Facility Covered ____________________

Location ____________________ Date __________

	Adequate	Inadequate	Not Applicable
1. Organization for Fleet Protection			
2. Personnel Education and Loyalty			
3. Employee and Public Relations			
4. Restricted Areas Within Terminals			
5. Control of Access to Terminals and Shops			
6. Protection of Records and Shipping Documents			
7. Guard Service			
8. Fencing and Other Anti-Personnel Barriers			
9. Protective Lighting			
10. Protective Alarm System			
11. Dispatch Center and Communications System			
12. Fire Protection			
13. Operational Safety Program			
14. Terminal and Shop Safety Program			
15. Vehicle Security Check			
16. Civil Defense Measures			
17. Alternate Schedules and Routes			
18. Plan for Restoration of Services			

Comments:

____

____

Important: This report may be used for a system and/or any appropriate unit thereof. It should be completed only after full consideration of the corresponding suggested items appearing on the Security Check List for Street and Highway Transportation Systems

Report prepared by:

____

PROPOSED DRAFT

Appendix B

SECURITY CHECK LIST FOR STREET AND HIGHWAY TRANSPORTATION SYSTEMS

1. ORGANIZATION FOR FLEET PROTECTION

a. Have security objectives and policies been clearly defined?

b. Have security plans and programs been adequately developed?

c. Have appropriate delegations of security authority and responsibility been accomplished?

d. Has each security function been assigned to competent personnel?

e. Have appropriate allocations of equipment, supplies, etc. been made?

f. Has a workable and practical security organization structure been established?

g. Have internal security procedures been developed and practiced?

h. Have supervisory and control procedures been established?

i. Have leadership and morale of employees been developed?

j. Have all necessary protective measures to insure continuity of service been applied?

k. Have provisions been made to test the security plan?

2. PERSONNEL EDUCATION AND LOYALTY

a. Loyalty Determination:

(1) Are all applicants and employees investigated?

(2) If not, are all individuals investigated and cleared who have access to vital information and operations?

(3) Is special attention given to aliens and foreign nationals?

(4) Are fingerprints taken?

b. Security Education, Information and Training:

(1) Are employees instructed in security methods?

(2) Does the method employed provide periodic training?

(3) Does the method used produce the desired results?

(4) Are employees instructed to report all suspicious acts or persons?

3. EMPLOYEE AND PUBLIC RELATIONS

a. Have measures been taken to enlist the support of employees and the public in security programs?

b. Do employees have representation in the development of security programs?

c. Are employee groups informed of the need for security and is their support requested?

d. Have the appropriate local civil defense organizations, local police and fire departments, and Federal and State regulatory agencies been contacted?

e. Have measures been taken to enlist the support of these organizations?

4. RESTRICTED AREAS WITHIN TERMINALS

a. Have all vital areas, and areas which are particularly susceptible to sabotage, been restricted?

b. Have protective measures been established with respect to restricted areas?

5. CONTROL OF ACCESS TO TERMINALS AND SHOPS

a. Does the access control system provide a means of identifying personnel who are authorized to have access?

b. Does the system facilitate the control of admission and egress of personnel?

c. Does the system provide a reasonably secure identification media and means for checking entry?

d. Does the system provide for a procedure for admission of non-employees?

e. Are controls applied to account for identification media on hand and to recover identification media upon expiration or when no longer required?

f. Do guards carefully compare individuals to their identification media?

g. Are visitors escorted?

h. Is a visitor register maintained?

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6. PROTECTION OF RECORDS AND SHIPPING DOCUMENTS

a. Are important papers in suitably locked, fire-resistant containers?

b. Have vital records been duplicated and safely stored?

c. Do a limited number of people have access to records?

d. Has a procedure been established for allowing access?

7. GUARD SERVICE

a. Are restricted areas locked or guarded?

b. Are all guards investigated?

c. Are guards trained?

d. Are guards armed?

e. Do they have uniforms or identification?

f. Are guards properly supervised when on duty?

g. Are the number of guard posts adequate to provide proper control at the access points and at the same time give adequate coverage to the perimeter barrier?

h. Is there a suitable communications system for the use of guards?

i. Are guard posts located and designed to provide maximum assistance to the guard?

8. FENCING AND OTHER ANTI-PERSONNEL BARRIERS

a. Is the vital area completely enclosed by a cyclone type fence or equal barrier?

b. Has due consideration been given to emergency entrances and exits?

c. If there is a water or rail approach to the facility, is this approach properly protected?

d. Have both sides of the fence been cleared of underbrush, debris, etc.?

e. Are openings, such as windows, air ducts, sewers, tunnel entrances, properly barricaded?

9. PROTECTIVE LIGHTING

a. Are vehicle storage yards and terminal aprons areas covered by protective lighting?

b. Is the protective lighting arranged so as to light up all approaches to the facility?

c. Are guard posts and vital areas located behind the light beam?

d. Are there alternate sources of power for lighting?

10. PROTECTIVE ALARM SYSTEM

a. Is an adequate alarm system provided?

b. Can guards quickly reach all areas after alarm is sounded?

c. Are any important areas left uncovered?

11. DISPATCH CENTER AND COMMUNICATIONS SYSTEM

a. Does the communication system provide comprehensive coverage of the facility?

b. Are there alternate means of communication?

c. Is fleet communication system adequate for emergency fleet operations?

d. Is the equipment tested periodically?

12. FIRE PROTECTION

a. Are fire regulations provided and kept up to date?

b. Is there an adequate program of housekeeping and fire prevention?

c. Are periodic inspections made of fire-fighting equipment?

d. Are employees properly trained in the use of fire-fighting equipment and in their duties in the event of fire?

e. Have arrangements been made with the local fire department for help when needed in such cases where special arrangements are necessary?

13. OPERATIONAL SAFETY PROGRAM

a. Are drivers and operational personnel adequately trained in traffic safety?

b. Are programs of incentives and awards for drivers designed to reduce accidents and stimulate safe and skilled vehicle operation?

14. TERMINAL AND SHOP SAFETY PROGRAM

a. Is an adequate safety organization established?

b. Are employees represented on this organization?

c. Is there an adequate safety education program?

d. Are protective equipment and clothing provided?

e. Are first-aid and medical facilities provided?

f. Are records evaluated to determine effectiveness of program?

g. Has advantage been taken of existing structure for providing protection against blast and radiation?

h. Have buildings been surveyed by qualified engineers to determine best shelter areas?

i. Are shelters away from danger of flying glass, heavy overhead weights and concentrations of steam or gas pipes or electric conduits?

15. VEHICLE SECURITY CHECK

a. Are adequate vehicle security checks included in regular maintenance and operating procedure?

16. EMPLOYEE PROTECTION

a. Has one individual been placed in charge of the security program?

b. Have groups been formed to provide necessary services, such as first-aid, fire-fighting, rescue, etc., in an emergency?

c. Does the facility have an effective warning system, including arrangements to receive warning from local Civil Defense?

d. Have shelter areas been designated? Are they clearly marked?

e. Has liaison been established with the local Civil Defense organization?

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f. Is there a well protected center for the control of emergency operations within the system or facility?

g. Are air raid and fire drills held regularly?

h. Have employees been trained in self-protection?

i. Have employee groups been trained in their emergency duties?

j. Have test exercises been held to test the effectiveness of the emergency organization?

17. ALTERNATE SCHEDULES AND ROUTES

a. Are alternate routes provided for in event of emergency?

b. Are alternate schedules planned for in event present schedules become impracticable?

c. Have these been coordinated with civil defense and other authorities?

18. PLAN FOR RESTORATION OF SERVICES

a. Organizing to meet Emergencies

(1) Is there a general organization plan for restoration of service?

(2) Are alternates for key personnel designated?

(3) Is there an adequate emergency communication system?

(4) Is there an adequate emergency system for the transport of personnel to required places?

(5) Have alternate headquarters for emergency operation been provided?

(6) Is there provision for adequate liaison and coordination with associated agencies, including Civil Defense groups?

(7) Have regular operating personnel been instructed in the extension of their normal duties required for protection against enemy action?

(8) Has provision been made to reinforce normal operating personnel during emergency with employees of other departments?

(9) Do arrangements exist for the utilization of personnel of other supply and related transportation organizations if required in an emergency?

(10) Are equipment and tools dispersed?

(11) Have arrangements been made for emergency procurement from suppliers of parts? fuels? other supplies?

(12) Are there arrangements for equipment and tools from other organizations?

(13) Have essential records been duplicated and dispersed?

(14) Is there provision for furnishing temporary living quarters for personnel if required?

(15) Is there provision for medical aid during the emergency?

(16) Have emergency repair personnel been provided?

(17) Is there adequate provision for gassing, lubrication and maintenance of transport?

(18) Have alternate fuel supplies been provided?

(19) Are alternate power supplies and interconnections with other systems provided?

(20) Have provisions been made for transmitting emergency schedules and routes to the public?

(21) Have cash credits been established in decentralized locations?

(22) Does the plan provide for alerting and mobilizing personnel and equipment promptly and are all personnel properly instructed regarding their duties when alerted?

b. <u>Testing the Plan</u>

(1) Has the plan been given reasonable test?

c. <u>Selective Restoration</u>

(1) Are key personnel indoctrinated in this principle?

(2) Have all vital community facilities been made known to key personnel and lists provided where required?

(3) Have tentative priorities been determined among vital elements for restoration?

P R O P O S E D   D R A F T Appendix C

AUTOMOTIVE VEHICLE SECURITY CHECK

Vehicle Number__________ Make_______________ Date_______________

Type of Vehicle____________________

GENERAL:	Inspection Check
Check under vehicle for gasoline, oil or water leaks	
Make general observation of outside of vehicle. Note evidences of damaged or stolen fixtures	
Lift hood, note important engine components for evidence of breakage	
Note electrical connections, wiring, etc. for looseness, shorting or for attached devices	
Note fuel lines, carburetor, fuel pumps, etc. for leakage, breakage, and cuts	
Check engine, oil and water. Watch for evidence of drainage or contamination	
Enter cab and start engine, noting instruments	
Check gauges, horn and switch on all lights, windshield wipers and so on	
Leave cab, check headlights, return and switch lights to other beam, and check.	
Check left front tire and wheel lugs. Note evidences of cuts or other abuse to tires, looseness of lugs and so on	
Observe front clearance lights, side marker lights and relectors	
Check right front tire and wheel lugs	

GENERAL:	Inspection Check
Check springs, body, trailer connections (if applicable), load, doors, etc.	
Check rear tires and wheel lugs	
Check tail lights, brake light, and note side and rear clearance lights or reflectors	
Observe condition of gas tank. Check for evidences of puncture or damage	
Check emergency equipment (as applicable):	
Torches, lanterns.	
Fuzees or flares.	
Flags.	
Spare bulbs.	
Fuses.	
First-aid kit.	
Axe.	
Check fire extinguisher for contents unless sealed.	
When pulling out check instruments, brakes and steering.	

ADDITIONAL CHECKS FOR TRAILERS:	
Check airhose connections and electrical lines to trailers	
Check coupling. Note particularly fifth-wheel devices and evidences of jamming or loose connections	

ADDITIONAL CHECKS FOR TRAILERS: (Contd)	Inspection Check
Check landing gear and make sure it is in working condition	
Check load. Assure that it is properly locked, sealed, or otherwise secured. Note evidence of theft or pilferage	

ADDITIONAL CHECKS FOR BUSES AND TRANSIT VEHICLES:	Inspection Check
Check emergency doors	
Check passenger packages. See that they are properly secured in racks or compartments	

Employee's Signature ____________________

Driver ____________________

Mechanic ____________________

(/) Items which are satisfactory

(X) Items which are not satisfactory, and explain defects

PROPOSED DRAFT

U.S. Department of Transportation
Federal Highway Administration

Highway Innovation Clearinghouse Study

DRAFT

Prepared for the
Federal Highway Administration
Office of Technology Applications

Prepared by the
Highway Innovative Technology Evaluation Center,
a service center of CERF

February 1998

Disclaimer

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Any opinions, findings and conclusions or recommendation expressed in this publication are those of the Highway Innovative Technology Evaluation Center and do not necessarily reflect the views of the Federal Highway Administration. Moreover, the data and information presented are believed accurate and the analyses credible.

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Barbara Harder of B.T. Harder, Inc. served as the consultant to the Steering Team and was instrumental in producing this report. Among the staff who worked on this project, CERF acknowledges the special efforts of Peter Kissinger, CERF Vice President and HITEC Director and Nicole Testa, CERF Communications & Online Services Manager.

Executive Summary

There is a growing consensus within the highway community for the need for an innovation clearinghouse which could provide more timely and efficient access to technology deployment programs within various state and national agencies. To address this need the Highway Innovative Technology Evaluation Center (HITEC) initiated discussions with a variety of organizations regarding the need to develop new databases and appropriate linkages with existing databases so that the highway community would have more effective access to information on activities such as HITEC, the AASHTO National Transportation Product Evaluation Program (NTPEP), FHWA Experimental Projects Program and Tabulation, and state product approval systems.

Upon initiating this endeavor, HITEC invited individuals from major organizations who were identified as key stakeholders in developing a highway innovation clearinghouse to participate on a Steering Team (see Acknowledgements). The Steering Team ultimately served to guide and direct the program from start through completion.

One of the initial requests asked of the Steering Team was to identify and catalogue existing information resources from the public and private sector, and academia. Appendix A of this report, which was intended to be used as a "stand alone" reference document, contains a synthesis of these existing programs and resources.

The Steering Team was also tasked with assessing the status and usage of these existing systems. To do so, the Steering Team designed a survey that was sent to states and other key organizations having well-developed product evaluation programs and individuals within organizations known to traditionally use data that could be contained in a clearinghouse. The findings of the survey are summarized in Chapter 3 of this report.

It is important to note that the innovation clearinghouse envisaged in this study is not a physical center, but rather a virtual organization that utilizes a matrix approach to information management that will link existing community resources together. Although virtual, the innovation clearinghouse clearly recognizes the vital importance of the human interface throughout the system.

Moreover, although the scope of the innovation clearinghouse was refined during the study, from its outset, **the study focused primarily on a clearinghouse linking Federal, state, and local test and evaluation, technology transfer and technology deployment programs, including demonstration of new technologies, and proprietary product evaluations**.

The key findings identified by this study include:

- Information resource providers support the need for a Highway Innovation Clearinghouse.
- Information resource providers in the public sector want to coordinate and collaborate to enhance the use of their respective data collections.
- Fragmentation of relevant information is pervasive.

- Technological solutions are available that will accommodate the needs of the clearinghouse concepts described in this document.
- People are the critical links in a virtual clearinghouse.
- The Internet was identified as the most viable vehicle for access.
- The state DOTs were seen to be the agencies that would receive the highest benefit from the implementation of a Clearinghouse.

Strategic Action Plan

The Steering Team recommends that the following strategic actions be taken:

- Continue to work on a Highway Innovation Clearinghouse. The tendency to delay to await enhanced technological tools or to "over plan" will only delay the outcome. It will not significantly enhance the quality.
- Strongly encourage FHWA, AASHTO, and TRB to jointly lead the task of developing a national consensus.
- Encourage the FHWA, consistent with its commitment to national technology deployment, to take the lead in promoting participant buy-in to the clearinghouse.
- Conduct pilot projects to demonstrate benefits and to test various technological solutions.
- Integrate follow-on Highway Innovation Clearinghouse work directly with other FHWA clearinghouse efforts.
- Enlist state participation in a Clearinghouse.
- Consider instituting some national policy to encourage participation.
- Develop a comprehensive marketing plan and commit substantial effort to marketing the concept of and benefits anticipated from a Clearinghouse.
- Identify a set of minimal data elements necessary to link all major programs together.

As defined in this study, this clearinghouse would focus on linking federal, state, and local test and evaluation, technology transfer and technology deployment programs. This would include demonstrations of new technologies and proprietary product evaluations. Technological solutions are now available, the public sector highway community desires to enhance its coordination and collaboration, and the specific user community has expressed a genuine need for such a tool.

This report encourages continued action to turn the Highway Innovation Clearinghouse concept into a practical and beneficial tool. The Steering Team looks forward to the implementation of a Highway Innovation Clearinghouse, bringing the highway community enhanced opportunities for enhanced quality of information that is received in an efficient and effective manner. Clearly, a Highway Innovation Clearinghouse is anticipated to reduce duplication of effort, increase the productivity of highway agencies, and allow more timely adoption of innovations in increasing numbers to enhance our nation's highway system.

Table of Contents

CHAPTER 1 INTRODUCTION AND SCOPE OF STUDY

1.1 Introduction

There is a growing consensus within the highway community for the need for an innovation clearinghouse which could provide more timely and efficient access to technology deployment programs within various state and national agencies. This is consistent with the findings and recommendations contained in a variety of reports from organizations such as the Transportation Research Board (TRB) Task Force on Highway Research in Industry, the TRB Committee of Approaches for Increasing Private Sector Involvement in the Highway Innovation Process, the TRB Committee on Conduct of Research, and the TRB Task Force on Measuring Technology Transfer Effectiveness. It is also consistent with a variety of activities underway throughout the highway community to more effectively utilize state of the art information systems technologies, most notably projects underway at the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA) and TRB.

Similarly, the international community, through such organizations as the World Road Congress (PIARC) and FHWA's involvement in its technical committees, has emphasized the need for more ready access to information on technology deployment in the U.S.

The origins for this study can be specifically traced to the Highway Innovative Technology Evaluation Center (HITEC) staff discussions with a variety of organizations regarding the need to develop new databases and appropriate linkages with existing databases so that the highway community would have more effective access to information on activities such as HITEC, the AASHTO National Transportation Product Evaluation Program (NTPEP), FHWA Experimental Projects Program and Tabulation, and state product approval systems.

To initiate the process, HITEC staff helped organize an "ad-hoc coordinating committee" that included key officials from FHWA, TRB, and AASHTO. This committee was established to foster coordination among the various national technology development, testing, evaluation, and deployment programs and to strengthen the working relationship between FHWA, TRB, AASHTO, and the Civil Engineering Research Foundation (CERF)/HITEC. An initial work product of the Committee was the "Highway Technology Research & Technology and Test & Evaluation Programs: An Overview report, which provided a summary of the major programs in existence.

From these discussions, HITEC recognized a need to more effectively coordinate ongoing activities at the Federal, state, and local levels and a desire on FHWA's part to enhance the technology transfer between the various highway agencies and other organizations, while taking full advantage of state of the art information systems and communications technology.

In light of the above. this study was designed to support FHWA and the state and local highway community by facilitating the development of a framework for a national clearinghouse on highway innovation.

1.2 Scope of Study

This study involved a series of planning activities designed to develop a framework and specific recommendations, which would hopefully lead to a national clearinghouse for highway innovation. The primary focus of these activities was to plan a clearinghouse that would more effectively coordinate the various information resources available in the highway community to increase efficiency and avoid duplication. Such a clearinghouse would also be designed to make this information more readily accessible to many users throughout the diverse highway community.

Thus, the innovation clearinghouse envisaged in this study is not a physical center, but rather a virtual organization that utilizes a matrix approach to information management that will link existing community resources together. Although virtual. the innovation clearinghouse clearly recognizes the vital importance of the human interface throughout the system.

Although the scope of the innovation clearinghouse was refined during the study, from its outset, the study focused primarily on a clearinghouse linking Federal, state, and local test and evaluation, technology transfer and technology deployment programs, including demonstration of new technologies, and proprietary product evaluations. In that context. the innovation clearinghouse examined in this study would not specifically include information on research programs, such as those data currently contained in the Transportation Research Information System (TRIS) or the AASHTO Research Advisory Committee (RAC) Research-in-Progress database. However, given the scope and wealth of information contained in various research programs, it was recognized that in order for any innovation clearinghouse to be accepted by the highway community, it would eventually need to be expanded to provide explicit links to those programs. Similarly, although the scope of this study focused on the U.S. highway community, it was recognized that the innovation clearinghouse would have application to and need to be explicitly linked to various international systems.

1.3 Study Process and Conduct

Throughout the study, HITEC served as a **facilitator** to bring the highway community together to identify needs, resources, and an implementation strategy that would build, wherever possible. on existing activities and resources. As described below, the study involved six specific tasks.

1.3.1 Task 1 - Steering Team

The major organizations that would be key stakeholders in an innovation clearinghouse were invited to participate in a Steering Team. This Steering Team served to guide and direct the study and provide linkage to databases and information, which could be key elements in the clearinghouse. HITEC facilitated three meetings of the Steering Team and supported other activities as required to encourage buy-in and participation from the highway community.

Steering Team members were selected in coordination with AASHTO, FHWA and TRB from the following organizations: the AASHTO Special Products Evaluation List (SPEL) Council, FHWA, relevant TRB and AASHTO Committees, the NTPEP Oversight Committee, the Local Technical Assistance Program (LTAP), representative state DOTs, and highway associations.

Barbara T. Harder, with B. T. Harder, Inc, served as a consultant on the study.

1.3.2 Task 2 - Identification of Resources

The objective of this task was to identify existing programs and to categorize the types of products that they provide (for example, current technologies under evaluation, the implementation status of the Strategic Highway Research Program (SHRP) technologies, or current and planned demonstrations) in terms of type of information and current method of access. In coordination with the Steering Team, HITEC attempted to identify and catalogue the following information:

- existing state and local product test, evaluation, and approval programs and associated databases;
- existing AASHTO, TRB/SHRP, FHWA, HITEC, and other national test and evaluation, technology transfer and deployment programs, and associated databases from those programs;
- existing private sector product test, evaluation and approval data, as applicable (not-for-profit organizations, trade associations, industry sponsored institute data, and others); and
- the status—extent of electronic format—of the databases.

To the extent practical, this study was coordinated with other ongoing clearinghouse activities such as the NCHRP 20-7 Task 82 "Enhancement for SPEL" study, the Washington State DOT World Wide Web (web) site's SHRP Implementation database, as well as the ongoing FHWA efforts to Re-engineer its Experimental Projects Program and Tabulation, study the Value of Information, and develop a Technology Resource Center (clearinghouse) within the Office of Technology Applications.

HITEC relied heavily on input from the Steering Team for this portion of the study. Efforts were supplemented, to the extent possible, by data collected from the Product Evaluation Information Survey conducted in conjunction with the NCHRP 20-7 Task 82, "Enhancement for SPEL" study. Information was received via e-mail or letter requests to, and followed by telephone interviewing of, database sponsors and users, and other research and technology professionals as required.

The Steering Team reviewed and commented upon the interim report documenting the findings from this task. The report included results of Task 2, as well as plans for Task 3, including a proposed survey instrument and target audience. The Steering Team recommendations were integrated into the final survey in Task 3 and into subsequent tasks of the project. The material contained in the interim report, with any changes recommended by the Steering Team, was incorporated into Chapter 2 of this final report.

1.3.3 Task 3 - Characterizing the User Needs and Capabilities

HITEC undertook a study of potential clearinghouse participants primarily from the public sector user community and secondarily from private sector nonprofit organizations and key trade associations. Representative participants were selected from a lengthy list of organizations identified in Task 2. The participants selected included a sufficiently robust cross-section of state DOTs and other organizations that enabled the development of a detailed survey mailing list as well as production of a description of the profiles of potential users. In this context, the term "users" connotes both members of the community who are developing information as well as those who access current systems. The following were developed:

- a detailed listing of user categories/types and user identity profiles within typical state DOT and other applicable organizations;
- a summary of the "state-of-use" of information maintained in the programs identified in Task 2 (how used—under what conditions, how much, how often...); and
- an assessment, including an importance ranking, by current users of the need for access to the identified program information/databases.

A 7-page survey instrument was mailed to a cross section of the highway community. To increase the response rate, HITEC produced hard copies and electronic announcements addressing the conduct of the survey. The Steering Team was an important instrument in assisting with the targeted distribution of the announcements, both by mail and electronically, through their respective organizations' information technology resources. The mail survey was supplemented with follow-on telephone inquires to the respondents and other users, as well as information received from the Steering Team.

The survey was not designed to provide a statistically valid sample of all members of the highway community, however, it was meant to be representative. It was specifically targeted to primary users of applicable data—particularly states having well-developed product evaluation programs and individuals within organizations holding positions known to traditionally use data that could be contained in an innovation clearinghouse.

A synthesis of the survey findings was prepared and presented to the Steering Team. The Steering Team reviewed and commented on this interim report. The Steering Team's recommendations were integrated into the conduct of subsequent tasks of the project. The material contained in the interim report, with any changes recommended by the Steering Team, was incorporated into Chapter 3 of this final report.

1.3.4 Task 4 - Clearinghouse Framework

Building on Tasks 2 and 3, a proposed framework (architecture) for a national clearinghouse for highway innovation was developed. This proposed framework contained the following:

- a listing of databases/clearinghouse modules which would be essential components in the clearinghouse as dictated by the needs of the user community and the availability of such resources;
- identification of missing elements in the framework—gaps in information which the community needs, as well as other missing elements;
- recommended linkages between these modules, building on those which already exist or which are currently under development, and recommendations on the types of information which would be transmitted through them; and
- requisite information system technologies, including intelligent decision support systems tools to create a value-added experience for users.

(See Chapter 4 of this report.)

1.3.5 Task 5 - Implementation Strategies

Various mechanisms to implement the clearinghouse were explored during the course of the study. Based on interest expressed by FHWA, HITEC specifically explored the Internet as an appropriate vehicle. Expert advice was sought to develop a preliminary management plan for the steps necessary to develop the linkages between various modules of the proposed clearinghouse and a public interface. The Steering Team considered implementation issues (barriers and boosters), quality of data, system maintenance requirements and mechanisms, and ultimately formulated specific recommendations to FHWA for an innovation clearinghouse that would best meet the needs of the highway community.

The objective of this task was to develop a strategic action plan outlining the required steps to implement the framework for the clearinghouse.

1.3.6 Task 6 - Reports

In addition to the interim reports provided in the earlier tasks, HITEC prepared two interim draft reports for consideration by the Steering Team, which each successive draft reflecting comments, input and direction received from the Steering Team. The second full report was discussed at length during a full Steering Team meeting.

Finally, once the Steering Team reached a consensus, HITEC prepared and published this final report for distribution to the highway community.

1.4 Selected General Definitions

In undertaking this study, HITEC and the Steering Team recognized that one of the inherent difficulties in scoping the effort was the lack of uniformity of definitions used throughout the community. Furthermore, it recognized that in actually developing and ultimately implementing a meaningful framework for a clearinghouse the community would probably need to develop such a consensus for key terms and definitions. In that context and illustrated in Figure 1, the following definitions were applied throughout the study and are used throughout this report.

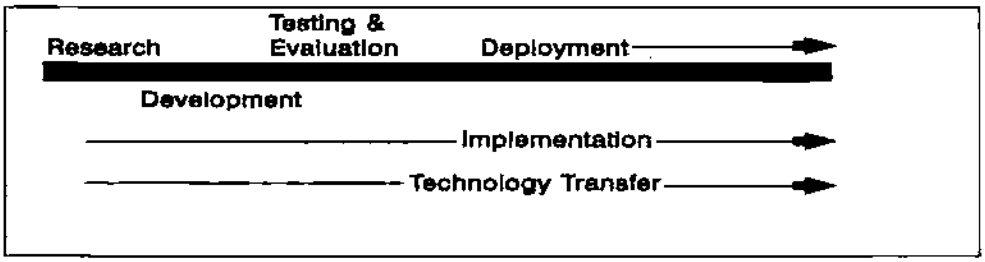


Figure 1 Definitions

- Research: a systematic controlled inquiry into a subject in order to discover or revise facts, usually containing analytical and experimental efforts to increase the understanding of causative relationships necessary for meeting defined needs.

  In general research can be basic or applied:

  - Basic research involves the study of phenomena whose specific application has not been identified; the primary purpose of this kind of research is to increase knowledge.

  - Applied research involves the study of phenomena relating to a specific, known need in connection with the functional characteristics of a system; the primary purpose of this kind of research is to answer a question or solve a problem (FHWA, p. 1-7).

- Development: adaptation, modification, and testing of an idea, process, or product for practical use under field conditions. Development is a continuation of the research process and is conducted to verify expected performance and improve the utility of the research result (Harder and Newlon, p. F-3).

- Testing & Evaluation: a systematic process of critical assessment to determine the characteristics, quality, or viability of a technology, followed by analysis of in-service demonstrations to measure performance against established criteria. The process utilizes unbiased methods to produce information upon which an informed decision can be made.

- Implementation: that part of the technology transfer process concerned directly with the mechanisms of putting specific sets of research findings into practical use. The full implementation process includes the development or revisions of policies, plans, specifications, standards, and so on, which must occur before new knowledge can be incorporated into practice (Burke, p. 21).

- Deployment: systematic or strategic distribution of implementation-ready products or new technologies, causing such innovations to be put into use in the field.

- Technology Transfer: activities that lead to the adoption, adaptation, or demonstration of a new technique or product by users. Technology transfer includes dissemination and other factors that lead to the eventual use of the innovation (Hodgkins, p.3).

Alternative definition from an earlier work based on the FHWA definition of Technology Transfer.

- Technology Transfer: the process by which existing research knowledge and new technology are transferred into useful processes, products, and programs. Use of the term implies the application of a conscious and positive effort to promote and accelerate the practical use of research knowledge and new technology (Burke, p. 21).

CHAPTER 2 INFORMATION AND OTHER AVAILABLE RESOURCES

A major objective of the study focused on identifying and examining the various information resources found within the highway community. The scope of the study detailed the following areas in which information resources were known to exist:

- state and local product test, evaluation, and approval programs and associated databases;
- AASHTO, TRB/SHRP, FHWA, HITEC, and other national test and evaluation, technology transfer and deployment programs, and associated databases from those programs; and
- private sector product test, evaluation and approval data, as applicable (compiled by not-for-profit organizations, trade associations, industry sponsored institute data, and others).

As the information resources were examined, the extent of the use of electronic formats was a primary area for review.

This chapter includes the identification of the various programs and activities that constitute the majority of information resources within the highway community. Following this discussion is a synthesis that describes a number of the broad characteristics of the information resources identified. The chapter then describes related activities and issues and concludes with a short summary of observations gained from the examination of the many resources available for a Highway Innovation Clearinghouse.

2.1 Identification of Programs and Activities

Information resources for this study are considered as being collections of highway information or data that are publicly available or that are circulated within and among transportation agencies. The format of and accessibility to the information varies substantially. Information may be contained in printed documents or electronically searchable databases; it may be accessible only through inter-agency distribution or via the Internet by a worldwide community.

At its initial meeting the Steering Team identified programs and activities having a history of supplying information to the highway community. The Steering Team's review concentrated on data sources from programs dealing with testing and evaluation, and then focused on technology transfer and deployment.

2.1.1 Testing and Evaluation Programs

The broadly defined information resources identified for testing and evaluation were as follows:

- Highway Innovative Technology Evaluation Center (HITEC)
- National Transportation Product Evaluation Program (NTPEP)
- Individual State Product Evaluation Programs
- Special Products Evaluation List (SPEL) (or its successor program)
- Ideas Deserving Exploratory Analysis (IDEA) Programs
- Federal Highway Administration Programs/Activities
    - ♦ Experimental Projects Program
    - ♦ Demonstration Program
    - ♦ Testing & Evaluation Projects (T&E)
    - ♦ Local Technical Assistance Program (LTAP)
    - ♦ Strategic Highway Research Program (SHRP) Implementation

2.1.2 Technology Transfer and Deployment Mechanisms

To further view the breadth of the available information resources, the Steering Team expanded the focus of its preliminary review to more carefully consider technology transfer and deployment mechanisms. This broadening exercise was an important addition to the Steering Team's examination of information resources. There is often a mission/objectives overlap among the various types of activities. For example testing and evaluation may also have some components of technology transfer in the efforts to further implement new products. Considering this potential overlap, the following programs or activities were put forth as potential candidates for a more detailed review.

- FHWA
    - ♦ Office of Technology Applications and its web site, TECHNET
    - ♦ Priority Technology Program (PTP)
    - ♦ Turner-Fairbank Highway Research Center and its web site
    - ♦ LTAP Clearinghouse and LTAP T^2 Centers
    - ♦ Border Technology Exchange Program
    - ♦ Federal Lands Technology Transfer
- Industry groups, trade associations
- National Cooperative Highway Research Program (NCHRP) Syntheses
- National Work Zone Safety Information Clearinghouse
- Northwestern Infrastructure Clearinghouse
- PC Trans software databases and publications
- State DOT newsletters, bulletins

- Transportation Conferences
    - PACRIM Expo
    - Transportation Research Board Annual Meeting
    - ITS America Annual Meeting
- Transportation libraries, industry, federal, state, academic
- Texas Transportation Institute (TTI) Clearinghouse Projects
    - National Quality Initiative
    - Metrication
    - SPEL
    - Geotextile T&E Center
- University Transportation Centers
- Vehicle Detection Clearinghouse
- World Interchange Network
- World Bank programs

2.1.3 Databases and Other Information Collections

In addition to identifying these information resources, the Steering Team further described databases or information known to exist within these programs or activities. Many of the programs, such as LTAP, Institute of Transportation Engineers (ITE), SHRP, and ITS America, have established clearinghouses. The following programs/databases show an array of information resources commonly available.

- SHRP Implementation
    - FHWA produced *FOCUS* newsletter
    - Evaluation and implementation data
    - SHRP database
    - Washington State DOT web site
    - Product deployment data
    - Regional Centers, Lead States Organizational Framework

- LTAP Clearinghouse
    - Training resources database
    - Publications in searchable form (CD-ROM)
    - Newsletters (CD-ROM)
    - List serve, chat room, e-mail

- ITE Clearinghouse
  - ITE publications
  - Information resources for traffic and transportation engineering

- TS America Clearinghouse
  - ITS America publications

- Individual State Product Evaluation Programs
  - Washington State DOT web site including in addition to SHRP related information, AASHTO RAC Research-in-Progress database, and testing and evaluation information resources and databases
  - Various states' new product evaluation databases, reports, and newsletters

- Transportation Research Information Service (TRIS)
  - Research in progress

2.1.4 State and Local Agencies

State and local transportation agencies sponsored the remaining programs and activities that were investigated for this study. The activities of the state DOTs represented on the Steering Team provided an excellent cross-section for examination. The Federal Highway Administration LTAP program manager provided a listing of local agencies that have been active in various product implementation and technology transfer efforts. Local organizations having national program contact with LTAP activities were considered more likely to sponsor some form of product testing and evaluation activities. These agencies were added to the list of identified information resources.

2.1.5 Information Resources for Examination

Based on these identification exercises HITEC developed the universe of information resources that would be examined for the study. As the study progressed several other information sources were added, reflecting continuing Steering Team input to the study process. The programs and activities reviewed for this study do not depict the definitive collection of information resources available to highway industry professionals. However the programs and activities examined 1) give a reasonable representation of the types of information resources of interest, and 2) include the primary collections of nationally available product testing and evaluation data. Figure 2 contains the information resources identified for examination during the course of the study.

INFORMATION RESOURCES FOR EXAMINATION

National

Border Technology Exchange Program—FHWA
Bureau of Transportation Statistics—USDOT
Coordinated Federal Lands Highway Technology Implementation Program—FHWA
Experimental Projects Program and Tabulation—FHWA
Geotextile Testing and Evaluation Clearinghouse (at TTI)
Highway Innovation Technology Evaluation Center (HITEC)
Infrastructure Technology Institute (at Northwestern University)
ITS America Clearinghouse
Institute of Transportation Engineers (ITE)
Local Technical Assistance Program (LTAP)—FHWA
National Quality Initiative Clearinghouse (at TTI)
National Transportation Product Evaluation Program (NTPEP)
National Work Zone Safety Information Clearinghouse
Non-Destructive Evaluation (NDE) Validation Center—FHWA
Priority Technology Program (PTP)—FHWA
SHRP Implementation and Lead States Program—AASHTO
SHRP Long Term Pavement Performance (LTPP) Program—FHWA
Special Products Evaluation List (SPEL)—AASHTO
Testing and Evaluation Projects—FHWA
Vehicle Detection Clearinghouse (at New Mexico State University)
World Bank Network Initiative
World Federal Technical Assessment Organization (WFTAO)
World Interchange Network (WIN)

State/Provincial

State Department of Transportation New Product Evaluation Programs

Arizona	Pennsylvania
Kansas	Washington
Mississippi	

Ontario Good Roads Association—The Road Authority

INFORMATION RESOURCES FOR EXAMINATION
Local/Municipal Local/Municipal Transportation Agencies New Product Evaluation Programs City of Austin, TX City of Milwaukee, WI North Little Rock, AR Chesterfield County, VA
Private Sector Industry Group Information Resources
Academia ITS Research Centers of Excellence Clearinghouse (at TTI) University Transportation Centers University Research Institutes

Figure 2 Information Resources For Examination

2.2 Synthesis of Information Resources

Each information resource provider was interviewed by telephone or requested to complete a short summary fact sheet requesting general information of interest to the study. The five primary objectives of developing the summaries are:

1) to give an overview of the various programs and activities that might be typical contributors to an innovation clearinghouse;
2) to gain knowledge regarding current users of existing information;
3) to show the variety of media and formats used as well as the distribution ranges of the materials;
4) to identify data access methods/costs and determine future plans for enhancements to data availability; and most importantly
5) to grasp an understanding of the content contained in the existing collections and databases.

An Information Resource Summary from each program or activity examined during the course of the study is contained in Appendix A.

The information requested from each resource provider is organized in the format contained in Figure 3.

INFORMATION RESOURCE SUMMARY FORMAT

Program or Activity Name
Description/Scope
Type(s) of Activity
    Research and Development
    Testing and Evaluation
    Technology Transfer
    Technology Deployment
Sponsor(s)
Typical Users
How are Findings or Results Reported and Disseminated?
Existing Information Collections/Databases
Who Maintains the Collections/Databases?
Location and General Format Description of the Data
How Can the Data Currently Be Accessed?
Access or Subscription Fees
Plans for Near-Term Enhancements to the Collections/Databases
Illustrative Example of Collection/Database Content
Current Use(s) of the Collections/Databases: (how used and how much from sponsor's perspective)
Contacts for more Information
    Program/Resource Coordinator
    Information Systems Coordinator

Figure 3 Information Resources Summary Format

The Information Resources Summaries yielded information for determining a general profile of the resources available to and users of an innovation clearinghouse. Information from the summaries is organized below according to the five objectives.

2.2.1 Overview of Programs and Activities

Geographic Reach

The programs and activities that produce the information resources fall easily into a geographic categorization: national, state, and local. The vast majority of national programs are either sponsored by the Federal Highway Administration as part of its ongoing program or have been created through requirements contained in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 (e.g. FHWA programs: Experimental Projects Program and Tabulation, Priority Technology Program, and Testing and Evaluation Projects). FHWA and the USDOT were tasked with accomplishing various efforts specified in ISTEA—a number of these were examined during the course of this study (e.g. National Work Zone Safety Information Clearinghouse, Infrastructure Technology Institute, and University Transportation Centers). It should be noted that the academic information resources examined in this study are funded as a result of ISTEA and are administered by various arms of the USDOT. A second significant source of nationally available data is state sponsored through AASHTO (e.g. NTPEP and SPEL). The activities of FHWA and AASHTO in the testing and evaluation area are particularly relevant to this study. Industry trade associations are the third group of nationally available information resources. These organizations usually provide two tiers of service, one level for the general public and a second, more comprehensive level of service for the members. Although several industry associations were examined, the private sector business role as individual organizations providing information resources was not a central area of inquiry. There is a wealth of information available from private sector organizations, yet this type of data is currently beyond the public sector information focus of this study. The inclusion of, for example, manufacturers, suppliers, and vendors to an innovation clearinghouse could be a future goal of an overall effort. This should in no way minimize the importance of the private sector material, yet the broad diversification of such information was more than could be appropriately addressed in this context.

State activities in testing and evaluation focus almost exclusively on the state's new product evaluation requirements. State programs vary in the level of sophistication. Many states' materials and testing laboratories are responsible for the state's new product evaluation program. Programs are generally funded either with state moneys or with federal-aid funds, often State Planning and Research Program resources. States also participate in federal-aid pooled fund efforts (e.g. Vehicle Detection Clearinghouse). While these activities are often state or regionally focused, they may also span a nation-wide geographic area.

Local or municipal agencies typically do not have programs or activities for new product testing and evaluation. During the course of examining local agencies, large and small cities were contacted to determine the new product testing and evaluation processes used. In essence, few programs of testing and evaluation within a municipal department of public works or transportation agency were found. Many local agencies rely on their state department of transportation's product specifications. Several local agencies performed evaluations when a product of particular interest emerged. These agencies then developed specifications for use if the product shows desirable performance levels. The review of local and municipal agencies was not extensive. The study focused on state and national efforts because of the reach of their programs and the extent of the data available. As with individual private sector company data, local and municipal activities might be considered for incorporation at a future time.

Type of Activity

The type of activity was used as a means to categorize the information resources. Each resource was examined in light of the major goals and outcomes of its program efforts. A number of the elements of the Research through Adoption Continuum (see Figure 1) were used for logically grouping the various information resources; these are 1) testing and evaluation, 2) technology transfer, and 3) technology deployment. A significant focus for an innovation clearinghouse is new product testing and evaluation programs. However, as seen in the information resources identification process, other programs and activities also produce information of interest to this study. The study examined only a few programs that concentrated on research. These typically were academic programs that also have a large interest in technology transfer. For purposes of this study and its categorization, we have included these academic programs within the technology transfer area although they also are significant research efforts.

A number of the programs consider their efforts as having two outcomes. In particular, technology transfer tends to accompany a number of the programs' outcomes that focus on the other types of activities. For example, when a program focuses on testing and evaluation, it also often assumes a technology transfer role in disseminating the findings of its efforts. Likewise, research and development programs, frequently also have technology transfer elements. Although these overlaps in program missions occur, generally each of the information resources examined has a primary focus. It is important to note that the programs and activities were specifically picked for inclusion in the study. Therefore, the bulk of the information resources examined had mission emphases in either testing and evaluation and/or technology transfer.

2.2.2 Current (Typical) Users

State departments of transportation professionals are most often mentioned as the typical users of the information resources examined in this study. Local agencies and regional authorities, private sector organizations (consultants, manufacturers, and vendors), and researchers and academia are also cited as users of the information resources. With the advent of electronic access, a number of programs have users worldwide. These users span a broad range of owners, operators, and constructors of highway facilities.

2.2.3 Information Formats

A majority of the information resources examined in this study are contained in electronic formats. Their one outstanding characteristic is the absence of a means to coordinate one database or electronic collection with another. Only in one instance is such database coordination now being discussed, integrating the updating of the FHWA Experimental Projects Program and Tabulation into the ongoing efforts to update the AASHTO Special Products Evaluation List. FHWA is making inroads to accessibility coordination by facilitating entry to its technology efforts through its Internet-based TECHNET, a technical information and services network/web site. Yet, even with these information resources, specific integration with other programs' resources has not yet been accomplished.

In general, most electronic databases or collections of information exist on computers housed at the sponsor's site (or the sponsor's contractor's site) and are typically stand-alone systems. The databases do not interact with other databases or rely on other electronic resources to assist in providing information. In addition, a number of the resources are contained on compact disks or diskettes—electronic media.

The lack of electronic integration and coordination must be considered in light of the available technology. For the most part there has been no electronic tool to enable such linkages. Moreover, many of the programs and activities have been created with specially earmarked funds for a unique purpose, not including interconnectivity with other related databases. Furthermore some databases are used solely by one agency (e.g. many of the state DOT new product evaluation efforts). Currently these databases are housed on one computer and used only by that agency's professionals.

Even in this age of computer proliferation, a number of the organizations supplying information resources effectively use a wide variety of formats from printed documents to personal contacts. The most often cited format after electronic formats is printed documentation, such as reports of the results of some specific activity. With new product evaluation, lists of approved products and the status of products undergoing evaluation are commonly expressed in printed reports. Additionally, a number of the information resources convey results of search of their electronic collections via printed output and reports.

The smaller the user agency or program, the more oriented it is generally to printed documentation or to information contained on electronic media formats (diskettes, CDs). On the other hand, the broader the geographic program reaches the more probable that the data is housed in a database on the sponsor's computer.

Information resources that focus on technology transfer tend to use the broadest choices of formats for conveying information. This may be due to the varied mechanisms used to convey technology or based on the needs of the users receiving the technology transfer material. These variations can include technology transfer from FHWA or a state DOT to a small municipal public works agency or an international agency dealing with rural low volume roads.

2.2.4 Information Distribution/Access and Future Enhancements

The manner in which the information resources have been geographically categorized provides some clues to the span of their distribution services. In general, national programs distribute information nation-wide and internationally. FHWA programs and activities in particular fit this comprehensive model. In addition, several information resources are specifically directed to the global community. For the most part, state DOT programs distribute information within their own state, either inside the transportation agency only or among local public works departments. Some DOTs distribute information to manufacturers and vendors as well. Information sharing among states within regional areas is growing.

Distribution of materials uses both the information push and pull methods—information resource providers "push" materials to the users through various incentives and marketing, or users create a "pull" on the resource providers through demand of specific materials. The focus of the content of the information resource defines the broad or narrow distribution of materials. No other general rules of thumb for distribution emerged from review of the information resources examined in this study. Because of the public nature of the information, other than funding availability, few limits are placed on dissemination. Distribution of information was only limited in programs or activities that were membership-based, and these were trade association or private sector based organizations' programs. Even most of these programs had non-member information distribution at some lesser level.

Most programs and activities have standard mailing lists to which printed material is sent periodically. Generally this information is summary in nature or highlights particular work being accomplished on one or more projects. Reports, newsletters, data sheets, and status summaries of activities are popular dissemination vehicles. As can be expected, there is significantly less control over targeting the materials to specifically fit user needs with the "push" distribution methods.

Many of the existing clearinghouses also provide information on request: information "pull." Requests are often made through telephone, fax, or in writing, and through electronic means such as the Internet. Clearinghouse information specialists then perform searches of their own databases, and often have established links to other information resources to which additional search requests can be made. This comprehensive search capability, accompanied by the specialist's expertise in understanding and having access to other available resources, is one of the most valuable assets enhancing information dissemination.

Almost without exception every program and activity that provides information resources is moving toward being available on an organization-wide Intranet or world-wide via the Internet. Well over half of the information resources studied have electronic access via the Internet as a means of providing information to users and interested parties. In this situation, information distribution is controlled by the individual accessing the database and depends on the level of sophistication for electronic searching possessed by the user. When performing electronic searches, the responsibility for knowing where data is housed is also placed upon the individual user. Links from one Internet site to another are useful; however, many site owners are now in a race to have the most extensive list of references available on the Internet. Nevertheless, all links tend to have equal weight because there is little descriptive data regarding the content of the link/referenced site. Electronic access has allowed significantly broader availability of information, yet has placed an equally significant responsibility on the individual user—knowing how to efficiently get the exact information needed.

To many of the sponsors' credit, information resources available on the Internet are also accompanied by a user e-mail correspondence function. Others, such as the Washington State DOT web site provide access to a technical representative. However, the burden of responding to information queries from a global user base can be overwhelming. Several sponsors have organized or are now considering subscription-based access to Internet discussion groups or similar limited access mechanisms that will guard the quality of information exchange.

Future activity for sponsors of information resources focus on either 1) getting the database or information collection available via the Internet, or 2) enhancing the capability of the Internet user to more easily find the specific information sought. The goal is to have information available electronically, yet the tools to locate and extract specific information or comprehensive information about an esoteric subject have not kept pace.

2.2.5 Content

The content of the information resources can be grouped into major areas, most of which relate to the mission of, or purpose for, creating the information resource. Clearinghouses, collections, and other information-based efforts inform the user community, enhance communications among the users, facilitate introduction of new technologies and transfer of technology, and provide a means for coordination among efforts and reduction of duplication.

Information resources examined in this study provided the following:

- results of activity—testing, research, and deployment technical findings and recommendations (results of efforts often will be described via abstracts or, increasingly, full text versions of reports);
- status of activity—stage of completion of an effort;
- personal contacts—who has or is doing a specific effort and how to contact the individual;
- activity sponsor, funding amounts, time completed, and other administrative details; and
- listings of completed or ongoing efforts accompanied by one or all of the above listed items.

The content of the information resources tells us that users are interested in knowing 1) what's been done, by whom, when, and with what result, and 2) whether others' efforts will help the user save time, money, and effort in accomplishing the task at hand.

The one overarching observation is that from the highest level of analysis, the content of the information resources is remarkably similar in types of data elements. Yet the continuing challenge is the variability in format, the level of detail, and accessibility.

2.3 Other Related Activities

This study was accomplished while many other activities are ongoing. Such a constantly changing background is the platform upon which the innovation clearinghouse would be built. The highway and transportation community in general has a vast amount of data needs and sources. To increase data handling capabilities and requirements, program activities show an acute awareness of the rapidly changing pace of technology. There is a migration toward increased sophistication with electronic formats. Many highway related information resources are being examined for updating or re-engineering due to the age of the systems and the enhanced technological resources now available to better access and disseminate the information.

Significant steps are being taken to enhance the value of information to users of technical information. Any efforts planned for an innovation clearinghouse must also coordinate with these and other current activities. Although such coordination is outside the scope of this study, links to these related activities are essential.

As an indication of this rapidly changing and increasingly sophisticated environment, a number of initiatives/activities provide illustrative examples:

- AASHTO's pursuit of enhancements to SPEL has been a valuable trendsetting activity. Because of the timeliness and appropriateness of that effort other activities such as the FHWA Experimental Projects Program is considering merging its activities with SPEL efforts. The successful revamping of SPEL may be a magnet for other similar/smaller efforts (note that the members of the NCHRP 20-7 Task 82 project panel have recently recommended that SPEL be relabeled AASHTO Products Evaluation List or APEL).

- The TRB Strategic Plan gives purposeful attention to future enhancements to the Transportation Research Information Services (TRIS) and in general, to improvements in TRB's information technology. TRIS is widely accepted as a standard throughout the highway and transportation community. Changes to TRIS will be important considerations in the formation of any innovation clearinghouse. Although research and development is not a focus of this study, these resources undergird activities that follow research and development on the Research to Adoption Continuum discussed in Section 1.4 above.

- The FHWA clearinghouse initiative concepts are in their infancy and rapidly being defined. In this respect it is important for this study to consider changing roles for FHWA. FHWA is directing its focus toward being a technology resource and a provider of information resources. These resources are the enabling assets for states to more effectively accomplish their programs.

- The AASHTO Lead State Program was developed to ensure that practical, real-world experience gained in the early application of SHRP technology is shared among all state departments of transportation and extended to other transportation agencies. A lead state is a transportation agency, along with associated contractors and materials suppliers, that has used one of the SHRP technologies on a large enough scale to develop the expertise needed for successful application. The Lead State assumes an obligation to share this expertise with other agencies on a formal basis. This program has shown to be an excellent vehicle to encourage the adoption of the SHRP research results, and as a model, it demonstrates how states can work together to enhance implementation and technology transfer activities (excerpted from FHWA web site).

- The global transportation community is becoming ever more accessible. International activities will be playing larger and larger roles and impacting U.S. activities in increasing ways. The magnitude of the global community's needs are staggering, thus a Highway Innovation Clearinghouse must have access to and be accessible by the global community.

- The private sector—manufacturers, suppliers, and vendors of products and services—is a continuing and increasingly important factor in the product testing and evaluation equation. More and more frequently private/public partnerships are being developed for a variety of highway applications including product implementation activities. The private sector has tremendous potential for contributing to increasing innovation adoption. The innovation clearinghouse must consider the appropriate integration with this domain as a valuable step in the evolution of a comprehensive clearinghouse activity.

A number of ongoing activities or issues were examined by the Steering Team to prepare the group for clearinghouse scoping activities. Of particular interest to the Steering Team was the "Enhancement for SPEL" project. A number of members on the Highway Innovation Clearinghouse Steering Team and HITEC staff have been closely associated with the SPEL project. For the SPEL project background information was gathered from users regarding the most desirable product information format, types of users' systems and electronic accessibility, existing database content/elements, willingness for participation, and other facts also relevant to aspects of an innovation clearinghouse. The general conclusions from a survey conducted during the course of the SPEL project show that users of SPEL, primarily the state DOTs find:

- World Wide Web access would serve the largest group;
- summaries, including status of evaluations, as well as contacts are desired; and
- links and integration with other product evaluation systems are desired.

Although there are other relevant findings from the SPEL effort, these three general findings provide encouragement for furthering the Highway Innovation Clearinghouse concept.

2.4 Resources Summary Observations

There are a few summary observations that are important to recap at this point of the study. The primary effort of examining the resources available for an innovation clearinghouse has been accomplished. The description of the framework is yet to be done. The following points should be kept in mind as further work on the framework is accomplished:

- Information resource providers show encouraging support for a Highway Innovation Clearinghouse.

- The time is right. Information resource providers will support enhanced coordination and collaboration. Interest in collaborative efforts is growing substantially. In part, this is due to more capable information technology tools promoting closer working relationships and facilitating information transfer. These changes underscore a need for institutional commitments to create new relationships or strengthen existing relationships that will form a foundation for a Highway Innovation Clearinghouse.

- Many information resources providers are "going electronic" (creating some electronic means to collect and express data) or during the next 12 months expect to make major enhancements to their electronic capabilities. A vast majority of those information resources currently maintained in some electronic format are either accessible on the World Wide Web or will be accessible within 6 to 12 months. Future activity for information resource sponsors focuses on either 1) getting the database/collection on the Internet, or 2) enhancing the capability of the Internet user to more easily find the specific information sought.

- State DOTs could most benefit by having access to better quality and quantities of data. A Clearinghouse could provide such benefits as are evidenced by the successful transfer of information in key areas as a result of the AASHTO Lead States Program.

- Fragmentation of information is pervasive—relevant data on one subject can be housed in a multitude of locations spread out among many resources. Although there is a movement toward collaboration, such fragmentation continues to persist and the trend is continuing. Information resources are growing in number and content. Additionally, the variability in format, level of detail and accessibility of data are major technological hurdles to overcome.

- Electronic databases/collections are proliferating in a realm that is increasingly devoid of guidance for fast, easy access to information. The user is required to be highly knowledgeable in locating information in a rapidly expanding universe of available data. The information specialist—one who is an expert in locating required information—must be part of a Clearinghouse. The personal expertise and personal contact (when required) are critical functions.

- The quality of the increasing amounts of electronically available data is an area of concern. There are no data quality standards; the user must be very discriminating—every user must evaluate each resource for accuracy and applicability. This process is costly. The cost of quality information is rising above the value/benefits of electronic access. Information resources contained in a Clearinghouse should be required to have met certain quality criteria. Such quality filters should reduce the overall cost of data access.

CHAPTER 3 USER NEEDS AND CAPABILITIES

3.1 Conduct of the Survey

Task three of the Clearinghouse Study was to undertake a study of a representative sample of potential clearinghouse participants from the public sector, private sector and key industry associations. These participants were selected from all organizations identified in the previous chapter, thereby representing a broad cross-section of the community. The survey participants were both users who develop information and those who access current systems.

For the purposes of gathering this type of information, it was determined that the survey did not have to be based on a statistically valid sample of the representative sample of the highway community. Instead, the focus of this survey was to obtain the insight and perspectives of the survey participants. Specifically, state departments of transportation that have established well-developed product evaluation programs and individuals within organizations holding positions known to traditionally use data that could be contained in an innovation clearinghouse were identified by the Steering Team and mailed the survey.

Because the survey was targeted to several different audiences, it was designed to be brief and easy to complete. Primarily, the questions were asked to solicit a response from high to low or approximate frequency of usage. This format was favored so respondents could easily complete the survey.

For reference, a copy of the survey is contained in Appendix B.

In May 1997, the survey was sent to a total of 108 identified users and was supplemented with follow-on telephone inquiries as well as input from the Steering Team. Of the 108 total surveys distributed, 43 completed surveys were received, a 39.8 percent response rate.

3.2 Results of Users Survey

3.2.1 Survey Respondents

Figure 4 below shows the types of respondents by category. All levels of government agencies responded to the survey as well as did research institutions and professional associations. The two that responded as "Other" were from industry/trade organizations.

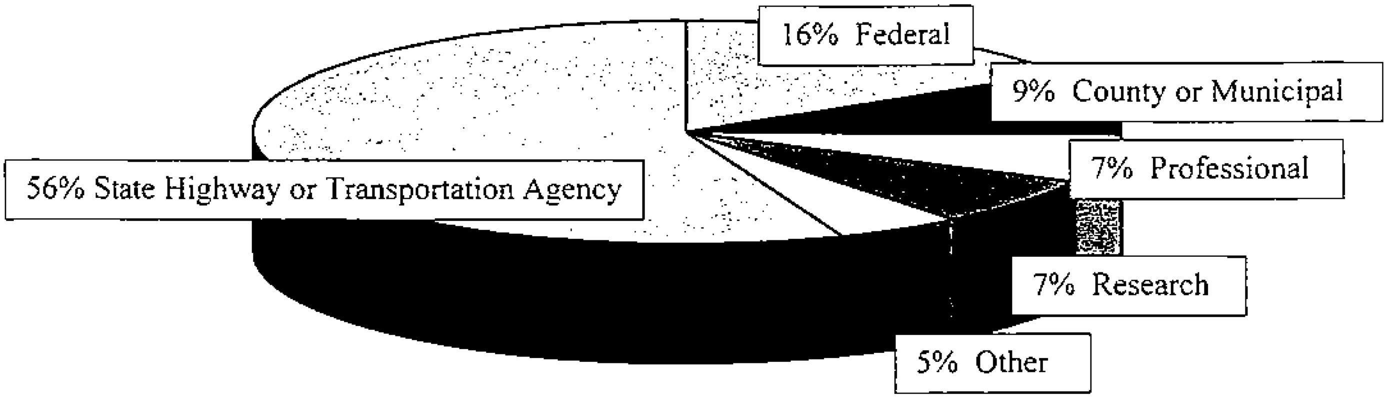


Figure 4 Who Responded to the Survey

The majority of respondents considered their primary activity performed within their functional area to be research & development, testing & evaluation of products, or technology transfer.

3.2.2 Information Use and Access

All of the respondents were asked questions about the number of sources of information they used to assist them and others within their agency, or organization, to perform their daily assignments. Specifically they were asked how many times they had contacted a specific listing of information clearinghouses, databases and other programs for information. The answers to the question are contained in Figure 5. In Figure 6, the numbers represent how many times the respondents had been contacted or received information from the same listing. The information could include newsletters, reports, CD-ROM collections, regular distributions from Internet-based collections, or other similar items.

Source	0	1-10	11-25	26-50	51-100	+100
Border Technology Exchange Program	38	4	1			
Experimental Projects Program	25	16	2			
Geotextile testing and Evaluation Clearinghouse	35	7	1			
HITEC	15	26	2			
ITE Clearinghouse	32	10	1			
ITS Clearinghouse	30	11	1			
CTEP	39	4				
LTAP	23	12	5	1	1	1
National Quality Initiative Clearinghouse	33	9			1	
NTPEP	22	17	4			
Northwestern Infrastructure Clearinghouse	40	3				
NDE Validation Center	38	5				
PTP	31	10	1	1		
SPEL	34	8	1			
Washington State DOT SHRP Database	35	7				1
SHRP LTPP	22	16	5			
FHWA Testing and Evaluation Projects	25	15	3			
Vehicle Detection Clearinghouse at NMSU	43					
World Bank Network	41	2				
WFTAO	42			1		
WIN	41			2		
State DOTs New Product Evaluation Programs	23	15	4	1		
Local/Municipal DPWs	34	8		1		
Industry Associations Info Sources	24	12	2	4	1	
Product Vendor, Suppliers, and Manufacturers	16	8	7	5	6	1
University Transportation Centers	31	10	1	1		
Research Centers of Excellence	28	14	2			

Figure 5 Number of Times Respondents Contacted Programs for Information

Source	0	1-10	11-25	26-50	50-100	+100
Border Technology Exchange Program	38	4				
Experimental Projects Program	30	12	1			
Geotextile testing and Evaluation Clearinghouse	39	4				
HITEC	31	10	2			
ITE Clearinghouse	35	8				
ITS Clearinghouse	38	5				
CTEP	39	4				
LTAP	28	10	1	2	1	1
National Quality Initiative Clearinghouse	39	4				
NTPEP	27	14	1		1	
Northwestern Infrastructure Clearinghouse	40	3				
NDE Validation Center	40	3				
PTP	34	7	1	1		
SPEL	38	5				
Washington State DOT SHRP Database	33	9				
SHRP LTPP	26	13	4			
FHWA Testing and Evaluation Projects	30	9	4			
Vehicle Detection Clearinghouse at NMSU	40	2		1		
World Bank Network	39	3		1		
WFTAO	42			1		
WIN	41	1		1		
State DOTs New Product Evaluation Programs	29	10	2	1	1	
Local/Municipal DPWs	37	5		1		
Industry Associations Info Sources	24	11	5	3		
Product Vendor, Suppliers, and Manufacturers	18	14	7	2	1	
University Transportation Centers Clearinghouse	34	6	1	2		

Figure 6 Number of Times Programs Contacted Respondents for Information

Other sources of related information that were identified included the following:

- Transportation Research Board's TRIS and Dialog systems
- Bureau of Transportation Statistics
- Indiana and Texas' Superpave Centers
- National Cooperative Highway Research Program
- State and national libraries
- AASHTO Metrication Clearinghouse
- National Technology Transfer Center
- Technology Transfer Society
- National Technology Information Service
- FHWA Report Center
- American Concrete Institute
- U.S. House of Representatives' Committee on Transportation and Infrastructure
- Virginia Polytechnic Institute & State University

Having identified the above sources for information, we asked the respondents to indicate how many of their contacts, both provider- and user-generated, were electronic. We defined electronic contacts as including data transfer via computers or related hardware/software. This included E-mail, electronic bulletin boards, CD-ROM, or the Internet. As is depicted by the following figures, very few respondents rely on electronically generated information.

Similarly, when we narrowed the request for strictly electronically generated requests for information on product testing, evaluation, approval, and deployment topics, very few of the respondents indicated that they utilized available systems. Figure 7 highlights respondents' answers.

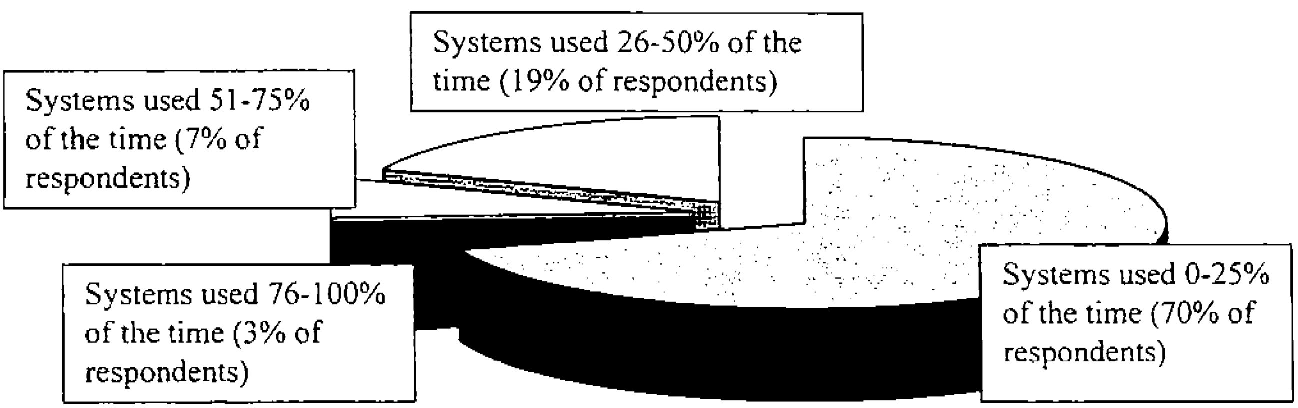


Figure 7 Percent of Respondents Utilizing Available Electronic Systems for Information Requests

Surprisingly, despite the minimal usage of these information sources, over 93 percent of the respondents indicated that they have Internet/World Wide Web capabilities, or will have within the next six months. In fact, more respondents replied that they had Internet capabilities than E-mail access. Figure 8 displays information sources available to respondents.

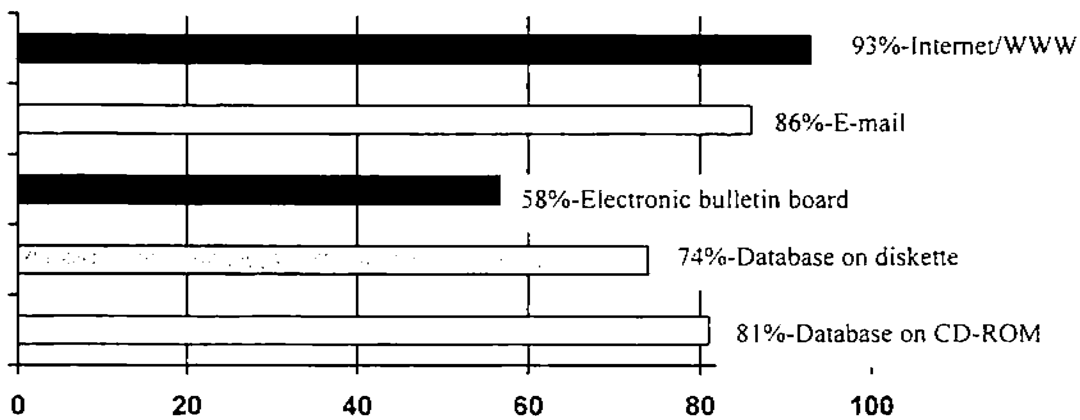


Figure 8 Information Sources Available to Respondents

When asked what the most frequent use of product testing, evaluation, approval, or deployment information from any means, received or requested was in the last 6 months, nearly 30 percent responded to reduce duplication of effort or to coordinate with other similar efforts. The second highest response, 22 percent, was to maintain state-of-art in their technical field. Overwhelmingly, the least used purpose (less than 2 percent) was for purchasing or procurement reasons.

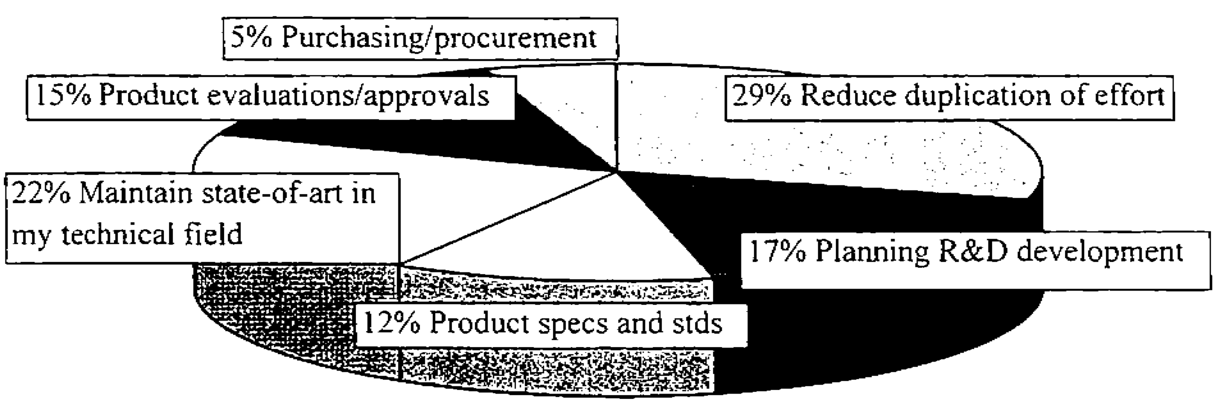


Figure 9 The Most Frequent Use of Product Testing, Evaluation, Approval or Deployment Information from any Means, Received or Requested in the Last 6 Months

Looking towards the future and as portrayed in Figure 10, these figures did not change significantly. Assuming an enhanced electronically-based system was developed in the next 3 years to assist the industry in facilitating their access to disparate clearinghouses, databases, and other programs, over 30 percent responded the greatest need would be to reduce duplication of effort and 26 percent said to maintain state-of art in their technical field. Similarly, only 1 percent answered that purchasing and procurement would be their reason for utilizing such a system.

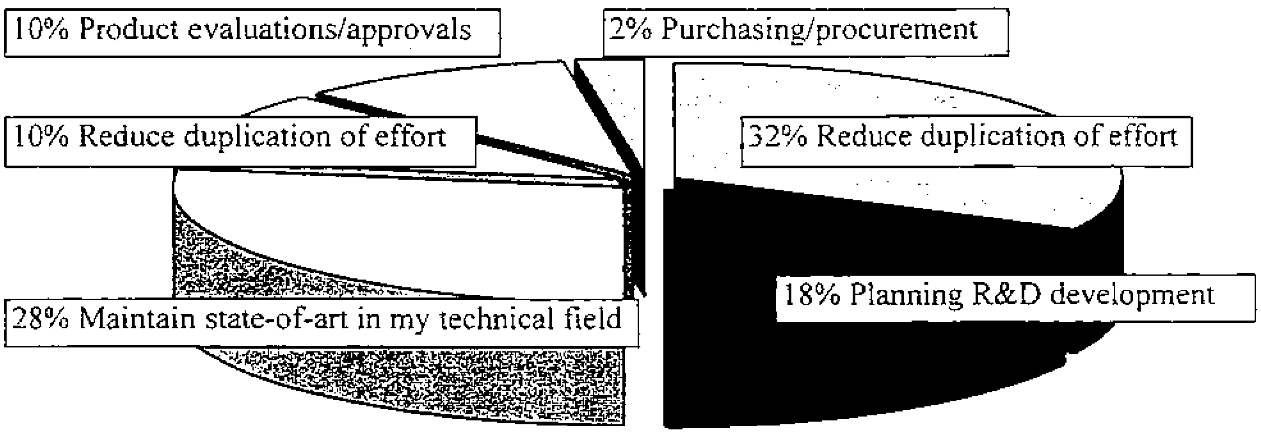


Figure 10 The Greatest Need if an Enhanced Electronically-Based System was Developed in the Next 3 Years

3.2.3 Barriers to Overcome

In conducting the survey, it was assumed that current clearinghouses and databases do not, on the whole, address the needs for product testing, evaluation, approval, and deployment adequately. By far (72.5 percent), respondents indicated that the most prominent reason was that the necessary information has not been collected and documented. And, 75 percent felt that **over 50%** of the effort to create such a system should be spent collecting and documenting information, whereas only 24 percent believed over 50% of the effort should go towards developing appropriate tools, both hardware and software, to access the system. Obviously, these are extremely significant findings when considering what if any further actions relative to a clearinghouse are appropriate.

A mere 5 percent cited a lack of commitment from their agency or organization to provide the necessary resources as the highest level of importance.

Respondents were also asked to provide any additional areas that they believed effort should be spent in creating an Innovation Clearinghouse. The following is a listing of those additional areas:

- Creating and maintaining an intuitive format/structure that links authoritative and reliable information
- Training users
- Marketing the system/advertising
- Developing procedures for constant updating of the information
- Administration and staffing
- Ensuring useful information is posted, not just research "stuff"
- Ensuring widespread availability to all providers of information and users

Respondents were also asked to identify the three top gaps for technical subjects that might be solved by having data available through an innovation Clearinghouse. Their responses confirmed the need to access this information easily and readily. The following is a comprehensive summary of the technical gaps cited:

- How to identify what information goes into the database
- Ready reference and product performance
- Tools and mechanisms for practitioners to search and share information quickly on "what works and why"
- Eliminate duplication of effort by learning from the experience of others
- Safety: countermeasures and effectiveness
- User familiarity and user-friendly
- Lack of knowledge of standards, tests and results of other state DOT work
- Clear definitions of product applicability, limitations, test program limits, and reporting of results in a common format
- Lack of sound databases
- Performance data (costs and benefits) of innovative products as well as sufficient background concerning the attributes of the technology and history use
- Quality of information, including consistency of data and evaluation documentation (screening of data by qualified expert)
- Maintenance
- Accuracy of data - due to difficulty in use and the problems with current databases
- Contact/networking information for both suppliers and customers
- Obtaining a consensus built by a significant body of users
- Lack of awareness of the existence of information and where to find it
- Credibility of results

Similarly, we asked the respondents what they saw as the most difficult barriers to implementing an electronic-based innovation Clearinghouse. The following are their responses:

- Getting everyone access who needs it, especially with current hardware and software incompatibility
- Incentives for inputting data into the database
- Updating the data
- Due to the variety of data forms and structures, a seamless interface could cause confusion as well as prove to be beneficial
- Inconsistency in data input
- Settling on the minimum platform requirements for access and across vital hot links
- Funding, both initially and long term
- Terminology standards and key word dictionary
- Gathering the information
- Ownership in separate databases, cooperation in combining (integration)
- Getting agreement on decision support tools
- Good indexing and cataloging of the information and the terminology/thesaurus
- Applicable cross links
- Different or "non-standard" testing and evaluation protocols
- Overcoming perceptions that the data is not useful or important among professionals
- Desire to change from known techniques, processes and material

3.2.4 Creating the Innovation Clearinghouse

Having identified current shortcomings and barriers to overcome, we asked what would be the most useful and productive format for them. Over 63 percent of those who responded indicated that an Internet/World Wide Web-based system of linkages, including intelligent decision support tools to enable seamless entry to the wide variety of electronic databases and clearinghouses, would be the most useful. Some 24 percent responded that a similar system comprised of hot links that point the user to the variety of sources already established on the Internet would be the most useful. Only 12 percent indicated that an integrated database containing information from the variety of available sources and accessed using common terminology through database software would be the most useful.

Hoping to take advantage of similar systems currently in use on the Internet, we asked what other industries besides transportation they were aware of operating on the Internet. Respondents offered the following as possibilities: medicine, law, libraries, environment, automotive, Encyclopedia Britannica, newspapers, concrete industries (via Aberdeen Group), defense, agriculture, private corporations, trenchless systems, American Concrete Institute, and ICRI.

3.3 User Survey Conclusions

The following summarizes the major conclusions from the HITEC Clearinghouse survey data.

Conduct of the Survey:

- The survey was sent to identify clearinghouse participants from the public and private sectors, and industry associations.

- Of the 108 surveys sent out, 43 were completed and returned to HITEC, a 39.8 percent response rate.

Results of User Survey:

- The majority of those responding to the survey, 56 percent, identified themselves as from state highway or transportation agencies.

- The majority of respondents considered their primary activity performed within their functional area to be R&D, testing and evaluation, or technology transfer.

- On the whole, the respondents indicated that they had contacts with very few of the information sources listed on the survey. Of those sources, industry associations and product vendors, suppliers and manufacturers were the most frequent contact.

- Despite the ever-increasing move to electronic-based formats, more than 70 percent of those responding said that they used electronic means less than 25 percent of the time.

- Similarly, a very small percentage (less than 5 percent) indicated they received or sought information electronically. To that end, the FHWA should play a major role in this effort, and at a minimum have some degree of direct involvement.

- Over half the respondents have never accessed AASHTO's electronic resources, CERF's CENET, and FHWA's web sites (including TECHNET). Forty-four percent have never accessed TRB's web site.

- The most frequent reasons cited for requesting information from any of the sources was to either reduce duplication of effort, plan R&D development, or maintain state-of-art skills in a technical field. Only about 10 percent of the respondents indicated they requested information for purchasing or procurement purposes.

- Nearly all of the respondents, 93 percent, have Internet access or will have access in the next 6 months.

- The biggest reason cited for lack of information availability to the users was that the information had not been documented and collected. Over 90 percent of the respondents believe that is the area where the majority of the effort needs to be spent developing and innovation Clearinghouse.

- A wide variety of barriers, obstacles and technical gaps were identified and provided by the respondents.

- Nearly 70 percent of those responding indicated that they would be willing to discuss and elaborate on their responses to the survey.

CHAPTER 4 CONCEPTUAL FRAMEWORK

Several important questions to ask in the process of formulating the framework for an Innovation Clearinghouse are "What exists currently?', "Where are we?" and, "Where do we want to be?" The first three chapters of this report attempt to define "Where we are." Chapter 4 embarks on the future, "Where do we want to be?" As a beginning to defining the framework, the context in which the clearinghouse will exist is examined. Following this are discussions of some technologies that may have application to the electronic structure of the clearinghouse. This chapter also presents the results of the Steering Team's scoping exercises that aid in defining the expectations of a Clearinghouse. The chapter concludes with a discussion of implementation strategies that will need to be addressed as the framework is carried from concept to practice.

4.1 Context for a Highway Innovation Clearinghouse

A number of contextual issues must be considered during the planning of a Clearinghouse. Several of these issues emerge as important aspects for the framework planning. Considering these, the following are foundational assumptions or tenets upon which a Clearinghouse could be built.

Formation of a Highway Innovation Clearinghouse highlights the importance of balancing the need to maximize the utility of existing data versus the need for additional data collection.

- Tensions may exist between the specific needs of the individual users and the general needs of the highway community at-large.

- Notwithstanding the potentially divergent needs of the individual and the community, a consensus is emerging on the key data elements that are most critical to the formation of a Highway Innovation Clearinghouse.

- Technology is changing at an ever-increasing pace. There is little technological coordination among information resource providers apart from the rush to have data accessible via the Internet.

- The creation of a Highway Innovation Clearinghouse is a significantly complex undertaking; there are no simple solutions.

- Because of the magnitude of the effort, diversity of potential participating organizations, and the importance of results, there is a clear need for national leadership. The Federal Highway Administration should be a participant in this effort—have some degree of involvement as a minimum.

- The Highway Innovation Clearinghouse in concept is a virtual vehicle. Although virtual—electronically based—it does not de-emphasize the need for the human element. The expertise of the information specialist is even more critical now considering the vast array of information resources available.

- Technology does not exist in a vacuum. skilled people are required to collaborate and make a Highway Innovation Clearinghouse work.

4.2 Information Systems Technologies

To complete the information collection aspect of this study, the Steering Team was given an opportunity to investigate several leading technologies that may have applicability to the structure of a Highway Innovation Clearinghouse. At a Steering Team meeting experts described technologies that may be applicable to a Highway Innovation Clearinghouse. The purpose of this exercise was to view representative technologies and to gather information regarding state-of-practice for data management and knowledge-based systems tools. The technologies examined were not exhaustive and provided broad overviews only. However, through these presentations, the Steering Team could determine if, in concept, any of the technologies used in other industries' applications might also be useful for innovative highway product applications.

The discussions of the technologies showed that the technologies might be quite useful. The Steering Team did not perform detailed analysis of the technologies presented and do not recommend any one technological solution. Rather, the Steering Team was satisfied that there are sufficient advances in computer-based tools that would support the Clearinghouse concepts. Determining the specific technological structure for the clearinghouse is a task yet to be done and not considered part of this initial study. The technologies presented to the Steering Team were:

- Data spidering and indexing technologies
    - ♦ technology that accesses a web site outside one's own domain, searches through it and prepares an index of the contents. This technology was discussed in conjunction with a presentation about the Infrastructure Technology Institute and the upcoming application of the indexing technology to enhance its information services.

- Data warehouses and data warehousing
  - technology that uses decision support tools and creates an environment in which to apply these tools to large and distributed data sets. Data warehouses contain specifically extracted data (from the larger data sets) required for management decision making. Intelligent query tools allow computerized data analysis and synthesis of information not heretofore able to be elicited from such data sources. Some of the tools used in this context are data mining and data fusion software. These types of software, through hypothesis testing, identify new relationships or regularities among data sets, thus discovering new facts and knowledge about the application. This software also allows more accurate prediction of current and future trends.

- Integration of disparate databases—brokering
  - the key to efficient and effective integration of databases is not necessarily changing the databases to be the same, but to develop software systems that act as brokers to access, interpret, and use in a real-time/dynamic fashion the various types of data from disparate sources—the presentation focused on such tools being used in a system developed by the Volpe National Transportation Systems Center [additional information regarding Broker Technology can be found in a paper presented at the IEEE "Second Annual Conference on Systems Integration" June 15-18, 1992, "Broker: A System Integration Approach." Clark, D., J. M. Krumm (DOT/VNTSC), and S. T. Bieleski, Jr. (Unisys)].

- Data management technology overview
  - various technologies for managing complex data requirements were presented to the Steering Team; no technology stood out as being uniquely suited to an innovation clearinghouse, however, the general overview of what types of data management are now being used was helpful.

No one technology emerged as a more likely candidate for eventual use. If fact, the technologies that will be selected to implement a Highway Innovation Clearinghouse may not be those that were examined in this study. The Steering Team's goal is not to select a technology, but to determine if current technology will support implementation. Technology will continue to evolve, and a Clearinghouse must use the most appropriate technology available at the time of development.

Some very important information gathered from these technical presentations was the pace at which technology is advancing and the capabilities, which are developing. The rate of change in capability is stunning. The most positive outcome is that newly existing or emerging technology will most likely accommodate the needs of a Highway Innovation Clearinghouse. The sobering aspect is that the rate of

change is so great. Extensive knowledge and wisdom will be required to select the most robust and long lived vehicle to carry forward the technological foundation for the clearinghouse.
Additional information regarding the technologies and materials distributed during the presentations are included in Appendix C.

4.3 Defining the Framework

The Steering Team performed a number of exercises that assisted in better defining the scope and characteristics of a Highway Innovation Clearinghouse. Initially, the team members each wrote a vision statement expressing their expectations and describing objectives, scope, structure, operations, and other elements of a Highway Innovation Clearinghouse. The Steering Team then identified specific clearinghouse attributes, listed the information resources that should be included, and identified categories of content for the types of information to be included in a Highway Innovation Clearinghouse.

4.3.1 Vision

The Steering Team vision statements were reviewed by the whole team and ranked according to which statement most closely represented a description of a Highway Innovation Clearinghouse. The two top ranked statements were synthesized into a vision statement that is included as Figure 11. This statement gives further descriptive information for the evolving framework.

Vision Statement for the Highway Innovation Clearinghouse

Scope: The purpose of a Highway Innovation Clearinghouse should be to facilitate innovation in the highway community by providing information, tools and resources. This information and other resources should help users learn about innovations, make decisions, validate their decisions, and find additional information and resources. Formats should include testing and evaluation reports, information on innovative technologies and materials, cost/benefit analyses, contact people, peer contacts, government reports and studies, and more.

The data contained in the clearinghouse should be very focused on product testing and evaluation materials. Expansion of the information contained in the database should follow an incremental approach. Such items that would be included in the clearinghouse are:

1. Product evaluations (such as the enhanced SPEL database); and include innovative materials (e.g. composites) and perhaps in time add innovative materials that are not yet commercial products; and
2. Innovative techniques, methods, and programs (e.g. ITI does remote global monitoring of bridges using acoustic emission sensors).
3. The clearinghouse could enhance its value by including practical tools for users: e.g., identification of ongoing problems and development and testing of practitioner solution kits.

Structure: The clearinghouse should be guided by a steering committee representing users and producers of information, organizations supporting and promoting highway innovation and organizations involved in organizing and disseminating information (such as libraries or clearinghouses). This steering committee will be responsible for providing feedback and guidance to the clearinghouse, promote solutions and guidelines for joint informational problems (such as the TRB Thesaurus or encouraging producers of information to produce reports and other documents in Internet readable format for example) and providing guidance on new data, standards for data and information, training, manuals or performance systems for assisting users in finding and using information. The steering committee should also identify gaps in information and evaluate the clearinghouse operations. They should also share information on information technologies.

Operations: In order to develop support and buy-in by potential customers, communication with these customers is important. Customers should be both users and producers of information. The electronic clearinghouse should both allow users to search for information from a variety of databases and information and point to other sources of information. A web site could also provide information on how to find or use, for example, industry-specific information. Especially important is how user-friendly the clearinghouse will be. User-friendly items like a slide show or eventually an interactive web-based information kiosk could be on the web site. Additionally, the clearinghouse should also provide users with documents as well as citations. Data to support use of an innovation should be available, and be easily accessible.

One of the most important other aspects is that this clearinghouse should be started and then evolve, rather than not doing anything until it is planned to death. It is time to be proactive, not just reactive.

Figure 11 Vision Statement

Several important aspects emerge from this vision statement. There is a general endorsement to stay focused on innovative products and techniques; there is a desire to proceed on an incremental basis —but to proceed, not delaying the effort through excessive planning; the Highway Innovation Clearinghouse should have a guiding body of users and providers of information and other highway community participants; and there is a very real need to work collaboratively with existing programs and sponsors.

4.3.2 Attributes

The Steering Team identified the most important elements or attributes of an electronic clearinghouse. These attributes were agreed upon as being desirable and are listed below in Figure 12 below.

ATTRIBUTES
■ Added value to information ■ Affordability ■ Broad-based ■ Communications capabilities ■ Database driven (i.e. structural format for the information you are pulling together, with indexing terms and descriptors) ■ Decision support tools ■ Discussion groups/listservs—keeping the experts ■ Easy-to-use ■ Expandable ■ Evolved based on needs ■ Human contact—help center concept ■ Identification of information gaps ■ Internet accessible ■ Interactive ■ Marketing and promotions ■ Quality filters included ■ Rapid implementation ■ Searchable ■ Simplicity ■ Steering committee ■ Up-to-date ■ User buy-in ■ Utilize existing data

Figure 12 Attributes

The Steering Team highlighted the need for intelligent tools to assist the searching capabilities of the clearinghouse users. However, at the same time, the Steering Team emphasized these decision support tools are not a replacement for the role of a Help Center which would support users with general information inquiry guidance and expertise.

4.3.3 Information Resources to be Included

In the continuing scoping exercises the Steering Team reviewed the Information Resources and identified the various resources that should be included in a Highway Innovation Clearinghouse.

INFORMATION RESOURCES TO BE INCLUDED
■ FHWA Experimental Projects information ■ FHWA Test and Evaluation program information ■ HITEC evaluations ■ ITE Technical Services information ■ NTPEP evaluations ■ SHRP implementation activities ■ SPEL products ■ State DOT product evaluation program information ■ Vendor and supplier information ■ Washington State DOT web site databases ■ WIN information

Figure 13 Information Resources to be Included

The above listing of the programs/informationresources (Figure 13) is a clear definition of what the Steering Team understood to be valuable initial contributing data for a Highway Innovation Clearinghouse.

4.3.4 Categories of Content

In a similar fashion to the other scoping exercises, the Steering Team also reviewed the categories of content that should be contained in a Highway Innovation Clearinghouse. The following list is representative of the types of categories of content desirable. This list, contained in Figure 14, is not exhaustive, but does include important content.

CATEGORY OF CONTENT

- Benefit and cost information
- Best practices
- Bureau of Transportation Statistics resources
- Directories
- Evaluations/testing-in-progress
- Experiences
- Experimental projects, especially feature projects from state and federal programs
- Lists of experts, contact people
- Management innovations
- Meetings/conference calendar
- New products, SPEL/enhanced SPEL
- Pooled fund projects (state and federal-aid)
- Product test results
- State Departments of Transportation and other transportation agencies
- Telephone lists
- Test and evaluation projects, FHWA projects and other related federal efforts
- Training opportunities
- University Transportation Centers project information

Figure 14 Category of Content

4.4 Implementation Strategies

The task of defining a Highway Innovation Clearinghouse also requires discussion of implementation strategies. As with any implementation effort, even during project formulation it is not too early to consider the impact of the results of research and development on the user community. Articulating options that were discovered during the conduct of this study is a first step in preparing potential sponsors and users to consider how to move the Highway Innovation Clearinghouse concepts into practice.

4.4.1 Factors Affecting Implementation

During the course of the study, several factors emerged that would considerably assist in realizing the Highway Innovation Clearinghouse's goals of increasing the use of innovative products and processes. A most immediate observation is the Steering Team is working together well and has expressed a desire to continue acting in an advisory capacity for the anticipated development of a Highway Innovation Clearinghouse. The motivation and vision contained within the Steering Team will provide a "running start" for the continuing efforts.

Throughout the conduct of the framework scoping exercises and in the general Steering Team discussion, a concern regarding state participation arose. The success or failure of a Clearinghouse rests with the quality and quantity of data that will be provided by such organizations as state departments of transportation. In this time of shortage of funds to support highway programs, providing efforts for a nationally oriented program that benefits the highway community at large is a difficult task. One of the major hurdles to successful implementation of a Clearinghouse will be to truly reduce duplication of effort particularly for data providers. The data input and maintenance of existing clearinghouse data must not be a duplicative process for data providers. State DOTs compile their own product testing and evaluation databases. They are being asked to contribute data to such efforts as SPEL and to participate in NTPEP and other similar efforts. Clearly the solution for maximizing state participation is to enable existing data to be incorporated into the clearinghouse structure, whether that data is the state's database or data already input to another national program.

Every indicator points toward using the Internet as the vehicle for carrying a Clearinghouse to the highway community. The information resource providers are showing a willingness to use this technical resource to its maximum advantage. Data management technology now also has the capability to accommodate higher-level decision support systems that may be required. At this time, technology is no longer a barrier to developing the clearinghouse.

One of the temptations of embarking on a new project that will rely on constantly changing and improving technologies, is the tendency to await the next, better solution. The Highway Innovation Clearinghouse can easily fall into this trap. Delays to await technological solution refinements will only postpone the implementation rather than significantly improve the outcome. The most difficult aspect of the technological solution will be to select technology that has a reasonable lifespan and that will be applicable to future technological developments.

A significant booster to the success of a Highway Innovation Clearinghouse will be a high level of effort expended in developing participant ownership. It will be critical to enlist the senior managers of the state DOTs/AASHTO officials, as well as FHWA officials, and others to support the clearinghouse. As with all major projects requiring broad collaboration, without the active support from top management, the implementation of a Highway Innovation Clearinghouse will be a difficult task. Plans for incorporating the opinions of senior managers and decision-makers are critical components of the overall effort.

Users and data providers alike will need a variety of materials to be informed about the clearinghouse—its use, operation, and participation in supply of data. A marketing plan will is essential to prepare for the practical application of the clearinghouse.

4.4.2 Management and Logistics

One of the most important actions yet to be taken is identifying the sponsoring organization. The Steering Team already acknowledges that FHWA involvement in such an effort is essential. The managing organization, whether FHWA or another national organization, must have the resources and capabilities to deal with all aspects of the public sector highway community and, in the future, to maximize the collaboration between the public sector and private sector partners. The decision of clearinghouse sponsor must be an early agenda item for future actions. Additionally, once a sponsoring organization is identified, the choice of clearinghouse administrators and its main residence is critical. If the highway community can be confident of the sponsorship and the technical expertise of those maintaining the clearinghouse, then implementation can move forward.

CHAPTER 5 FINDINGS AND STRATEGIC ACTION PLAN

5.1 Findings

The key findings identified by the study and specifically relevant to its scope include:

- Information resource providers support the need for a Highway Innovation Clearinghouse.
- Information resource providers in the public sector want to coordinate and collaborate to enhance the use of their respective data collections. Such enhancements are seen as a direct link to a more rapid adoption of innovative products into the highway system.
- Fragmentation of relevant information is pervasive—data on one subject can be housed in a multitude of locations spread out among many resources. Although there is a movement toward collaboration, such fragmentation continues to persist and the trend is continuing. Information resources are growing in number and content. Additionally, the variability in format, level of detail and accessibility of data are major technological hurdles to overcome.
- Technological solutions are available that will accommodate the needs of the clearinghouse concepts described in this document. For example, there are very promising technological avenues to pursue for reducing duplication of effort in database creation and maintenance.
- The content of many information resources is remarkably similar in type of elements. This gives the Steering Team confidence in confirming the need for a clearinghouse to be used as a coordination vehicle. This similarity of data elements helps prioritize the types of elements that are considered important to users.
- People are the critical links in a virtual clearinghouse. The expertise of an information specialist is more important now than ever before, considering the proliferation of data resources and the expanding amounts of data now accessible via the Internet and the World Wide Web.

- The Internet was identified as the most viable vehicle for access to a Highway Innovation Clearinghouse.

- The state DOTs were seen to be the agencies that would receive the highest benefit from the implementation of a Clearinghouse.

- The Steering Team desires to continue its involvement in an advisory capacity for future Clearinghouse efforts.

- A Highway Innovation Clearinghouse must not present significant new data management responsibilities for information resource providers. Technological solutions are preferred over labor intensive solutions for resources providers.

- The private sector plays an important role in the implementation of innovative products. As an initial step, this study focused on public sector organizations, yet considered the private sector partners as one of the first incremental additions to a Clearinghouse.

5.2 Strategic Action Plan

As a result of its efforts, the Steering Team recommends that the following strategic actions be taken to further the development of a Highway Innovation Clearinghouse:

- Continue the work on a Highway Innovation Clearinghouse. The tendency to delay to await enhanced technological tools or to "over-plan" will only delay the outcome, not significantly enhance quality.

- Keep the Steering Team as an advisory body for the ensuing effort.

- Strongly encourage FHWA, AASHTO and TRB to jointly lead the task of developing a national consensus in support of a Highway Innovation Clearinghouse.

- Encourage FHWA, consistent with its role of commitment to national technology deployment, to take the lead in promoting participant buy-in to the clearinghouse.

- Develop a classification system for contents of a Clearinghouse, including categories of material.

- Integrate follow-on Highway Innovation Clearinghouse work directly with other FHWA clearinghouse efforts.

- Enlist state participation in a Clearinghouse; it is essential. Easing the barriers that would prevent a state DOT from participating should be a primary goal of all development and implementation efforts. It is absolutely critical to the success of this project that top management from the state DOTs and federal level buy-in and support this effort.

- Consider instituting some national policy to encourage participation—for example if a program receives federal-aid funding, in the technology transfer plans the program is to specifically address linkages to a Highway Innovation Clearinghouse.

- Develop a comprehensive marketing plan and commit substantial effort to marketing the concept of and benefits anticipated from a Clearinghouse.

- Consider new management policies for data terms, storage, and use. Developing such broad policies will be productive efforts to start the process of facilitating linkages and standardizing some elements among the various data collections. These management policies will increase the potential for understanding and being part of a larger whole—bringing significantly enhanced collaboration.

- Identify a set of minimal data elements necessary to link all major programs together.

- Develop a common terminology for technical and data elements. This effort should be conducted in conjunction with other ongoing, relevant projects such as the newly developed Transportation Thesaurus developed by AASHTO through the NCHRP program.

- Conduct pilot projects to demonstrate benefits and to test various technological solutions. Example pilot projects are:

    - Create a decision support system and tools for two national product evaluation programs/lists and three states product evaluation lists. This would be a pilot system demonstrating the feasibility of linking together dissimilar database formats and platforms.

    - Perform a pilot project that looks at three to five databases to determine if there is any value in merging and standardizing the format, access and other items necessary to provide common use.

    - Create a project that demonstrates the willingness for and capabilities of the user community to participate in a Clearinghouse. This project arises from concern that the users may have barriers and limitations to full participation.

5.3 Summary

The report and its appendices have been prepared to continue the discussion and prompt action on the concept of a nationally based Highway Innovation Clearinghouse. As defined in this study this "clearinghouse" would focus on linking federal, state, and local test and evaluation, technology transfer and technology deployment programs, including demonstrations of new technologies and proprietary product evaluations. Technological solutions are now available, the public sector highway community desires to enhance its efforts of coordination and collaboration. and the specific user community has expressed a genuine need for such a tool.

The report encourages continued action to turn the Highway Innovation Clearinghouse concept into a practical, beneficial tool. The Steering Team looks forward to the implementation of a Highway Innovation Clearinghouse, bringing the highway community opportunities for enhanced quality of information, that is received in an efficient, effective manner. Clearly, a Highway Innovation Clearinghouse is anticipated to reduce duplication of effort, increase the productivity of highway agencies, and allow more timely adoption of innovations in increasing numbers to enhance our nation's highway system.

REFERENCES

1. Federal Highway Administration, Turner-Fairbank Highway Research Center, "Research, Development, and Technology Program Manual," Washington, DC, February 1984.

2. Harder, B. T. and H. Newlon, Jr., "Research Program Management Participant's Notebook," National Highway Institute Course No. 33043, Federal Highway Administration, Washington, DC, May 1991.

3. Burke, J. E., "Administration of Research Development, and Implementation Activities in Highway Agencies, *National Cooperative Highway Research Program Synthesis of Highway Practice Number 113*, Transportation Research Board, National Research Council, Washington, DC, December 1984.

4. Hodgkins, E. A., "Technology Transfer in Selected Highway Agencies," *National Cooperative Highway Research Program Synthesis of Practice Number 150*, Transportation Research Board, National Research Council, Washington, DC, December 1989.

Appendix A

Highway Information Resources: Testing & Evaluation, Technology Transfer and Technology Deployment

Table of Contents for Appendix A

SECTION 1

SECTION 1 TASK SCOPE AND PURPOSE

1.1 Purpose

This document has been prepared as a result of the research performed during the conduct of the Highway Innovation Clearinghouse Study. The study was designed to develop a "framework" and specific recommendations, which would hopefully lead to a national "clearinghouse" for highway innovation. The primary focus of these activities was to plan a "clearinghouse" that would more effectively coordinate the various information resources available in the highway community to increase efficiency and avoid duplication. Such a "clearinghouse" would also be designed to make this information more readily accessible to many users throughout the diverse highway community. As part of the study, information resources were examined to determine the types and variety of existing and available data.

The materials contained in this document are brief summaries (2 to 3 pages each) of the more than 40 resources used within the highway community to provide critical information on highway innovative products and processes. Specific areas of inquiry were focused on information resources that 1) are collections and documentation of product testing and evaluation experiences and related programs, 2) programs and activities that promote technology transfer within the highway community, and 3) programs and activities concentrating on deployment of innovative technologies.

In addition to supplying individual summaries, the document also includes a cross-reference index by organization and program activity. Readers desiring more information on any information resource are encouraged to contact the individual listed in the "For More Information" section of each summary.

Although a broad spectrum of information currently available has been included, the study does not purport to be a general reference on all information resources relevant to the highway community and specifically does not include information on research and development programs and activities.

1.2 Task Scope—Identification of Resources

The study was accomplished with the strong support and contributions by an expert Steering Team. HITEC was facilitator for conduct of the study. The objective of Task 2 was to identify existing programs and to categorize the types of products that they provide (for example, current technologies under evaluation, the implementation status of SHRP technologies, or current and planned demonstrations) in terms of type of information and how it can now be accessed.

In coordination with the Steering Team, HITEC identified and catalogued the following types of information:

- existing state and local "product test, evaluation, and approval" programs and associated databases
- existing AASHTO, TRB/SHRP, FHWA, HITEC, and other national test and evaluation, technology transfer and deployment programs, and associated databases from those programs
- existing private sector product test, evaluation and approval data, as applicable (not-for-profit organizations, trade associations, industry sponsored institute data, and others)
- the status—extent of electronic format—of the databases

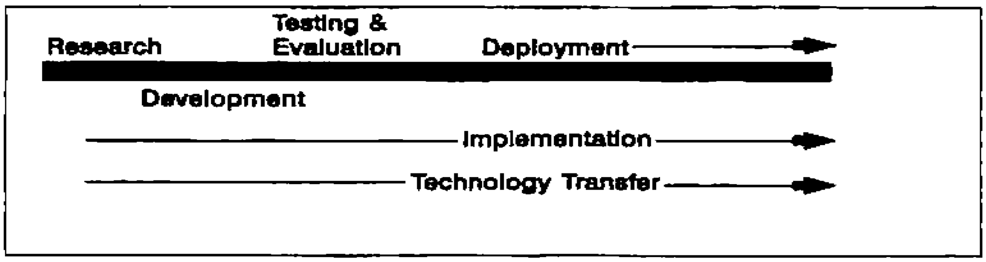
To the extent practical, HITEC coordinated this activity with other ongoing "clearinghouse" activities such as NCHRP 20-7 study on an "Enhanced SPEL" (the AASHTO Product Evaluation Listing), Washington State SHRP Implementation web site, as well as the ongoing FHWA efforts to Re-engineer the Experimental Projects Program, study the Value of Information and develop a Technology Resource Center (clearinghouse) within the Office of Technology Applications.

Although the scope of this "clearinghouse" was refined during the study, from its outset, the study focused primarily on a "clearinghouse" linking Federal, state, and local test and evaluation, technology transfer and technology deployment programs, including demonstration of new technologies, and proprietary product evaluations. In that context, the "clearinghouse" examined in this study would not specifically include information on research programs, such as those data currently contained in the Transportation Research Information System (TRIS) or Research in Program systems. However, given the scope and wealth of information contained in various "research" programs, it was recognized that in order for any "clearinghouse" to be accepted by the highway community, it would eventually need to be expanded to provide explicit links to those programs. Similarly, although the scope of this study focused on the U.S. public sector highway community, it was recognized that the "clearinghouse" would have application to and need to be explicitly linked to various international systems as well as to the private sector—representing manufacturers, vendors, and suppliers of innovative highway products.

1.3 Selected General Definitions

In undertaking this study, HITEC and the Steering Team recognized that one of the inherent difficulties in scoping the effort was the lack of uniformity of definitions used throughout the community. Furthermore, it recognized that in actually developing and ultimately implementing a meaningful "framework" for a "clearinghouse" the community would probably need to develop such a consensus for key terms and definitions.

In that context, the following definitions were applied throughout the study and are used throughout this report.



Research Study: a systematic controlled inquiry into a subject in order to discover or revise facts, usually containing analytical and experimental efforts to increase the understanding of causative relationships necessary for meeting defined needs.

In general research can be applied or basic.

Basic research involves the study of phenomena whose specific application has not been identified; the primary purpose of this kind of research is to increase knowledge.

Applied research involves the study of phenomena relating to a specific, known need in connection with the functional characteristics of a system; the primary purpose of this kind of research is to answer a question or solve a problem. (FHWA, p. 1-7)

Development Project: adaptation, modification, and testing of an idea, process, or product for practical use under field conditions. Development is a continuation of the research process and conducted to verify expected performance and improve the utility of the research result. (Harder and Newlon, p. F-3)

Test & Evaluation: a systematic process of critical assessment to determine the characteristics, quality, or viability of a technology, followed by analysis of in-service demonstrations to measure performance against established criteria. The process utilizes unbiased methods to produce information upon which an informed decision can be made.

Implementation: that part of the technology transfer process concerned directly with the mechanisms of putting specific sets of research findings into practical use. The full implementation process includes the development or revisions of policies, plans, specifications, standards, and so on that must occur before new knowledge can be incorporated into practice. (Burke, p. 21)

Deployment: systematic or strategic distribution of implementation-ready products or new technologies, causing such innovations to be put into use in the field.

Technology Transfer: the process by which existing research knowledge and new technology are transferred into useful processes, products, and programs. Use of the term implies the application of a conscious and positive effort to promote and accelerate the practical use of research knowledge and new technology. (Burke, p. 21)

1.4 References

1. Federal Highway Administration, Turner-Fairbank Highway Research Center, "Research, Development, and Technology Program Manual," Washington, DC, February 1984.

2. Harder, B. T. and H. Newlon, Jr., "Research Program Management Participant's Notebook," National Highway Institute Course No. 33043, Federal Highway Administration, Washington, DC, May 1991.

3. Burke, J. E., "Administration of Research Development, and Implementation Activities in Highway Agencies, *National Cooperative Highway Research Program Synthesis of Highway Practice Number 113*, Transportation Research Board, National Research Council, Washington, DC, December 1984.

4. Hodgkins, E. A., "Technology Transfer in Selected Highway Agencies," *National Cooperative Highway Research Program Synthesis of Practice Number 150*, Transportation Research Board, National Research Council, Washington, DC, December 1989.

SECTION 2 PROGRAM/INFORMATION RESOURCES

2.1 Programs of National Scope

Border Technology Exchange Program

Description/Scope:
The Border Technology Exchange Program (BTEP) is designed to enhance and expand the binational working relationships of the border state departments of transportation. The BTEP serves to create opportunities for transportation officials in the border region to improve the planning, design, construction, and operation of land transportation facilities. Program goals are: create a permanent technology exchange process; enhance institutional, technical, and legal compatibility and understanding; improve transportation systems in border regions; enhance professional and cultural understanding; and enhance professional and technical capabilities.

The program is a federal-aid activity wherein border states may apply for project funding for efforts that further program goals. The projects funded through the program vary widely according to the priorities of the various states.

Type of Activity:
_T&E _X_ Technology Transfer _Technology Deployment

Sponsor(s):
Federal Highway Administration, Office of International Programs

Typical Users:
Border region state departments of transportation

Existing Information Collections/Databases:
There is no collection of accessible information from this program. BTEP is a program that funds projects to facilitate solving border states issues. There is no plan to have historical project information available in a publicly available database.

In general the BTEP solicits project proposals in February, reviews the submittals and notifies states of funding availability by April. Projects may be for training, staff exchange, technical assistance, demonstration projects, and other technology transfer oriented activities. States are responsible for submitting accomplishments reports to the BTEP office. These reports are not intended for public distribution.

Technical areas of current consideration are:

- Value Engineering
- Electronic communication and information systems
- Planning
- Design
- Construction
- Maintenance
- Management
- Supervision
- Technology Transfer

The program is relatively new (third year). BTEP participants are currently developing a strategic plan, which will identify priorities and goals for the future.

For More Information:

Program/Resource Coordinator
Tere Franceschi
Project Manager
Office of International Programs, HPI-10
Federal Highway Administration, Rm. 3327
400 Seventh Street, S.W.
Washington, DC 20590
Telephone: 202-366-9775
Fax: 202-366-9626

Bureau of Transportation Statistics

Description/Scope:
The Bureau of Transportation Statistics (BTS) provides a wealth of critical transportation data for use by the public at large.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
U. S. Department of Transportation

Typical Users:
The typical users are the broad groups of transportation professions who require statistical information, other related transportation data, and technical assistance; and the general public seeking transportation data and information.

How are Findings or Results Reported and Disseminated?
BTS collects or develops data for its databases and programs. A variety of products are available from BTS in CD-ROM, disk, print, and electronically through the agency's web site. Information bulletins are distributed to interested parties and those having ordered materials from BTS. BTS actively markets its products at transportation conferences and meetings.

Existing Information Collections/Databases:
The numbers and types of databases available are extensive. Products range from commodity flow surveys to national transportation statistics, highway statistics (annually), transportation agency financial statistics, national transportation data archive, state transpiration analysis tables, and many others. Databases extend to all transportation modes.

Who Maintains the Collections/Databases?
Bureau of Transportation Statistics

Location and General Format Description of the Data:
Each database is formatted for maximum utility. There is no general data format for the many databases.

How Can the Data Currently Be Accessed?
Data can be requested from BTS via telephone, email, or fax on demand. Statistical information is available electronically on CD-ROM or disk as well as via the Internet at the BTS web site: http://www.bts.gov/.

Access or Subscription Fees:
There are no access fees for BTS data. Only certain air transportation reports are sold, all other items are free.

For More Information:

Program/Resource Coordinator
Robert C. Zarnetske
Acting Assistant Director, Information Technology
Bureau of Transportation Statistics
U.S. Department of Transportation
400 Seventh Street, SW, Room 3430
Washington, DC 20590
Telephone: 202-366-5081
Fax: 202-366-3640
Email: Robert.Zarnetske@bts.gov

Coordinated Federal Lands
Highway Technology Implementation Program

Description/Scope:
The Coordinated Federal Lands Highway Technology Implementation Program (CTIP) began in 1984 as a mechanism to identify, study, and disseminate new techniques for the management, design, and construction of federally owned roads. The CTIP coordinates technology sharing and development among FHWA's Federal Lands Highway Office and its associated federal agencies. It provides a forum for identifying, studying, and documenting new technology and techniques for use by federal agencies on federal roads.

The technology development and transfer activities of the CTIP are directed at the national level by a Council composed of representatives from the Federal Lands Highway Office and its associated federal agencies. The Council provides policy guidance for the program, prioritizes the studies carried out in its name, and oversees the effective management of the program.

The Council's voting members are senior officials representing:

- Forest Service
- Bureau of Indian Affairs
- National Park Service
- Bureau of Land Management
- FHWA Associate Administrator for Research and Development
- FHWA Federal Lands Highway Program (FLHP) Administrator

Other nonvoting members are:

- U.S. Army Corps of Engineers
- Military Traffic Management Command and Transportation Agency
- Fish and Wildlife Service

Studies are proposed by CTIP Council members. The studies must be applicable to most or all roads of the FLHP; must synthesize existing knowledge and interpret it for use on federally-owned land such as low-volume and scenic roads; be of low cost and short duration ($100,000 and 18 months for example); and be immediately implementable. Extensive research and maintenance activities are not eligible for program funding.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Federal Highway Administration

While the CTIP is funded by the Federal Lands Highway Program, participating agencies are encouraged to contribute funds to leverage the size and the priority of projects.

Typical Users:
Transportation professionals within federal, state, and local agencies dealing with low-volume or scenic roads

How are Findings or Results Reported and Disseminated?
The CTIP Council members receive copies of the final study reports for distribution within their respective agencies. Copies of the studies are available also through the National Technical Information Service.

Existing Information Collections/Databases:
There is no specific database available for public use.

For More Information:

Program/Resource Contact
Bill Cross
FHWA Federal Lands Highway Office
400 Seventh Street, SW, Rms. 4136 and 4206
Washington, DC 20590
Telephone: 202-366-9479
Fax: 202-366-7495

Experimental Projects Program and Tabulation

Description/Scope:
The Federal Highway Administration's Experimental Project Program allows states the limited use of non-standard and proprietary products in federal-aid construction projects. These products are then evaluated on an experimental basis.

Title 23 prohibits federal participation in payment for premium or royalty on any patented or proprietary material, specification, or process specifically set forth in the plans and specification unless, 1) the item is purchased competitively with equally suitable unpatented items, 2) state certifies item is necessary for synchronization with existing facility, or 3) the item is used for research, or for a distinctive type of construction on relatively short section of road for experimental purposes.

Products or processes considered are either proprietary in nature or commercially available, or a new use or application of technology that does not meet the State's current standards, specifications, or procurement requirements. Projects are initiated by the states. Evaluations are usually limited to construction inspections and follow-up for several years with minimal data collection. For the evaluation states may initiate a research study which may or may not be funded with State Planning and Research monies. The program has been used as a means of getting products incorporated into "trial use" construction.

The program dates back to 1959. Requirements for Experimental Projects are prescribed in the Federal Highway Administration Federal-aid Program Guide, Section G6042.4 Code of Federal Regulations, "Material or Product Selection," 23 CFR 635.411 Ch. 1(4-1-94 edition). The National Experimental Projects Tabulation (NEPT) is the documented listing of projects performed under this program.

The Federal Highway Administration is currently examining the need to re-engineer the Experimental Projects Program, NEPT, data collection, and reporting mechanisms. The NEPT Task Force formed to advise FHWA on these activities met in late Spring 1997. Discussion is ongoing regarding merging aspects of this program mission and its documentation functions with the current revisions being planned for the AASHTO Special Products Evaluation List. (See summary below.)

Type of Activity:
_X_ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users:
State departments of transportation—materials, design, construction, and testing and evaluation professionals; local agencies, contractors, and vendors

How are Findings or Results Reported and Disseminated?
Construction reports and periodic evaluations are required. These are generally completed by the states and forwarded to the Federal Highway Administration on FHWA Form 1461 or by floppy disk. Data is compiled into the National Experimental Projects Tabulation, and 1461 forms have been scanned to produce a CD-ROM collection. Compilation and distribution of the data has been difficult due to staff shortages and other priorities on the FHWA mainframe. Considering the re-engineering effort is underway, access to the data is somewhat limited.

Existing Information Collections/Databases:
Although the system has collected data for many years, most data of interest is five years old or less. For the re-engineering effort, a feasibility/analysis of transferring data collected in the past five years to a new system is in progress. The preliminary conclusions of the analysis are pointing toward not transferring the data, but beginning a new database structure starting with current data.

Who Maintains the Collections/Databases?
Data is maintained by FHWA, State and Local Programs Team, Technology Management Division, Office of Technology Applications.

Location of the Database:
The database resides on the FHWA mainframe computer system.

How Can the Data Currently Be Accessed?
In the recent past data has been available on CD-ROM format, yet due to staff shortages, there is little activity in accessing the data and in distributing NEPT reports.

Access or Subscription Fees:
There are no fees associated with accessing data from the program.

Plans for Near-Term Enhancements to the Collections/Databases:
The re-engineering effort discussed above will generate significant positive changes for the program.

Illustrative Example of Collection/Database Content:
The NEPT database contains information such as: reporting agency, project number, construction project number, location, project title, status of project cost and quantity, types of reports available, evaluation problems and performance, type of application, and general remarks.

For More Information:

Program/Resource Coordinator
Robert Kelly
FHWA, Office of Technology Applications, HTA-10
400 Seventh Street, SW Rm. 6322
Washington, DC 20590
Telephone: 202-366-1565
Fax: 202-366-7909
E-mail: robert.kelly@fhwa.dot.gov

Highway Innovation Technology Evaluation Center

Description/Scope:
Highway Innovation Technology Evaluation Center is a national service center that facilitates the conduct of national performance benchmark evaluations of innovative technologies (products) for the highway community. HITEC accepts applications from owners of technologies that are market-ready and have no existing standard (i.e. there is no nationally recognized standard or specification that can be used to measure the performance of the product). The HITEC process uses a collaborative team approach to develop "evaluation criteria" which might be considered as a pre-standard. Most projects involve the evaluation of a single technology or product. However, in certain instances, an evaluation of a group of technologies is conducted.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Federal Highway Administration

HITEC is a service center of the Civil Engineering Research Foundation (CERF), the research arm of the American Society of Civil Engineers.

Typical Users:
Public sector transportation officials involved with new product testing, highway engineering, and technology transfer; from such organizations as the Federal Highway Administration, state departments of transportation, and local departments of transportation and public works.

How are Findings or Results Reported and Disseminated?
A one page "Product Bulletin" is issued at key stages in the life of a project. When a project is completed, the findings are documented in two final reports:

- A "Summary Report," which is a 3-5 page executive summary report, and
- A comprehensive "Technical Evaluation Report."

These reports are distributed to key federal, state and local officials involved in new product testing, highway engineering and technology transfer.

In addition, information on ongoing HITEC projects will be summarized and the information is made available on the World Wide Web at http://www.cerf.org/hitec

Existing Information Collections/Databases:
A database containing information on each product evaluated is the single information resource. This database is essentially an internal working tool used to produce literature and documentation on evaluations.

Who Maintains the Collections/Databases?
The Civil Engineering Research Foundation

Location and General Format Description of the Data:
All HITEC evaluation data is located in the HITEC offices at the Civil Engineering Research Foundation, Washington DC. HITEC evaluation information is stored in a Microsoft Access database. Information is also available on its web site (see above).

How Can the Data Currently Be Accessed?
HITEC evaluation reports, product bulletins and highlights data sheets are available through requests by telephone, fax, e-mail, or postal system. General information is currently available on its web site.

Access or Subscription Fees:
HITEC is a fee-based center where the owners of the technology (HITEC applicants or clients) are charged a fee to cover the costs of planning and conducting the evaluation. HITEC has an "Associate Membership Program" that entitles members to a full spectrum of available information on its web site as well as password access to the private "Associates Only" area. The private web site includes e-mail exchange, direct links to all the state departments of transportation, and discussion forums. Associate members receive a 25 percent discount on all HITEC Technical Evaluation Reports.

Plans for Near-Term Enhancements to the Collections/Databases:
The HITEC web site is continually being revised to address the needs of its members.

Illustrative Example of Collection/Database Content:
The HITEC database contains the following fields: project name, status, client (technology owner) name, what technology was evaluated, date of evaluation, evaluation panel members, who is working with the product currently, and if the evaluation is finished, an abstract of the results of the evaluation.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective):
HITEC receives an average of 100 requests for information monthly. HITEC also disseminates its newsletter, HITEC Highlights, and product bulletins on its ongoing evaluations. HITEC also distributes summaries on new technical reports three times a year to approximately 300 individuals and agencies.

For More Information:

Program/Resource Coordinator
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Information Systems Coordinator
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Infrastructure Technology Institute at Northwestern University

Description/Scope:
The Infrastructure Technology Institute (ITI) was established in the Fall 1992 with a six-year appropriation from the Intermodal Surface Transportation Efficiency Act of 1991. The Institute was designed to capitalize on Northwestern University's strengths in infrastructure-related research and training and to create a technology transfer mechanism to help rebuild the nation's crumbling infrastructure. The goals of the Institute are to create state-of-the-art laboratories and conduct research; develop new technologies, tools, and ideas, train new and retrain current employees to meet needs of public works systems, and accelerate identification, refinement, evaluation and transfer of innovations that address infrastructure problems.

The Institute offers library services, seven clearinghouses for various infrastructure areas, publication distribution, and outreach services as part of its very broad technology transfer functions.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
U. S. Department of Transportation, Research and Special Programs Administration

Typical Users:
The Clearinghouses and the Institute have a mix of public and private sector users, from the U.S. and worldwide. Consultants, academia and the public sector are all users. Public sector transportation users are state departments of transportation and local agencies.

How are Findings or Results Reported and Disseminated?
The main activity is through the ITI web site (http://iti.acns.nwu.edu/)and through personal contact with the ITI Librarian. A gopher service was the original electronic format for the Institute, it still exists, but the web site has supplanted it. The intent of the Institute is to be an electronic access vehicle, yet the Institute will disseminate publications and other materials by individual request through the mail if required.

Existing Information Collections/Databases:
It is ITI goal to present a one-stop-shop approach. Much of the clearinghouse information is full text. The Institute has a broad collection, which can be accessed through the Librarian if materials are not available through the web site.

The Institute's clearinghouses are as follows:

- General Clearinghouse for Infrastructure
- Bridges
- General/ISTEA
- Highway
- Technology Transfer
- Water Resources
- Time Domain Reflectometry

Who Maintains the Collections/Databases?
The databases are maintained by ITI as an integral part of the mission of the program.

Location and General Format Description of the Data:
The databases are housed in the Northwestern University computer system. The original data for the gopher service was ASCII text documents. Many of these documents have been retained and migrated to the new web based system. The system will accept as input a variety of common file formats, which facilitate the acceptance of data from a wide base of sources. The system is a UNIX database and retrieval system.

How Can the Data Currently Be Accessed?
Primary access is through the ITI web site. (See above.) Personal requests may be made to the Librarian.

Access or Subscription Fees:
There are no fees associated with acquiring materials from the ITI. Reports are generally distributed at no cost. Copying of various materials, when required, is also performed at no cost.

Plans for Near-Term Enhancements to the Collections/Databases:
The enhancements to ITI involve improved access mechanisms. Other areas of the University have had a good deal of success with a new very powerful search tool, LiveLink from OpenText, Inc. This tool will perform spidering of multiple external sites. (i.e. it has the capability to search through and index the contents, and make links to multiple sites external to the originating database/site.) This type of tool has sufficient power to perform multiple site searches without the necessity of hoping from one link to another to another. The potential for such a tool to tie together disparate data sets looks very promising for this type of information provider.

Illustrative Example of Collection/Database Content:
The main collection focuses on reports of research findings and state of practice activities within the infrastructure community. The various databases are organized by topic to ease the access of data.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)
The ITI has a full time Librarian to support user requests for information.

For More Information:

Program/Resource Coordinator
Kathryn Heavey
ITI Librarian
Northwestern University Science and Engineering Library
2233 North Campus Drive
Evanston, IL 60208-3530
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Fax: 847-491-4655
Email: k-heavey@nwu.edu

ITS America Clearinghouse

Description/Scope:
With such a massive public/private buildup of advanced transportation systems under way, ITS America serves the need for a single, coordinating organization to function as a clearinghouse for Intelligent Transportation Systems (ITS) related information. ITS also serves as a forum through which public and private sector stakeholders can work to meet the challenges such a revolutionary development represents.

ITS America mission is to foster public/private partnerships that will increase the safety and efficiency of surface transportation through the accelerated development and deployment of advanced transportation systems.

ITS members participate in a number of technical committees each charged with the responsibility of planning the development and deployment of a particular family of technology applications. Other committees deal with the many cross-cutting challenges facing the successful deployment of ITS, such as standards setting, safety, legal, and institutional issues. (Excerpted from ITS web site.)

Type of Activity:
__ T&E _X_ Technology Transfer _X_ Technology Deployment

Sponsor(s):
Membership organization: members include federal, state, local, and foreign government agencies, national and international corporations involved in the development of ITS, universities, independent research organizations, and public interest groups among others.

Typical Users:
A broad spectrum of transportation, telecommunications, and electronics industry professionals in the public and private sector both in the U.S. and worldwide.

How are Findings or Results Reported and Disseminated?
The major access to ITS data is via its web site: http://www.itsa.org/ The web site provides a public information and status of activities area as well as a members only space. Only members may access the extensive database of ITS-related materials. The members area also contains news bulletins, committee activities information, contracting opportunities, interactive bulletin board, and an extensive list of links to other web sites.

Existing Information Collections/Databases:
The ITS America database is the most comprehensive repository of ITS-related information available.

Access or Subscription Fees:
Membership in ITS America includes access to the members web site area containing detailed ITS-related materials.

For More Information:

Contact
ITS America
400 Virginia Ave. SW, Suite 800
Washington, DC 20024-2730
Telephone: 202-484-4586
Fax: 202-484-3483

Institute of Transportation Engineers (ITE)
Technical Request Service

Description/Scope:
The Institute of Transportation Engineers (ITE) is an international educational and scientific association of transportation and traffic engineers, transportation planners, and other professionals who are responsible for meeting mobility and safety needs. The Institute facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development, and management for any mode of transportation by promoting professional development of members, supporting and encouraging education, stimulating research, developing public awareness, and exchanging professional information, and by maintaining a central point of reference and action. The Institute has ten councils that produce products for educating members and set standards among other items. The topical areas of focus for the councils are:

- traffic engineering
- transportation planning
- transportation safety
- intelligent transportation systems
- transportation demand management
- transit
- transportation education
- transportation expert witness
- transportation consultants
- transportation industry

(Excerpted from ITE documentation)

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Membership organization

Typical Users:
Transportation and traffic engineers, transportation planners, and other professionals who are responsible for meeting mobility and safety needs

How are Findings or Results Reported and Disseminated?
The Institute operates a Technical Request Service for members and non-members. This service is designed for transportation professionals to call, fax, or e-mail the Institute with requests for technical information or for assistance in locating specific information elsewhere. General information about the organization can be found on the organization's web site: http://www.ite.org/

Existing Information Collections/Databases:
[description to be added]

How Can the Data Currently Be Accessed?
Contact the ITE Technical Request Service. ITE also may be contacted via their web site. (See above.)

Access or Subscription Fees:
The Technical Request Services are free to members and non-members of ITE.

Plans for Near-Term Enhancements to the Collections/Databases:
[plans to be added]

Illustrative Example of Collection/Database Content:
[example to be added]

For More Information:

Program/Resource Coordinator
Laura A. Hazan
Information Services Librarian
Technical Requests, Webmaster
Institute of Transportation Engineers
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Local Technical Assistance Program (LTAP)

Description/Scope:
The LTAP Technology Transfer Clearinghouse is an established proactive information resource linking 57 technology transfer centers that are the primary component of the Local Technical Assistance Program. The Clearinghouse is a fundamental component in the LTAP mission—that of gathering and disseminating the latest in highway-related thoughts and developments to local transportation policy makers and transportation professionals in the field. The LTAP Technology Transfer Clearinghouse serves as a coordinating mechanism, information disseminator, and primary network facilitator. In general the Clearinghouse does not directly serve the individual local agencies, but supports the centers in their contact with all members of the local transportation community.

Type of Activity:
__T&E _X_ Technology Transfer ____ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users:
The 57 Local Technology Assistance Program Technology Transfer Centers are the primary users of the Clearinghouse information resources. The various centers are located at state departments of transportation and universities throughout the nation.

How are Findings or Results Reported and Disseminated?
Clearinghouse information can be requested and is disseminated via personal contact, telephone, e-mail, fax, postal service, and a newly created Internet web site. In particular, the Clearinghouse disseminates applicable Federal Highway Administration generated information to the centers.

Existing Information Collections/Databases:
The Clearinghouse maintains information on the activities and needs of the various centers as well as is a source/contact point for information on the latest thought and innovations for highway applications that are transferable to the local transportation/public works community.

Who Maintains the Collections/Databases:
The Clearinghouse collections are maintained by the American Public Works Association, the organization contracted by FHWA to conduct and staff the activity.

Location and General Format Description of the Data:
Most basic Clearinghouse information resides at the American Public Works Association, the various technology transfer centers, state departments of transportation, FHWA, and universities. A vast array of other transportation information resources is incorporated as required. The

technology/information focus is on application of generally accepted processes and products for the local transportation community.

The Clearinghouse provides a newsletter, electronic listserve, e-mail connections to all centers with e-mail access, a Resource Directory (materials available to share among centers), LTAP Training Exchange (centers' training activities information), lending library, video copying center, CD-ROM training resources.

How Can the Data Currently Be Accessed?
Data is accessed by personal contact, telephone, e-mail, fax or postal service. The web site is two tiered, first tier—public web site - general information, second tier—access by technology transfer centers and FHWA only—information resources are being developed for this medium.

Access or Subscription Fees:
The video copying service charges $10 per copy for each video copied. There are no other standard access or subscription fees. If a request is made for a large number of the same publication, users may be required to pay cost of production by the publisher.
World Wide Web site address: http://patriot.net/~ltap/ltap.html

Plans for Near-Term Enhancements to the Collections/Databases:
Significant progress in enhancing the web site is expected during the next six months.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)
The Clearinghouse has an average of between 25 to 40 requests for information each month. This does not include the regular dissemination of its newsletters and standard publications and FHWA reports.

For More Information:

Program/Resource Coordinator
Lisa Haakon Pogue, Director of Technology Transfer
LTAP Technology Transfer Clearinghouse
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Fax: 202-737-9153
E-mail: ltap@patriot.net

National Quality Initiative Clearinghouse (at TTI)

Description/Scope:
Through the establishment of its Standing Committee on Quality, AASHTO has made a commitment to advocate, advance, investigate, and share principles and programs of continuous quality improvement among its member departments. The Committee's responsibilities include serving as a clearinghouse for member departments by continuously collecting and disseminating information on current and emerging quality initiatives and successes. Through the AASHTO National Cooperative Highway Research Program, a consultant was hired to develop an electronic based clearinghouse (excerpt from NCHRP Progress Report, Project 20-7, Task 80).

The planned outcome of the consultant's work was a set of databases accessible by the World Wide Web. The database contains fairly extensive information based on responses to a questionnaire conducted in connection with the current project. The web site also contains pointers to reference sources and contacts regarding quality publications of participating organizations.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
American Association of State Highway and Transportation Officials

Typical Users:
AASHTO Member Departments, FHWA and other AASHTO affiliated organizations.

How are Findings or Results Reported and Disseminated?
Quality initiative information will be disseminated via an Internet web site, initially located at the Texas Transportation Institute (project consultant). Links to the database from AASHTO and the National Quality Initiative web sites (for example) will be developed. This interim step will be made prior to the final decision regarding the permanent location of the database.

Existing Information Collections/Databases:
A survey of states was made in 1994 and is available through the Committee as a committee internal report. It has not been published by AASHTO. Additionally there was a computer disk copy made, but it is not generally in common use. The database is called Clipper.

The 1997 project surveyed the AASHTO member departments, some offices of FHWA and various National Quality Initiative members. New databases have been created from this information. The databases capture AASHTO Member Department quality initiative experiences. Related publications and other materials of interest published by the states are available directly from the originating state.

Who Maintains the Collections/Databases?
No decisions regarding ongoing maintenance have been made.

Location and General Format Description of the Data:
Initially the database will reside on the Texas Transportation Institute server (tti.tamu.edu/). The software used for the database is Inmagic DB/Text Web Publisher.

How Can the Data Currently Be Accessed?
Data from the results of the 1994 survey is available as a committee internal report. Data from the 1997 survey can be viewed on the pilot web site: http://tti.tamu.edu/quality/search.htm

Access or Subscription Fees:
There are no access or subscription fees for Committee material.

Plans for Near-Term Enhancements to the Collections/Databases:
Consultant efforts for pilot system are to be completed by October 31, 1997. Selection of a permanent home for the system has yet to be determined, but such decisions should be forth coming shortly.

Illustrative Example of Collection/Database Content:
The database will contain information such as the state or agency contributing the quality initiative experience, contact person at the agency, description of the quality initiative in narrative form, and availability of full text or related published materials and their sources.

For More Information:

Program/Resource Coordinator
Kay Nichols
Texas Transportation Institute
Information & Technology Exchange Center
707 Texas Ave. Building D, Suite 106
College Station, TX 77840-1967
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National Transportation Product Evaluation Program (NTPEP)

Description/Scope:
The purpose of the National Transportation Product Evaluation Program (NTPEP) is to pool the professional and physical resources of the individual participating member departments of the American Association of State Highway and Transportation Officials (AASHTO). This will provide a focus of resources to test materials of common interest in order to improve the cost-effectiveness of the participating member department operations. The program provides industry with a central focal point to initiate the process of testing and evaluation of materials through one sample submission rather than separate samples of the same material to each department where it will be used.

NTPEP tests and evaluates materials that are already being used by the AASHTO member departments. The member departments through a consensus process identify the materials or products identified for testing and evaluation. Each year NTPEP conducts a national survey of the member departments to determine what additional products, materials or devices should be added to the test and evaluation program. At the annual meeting of the NTPEP Oversight committee a consensus is reached on which materials, products or devices should be added to the evaluation process. Once the material, products, or devices have been identified for evaluation a project panel is established to develop a work plan to identify the test and evaluation procedures.

Once the materials or product is identified for testing, the NTPEP Coordinator sends a solicitation letter with a specific time cycle to industry and its associations inviting them to participate in the NTPEP test and evaluation program.

The products or material are evaluated and tested against current AASHTO and ASTM standard specification or member department specifications that the National Transportation Product Evaluation Program oversight committee accepts for use in the evaluation procedure. Some modification of the standard protocols may be necessary to provide for the comparison of products.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
American Association of State Highway and Transportation Officials

Typical Users:
State departments of transportation—materials, design, construction and testing and evaluation professionals; local agencies, contractors, and vendors; some local transportation agencies

How are Findings or Results Reported and Disseminated?
Upon completion of the testing and evaluation, reports are printed and distributed to all member departments. Copies of the reports are furnished to all the manufacturer/suppliers that submitted material, products or devices for evaluation. All reports are available through the AASHTO publication process.

The program maintains a web site that provides general information regarding the program at http://www.aashto.org under the products and services.

Some portions of evaluation reports are available from the web site at this time, short descriptions are web site viewable. Downloadable information files are in zip format (expandable after download) and contain spreadsheet data and other facts regarding the evaluation.

Existing Information Collections/Databases:
Currently there is no publicly available database for NTPEP product evaluations.

Who Maintains the Collections/Databases?
All evaluation information is maintained by AASHTO.

General Format Description of the Data:
NTPEP requests that evaluation reports be formatted in WordPerfect and Excel programs but has the capability to handle other commonly available software documents.

Access or Subscription Fees:
Reports are sold through the AASHTO publication office.

Plans for Near-Term Enhancements to the Collections/Databases:
NTPEP is planning to make considerably more of its information available through its web site. Goals are to have full text versions of reports available, when possible, as well as options for downloadable full text reports.

For More Information:

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Engineering Project Coordinator -- NTPEP
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E-mail: stevel@aashto.org

National Work Zone Safety Information Clearinghouse

Description/Scope:

The establishment of a National Work Zone Safety Information Clearinghouse was originally initiated as a result of a recommendation stemming from the December 1994 National Work Zone Safety Conference, and subsequently to comply with Section 358 (b) of the National Highway System (NHS) Designation Act of 1995. The Act requires the Secretary of Transportation to make use of a variety of ways to improve construction site safety. One of six methods listed is the establishment of a work zone safety clearinghouse to provide information and technical assistance to other government agencies, public and private organizations, and the general public to promote increased safety, knowledge, and understanding of travel in work zones. The exploration of developing a national clearinghouse was also included in the National Work Zone Safety Program developed by the Federal Highway Administration (FHWA) as a result of Section 1051 of the Intermodal Surface Transportation Efficiency Act of 1991.

The FHWA has executed a cooperative agreement with a national association with the following objectives:

- to establish, operate, manage, and maintain a National Work Zone Safety Information Clearinghouse
- to provide an initial single contact point for potential users soliciting information concerning the safe and effective operations of work zones
- to provide access to the clearinghouse via telephone and e-mail, for example
- to phase out federal financial support of the clearinghouse over a three-year period and have the clearinghouse become self-supporting
- to store print and audio-visual materials applicable to work zone safety, operate and maintain a materials control system, and duplicate/distribute on request

Type of Activity:

__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):

Federal Highway Administration

Typical Users:

State and local transportation agencies, researchers, academia, consultants, construction industry, and other public and private organizations concerned with construction site safety, and the general public

How are Findings or Results Reported and Disseminated?
The project will have an Internet-based inquiry/retrieval system as well as access via an 800 number telephone contact or via mail systems. The access will be designed to allow a broad spectrum of users having varying degrees of technological capabilities. Information will be disseminated by the most effective means for the user.

Access or Subscription Fees:
There will be no fees for the system during the initial three years of operation. The organization selected to create and maintain the clearinghouse will propose a means for the continuing viability of the clearinghouse absent federal-aid funds.

Plans for Near-Term Enhancements to the Collections/Databases:
The effective date of the cooperative agreement is October 1, 1997. Under the terms of the agreement the clearinghouse is to be operational within four months of the effective date, which would be around February 1, 1998.

Illustrative Example of Collection/Database Content:
The following list identifies the topics of interest and prime areas for user inquires. Databases or appropriate referral persons are to be included as part of the clearinghouse.

- National Accident Data (including National Highway Traffic Safety Administration's Fatal Accident Reporting System access; and state accident record contact persons)
- Catalog of Work Zone Outreach Material (state and federal safety-related public outreach material)
- Training Courses and Certification Programs
- Laws Relating to Work Zones (federal laws and contact persons for state laws and regulations)
- Specifications (federal work zone standard construction specifications from the Manual of Uniform Traffic Control Devices, and other applicable federal standards and requirements; state work zone-related standard construction specifications and special provisions; and state contact persons)
- Technology/Equipment—New Traffic Control Devices and Safety Technology (including input from HITEC and NTPEP)
- Work Zone Safety Related Research and Development (access to the Transportation Research Information Service (TRIS), including information from NCHRP, FHWA, American Association of Civil Engineers, ITE, and ITS America; and state research contact persons)
- Current Practices (state contact persons and national experts nation-wide who are knowledgeable about current practices) experts industry wide

For More Information:

Program/Resource Coordinator
Joseph Lasek
Office of Highway Safety HHS-11
Federal Highway Administration
400 Seventh Street, SW, Rm. 3407
Washington, DC 20590
Telephone: 202-366-2174

Non-Destructive Evaluation (NDE) Validation Center

Description/Scope:
The Nondestructive Evaluation (NDE) Validation Center is to provide researchers, industry, and state transportation agencies with quantitative, independent, and reliable validation of NDE methods. The Center will develop specimens and methodologies to validate NDE performance both in the laboratory and in the field and serve as a resource for the highway and bridge inspection community.

The primary role of the NDE Validation Center will be to develop and execute effective test protocols for validating the performance of NDE methods (not products). Component specimens and test bridges will serve as critical resources in the process by simulating the many factors that effect the reliability of NDE methods. Testing at the center will help define the proper application and limitations of size, material properties, or structural condition. The validation process will provide performance parameters for NDE methods, procedures, and systems to enhance safety and maintenance inspections of the highway system.

The Center is not yet functional. Center facilities will be located at the FHWA Turner-Fairbank Highway Research Center. Construction of the Center's laboratory is to begin in late Summer 1997.

Center staff are currently negotiating to have seven bridges available for use (six bridges owned by a state department of transportation, one owned by a turnpike authority). Component specimens from nation-wide sites are now also being collected. The benefit of these bridges and specimens will be to enable researchers and inspectors to have actual field sites/components upon which to base experiments and methodology testing.

Type of Activity:
_X_ T&E _X_ Technology Transfer ___ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users:
State and local transportation agencies, researchers, academia, manufacturers, and vendors concerned with inspection of highway components

Access or Subscription Fees:
There are plans for a fee-based system for use of the physical components library provided by the Center. Further details of the fee system are to be decided.

Plans for Near-Term Enhancements to the Collections/Databases:
The Center plans to have available a Library of Fatigue Cracks, actual specimens of field components as well as instrumented bridges for methods testing.

A web page is planned for the Center, which will include links to other NDE sites as well as will contain summaries of workplans, and results of projects. Future planning calls for the ability to log into a test bridge and take readings from its instrumentation. (It is unknown at this time whether this process can be done real-time or if the Center will have to provide periodic technical updates.)

For More Information:

Program/Resource Coordinator
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NDE Validation Center
Turner-Fairbank Highway Research Center
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Priority Technology Program (PTP)

Description/Scope:
Priority Technologies Program (PTP) is a Federal Highway Administration program to accelerate the deployment of new or innovative technology by the successful testing and evaluation of technologies which have high potential for bringing real benefits to transportation users. It was created to be the vehicle for a new way of delivering innovative technologies.

PTP is to stimulate and provide incentives to develop partnerships where the Federal Highway field offices are provided with significant responsibilities and fiscal resources for executing the program as well as a larger role in setting the direction and administration of the program.

This program has a national focus, specifically for accelerating the deployment of innovative technologies, which have high potential for bringing real benefits to highway users. In most cases, these would be technologies that have already be commercialized but under-utilized. The focus is getting the technology "on the ground" and applied to solve real problems and deliver real benefits. Program funds are made available to each Federal Highway Region and Federal Lands Highway Program Office. Each Region selects projects in accordance with developed guidelines. Each project has a clear and detailed evaluation plan to compare the technology with that normally used and to analyze the before and after impact of the technology. AASHTO and ASTM standards are used where applicable.

Type of Activity:
__ T&E __ Technology Transfer _X_ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users/Participants:
State departments of transportation, national laboratories, and local transportation agencies

How are Findings or Results Reported and Disseminated?
Because the program is still relatively new, there is not yet a body of findings or results available. PTP projects are listed on the web site. The projects are searchable by FHWA region, subject area, and through a general key word search utility. It is anticipated that findings and results will be published by the cooperating states, along with annual reporting by the Federal Highway Administration.

Existing Information Collections/Databases:
There is a database used for internal FHWA purposes. PTP projects are listed on the web site. (See enhancement information below.)

Who Maintains the Collections/Databases?
Federal Highway Administration, Office of Technology Applications

General Format Description of the Data:
The software used for this program is Microsoft Access.

How Can the Data Currently Be Accessed?
The web site address is: http://www.hend.com/6005/

Access or Subscription Fees:
There are no access or subscription fees associated with acquiring PTP information. Reports may be available sale through the National Technical Information Service.

Plans for Near-Term Enhancements to the Collections/Databases:
There are plans to make full project data available on the PTP web site. The details to be included will be results of the project along with a full description of the project and pointers to other project partners, as applicable.

Illustrative Example of Collection/Database Content:
An example of project initiated incorporate a variety of technologies such as bioremediation of contaminated soils, evaluation of LED signals, video tape data collection, geographic information systems, and ignition ovens for asphalt content determination.

The database that will be created will describe the project, identify performing agency and partners, funding sources and amounts, start and complete dates, and give a status code indicating the stage of progress of the project.

For More Information:

Program/Resource Coordinator
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Long Term Pavement Performance (LTPP) Program

Description/Scope:
The goal of the ongoing, 20-year Long-Term Pavement Performance (LTPP) studies is to give state and provincial transportation departments—the owners and customers of the LTPP program—the information and tools they need to build and maintain longer-lasting pavements.

Outcomes of this very large effort are LTPP products—information, computer software, analysis procedures, testing procedures, design procedures, and guidelines—derived from the LTPP data base or resulting from the research effort and delivered in a form that can be used by the stakeholders to build better pavements. The LTPP products fall in four general categories:

- Pavement design guides and maintenance strategies
- Pavement monitoring procedures
- Material testing
- Equipment standards and calibration procedures

The products in Category 1 will primarily result from the analysis of the LTPP database. The analysis products will be either qualitative or quantitative, depending on the level of effort expended in their development. Analysis is already under way with a major effort beginning in 1996.

The products in Categories 2, 3, and 4 already exist and are being used by the LTPP program. Some of these products have been adopted by AASHTO and are being commercially manufactured and used, or are available for use. Information on these products is available from FHWA's Office of Technology Applications. The majority of these products can be considered research grade and may need to be modified for general engineering applications. The LTPP Implementation Technical Working Group will be reviewing these products for their state of readiness, applicability, packaging, and delivery methods.

Type of Activity:
_X_ R&D   _X_ T&E   _X_ Technology Transfer   __ Technology Deployment

Sponsor(s):
The LTPP program represents a cooperative effort of the highway community. The original partners in establishing SHRP and LTPP were the state departments of transportation, AASHTO, TRB, industry, academia, and FHWA. During the life of SHRP, this list of partners expanded to include the Canadian Provinces, the Canadian Strategic Highway Research Program (C-SHRP), and more than 30 other countries. This partnership extended beyond the development of the objectives and experimental plan to include the administrative and technical management of SHRP, in addition to sharing the workload in collecting and providing the data. This partnership continues today as FHWA leads the LTPP studies.

Typical Users:
State and provincial departments of transportation, industry, local and regional transportation facilities, other government agencies, academia, research institutions, and the international pavement engineering community

How are Findings or Results Reported and Disseminated?
The findings and results of work-to-date are available in print form from the Federal Highway Administration.

Existing Information Collections/Databases:
The LTPP database represents the largest pavement performance database ever produced. It contains sufficient data to produce products today that will significantly improve pavement performance.

The LTPP data base can be considered a very large information warehouse (in fact, if you took all the information stored in the data base at this time and stored it on standard 1.44-megabyte disks, and then stacked the disks, the pile would reach 8.5 stories high). In some respects, the database can be considered as more of a tool—or parts bin—for making products. Although the customers for the LTPP products are the states and provinces, the initial user of the database in the majority of cases will be the pavement researcher who produces the products. With advancements in computer technology, and as the LTPP procedures become refined, the database will become more of a product that can be readily used by the states.

Some products are already available, including those related to materials testing, pavement performance monitoring, and equipment standards and calibration procedures. Still under development are products directed at the selection and effectiveness of maintenance strategies, performance of various rehabilitation techniques and materials, and the selection of design features for new or total reconstruction.

Who Maintains the Collections/Databases?
Federal Highway Administration—the Pavement Performance Division in the Office of Engineering R&D maintains the databases.

The Regional Offices are the main liaison with the states and provinces and are responsible for both collecting data on the pavement monitoring sections and processing the data supplied by the highway agencies.

How Can the Data Currently Be Accessed?
Considerable information is available from the LTPP web site:
http://www.tfhrc.gov/pavement/ltpp/ltpphome.htm

The LTPP database access via the web site in currently under construction.

For More Information:

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SHRP Implementation and Lead States Program

Description/Scope:
The AASHTO Lead State Program was developed to ensure that practical, real world experience gained in the early application of SHRP technology is shared among all state departments of transportation and extended to other transportation agencies. A Lead State is a transportation agency, along with associated contractors and materials suppliers, that has used one of the SHRP technologies on a large enough scale to develop the expertise needed for successful application. The Lead State has also assumed the obligation to share this expertise with other agencies on a formal basis.

The program promises to be a new approach to highway technology deployment and transfer by making most of the "user as teacher" concept and by involving in the implementation process those private sector groups directly affected by the technology. Currently, three or more lead states have been designated for each of seven high priority SHRP technology areas. The Lead States have organized into Lead State Teams for each technology to maximize efficiency and minimize unnecessary duplication of effort.

Lead State Teams are comprised of professional staff from the Lead States along with volunteer private sector participants. As Lead States undertake pioneering projects involving high priority SHRP products, the Teams will capture lessons learned and transfer those lessons to the highway community at large. (Excerpted from Lead States Program description material.)

The program is to increase the opportunity for and facilitate the broad adoption of high priority SHRP products. It is anticipated that the mission will be accomplished by the year 2000.

Type of Activity:
__ T&E _X_ Technology Transfer _X_ Technology Deployment

Sponsor(s):
American Association of State Highway and Transportation Officials

Typical Users/Participants:
The Lead State Program has a large number of individuals participating in a variety of differing roles. Key groups are Lead State Teams, agency members (state and local agency professionals engaged in early application of high priority SHRP products), private sector members (professional staff of commercial entities engaged with Lead State Teams). Lead State support organizations such as: AASHTO Task Force on SHRP Implementation, FHWA Regional and Divisional Staff, and D.C. Support Group (comprised of SHRP implementation staff of AASHTO, TRB, and FHWA with assistance from Maryland DOT.)

Existing Information Collections/Databases:
While the Lead States Program does not focus on data collections or specific databases, the concept is one, which is important to describe in the information resources section of this report. The framework used for technology deployment and transfer is a new model for the highway community. The program brings together a multitude of private and public sector bodies and provides a mechanism through which enhanced collaboration can occur. The framework promises to markedly increase the opportunities for introducing innovative products to the highway system.

How Can Data Currently Be Accessed?
As a pilot effort, the Winter Maintenance Lead State Team is in the process of developing a web site that demonstrates the information sharing and communications advantages a virtual clearinghouse. The web site will contain a location for peer to peer technical assistance, a comprehensive view into research and technology activities in winter maintenance topics, as well as news and events listing.

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Special Products Evaluation List (SPEL)

Description/Scope:
The AASHTO Product Evaluation Listing is a product of the AASHTO Subcommittee on Materials, SPEL Council. SPEL's purpose is to provide information about special highway-oriented products that have been evaluated in some manner by state highway or transportation departments. The system is a means by which states may conserve resources and avoid duplication effort. SPEL has been in existence for more than 20 years.

There is a growing consensus of the need for more timely and efficient access to information on proprietary products tested or evaluated by the various state or national programs. The Subcommittee working through its SPEL Council has initiated an NCHRP study that is examining the feasibility of replacing the existing SPEL database with a new more accessible system that would provide more useful information to the highway community (excerpted from NCHRP Progress Report and study materials, Project 20-7, Task 82).

The new database is being informally called the AASHTO Product Evaluation Listing.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
American Association of State Highway and Transportation Officials, Subcommittee on Materials

Typical Users:
State departments of transportation— materials, design, and testing and evaluation professionals, and other highway facility owners such as turnpike authorities and local agencies, and Canadian provincial transportation departments

How are Findings or Results Reported and Disseminated?
Every two years through 1991, FHWA published a hard copy of the information contained in the SPEL database, called the "Blue Book." Since 1985 the database has been accessible via modem connections to the FHWA mainframe computer. Plans to move SPEL to a PC-based system were not implemented due to FHWA staff shortages. In recent years little use has been made of SPEL and the data are becoming outdated. (Excerpt from NCHRP Project 20-7, Task 82 materials.)

Existing Information Collections/Databases:
SPEL biannual publications were available through 1991.

The SPEL database contains AASHTO Member Departments' information concerning new products being evaluated through the early 1990s. Because of the declining input to the database, it is becoming outdated.

The new database being created as a result of the NCHRP project will contain new information, collecting current data and going forward. The consultant has converted the old SPEL database to the new system for agencies to review.

Who Maintains the Collections/Databases?
FHWA maintains the database for the AASHTO Subcommittee on Materials. The project consultant, the Texas Transportation Institute (TTI), is maintaining the pilot database created in conjunction with the NCHRP project.

Location and General Format Description of the Data:
The old SPEL database is located on the National Institutes of Health mainframe computer system. The pilot database created for the NCHRP project will be located at TTI.

The plans for the new database will include a process, which will allow input from a variety of sources. The system is envisioned to have options of direct local agency input as well as batch input by the system administration organization. Some states have requested that the database include the capability to input data using the states' own product evaluation formats.

The software system to be used is Inmagic DB/Text Web Publisher.

How Can the Data Currently Be Accessed?
The old SPEL database is not being used to any great degree at present. The pilot database will be accessible via the TTI web site: http://tti.tamu.edu/prodeval/The project completion date is October 31, 1997.

Access or Subscription Fees:
There are no fees associated with accessing SPEL data. No decisions have been made to-date regarding continuation funding, so all options remain open.

Plans for Near-Term Enhancements to the Collections/Databases:
As described, the NCHRP project efforts will produce a pilot database, which will be evaluated for full-scale implementation. No decisions have been made regarding this implementation.

Illustrative Example of Collection/Database Content:
The pilot database will contain description of the product, manufacturer, evaluation results (completed, accepted), testing procedures, date performed, and agency, evaluation, and manufacturer contact information, among other items. The database records will contain required information as well as associated information, which may vary among the participating organizations.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)

As a result of a survey conducted during the course of the NCHRP project, a majority of respondents replied that they would be "heavy users" of the system. It is estimated that for early implementation approximately 30-35 states might be regular participants in the new system.

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Testing and Evaluation Projects

Description/Scope:
Federal Highway Administration Office of Technology Application Test and Evaluation Projects are one part of the Federal Highway Administration Office of Technology Applications (OTA) program. Test and Evaluation Projects evaluate innovative or emerging technologies that have been identified as having a great potential for use nationwide. The program has been operational since OTA came into existence in 1990. Products are generally commercially available, in limited use, or outputs from research and development programs.

The program covers all areas of highway technology, including asphalt and concrete pavement, environment, structures, geotechnology, hydraulics, safety, motor carriers, and traffic operations and management.

Projects are initiated by Federal Highway Administration in coordination with the agency's research, development and technology program goals.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users:
State and local transportation agencies, researchers, academia, manufacturers, and vendors concerned with testing and evaluating new products in the highway

How are Findings or Results Reported and Disseminated?
Findings and results are in the public domain and are published and disseminated as Federal Highway Administration technical reports and in the Technology Applications Programs Report. A list of project information is also available on the OTA web site.

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Texas DOT/TTI Hydraulics And Erosion Control Laboratory

Description/Scope:
The Texas (TX) DOT/TTI Hydraulics and Erosion Control Laboratory (HECL) provides TX DOT the capability of using selected erosion control products which have demonstrated their capability of protecting the natural environment through controlled performance evaluations. These evaluations are accomplished at the HECL located at TTI. The testing facility encompasses 21 acres and includes an L-shaped embankment, a series of 10 at-grade channels, water reservoirs, pumping stations, and various instrumentation. Testing and evaluation activities focus on products dealing with slopes and channel flow. Products are accepted for evaluation based upon space availability and upon the position of the waiting list maintained by the TTI facility manager.

HECL efforts also provide industry with a uniform, fair, and timely testing program for products they propose for use within TX DOT's construction and maintenance activities, and for new products developed by industry. HECL seeks to establish and maintain the greatest number of individual products on the TX DOT Approved Products List (APL) as possible, provided those products have demonstrated their capability to meet TX DOT minimum standards for performance. (Excerpted from HECL Annual Report, February 1997.)

Type of Activity:
_X_ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Texas Department of Transportation

Typical Users:
Texas DOT construction and maintenance personnel and other state and local agencies seeking reliably tested and evaluated products. Manufacturers, vendors, and suppliers of embankment, flexible channel liner and hydraulic mulch products.

How are Findings or Results Reported and Disseminated?
The evaluations are compiled in an annual report of field performance testing prepared by the TX DOT Construction and Materials Division and TTI. The testing and evaluation experiences are also documented in an annual report produced by TTI. Distribution of materials is via standard distribution channels for TX DOT and for TTI reports.

Existing Information Collections/Databases:
The information gained through the testing and evaluation is incorporated into the TX DOT Approved Products List.

Who Maintains the Collections/Databases?
The database is maintained by TTI and by the Texas DOT Construction and Maintenance Division.

How Can the Data Currently Be Accessed?
In addition to printed reports from TX DOT or TTI, Internet web sites are being maintained by TX DOT at http://www.dot.state.tx.us under the "Construction and Maintenance Division", and by TTI at http://tti.tamu.edu/divisions/econ/env_management.

Access or Subscription Fees:
There are currently no evaluation fees required from participants in the program. Printed reports are available from TX DOT without charge. Printed reports are available from TTI for a fee.

Plans for Near-Term Enhancements to the Collections/Databases:
In addition to near-term goals of having a complete listing of product evaluations, there are plans for incorporating a search tool for the database. No definite timeframe has been discussed for this enhancement.

Illustrative Example of Collection/Database Content:
Evaluation procedures, approval information, minimum performance standards, product private labels, brand or trade name revisions, product descriptive material, performance data including a record of performance data, standard specifications, proposed product list.

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Vehicle Detection Clearinghouse
(at the New Mexico State University)

Description/Scope:
The Vehicle Detection Clearinghouse (VDC) is a federal-aid pooled fund project in which approximately 25 state departments of transportation participate. The VDC has been in existence since January 1997. The Clearinghouse is to provide information to transportation agencies on the capabilities of commercially-available vehicle detectors by gathering, organizing, and sharing information concerning tests and test procedures in a timely, efficient, and cost-effective manner. The Clearinghouse will be a catalyst for developing standard test protocols.

As a new program, the Clearinghouse is in the process of compiling contact lists, test reports, test protocols, product literature, and related materials. Among its activities, the Clearinghouse is participating in an American Society for Testing and Materials management committee with the goal of developing at least one new standard testing procedure within one year.

Type of Activity:
_X_ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Approximately 25 state departments of transportation through the Federal Highway Administration pooled fund program.

Typical Users:
State department of transportation traffic monitoring professionals

How are Findings or Results Reported and Disseminated?
The primary means of distributing information is through the Clearinghouse web site. (http://www.nmsu.edu/~traffic/) The Clearinghouse also supports a List Serve which functions as a communication tool for vehicle detector users, manufacturers, and the research community.

Existing Information Collections/Databases:
There are currently two primary searchable databases included in the Clearinghouse, one for state agency data and the second for vendor equipment data. Report data is organized into four major topical areas: Traffic Monitoring Conference Abstracts, Vehicle Classification Abstracts, Weigh-in-Motion Abstracts and Miscellaneous Abstracts.

Who Maintains the Collections/Databases?
The Clearinghouse is maintained by the Southwest Technology Development Institute at the New Mexico State University.

Location and General Format Description of the Data:
The database resides on the New Mexico State University's computer system. The data is organized via database programs from the University's mainframe system. They are also using Excite for Web Servers and Altavista search engines. The site was created with PageMail, web site builder software.

How Can the Data Currently Be Accessed?
The data can be accessed through the Clearinghouse web site. (See above.)

Access or Subscription Fees:
There are no access or subscription fees for the Clearinghouse.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)
The Clearinghouse is just getting started. There are no use statistics available at this time.

For More Information:

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New Mexico State University
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World Bank Knowledge Management Initiative

Description/Scope:
The World Bank Knowledge Management Initiative is a program being developed by the Bank to provide expertise in a series of approximately 12 broad technical areas. The Initiative will be available to inform, train, and provide technical assistance and other technology transfer activities for international users interested in becoming more knowledgeable about the general topics.

The World Bank is currently soliciting participants for the Initiative. The Initiative participants will be expected to provide staff expertise/counsel in the respective technical areas. Transportation is only one of the broad technical topics being considered for the Initiative. For the purposes of the Innovation Clearinghouse Study, this initiative is an international technology transfer mechanism. It will not be specifically dealing with incorporating highway innovative technologies into transportation systems.

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World Federation Technical Assessment Organization (WFTAO)

Description/Scope:
The World Federation of Technical Assessment Organizations (WFTAO), established in September 1996, is a network of organizations that are engaged in issuing Technical Assessments (testing and evaluating technologies/products to determine suitability for use) in the construction field. WFTAO's mission is to enhance and promote the role of "Technical assessments of innovative and non-standardized systems and products in the construction field worldwide and to develop the mutual confidence on technical assessments made by its members." WFTAO's goal is to foster harmonization of "technical assessment processes" and eventually mutual acceptance of "findings and results."

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
WFTAO is a fee-based "association" of public and private organizations engaged in "technical assessments" in the construction field. CERF's Innovation Centers—HITEC and EvTEC, and CEITEC are members of WFTAO.

Typical Users:
Presently, WFTAO's mission is involved with enhancing coordination and collaboration within its membership only. Thus it does not provide any direct service to "other users."

How are Findings or Results Reported and Disseminated?
Findings from technical assessments are only available from members of WFTAO, not from WFTAO per se.

Existing Information Collections/Databases:
WFTAO does not have a centralized database. Individual members have a variety of databases.

Who Maintains the Collections/Databases?
Individual members

Access or Subscription Fees:
Varies from member to member

Plans for Near-Term Enhancements to the Collections/Databases:
WFTAO will be developing an electronic network to coordinate activities (see HITEC).

For More Information:

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World Interchange Network (WIN)

Description/Scope:
The World Interchange Network (WIN) was officially instituted during the PIARC (Permanent International Association of Road Congress, now known as the World Road Association) XXth World Road Congress held in Montreal, Canada in September 1995. WIN has been organized to be the international non-governmental organization devoted to promoting the exchange of road-related information and knowledge. Through WIN, a client can identify experts and then may follow up with the expert to accomplish the transfer of transportation information. The global electronic nature of the network assures communication speed heretofore unknown in the international road community. Goals of WIN are to establish a network of as many subscribers as possible to reach out with transportation expertise to those in less developed or newly industrialized countries. WIN has the potential to significantly improve access to international transportation experts throughout the world.

WIN currently consists of 148 members in over 54 countries. There are 62 nodes on the network located in over 32 countries. Nodes are individual sites or transfer centers. The function of nodes is to analyze requests and identify a technical contact, if appropriate. Once a referral is made, the initiator and the technical contact communicate in whatever manner is most convenient and then determine the most appropriate way to exchange information.

WIN is currently undergoing a three-year trial period. The organization is based in Montreal and is operating with seed funds from various international and national organizations. The Network has had a very positive beginning and there is great future potential for the program.

Type of Activity:
__ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor and Participant(s):
Various institutions involved in WIN cover the spectrum of public, private, academic, and non-profit sectors.

Typical Users:
Worldwide transportation community

How are Findings or Results Reported and Disseminated?
The network is currently accessible via its web site: http://www.rme-win-rmi.qc.ca

Existing Information Collections/Databases:
The web site lists member organizations (network nodes) and provides the opportunity to request information from the network.

For More Information:

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2.2 Examples of State Departments of Transportation New Product Evaluation Programs

Arizona Department of Transportation New Product Evaluation Program

Description/Scope:
The Product Resource Investment Deployment and Evaluation (PRIDE) Program is the Arizona Department of Transportation's (ADOT) product evaluation program. It is administered and facilitated by the Arizona Transportation Research Center (ATRC). The program reviews and evaluates new products for the department and produces the Approved Product List, which catalogs all new products, approved for use. The program accomplishes its work through three participatory technical committees: Traffic Control Products Evaluation Committee; Maintenance Products Evaluation Committee; and Materials Products Evaluation Committee. The New Products Policy Committee, which is responsible for the overall success of the program, coordinates the three committees' activities.

New product information is submitted by vendors and manufacturers in specific format and includes detailed product information. This packet of materials is the basis for the evaluation and review. The ATRC New Products Engineer performs the technical review as well as verifies other users' experiences. Should this screening show the product to be appropriate, the product is included in the Approved Product List (APL). A summary report of evaluation is prepared (up to 2 pages in length). The Approved Products List is included in a PRIDE database.

New products on the APL may be used in construction projects. If specifications have not been written for the product, a request for product evaluation is made after the product has had at least two years in service. This provides performance feedback and if appropriate, information as input to the writing of a specificationThis process assists in the complex effort involved in specification writing and assists in getting valuable new products into the field more readily.

Type of Activity:
_X_ T&E __ Technology Transfer _X_ Technology Deployment

Sponsor(s):
Arizona Department of Transportation; funding source is the federal-aid State Planning and Research Program.

Typical Users:
The APL has broad use throughout the department and especially with members of the technical committees described above including assistant state engineers, technical professionals in the respective areas, central and field office personnel.

How are Findings or Results Reported and Disseminated?
Product evaluation summaries are distributed to the technical committees. The committee members are the primary conduits for all new product information dissemination within the department. The ATRC has published a PRIDE Annual Report, which provides a full recap of program activities. (A New Products Evaluation Engineer was just recently appointed, an Annual Report for the past year may not be available.) Published Annual Reports are available through NTIS.

Application forms for submitting products for evaluation are found on the ATRC web site. http://www.dot.state.az.us/about/atrc/pride.html

Existing Information Collections/Databases:
PRIDE Approved Products List, which includes a tracking function especially valuable to update vendors on the status of their products' evaluations.

Who Maintains the Collections/Databases?
The database is maintained by the New Product Evaluation Engineer of the ATRC staff.

Location and General Format Description of the Data:
The database currently resides in the ADOT computer system and uses an older software relational database program (Revelation).

How Can the Data Currently Be Accessed?
The database is accessible by ADOT technical staff through the ADOT computer system.

Access or Subscription Fees:
There are no fees associated with accessing PRIDE data or the APL.

Plans for Near-Term Enhancements to the Collections/Databases:
Plans are now being made to include access to the APL via the ATRC web site. This new process will also allow the retrieval of evaluation policy and forms through the ATRC web site. The database will reside on a wide-area network system, available throughout the department.

The database will be converted to a new system using MicroSoft Access software.

ATRC is also investigating the possibility of more involvement from local agencies. ATRC is planning to coordinate some new product activities with the Local Technical Assistance Program efforts. There is potential that ATRC will be able to maintain a database for local projects as well as do some follow-up evaluations on in field products.

Illustrative Example of Collection/Database Content:
The database includes product name, vendor/manufacturer, dates of contact (tracking of events), and status of evaluation.

For More Information:

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Kansas Department of Transportation New Product Evaluation Program

Description/Scope:
The Kansas Department of Transportation (KDOT) evaluates new highway construction and maintenance products, materials, and procedures to determine whether they improve the agency's efficiency over currently used products or methods or satisfy an agency need. The Bureau of Materials and Research is the responsible organization within the agency for administrative and technical coordination of the activities. The department's Research Steering Committee is responsible for determining acceptability for department use of all new products or processes. Vendors and manufacturers desiring to have products evaluated submit a standard form and full complement of information regarding their products. KDOT accepts and utilizes testing from other state and federal agencies and recognizes independent research entities such as HITEC and NTPEP when evaluating new products. KDOT will duplicate such tests only when particular Kansas materials warrant additional testing for verification. The Technology Transfer Engineer shepherds the application through the new product evaluation process.

The Research Steering Committee performs its initial review and assigns an expert in the relevant area to perform a detailed evaluation. The evaluation is circulated to the committee for its decision regarding approval or rejection of the product for use by the department. A database containing new product evaluation information has been created.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Kansas Department of Transportation, some Federal-aid State Planning and Research funds are used for the administrative oversight functions.

Typical Users:
Design, construction, maintenance, materials and research, and other department technical personnel; field forces tend to make personal contact with the Bureau of Materials and Research; vendors requesting status of the evaluation

How are Findings or Results Reported and Disseminated?
Evaluation information is available through evaluation reports, and summary information as output from KDOT new products' evaluation computer systems database, and on the Internet.

Existing Information Collections/Databases:
The collection consists of evaluation information from all products reviewed and evaluated by KDOT.

Who Maintains the Collections/Databases?
The Bureau of Materials and Research

Location and General Format Description of the Data:
The data is contained in an Access database on the Materials and Research server. Older product information has recently been entered into the Access database with newer evaluations. Some of this older information is out-of-date. The department has not had the resources required to maintain these data. Information from the past 2 or 3 years is to be available shortly on the KDOT web site: http://www.ink.org/public/kdot/business/

How Can the Data Currently Be Accessed?
All information is available on the Kansas DOT intranet in a static table, giving the product information and approval status. Contact with the Bureau of Materials and Research can assist with supplying any additional information. The Bureau makes available periodic reports summarizing new product assessments, implementations, and evaluations.

Access or Subscription Fees:
There are no fees associated with this activity.

Plans for Near-Term Enhancements to the Collections/Databases:
KDOT will soon have a new products listing available on their web site. This will be a searchable state table and will contain information for KDOT employees as well as vendors seeking information about product approval status. The department also plans to include a web site process by which vendors may submit new product evaluation applications forms.

Illustrative Example of Collection/Database Content:
The database contains: product name, vendor and vendor contact person, product code/category, disposition (approved, need more info or other actions, not approved, and others), date application received, date of most recent or final action. This information is available in print at present and will be available electronically via the web site.

For More Information:

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Mississippi Department of Transportation Product Evaluation Program

Description/Scope:
The Mississippi Department of Transportation (MDOT) Product Evaluation Committee is the primary body that governs all new product evaluation activities. The committee is a non-policy making body of technical and administrative advisors to the Chief Engineer. The committee reviews and evaluates new materials, new products, and new procedures proposed to the department and makes appropriate recommendations regarding use (from adoption to rejection). The committee is comprised of state engineers and managing technical engineers in the various disciplines, construction, maintenance, materials, traffic, bridge, roadway design, research, information systems, and planning, among others.

A primary goal of the committee is to encourage development and introduction into the highway field of new and improved products, materials, and processes. In conjunction with a product approval, the committee investigates the effort required to implement a specification and through department channels forwards its determinations for appropriate actions.

The committee considers manufacturer or vendor proposals through an individual product review subcommittee formed to study each submittal. Reports of evaluation are presented to the committee.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Mississippi Department of Transportation, funded through state moneys

Typical Users:
The evaluation reports are used by a broad spectrum of department technical areas, those represented on the committee, in particular construction and maintenance, and including the six district offices.

How are Findings or Results Reported and Disseminated?
As they become available, reports are widely distributed throughout the department. Reports are presented at quarterly Evaluation Committee meetings. Data for the approved product sources is stored on floppy disk. Committee minutes provide documentation of products evaluations. These minutes and the approved sources of materials are distributed to committee members.

Existing Information Collections/Databases:
The Materials Division is the lead organization for information collection regarding new products. The collection is comprised of individual product evaluation reports. Hard copy listings of approved sources of materials are maintained with distribution made within the Department.

Who Maintains the Collections/Databases?
The Materials Division

Location and General Format Description of the Data:
All material now is in report format.

Plans for Near-Term Enhancements to the Collections/Databases:
The department is implementing a wide-area network computer system. The new product evaluations' reporting is considered to be an appropriate application for such electronic format. The department is reviewing the options for computerizing this material.

For More Information:

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Pennsylvania Department of Transportation New Product Evaluation Program

Description/Scope:
The Pennsylvania Department of Transportation (Penn DOT) has had a new product evaluation program for as many as 30 years. The program utilizes a standard requirement application form for product manufacturers and vendors to apply for consideration by the program. The program continually has more applications than can be handled. Like many other organizations, Penn DOT is experiencing the lack of resources to accomplish this growing workload.

The New Products Evaluation Program is the sole source of approval for new products for use in Penn DOT highway applications. Recently, the department underwent a re-engineering of the process used for product evaluation with the goal of a more timely implementation of new products and technologies. A brief risk assessment will be made early on in the process to determine the extent of the evaluation required and information from other agencies will be used where applicable. Provisional specifications will be developed for new products to make them available for contracting while the placements are monitored for performance. Formal field evaluations will continue to be used for products that are deemed medium-high risk, or where little information is available concerning actual field placement performance.

In addition to the re-engineering effort that is currently being implemented, the department will be utilizing university and private sector partnerships for materials testing and evaluation related efforts and their implementation, among other items.

Type of Activity:
_X_ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Pennsylvania Department of Transportation
Federal-aid State Planning and Research moneys fund field evaluations.

Typical Users:
Penn DOT construction, maintenance, and design professionals; Local/municipal agencies public works departments; manufacturers and vendors.

How are Findings or Results Reported and Disseminated?
At present, Penn DOT new product evaluations data is available upon request from the Division of Engineering Technology and Information, Bureau of Construction and Materials. Field evaluation reports, when available, are available to department employees and to others expressing an interest in and need for the data.

Existing Information Collections/Databases:
The existing database is a current listing of descriptive data on each approved new product.

Who Maintains the Collections/Databases?
Penn DOT Materials Laboratory maintains the databases on its in-house IBM AS400 computer system.

How Can the Data Currently Be Accessed?
Data is accessed in batch mode—upon request producing printed documentation for distribution.

Access or Subscription Fees:
There are no fees associated with this program.

Plans for Near-Term Enhancements to the Collections/Databases:
Penn DOT plans to provide additional guidance to manufacturers and vendors so that more complete application packages are received. New forms have been developed to insure that all needed information is included for a faster review of the product.

The re-engineering effort includes development of a new database for product evaluations with future Internet accessibility. Vendors and other interested parties will be able to check on current evaluations through the Internet. The database and access to it are anticipated to be on-line in early 1998. The department is also actively participating in the development of AASHTO Product Evaluation List (APEL), the revised Special Products Evaluation List (SPEL).

Illustrative Example of Collection/Database Content:
The new database being developed will include information compatible with the APEL database including product name, vendor, manufacturer, contact information, status of evaluation and other similar information.

For More Information:

Program/Resource Coordinator
Gerald Malasheskie, PE
Chief, Engineering Technology & Information Division
Bureau of Construction and Materials
Department of Transportation
1118 State Street
Harrisburg, PA 17120
Telephone: (717) 787-7150
Fax: (717) 787-5955

Washington State Department of Transportation SHRP Evaluation & Implementation Database

Description/Scope:
The Washington State Department of Transportation (WSDOT) SHRP Database was established as the state's response to facilitate the implementation of SHRP results. The database serves to enhance communications among the states, AASHTO, TRB and others in the highway community. The objectives of the SHRP Evaluation and Implementation Database are:

- facilitate objective evaluation and eventual implementation or rejection of SHRP products,
- coordinate the exchange of product evaluations, SPS and GPS test site histories, meeting minutes, and questions, answers, and comments between the individual states, and
- provide international, federal, state, local, and private partners with access to the most comprehensive SHRP resource available.

Individual states are invited to contribute information to the database to increase its overall value for all users. The database is designed to be a comprehensive, interactive resource available via the Internet.

The database was created after extensive information seeking from the states regarding their assessment of the usefulness of such a tool.

Type of Activity:
_X_ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Washington State Department of Transportation

Typical Users:
A very broad spectrum of highway professionals from state DOTs industry academia—including those participating in SHRP; national and international highway community members.

How are Findings or Results Reported and Disseminated?
Data are input to the database via disk, which is then put into the database by WSDOT. WSDOT contacts states and provinces for input data twice per year in approximately June and November. Data may be sent in most general formats. Smaller contributors may fax in completed data information forms. Material is distributed via the web site:
http://www.wsdot.wa.gov/fossc/OTA/SHRP

Existing Information Collections/Databases:
The information found in the database is:

- evaluations of individual SHRP products,
- directories of key federal, state, and local personnel and vendor contacts,
- moderated discussion groups for each of the four SHRP program areas,
- information regarding SPS and GPS pavement performance test sites, and
- a calendar of upcoming events.

Personnel from state and local transportation agencies, FHWA, TRB, AASHTO, and academic and industry professionals have completed the product evaluations in the database.

Who Maintains the Collections/Databases?
WSDOT

Location and General Format Description of the Data:
The database resides on the WSDOT mainframe computer system. The system was written in PowerBuilder a product of Power Soft Corp.

How Can the Data Currently Be Accessed?
Via the web site as mentioned above. WSDOT staff fields technical questions by telephone calls or email.

Access or Subscription Fees:
There are no access or subscription fees associates with this database.

Plans for Near-Term Enhancements to the Collections/Databases:
The web site is continually evolving, near term future plans are to transition to address more needs of the current SHRP lead state consortia/organizations being formed. WSDOT is actively involved in planning a web site addition for one of the technical topics, anti-icing. This new database will contain experiences in snow and ice control, team activities and progress. These changes reflect the movement toward a focus on the technologies having come from SHRP and not oriented toward the actual research program. Much of this conceptual change originated in the AASHTO Task Force on SHRP Implementation.

Illustrative Example of Collection/Database Content:
The evaluation portion of the database contains information such as: product name, manufacturer/vendor, primary recommended use of product, alternate uses, cost, other products that may serve the same function, required staff training, evaluator contact, and more.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)

Once people were aware of the resource provided by the database, they started calling and sending e-mail. In early 1997, the WSDOT web site had 1120+ unique hits per week. WSDOT has been receiving 80-100 e-mail messages a day. The direct contacts are requests for information and contact names among other items. The high activity shows a strong need for such a technical assistance response service.

For More Information:

Program/Resource Coordinator
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Olympia, WA 98504
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E-mail: bcarr@wsdot.wa.gov

Information Systems Coordinator
Mark E. Hambrick
Technology Implementation Coordinator
Washington DOT
Transportation Building
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Olympia, WA 98504
Telephone: 360-705-7509
Fax: 360-705-6889
E-mail: mhambric@wsdot.wa.gov

2.2 Local/Municipal Departments of Transportation/Associations

A number of medium-sized local and municipal authorities and departments of public works were contacted during the course of this study. The purpose of contacts with this group of transportation professionals was to determine the level of activity or sponsorship of testing and evaluation programs. In general medium to smaller local and municipal departments of transportation or public works do not have major resources committed to the testing and evaluation of new products and processes. Included in the examples is a County Utilities organization, which does show the type of effort when a formal program is instituted. However, for the most part these agencies rely on their respective state departments of transportation for approved new products for highway applications. These local/municipal agencies in general were interested in the types of information that an innovation clearinghouse could provide. These agencies could very much be part of the user community for a Highway Innovation Clearinghouse.

These local/municipal organizations were selected from a list provided by the FHWA Local Technical Assistance Program Manager. The individuals have in the past been involved with or active in some LTAP program offering or related services.

City of Milwaukee, Department of Public Works, Roads and Streets Division

Description/Scope:
The City of Milwaukee does not have a formal process for new product testing and evaluation. As the need arises and under the direction of senior officials, new products may be tested and evaluated. The most common means of performing tests and evaluations is in partnership with vendors. Each test and evaluation project is customized to the product with specific emphasis on the ultimate benefit to the agency. There is no formal reporting process, yet as appropriate evaluation documentation is produced. The basis for selection of a testing and evaluation exercise is if there is promise to improve operations, and if it fits the agency's needs and budget. In general for new product evaluation information, the City relies on the new product approval list from the state department of transportation.

Evaluations data is used in developing specifications, reports and standard specification documentation are the primary dissemination mechanisms.

A number of organizations within the department (such as Maintenance) have Internet connections. The use of Internet for coordination and reducing duplication of effort is in the early stages and is growing.

For more information:

James Purko
Field Operations Manager
City of Milwaukee, Department of Public Works
Roads and Streets -- Maintenance Division
Municipal Building,
841 North Broadway, Room 701
Milwaukee, WI
Telephone: 414-286-3437
Fax: 414-286-5993

City of Austin, Department of Public Works

Description/Scope:

The City of Austin roads and streets organization does not perform testing and evaluation on new products or processes. It relies on the state testing program and its approved new products list. Over the past years the City has tested and evaluated a few items, yet there is no policy or resources specifically committed to this function. As information, the city water and wastewater organization has an evaluation committee that reviews new products such as pipes, manhole valves, and other related items.

The City of Austin is connected to the Internet. Regarding an innovation clearinghouse, "it would be good to have a place to go to see what other's experiences have been with new products, very much in favor of such a clearinghouse effort."

For more information:

James Lund
Supervisor of Materials
Department of Public Works
One Texas Center
505 Barton Springs Road
P.O. Box 1088
Austin, TX 78767
Telephone: 512-440-8444
Fax: 512-499-7088

City of North Little Rock

The City of North Little Rock has no formalized testing and evaluation program. They specifically rely on the state department of transportation's new product approval list. The City is not required to use state specifications for city road and street construction, but usually does. The City maintains no database or collection of products.

For More Information:

Robert Ward
City of North Little Rock
1124 N. Orange Street
North Little Rock, AR 72114
Telephone: 505-340-5355

Chesterfield County, Virginia—Utilities Department

The Chesterfield County Utilities Department reviews and evaluates new products and technologies in conjunction with its process of developing standard specifications for utility products and procedures. The Product Design and Review Committee is responsible for approval of all new products. A formal process of application, field-testing and evaluation (if required), vendor presentations to the Committee, and consultation with other users of the products are standard elements the County's product approval procedures. The Product Design and Review Committee are also responsible for specification updates. The organization publishes a comprehensive Water and Sewer Specifications and Procedures manual which is available (for fee) to contractors and other interested parties.

In general, new products are incorporated into the County's specifications and therefore the County does not have a publicly available database of approved new products. The County does publish an "Approved Materials and Manufacturers List and Materials Specifications" as part of the Specifications and Procedures manual. The Specifications and Procedures manual is the primary vehicle used for dissemination of all information.

The County is interested in coordination of efforts among the regional water and sewer organizations and is working toward regional specifications. There is interest in reducing duplication of effort, in understanding experiences from others in the industry, and in enhancing working relationships with their state counterparts. The concept of an innovation clearinghouse was seen as a very positive step for increasing the likelihood of introducing innovations.

Although this organization directs its focus to utilities, it shows the type of involvement local/municipal organizations can have in either providing or using information provided by an innovation clearinghouse.

For more information:

Robert B. Wilson
Engineering Supervisor
Operations and Maintenance
Chesterfield County Utilities Department
P.O. Box 40
Chesterfield, VA 23832
Telephone: 804-751-4340
Fax: 804-751-4607

Ontario Good Roads Association—The Road Authority

Description/Scope:

The Road Authority is an Internet based interactive service to the highway community that provides source products and services related to construction and maintenance of municipal roads and bridges. The system is being designed to enable municipalities to deliver more cost-effective solutions to road system problems. The objective of the Road Authority is to collect, organize, and disseminate information concerning products and services that are used throughout the transportation sector. The Road Authority will publish standards and technical literature related to the construction and maintenance of roads, bridges, and other infrastructure components.

The Road Authority web site facilitates communications between products and service suppliers on one hand and users on the other. Primary categories such as manufacturers, products, contractors, service companies, consultants, and standards will be quickly and easily accessible. The system is layered so that technical information such as product evaluations, test results, or design specification changes can be linked to primary sources, or appropriate service providers—accessing one information category to call up electronic links to related information. The Road Authority site can also provide hot links to existing supplier web sites. The web site came on line during Summer 1997 and is still under construction. Some example entries are currently accessible. (Excerpted from web site.)

Type of Activity:
_X_ T&E _X_ Technology Transfer __ Technology Deployment

Sponsor(s):
Ontario Good Roads Association (OGRA)

Typical Users:
Municipal and provincial, as well as state highway construction and maintenance personnel, are the typical users. Principally "inking the OGRA municipal members to their marketplace." The web site has potential for being a resource to a broad spectrum of public and private sector users.

How are Findings or Results Reported and Disseminated?
A Classification Steering Committee has been established to classify products and services according to a classification matrix. Details on committee activities and the process for companies to submit product and service information will be published later in 1997.

Existing Information Collections/Databases:
The database is currently being built. Major categories to be included are:

- products and services related to companies and consultants
- standards relating to construction, operations, and maintenance issues
- designs
- testing results, reviews, and qualifications
- evaluations

Linked information categories:

- application and product listings
- technical drawings and specifications
- transport services
- laboratories
- manufacturers and distributors of materials and equipment
- engineering consultants
- contractors, their specialties, abilities, and experience
- standards, methodologies, and practices
- road authorities from Ontario, Canada, USA, and around the world
- service companies (legal, insurance)
- educational and training courses, seminars, conferences, and other relevant programs

Who Maintains the Collections/Databases?
The Ontario Good Roads Association

Location and General Format Description of the Data:
The data is organized as a knowledge-based relational interactive database. Data entries provide short synopses of information with hot links to more in-depth information and related topics and sources.

How Can the Data Currently Be Accessed?
The Road Authority web site: http://wwww.roadauthority.com/

Access or Subscription Fees:
There are no fees for public sector users and municipal members of the OGRA. A fee schedule for private sector organizations and non-members is available on the web site.

Plans for Near-Term Enhancements to the Collections/Databases:
By the end of 1997 or early 1998, the site could offer quick access to an estimated 1,000 products and hundreds of services and related information.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)
Web site and database are currently under construction.

For More Information:

Program/Resource Coordinator
George Gera
President
The Road Authority
530 Otto Road, Unit 2
Mississauga, Ontario L5T 2L5
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Email: info@RoadAuthority.com

2.3 Industry Groups Information Resources

In addition to several industry groups' summaries included in this document (ITE, ITS America), other highway industry associations were contacted to determine the if these organizations provided information and databases which were available to the highway community at large. In general, the associations were membership driven and provided specific industry related information (for fee) to the public or highway community at large. Most of these organizations considered that their mission was technology transfer and to be a national voice for their specific area of interest. The organizations had World Wide Web sites and were optimistic regarding the enhanced communications provided by the Internet.

National Asphalt Pavement Association

Description/Scope:
Since its founding in 1955, the National Asphalt Pavement Association (NAPA) has been providing comprehensive answers and definitive solutions to the questions and concerns of the Hot-Mix Asphalt (HMA) industry. NAPA is the only national organization to exclusively serve the independent HMA producers and contractors across the nation. NAPA promotes the use of hot-mix asphalt pavements through programs of engineering, education, and research. The Superpave mix design system and stone matrix asphalt are two innovations that NAPA is actively researching and promoting through technology transfer and training programs. Membership is open to for-profit organizations in the hot-mix asphalt industry.

NAPA's web site address is http://www.hotmix.org. The organization has a publications catalog available and provides the most current texts/handbooks on mix design, construction, and maintenance for hot-mix products and procedures.

For more information:

Margaret Cervarich
National Asphalt Pavement Association
5100 Forbes Blvd.
Lanham, MD 20706-4413
Telephone: 301-731-4748
Fax: 301-731-4621

American Concrete Institute

The American Concrete Institute (ACI) strives to be the world's premier developer and disseminator of information on the use of concrete for structures and facilities. It is a membership-based organization of over 18,000 individuals from over 100 countries. Members represent engineering and architectural professions, contractors and materials producers, as well as government and academia.

ACI has a comprehensive web site (address is http://www.aci-int.org) which provides information on the organization and its activities as well as access to its library and bookstore. The Library has an on-line search capability. Products may be purchased online from the bookstore. Such items as codes and standards, technical reports, handbooks and manuals, CD-ROM products and software, periodicals, and videos are available. The web site has information for members, yet most information is accessible by the general public.

For more information:

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American Concrete Institute
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Farmington, MI 48333
Telephone: 248-848-3700
Fax: 248-848-3701
Email: jglumb@aci-int.org

2.4 Academic Information Resources

ITS Research Centers of Excellence Clearinghouse (At TTI)

Description/Scope:
The Federal Highway Administration has funded three Research Centers of Excellence (RCEs) to engage in research of ITS technology. The Centers are:

- University of Michigan ITS Research Center of Excellence
- Texas A&M ITS Research Center of Excellence
- Virginia Tech ITS Research Center of Excellence

A fourth center, while not formally part of FHWA's RCE program, is funded by the U.S.DOT, Research and Special Programs Administration and shares common goals and objectives with the other RCEs.

- University of Minnesota ITS Institute at the Center for Transportation Studies

The ITS Research Centers of Excellence Clearinghouse manages the information produced by the three RCEs.

Type of Activity:
_X_ R&D __ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
Federal Highway Administration

Typical Users:
State departments of transportation, researchers and industry representatives with interest in ITS technologies

How are Findings or Results Reported and Disseminated?
Currently the collection is comprised of completed projects by the various RCEs. The reports and findings can be accessed by making a request to the RCE Clearinghouse Coordinator. Reports from research activities are also distributed by the individual institutions that performed the research.

How Can the Data Currently Be Accessed?
The three RCEs web sites are as follows:

Texas A&M: http:/tti.tamu.edu/rce/
University of Michigan: http://its.engin.umich.edu/itsrce
Virginia Tech: http://www.ctr.vt.edu/and University of Minnesota: http://www.umn.edu/cts/

Access or Subscription Fees:
There are no fees associated with requests for reports.

Plans for Near-Term Enhancements to the Collections/Databases:
The Clearinghouse plans to have a searchable database located on the Internet in the future.

Current Use(s) of the Collections/Databases: (how used and how much—from sponsor's perspective)
The current TTI web site has experienced high use, in February 1997, there were 3,400 hits including 800 individual user sessions (about 120 users a day). Web site hits are from worldwide sources.

For More Information:

Program/Resource Coordinator
Gary Lobaugh
Clearinghouse Program Coordinator
ITS RCE Program Clearinghouse
The Texas Transportation Institute
Texas A&M University System
College Station, TX 77843-3135
Telephone:
Fax: 409-845-9848
E-mail: g-lobaugh@tamu.edu

University Transportation Centers and University Research Institutes

Description/Scope:
The University Transportation Centers (UTC) includes 10 regional centers within the 10 Federal regions. In addition, under the provisions of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), UTC has three national centers.

The 10 regional centers are as follows:

- The New England University Transportation Center (Region 1) includes Massachusetts Institute of Technology, Harvard University, University of Connecticut, University of Maine, University of Massachusetts, University of New Hampshire, University of Rhode Island, and University of Vermont. The center focuses on strategic management of transportation systems. For further information, contact Thomas Humphrey at (617) 253-4978.

- The University Transportation Research Center (Region 2) includes the City University of New York, New Jersey Institute of Technology, New York University, Polytechnic University, Princeton University, Rensselaer Polytechnic Institute, Rutgers University, State University of New York, Stevens Institute of Technology, University of Puerto Rico, and University of the Virgin Islands. This center specializes in regional mobility and urban/suburban accessibility. For further information, contact Robert Paaswell at (212) 650-8050.

- The Mid-Atlantic Universities Transportation Center (Region 3) includes The Pennsylvania State University, University of Pennsylvania, University of Virginia, Virginia Polytechnic Institute and State University, and West Virginia University. This center concentrates on advanced technologies in transportation and management. For further information, contact James Miller at (814) 863-1909.

- The Southeastern Transportation Center (Region 4) includes Duke University; Georgia State University; North Carolina A&T State University; North Carolina State University; University of North Carolina, Chapel Hill; University of North Carolina, Charlotte; University of Florida; University of Kentucky; University of South Florida; University of Tennessee; and Vanderbilt University. The theme of this center is to improve transportation safety. For further information, contact Stephen Richards at (423) 974-5255.

- The Great Lakes Center for Truck and Transit Research (Region 5) encompasses Central State University, Michigan State University, Michigan Technological University, Northwestern University, The University of Michigan, and Wayne State University. This center specializes in commercial transportation. For further information, contact Thomas Gillespie at (313) 936-1064.

- The Southwest Region University Transportation Center (Region 6) includes Texas A&M University System; Texas Southern University; and University of Texas, Austin. The center concentrates on sustainable transportation for mobility and economic strength. For further information, contact Dock Burke at (409) 862-2946.

- The Mid-America Transportation Center (Region 7) includes Kansas State University; Kansas University; University of Missouri, Columbia; University of Missouri, Rolla; University of Missouri, Lincoln; and University of Nebraska, Lincoln. This center started operations in July of 1995, and its theme revolves around improving the design and operations of transportation facilities and services in mid-America. For more information, contact Patrick McCoy at (402) 472-5019.

- The Midwest Transportation Center (Region 7) includes Iowa State University and The University of Iowa. It specializes in transportation actions and strategies to accommodate economic shift. For more information, contact Thomas Maze at (515) 294-8103.

- The Mountain-Plains Consortium (Region 8) members are Colorado State University, North Dakota State University, University of Wyoming, and Utah State University. The consortium specializes in rural and non-metropolitan transportation. For further information, contact Gene Griffin at (701) 231-7767.

- The University of California Transportation Center (Region 9) includes the University of California, Berkeley; University of California, Davis; University of California, Irvine; University of California, Los Angeles. This center focuses on improving accessibility for all persons. For more information, contact Melvin Webber at (510) 643-7378.

- Transportation Northwest (TRANSNOW) (Region 10) consists of Oregon State University; Portland State University; University of Alaska, Fairbanks; University of Idaho; University of Washington; and Washington State University. This center specializes in management and planning of intermodal operations. For further information, contact Nancy Nihan at (206) 543-8255.

The 3 regional centers are as follows:

The National Center for Transportation and Industrial Productivity at the New Jersey Institute of Technology focuses on improving productivity through transportation. For more information, contact Louis Pignataro at (410) 319-3666.

- The National Center for Transportation Management, Research, and Development at Morgan State University focuses on the link between transportation and economic development. Call (410) 319-3666 for general information.

- The Mack-Blackwell National Rural Transportation Study Center at the University of Arkansas specializes in improving the quality of rural life through transportation. For more information, call Jack E. Buffington at (501) 575-7957.

University Research Institute: In addition, ISTEA authorized the following University Research Institutes (URI):

- The Institute for National Surface Transportation Policy Studies, San Jose State University, analyzes ways of improving, developing, and operating the Nation's surface transportation programs.

- The Infrastructure Technology Institute, Northwestern University, studies techniques to evaluate and monitor infrastructure conditions, works to improve information systems for infrastructure construction and management, and studies new materials and processes for constructing and rehabilitating public works facilities.

- The Urban Transit Institute is affiliated with the University of South Florida, North Carolina A&T State University, and a consortium of Florida A&M, Florida State University, and Florida International University. This is an interdisciplinary institute for the study and dissemination of techniques to address the diverse transportation problems of urban areas experiencing significant and rapid growth.

The Institute for Intelligent Vehicle-Highway Concepts, located at the University of Minnesota, Center for Transportation Studies, conducts research and recommends activities that focus on methods to increase roadway capacity and enhance safety. The intelligent vehicle-highway systems technologies will be researched, and recommendations will be made which, through the use of these technologies, reduces negative environmental effects of transportation facilities.

The Institute for Transportation Research and Education, University of North Carolina, conducts research and directs technology transfer and training for State and local transportation agencies improving the overall surface transportation infrastructure.

The UTC Program conducts basic and applied research as supported by local sponsors, and supports the development of future transportation professionals through graduate studies and programs.

The UTC conducts infrastructure research and education concerning the transportation of people and goods; and it publishes and disseminates research results. More than 600 research studies have been initiated in the first 6 years of operation. Research covers three modes of surface transportation and a broad range of multimodal topics.

The centers direct educational energies toward undergraduate and graduate students. To encourage expanded participation in the transportation workforce, the centers also emphasize education for minorities and women. Each center has a lead university that manages the consortium and has a theme around which research and education activities are focused.

Type of Activity:
_X_ R&D __ T&E __ Technology Transfer __ Technology Deployment

Sponsor(s):
U.S. Department of Transportation, Research and Special Programs Administration

The UTC program benefits all surface transportation. The UTC program is managed by the Research and Special Programs Administration (RSPA) and assisted by the Federal Transit Administration and FHWA.

Each UTC provides funding, which is matched by research activity partners/participants.

Typical Users:
Federal and state transportation professionals, researchers institutes and academia

How are Findings or Results Reported and Disseminated?
Information is available through the University Transportation Centers Program Clearinghouse at (814) 863-3614. Reports are disseminated by the individual institutions.

Existing Information Collections/Databases:
The collection is primarily the list of research projects performed through the program and includes contacts information at the performing institution.

Who Maintains the Collections/Databases?
Pennsylvania State University, UTCP Clearinghouse

How Can the Data Currently Be Accessed?
Data may be accessed by contacting (telephone, fax, mail) the Clearinghouse or through contacts at any of the individual consortium centers or institutions.

Access or Subscription Fees:
There are no fees associated with acquiring information, except for out-of-print items, there may be a copying charge.

Plans for Near-Term Enhancements to the Collections/Databases:
The Clearinghouse is planning a web site that will have a searchable database containing reports generated by the various institutions. The software to be used will be Microsoft Access.

Illustrative Example of Collection/Database Content:
Report title, principal investigator, university, funding source, abstract, start and end date, and number of pages in report.

For More Information:

Program/Resource Coordinator
Ann Marie Hutchinson
UTCP Clearinghouse
Mid-Atlantic Universities Transportation Center
Pennsylvania State University
Pennsylvania Transportation Institute
Research Office Building
University Park, PA 16802-4710
Telephone: 814-863-3614
Fax: 814-865-3039

Information Systems Coordinator
Susan Rossman
Database Manager, Database Search
Telephone: 814-863-3456
Fax: 814-865-3039

2.5 Other Resources Deserving Discussion

There are a number of very important resources that are major contributors to the dissemination of information, technology transfer, and promotion of innovation throughout the highway industry. These information resource providers do not uniquely focus on new product or process testing and evaluation, and therefore they were not included in the brief summaries contained in this appendix. The Steering Team, however, expressed a desire to highlight these resources to indicate their significance, relevance, and stature among highway professionals.

AASHTO VAN and Internet Activities

The American Association of State Highway and Transportation Officials (AASHTO) supports a network service function called the Value-Added Network (VAN). The AASHTO VAN provides linked computer services to the AASHTO Member Departments, the Federal Highway Administration, and the Transportation Research Board. The VAN's electronic information system provides an electronic mail, interactive forum, retrieval of AASHTO's weekly *Journal* and allows access to other information such as several of the FHWA fiscal management reporting and reimbursement systems.

During the past six months AASHTO has committed considerable resources to its new web site The address is: http://www.aashto.org. The web site provides information about the organization, current and past years' volumes of the *AASHTO Journal* and *Regs Report*, descriptions and contacts for AASHTO programs and services (such as the National Transportation Product Evaluation Program and the SHRP Product Implementation activities), ISTEA recommendations, meeting and events notices, as well as how to obtain publications from AASHTO.

Construction SuperNetwork

The Construction SuperNetwork is an interactive community for members of the concrete and masonry industries. The Aberdeen Group is a privately owned company and produces educational books and videos, electronic media, directories, five construction magazines, and conducts worldwide trade shows and other information services for the concrete and masonry construction industries. The mission of The Aberdeen Group is to strengthen and grow the concrete and masonry industries worldwide through information services. This site can be found at www.supernetwork.net.

Transportation Research Board Web Site

The Transportation Research Board maintains a web site that provides a comprehensive and extensive view into a multitude of resources within the research and technical arenas of transportation research. The TRB web sit includes information about its organization and membership; activities carried out by its Technical Activities Division and the Cooperative Research Programs it administers; its publications and ordering information, as well as a soon to be active link into its popular database, the Transportation Research Information Service (TRIS). The TRIS database is a valuable tool to help researchers be more informed about research, development, and technology transfer projects thus providing cooperation and collaboration among transportation researchers. TRIS also serves as a valuable tool to reduce duplication of effort and thus allows transportation researchers to more effectively utilize research funds. TRB information resources include primarily results of research and development efforts and do not specifically address the new product testing and evaluation arena. It must be noted that TRB in general, and particularly through its web site, is a major factor in the dissemination of leading edge technical information within the transportation community. In addition to the information generated by TRB, the web site also includes one of the most complete lists of links to domestic and international transportation research organizations and transportation agencies found on the web. The TRB web site address is http://www.nas.edu/trb/

FHWA Web Site including TECHNET

The Federal Highway Administration provides a comprehensive view into its programs and activities through its web site which includes the full activities of the agency including, among many, the research, development, and technology efforts at the Turner-Fairbank Highway Research Center and in particular the Office of Technology Applications (OTA), HIGHWAY TECHNET. TECHNET is OTA's online highway technology resource center that provides users with the most current information on its technology projects in pavements, assessments and marketing, safety, structures, and traffic. Currently TECHNET highlights its "RoadSavers" which document the results of implementing the products produced by the Strategic Highway Research Program, provides a Directory of Superpave Resources, and discusses digital camera technology for bridge inspection. Information resources such as FHWA's Testing and Evaluation program and other activities conducted through OTA are accessible at TECHNET. A number of these programs are described in the information resources summaries contained in this appendix. The FHWA TECHNET web site address is http://www.ota.fhwa.dot.gov/.

World Road Association (WRA formerly PIARC)

World Road Association (formerly PIARC) - was founded in 1909 following the 1st International Road Congress held in Paris in 1908. It is the oldest international association concerned with Road Engineering, Road Policy and the Management of Road Networks. It has evolved since and now boasts 91 Member Governments and other Members in 129 countries worldwide. The World Road Association is a non-political and non-profit making association. The general aims of the association are to facilitate international co-operation and to foster progress in:

- the formulation of road and road transport policies and the development of road technology taking full account of sustainable development, user's perspective, including safety and value for money, and
- the improvement of knowledge transfer with priority given towards developing countries and countries in transition.

To achieve these aims, PIARC creates and coordinates Committees and Working Groups, organizes a quadrennial World Road Cóngress and various technical seminars, and publishes a large number of documents including a quarterly magazine.
The Association comprises several categories of members: Governments, Regional Authorities, Collective Members and Individual Members. The Association seeks the active participation of all members be they from a developed, transitional or developing country. Member countries are able to create National Committees. These Committees play an important role in the activities of the Association and represent PIARC in their countries.

WRA established the World Interchange Network and is one of the active nodes of WIN (see information resource summary in this appendix). Among the many services WRA provides, it has established a comprehensive list of road terminology as well as provides information on materials and testing activities of its member organizations. Information about these and other services is available through the WRC web site. The WRA web site address is: http://www.piarc.lcpc.fr/.

Section 3 Summary Information

3.1 Cross Reference by Major Activity

Test and Evaluation:

Experimental Projects Program & Tabulation
Highway Innovation Technology Evaluation Center
National Transportation Product Evaluation Program (NTPEP)
Non-Destructive Evaluation (NDE) Validation Center
Long Term Pavement Performance (LTPP) Program
Testing and Evaluation Projects
Texas DOT/TTI Hydraulics and Erosion Control Laboratory
Vehicle Detection Clearinghouse (at the New Mexico State University)
World Federation Technical Assessment Organization (WFTAO)
Arizona Department of Transportation New Product Evaluation Program
Kansas Department of Transportation New Product Evaluation Program
Mississippi Department of Transportation Product Evaluation Program
Pennsylvania Department of Transportation New Product Evaluation Program
Washington State Department Of Transportation SHRP Evaluation and Implementation Database
Ontario Good Roads Association—The Road Authority

Technology Transfer

Border Technology Exchange Program
Bureau of Transportation Statistics
Coordinated Federal Lands Highway Technology Implementation Program
National Quality Initiative Clearinghouse (at TTI)
National Work Zone Safety Information Clearinghouse
Non-Destructive Evaluation (NDE) Validation Center
Long Term Pavement Performance (LTPP) Program
SHRP Implementation and Lead States Program
Special Products Evaluation List (SPEL)
Testing and Evaluation Projects
Texas Dot/TTI Hydraulics and Erosion Control Laboratory
Vehicle Detection Clearinghouse (at the New Mexico State University)
World Interchange Network (WIN)
Washington State Department Of Transportation SHRP Evaluation and Implementation Database
Ontario Good Roads Association — The Road Authority

Technology Deployment

ITS America Clearinghouse
Priority Technology Program (PTP)
SHRP Implementation and Lead States Program
Arizona Department of Transportation New Product Evaluation Program

R&D

ITS Research Centers of Excellence Clearinghouse (at TTI)
University Transportation Centers
Long Term Pavement Performance (LTPP) Program

3.2 Cross Reference by Sponsor

American Association of State Highway and Transportation Officials (AASHTO)

National Quality Initiative Clearinghouse (at TTI)
National Transportation Product Evaluation Program (NTPEP)
SHRP Implementation and Lead States Program
Special Products Evaluation List (SPEL)

Federal Highway Administration (FHWA)

Border Technology Exchange Program
Coordinated Federal Lands Highway Technology Implementation Program
Experimental Projects Program & Tabulation
Highway Innovation Technology Evaluation Center
Local Technical Assistance Program (LTAP)
National Work Zone Safety Information Clearinghouse
Non-Destructive Evaluation (NDE) Validation Center
Priority Technology Program (PTP)
Long Term Pavement Performance (LTPP) Program
Testing and Evaluation Projects

U.S. Department of Transportation

Bureau of Transportation Statistics
Infrastructure Technology Institute at Northwestern University

State Departments of Transportation

Arizona Department of Transportation New Product Evaluation Program
Kansas Department of Transportation New Product Evaluation Program
Mississippi Department of Transportation Product Evaluation Program
Pennsylvania Department of Transportation New Product Evaluation Program
Texas Department of Transportation/TTI Hydraulics and Erosion Control Laboratory
Washington State Department of Transportation SHRP Evaluation and Implementation Database

Local/Municipal Departments of Transportation/Associations

City of Austin, Department of Public Works
City of Milwaukee, Department of Public Works, Roads and Streets Division
Chesterfield County, Virginia—Utilities Department
Ontario Good Roads Association—The Road Authority

Industry Groups Information Resources

National Asphalt Pavement Association
American Concrete Institute
ITS Research Centers of Excellence Clearinghouse (at TTI)
University Transportation Centers
University Research Institutes

Master Listing of Acronyms

AASHTO - American Association of State Highway Officials
ACI - American Concrete Institute
BTEP - Border Technology Exchange Program
BTS - Bureau of Transportation Statistics
CERF - Civil Engineering Research Foundation
CTIP - Coordinated Federal Lands Highway Technology Implementation Program
FHWA - Federal Highway Administration
FLHP - Federal Lands Highway Program
HITEC - Highway Innovative Technology Evaluation Center
ISTEA - Intermodal Surface Transportation Efficiency Act
ITE - Institute of Transportation Engineers
ITS - Intelligent Transportation Systems
ITI - Infrastructure Technology Institute (at Northwestern University)
LTAP - Local Transportation Assistance Program
LTPP - Long Term Pavement Performance Program
NAPA - National Asphalt Pavement Association
NCHRP - National Cooperative Highway Research Program
NDE - Non-Destructive Evaluation
NEPT - National Experimental Projects Tabulation
NHI - National Highway Institute
NTIS - National Technical Information Service
NTPEP - National Transportation Product Evaluation Program
OTA - Office of Technology Applications
PTP - Priority Technology Program
RCE - Research Center of Excellence (for ITS)
RSPA - Research and Special Programs Administration
SP&R - State Planning and Research Program
SPEL - Special Products Evaluation List
TRIS - Transportation Research Information Service
TTI - Texas Transportation Institute
TRB - Transportation Research Board
URI - University Research Institute
UTC - University Transportation Centers
VDC - Vehicle Detection Clearinghouse
WIN - World Interchange Network
WRA - World Road Association (formerly PIARC)

Appendix B

Innovation Clearinghouse Survey

The following questions are designed to help us assess the interests and needs of your agency or organization concerning electronic data and information access. The results of this survey will be used to organize and create an electronic clearinghouse that will serve as a "home base" or "gateway" to the numerous and various existing resources available.

This survey has been distributed to both the suppliers and users of informational resources as well as a random sample of individuals within select state transportation agencies. Note if your organization is both a supplier and user of information, please answer this survey from the perspective of a user.

Your participation is a vital step in this process of developing an unprecedented Clearinghouse for the exchange of information in the highway and transportation community. Please return the completed survey **by July 11, 1997** via fax at (202) 789-5345. Thank you for your time and assistance.

SECTION 1 - General Information

The following questions are designed to help us classify your organization and to determine the types of activities performed within your functional area that prompt contact with clearinghouses databases, or other program resource materials.

1. **What category best describes your organization? (*Check one*)**

- ☐ Federal Government
- ☐ State Highway or Transportation Agency
- ☐ County or Municipal Government
- ☐ Research Institute (e.g., academic, testing, evaluation laboratory)
- ☐ Engineering or Consulting Services
- ☐ Product Invention, Manufacturing and/or Marketing
- ☐ Technology Transfer Center
- ☐ Professional Association
- ☐ Other ____________________

2. **Which area best describes the primary activity performed within your functional area? (*If your involvement includes more than one of the activities, please only rank the most frequently performed activity as 1, the next most frequently performed activity as 2, and the third most frequently performed activity as 3*).**

______Research and Development
______Testing and Evaluation
______Technology Transfer
______Technology Deployment (including other general implementation activities)
______Design
______Specifications
______Purchasing/Procurement
______Operations
______Maintenance
______Other

SECTION 2 - Information Use and Access

There are a number of sources that may provide information to assist you and others within your functional team to perform your daily assignments. We'd like to know about your contact (receipt or request of information) with a number of information clearinghouses, databases, and other programs.

Please be sure to give us the information regarding the actual organization with which the contact was made. For example, if you were to have requested information from a technology transfer organization about another organization, make sure to record your activity for both organizations.

3. **Approximately, how often have you had received product information or made requests from the following clearinghouses, databases or other programs during the past six months, and/or is there other information that you have received/requested not listed here? If so, please include its source at the end of the table. Please indicate the contacts you have had or made in the past six months.** ***Note: Information dissemination is a result of the information provider sending information to you, it may be newsletters, reports, CD-ROM collections; regular distributions from Internet-based collections; or other such items.***

   Information requests are those inquiries made by you from the information providers, such requests may be for written documentation, CD-ROM collections, Internet inquiries of databases, and other such items.

   We understand this is an estimate. We are looking for order-of-magnitude data to determine the types/levels of information contacts that are occurring. (*Rank: a = 0 contacts, b = 1-10 contacts, c = 11-25 contacts, d = 26-50 contacts, e = 55-100 contacts, f = over 100 contacts*)

Information Source	Information contacts resulting from provider generated contact in last 6 months	Information contacts resulting from user generated contact in last 6 months
Border Technology Exchange Program		
Experimental Projects Program – FHWA		
Geotextile Testing and Evaluation Clearinghouse (at Texas Transportation Institute/TTI)		
Highway Innovative technology Evaluation Center (HITEC)		
ITE Clearinghouse		
ITS America Clearinghouse		
Coordinated Technology Exchange Program – FHWA Federal Lands		
Local Technical Assistance Program (LTAP) – FHWA		
National Quality Initiative Clearinghouse at TTI		
National Transportation Product Evaluation Program (NTPEP)		
Northwestern Infrastructure Clearinghouse		
Non-Destructive Evaluation (NDE) Validation Center – FHWA		

Priority technology Program (PTP) – FHWA		
Special Products Evaluation List (SPEL)		
Washington State Department of Transportation SHRP Database		
SHRP Long Pavement Performance (LTPP Program)		
Testing and Evaluation Projects – FHWA		
Vehicle Detection Clearinghouse (at New Mexico State University)		
World Bank Network/Databases		
World Federal Technical Assessment Organization (WFTAO)		
World Interchange Network (WIN)		
State Departments of Transportation New Product Evaluation Programs		
Local/Municipal Departments of Public Works or Transportation new Product Evaluation Data		
Industry Associations Information Resources		
Product Vendor, Suppliers, and Manufacturers		
University Transportation Centers Program Clearinghouse (at Penn State or other Centers' data)		
Research Centers of Excellence (at TTI, University of Minnesota, or University of Michigan)		

Other Information Sources Please List Give Contact Information		

4. **Approximately how many of the above contacts (percentage of total contacts for each category) were electronically based contacts? Electronically based means use of data transfer via computers or related hardware/software (i.e., computer generated communications, e-mail, electronic bulletin boards, CD-ROM, or Internet/World Wide Web).**

For user generated contacts, if any part of the transaction was done via electronic request/receipt please include it as an electronically based contact.

Percent of *provider* generated contacts that were electronically based
______ 0-25 percent ______ 26-50percent ______ 51-75 percent ______ 76-100 percent

Percent of *user* generated contacts that were electronically based
______ 0-25 percent ______ 26-50 percent ______ 51-75 percent ______ 76-100 percent

5. **In the past six months, approximately how many times have you used the following electronically based resources for information regarding product testing, evaluation, approval, and deployment topics?** ***(Rar. a = 0 contacts, b = 1-10 contacts, c = 11-25 contacts, d = 26-50 contacts, e = 51-100 contacts, f = over 100 contacts)***

_______AASHTO electronic resources
_______Civil Engineering Research Foundation CENET
_______Transportation Research Board Web Site
_______FHWA Web Site including TECHNET
_______Other Site ______________________________
_______Other Site ______________________________
_______Other Site ______________________________

6. **During the past six months what is the most frequent use of product testing, evaluation, approval, or deployment information that you received or requested (from any means, electronically-based or not)?** ***(Rank: 1 = most used, 7=least used)***

_______Reduce duplication of effort/coordination with other similar efforts
_______Planning research and development projects
_______Product specifications and standards
_______Maintain state-of-art in my technical field
_______Product evaluations/approvals
_______Purchasing/procurement
_______Other ______________________________

7. **What capability for electronic access to a number of these information sources do you have or will have in the next six months?** ***Check all that apply.***

- ☐ Database on CD-ROM (with periodic updates)
- ☐ Database on diskette (with periodic updates)
- ☐ Electronic bulletin board
- ☐ E-mail
- ☐ Internet/World Wide Web
- ☐ Other ______________________________

8. **In the next three years, if there were an electronically-based, enhanced system - an Innovation Clearinghouse - that facilitated your access to various clearinghouses, databases, and other programs related to product testing, evaluation, approvals, and deployment, where would it provide the most utility for you?** ***(Rank: 1 = most utility, 7 or 8 = least utility; please do not use duplicate numbers for ranking).***

_______Reduce duplication of effort/coordination with other similar efforts
_______Planning research and development projects
_______Product specifications and standards
_______Maintain state-of-art in my technical field
_______Product evaluations/approvals
_______Purchasing/procurement
_______Other ______________________________

9. **It is common understanding that as a whole, current clearinghouses and databases do not completely address all needs for product testing, evaluation, approval, and deployment. We would like to have a better understanding of why this is so. Why is information not available to you? (*Rate: 3=highly important factor for information not being available, 2=moderately important factor for information not being available, 1=not an important factor for information not being available, 0 = does not apply*).**

______ Information has not yet been documented/collected.
______ To my knowledge appropriate tools do not exist to allow me to access the information.
______ There are tools to access the information, but my organization uses other tools not compatible with those needed.
______ My organization does not commit resources for support of tools to access this information.

10. **If an Innovation Clearinghouse to access product testing, evaluation, approval, and deployment information were developed where should effort be spent? (*Indicate a percentage for each area that when totaled equals 100 percent*).**

Percent
______ Collecting/documenting information to be available via the Innovation Clearinghouse
______ Developing appropriate tools (hardware and software) to access the data
______ Other activity ______________________________

12. **What are the three top gaps for technical subjects regarding product testing, evaluation, approval, and deployment that might be solved by having data available through an Innovation Clearinghouse? Please be as specific as possible.**

1. ______________________________
____
____

2. ______________________________
____
____

3. ______________________________
____
____

13. **If such an Innovation Clearinghouse were to be developed, please describe what would be most useful and productive for you.** ***(Rate: 3=most useful, 2=moderately useful, 1=somewhat useful, 0=not useful).***

______ An Internet/World Wide Web based system of linkages including intelligent decision support tools to enable seamless entry to the wide variety of electronic databases and clearinghouses.

______ An integrated database containing information from the variety of sources accessed by use of common terminology and through specific database software.

______ An Internet/World Wide Web based system of hot links that point the user to the variety of sources causing the user to perform the search and identification of appropriate resources.

______ Other, please describe ______________________________

14. **Regardless of its ultimate form, what are the most difficult barriers you see to implementing an electronic-based Innovation Clearinghouse?**

1. ______________________________

2. ______________________________

3. ______________________________

15. **To your knowledge, are there other industries besides transportation that have broad-based clearinghouse systems in operation?**

____

16. **Please give any additional comments or recommendations** ***(If you need additional space to answer please continue on a separate sheet of paper and reference this question).***

____

We would appreciate you and your organization's willingness to discuss your responses once all respondent data has en compiled. Let us also assure you that individual respondent information will be kept confidential.

Name & Title ____

Organization ____

Address ____

____

Telephone ____________ Fax ____________ E-mail ____________

I would be willing to discuss the survey ________

Thank you for taking the time to compete this survey. Your input will be carefully reviewed and used in planning a framework for an Innovation Clearinghouse. Please return the completed survey by **July 11, 1997** via fax at (202) 789-5345 or mail to:

HITEC
c/o CERF
1015 15th Street, NW
Suite 600
Washington, D.C. 20005
(202) 842-0555

Appendix C

Synopses of Technology Presentations

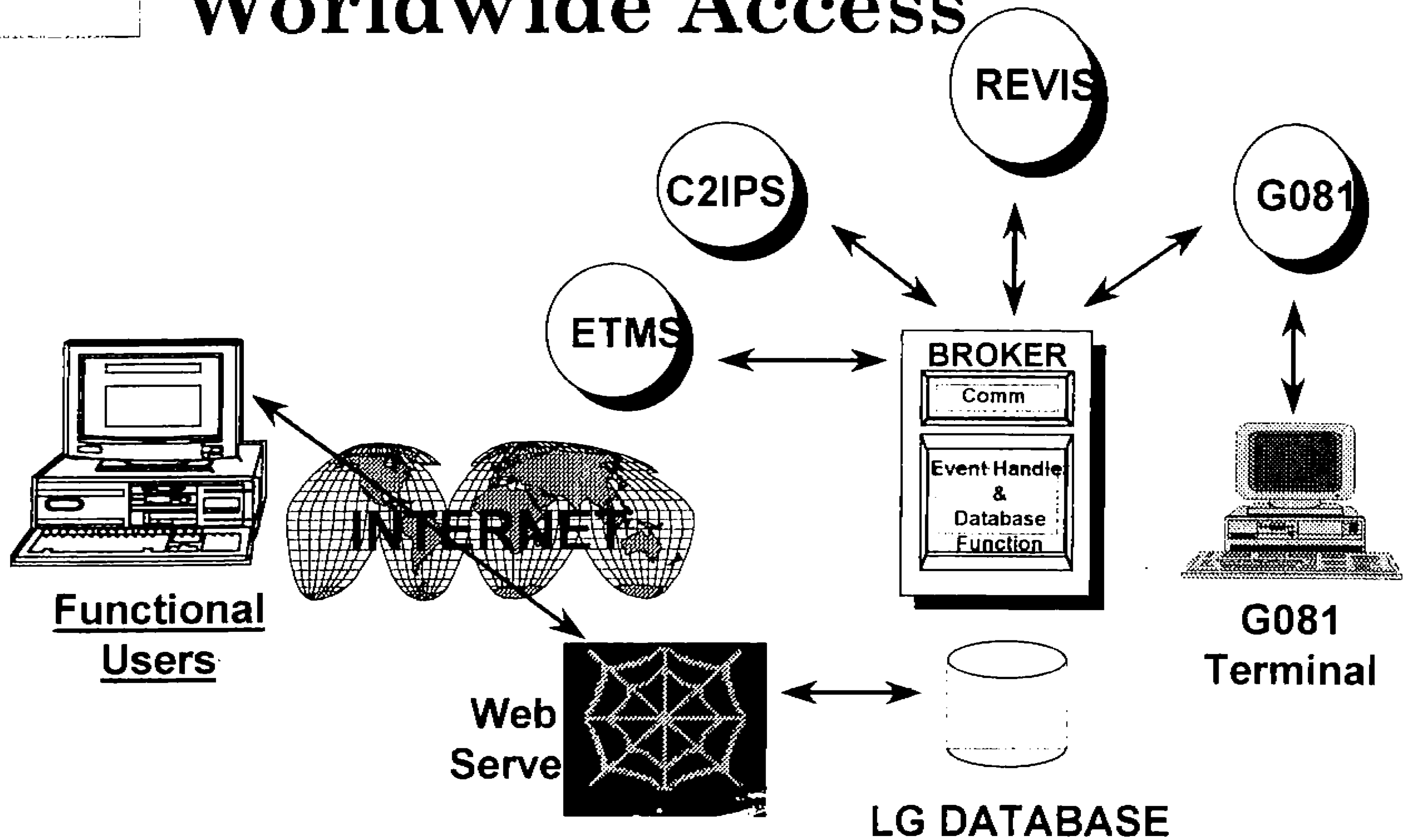
Volpe National Transportation Systems Center

Volpe Support to U.S. Air Mobility Command Using Broker and Internet Technologies

US DOT/Volpe Center

John M. Krumm

Worldwide Access



Some of the systems involved

- **G081 (CAMS for Airlift)** circa 1975
  - Central database used to manage heavy airlift
- **Information Broker** *Volpe* developed in 1993
  - Logistics system that shares data between numerous systems
- **C2 IPS** (Information Processing System) in development
  - A Base Level Command & Control System
- **ReVIS** (Registered Vehicle Information System)
  - A Base Level Specialized Vehicle System
- **ATMS** (Air Traffic Management System)
  - An FAA airline tracking system

The Data Warehouse & Data Warehousing: Essential Concepts and Implications for the Community of Knowledge Workers

Presentation to

The Civil Engineering Research Foundation

Highway Innovation Clearinghouse Steering Committee

by

Mr. Christopher J. O'Shea

Vice President and Chief Operating Officer

Barquin and Associates, Inc.

July 24, 1997

Inmon's Definition

- A data warehouse is:
  - Subject oriented
  - Integrated
  - Time variant
  - Non-volatile
  - "[A] collection of data in support of management's decision making process"

Wm. Inmon (1990)

Other Definitions

- *"A data warehouse is a complete repository of complex data extracted from transaction systems that is available for ad hoc access by knowledge workers."*

S. Brobst

- *"Data warehousing is the consolidation of data from multiple sources into a query database."*

H. Edelstein

- *"The delivery mechanism for providing integrated business information to your organization."*

C. Burleson and D. Tabler

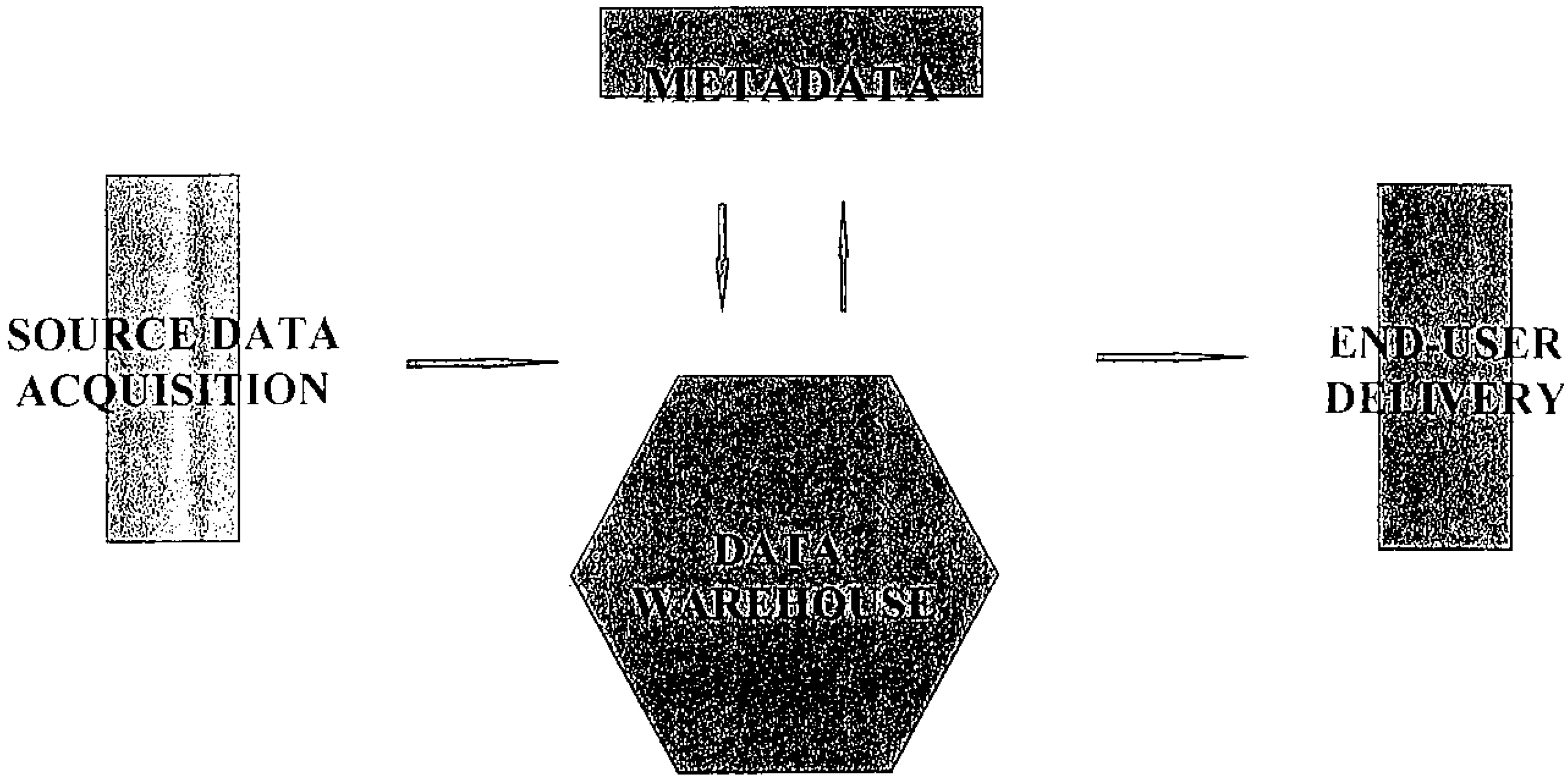
Basic Points to Keep in Mind

- **The 'Data Warehouse' (aka 'clearinghouse')** as powerful, organic, and dynamic analytical computing environment for decision support and related purposes [noun]

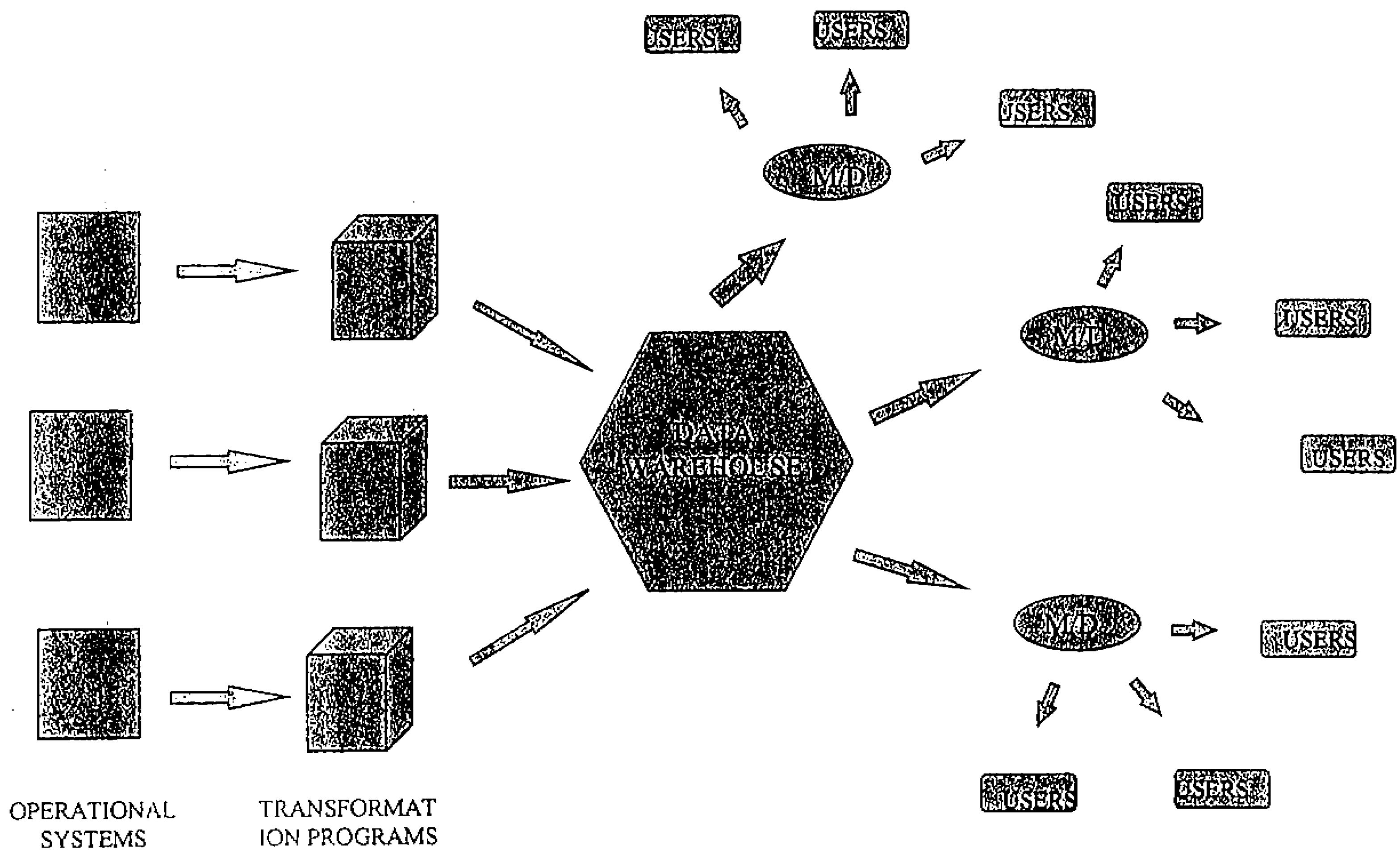
- **'Data Warehousing'** - Two perspectives ...
  - 'Data Warehousing' as a term to describe *a basket of essential enabling technologies or tools designed to empower management at all levels of the enterprise* [adj]
  - 'Data Warehousing' as a term to describe *an act or process through which to manipulate and transform data resources into information assets* [verb]

Source: C. J. O'Shea - 3/97

Major Components of the Data Warehouse



Example of Typical Data Warehouse Architecture



Types of Data Warehouses

- Decision Support Data Warehouse
- Data Mart
- Operational Data Store
- Virtual Data Warehouse

Classic Problem: Inaccessible Data Resources ...

- Many databases originally implemented as very complex data structures
- End-user access limited by lack of connectivity, absence of data standards, dearth of support for older applications, and aged media

Transaction vs. Analytical Processing

- Transaction processing
  - *Capture and storage* of data about on-going operations
  - Basic to running and maintaining the business
- Analytical processing
  - *Extraction of meaning* from transactions
  - Key to improving the business

Why Do We Need Data Warehouses?

- Information systems often are not integrated
- Incompatible data structures
- Multiple access paths to data
- Inaccessible data
- Out-of-date data
- Inconsistent data formats
- User reports are difficult or very nearly impossible to obtain

In Summary, Data Warehouses Are Needed In Order To ...

- Provide a single view of the business
- Assure an integrated enterprise model
- Increase yield from the data resources of the enterprise
- Consolidate data from disparate sources
- Obtain answers to key questions about the business, and
- With minimum interruption to operational systems

Things to Consider Before You Build ...

	WHY IS THE INFORMATION NEEDED?	
HOW BUSY ARE THE OPERATIONAL COMPUTERS?	FOR REAL-TIME TRANSACTION BASED DECISIONS	FOR PATTERN-BASED DECISIONS
PROCESSING POWER AVAILABLE ON EXISTING EQUIPMENT	VIRTUAL DATA WAREHOUSE	ENTERPRISE DATA WAREHOUSE OR DATA MART
ADDITIONAL HARDWARE IS REQUIRED	OPERATIONAL DATA STORE	ENTERPRISE DATA WAREHOUSE OR DATA MART

Implications

- Paradigm Shift
- Changing Roles and Responsibilities
- New Kinds of Questions
- New Questions Opening Up New Possibilities
- Innovation is *the* Outcome

Conclusions

- The 'Data Warehouse' is here to stay.
- 'Data Warehousing' concepts and tools will continue to evolve, converge, and proliferate at a rapid pace.
- Continuing advances in the art will give rise to uses that are not presently foreseeable.
- Growing understanding of essential concepts, tools, and applications will enable end-users of all kinds throughout various enterprises and across industries to transform *data resources* into *information assets* that will create, in turn, competitive advantage(s), encourage innovation, and facilitate technology transfer throughout whole industries and sectors of the economy.
- In the future, no matter what the *business of the business*, it will be the community of 'knowledge workers' that will become the true 'innovators' of the information age.

NCHRP 20-7(82)

Enhancements for the Special Products Evaluation List

Overview

- Survey findings
  - Survey I
  - Survey II
  - Discussed together
- Recommendations
- What happens next?

Survey findings - General

- Web access would serve largest group
- Summaries as well as contacts desired
- Links and integration with other product evaluation systems desired

Recommendations - General

- Get database and Web site up and running
- Develop alternate access in next phase
- Provide both summaries and names of contacts
- Link with other product evaluation systems

Survey findings - Products

- Retain listing as long as product is in use
- Include both completed evaluations and those in progress
- Less interest in products
  - Not meeting existing specification
  - Proposed for evaluation

Recommendations - Products

- Retain listing while product is in use, verified annually
- Include both completed evaluations and those in progress
- Include other listings at discretion of state supplying

Survey findings - State systems

- More than half of agencies have computerized product evaluation system
- Variety of platforms, software packages, and data structures used
- Manufacturer submission forms are very similar
- Many agencies still using SPEL product category codes or variant

Recommendations - State systems

- No particular platform or data structure dominates state DOTs
- Most states have customized their databases for their internal purposes
- No one state agency system can serve as model
- Work with states to develop more consistency

Survey findings - State DOT participation

- Over half the state DOTs say they would contribute evaluation records
- They say "Making it easy" would be the best incentive to participate
- They want system to be actively maintained

Recommendations - State DOT participation

- Pilot test all web pages to make process "easy"
- Work with states to establish other submission methods
- Contact states regularly to verify previous and encourage future submissions
- Establish feedback though web site to identify problem areas

Survey findings - Populating the database

- Willing to enter new evaluations into WWW form or other menu-driven system
- Some agencies interested in sending batches electronically
- Prefer that contractor work with them to convert older data
- Imported SPEL data is 2nd choice for adding older data

Recommendations - Populating the database

- Create WWW form for new evaluations
- Test SPEL data for feasibility of import
- Work directly with selected states to convert older data
- Set up template for word-processor or spreadsheet entry

Survey findings - Database fields

- Numerous fields, but simple to use
- Some agencies wanted to omit fields that would be hard to keep current
- Almost half of respondents would accept vendor input in one or more fields, but others are opposed

Recommendations - Database fields

- Eliminate selected field to simplify data entry and database maintenance
- Add fields for housekeeping and linking purposes
- See report for specified fields recommended
- Additional input will be needed on "multiple choice" fields

Survey findings - Potential users

- Over half the state DOTs said all potential users should have access
- Strong interest in blocking "sensitive" data from public view
- Some respondents said their agencies might contribute less information because of liability concerns

Recommendations - Potential users

- Web site should be open to all users during pilot phase
- As needed, restrict some portions from certain users at a later date
- Define "sensitive" fields
- Keep content brief to limit liability issues
- Collect certain otherwise "sensitive" information from vendors

Survey findings - Other

- Majority of respondents would use a system the same amount whether or not a password was required
- More than 1/3 of agencies said they would like to post
  - Product evaluation procedures
  - Links to home page
  - Product evaluation forms

Recommendations - Other

- Password for viewing can be implemented if problems develop
- Password proliferation can frustrate users, discourage "quick hits"
- Give agencies opportunities to post or link to additional relevant files

Survey findings - Naming the system

- Respondents supplied 35 ideas for names, including
  - SPEL
  - SPEL II
  - UltraSPEL
  - NPED (National Product Evaluation Database)
  - William
  - And more!

Recommendations - Naming the system

- Considerations
  - Pronounceable acronyms seem popular
  - Avoid confusion with other systems
  - Should consider ultimate targeted audience
    - "National" assumes U.S. only
    - "State" assumes states only
- Rumor says: "SPEL" is out of the running

Panel Recommendations - Naming the system

- AASHTO Product Evaluation Listing
- No acronyms, please!

Additional recommendations

- Hardware and software
  - Hardware needs are fairly clear
  - Database software could use more research
- Staffing needed
  - Technical
  - Administrative
  - Quality control
  - Marketing

HITEC

HIGHWAY INNOVATIVE TECHNOLOGY EVALUATION CENTER

1015 15th Street, NW
Suite 600
Washington, DC 20005
tel: 202/842-0555
fax: 202/789-2943

TO: Highway Innovation Clearinghouse Study Steering Committee

FROM: Peter Kissinger Peter

DATE: June 10, 1998

As you know, our Clearinghouse study report was delivered to FHWA several months ago. Since then it has undergone internal review but it has not yet been circulated for external review.

However, based on recent discussions with OTA officials, I understand that it will be circulated shortly for external review along with some material on the "Value of Information" study and the internal FHWA/OTA Technology Resource Center initiative.

If I learn more, I will pass it along. Thanks!

cc: Barbara Harder

L:\HITEC\PROJECTS\CHOUSE2\0304MEMO

Terry Mitchell

U.S. Department of Transportation
Federal Highway Administration

400 Seventh St., S.W.
Washington, D.C. 20590

JUN 23 1998

Refer to: HTA-2

Francis B. Francois, Executive Director
American Association of State Highway and Transportation Officials
444 North Capitol Street, NW, Suite 249
Washington, DC 20001

Dear Mr. Francois:

I am writing to you and our other partners in the transportation Research and Technology (R&T) community to solicit your input on how we can best serve the community's needs for knowledge sharing and information management.

I think we all share a common goal of providing transportation professionals with easy access to comprehensive, accurate, and up-to-date information. As our organizations struggle to harness the latest information technology, we need to collaborate so we can move forward with a common vision. Toward that end, I want to share with you a number of activities that we have initiated within the last year here at the Federal Highway Administration's Office of Technology Applications (OTA), in order to get your thoughts regarding next steps.

Knowledge Management: OTA has initiated a pilot project to establish a knowledge-sharing network. The structure of the knowledge-sharing software provides a way to capture and disseminate information and knowledge within a specific community of practice. The structure allows for collaborative work among a designated community of users, as well as for the archiving and distribution of documents, including publications, technical data, meeting minutes, etc. There are different levels of user interface, so that some documents or areas will be available to the public, while other areas, where more confidential discussions or documents are stored, are for restricted use. The pilot project is being conducted with American Management Systems, Inc. An Executive Summary of Transportation Knowledge Sharing is enclosed, detailing ideas regarding how knowledge sharing can be applied both within the FHWA and throughout the transportation community.

Innovation Clearinghouse: OTA conducted a study in partnership with the Civil Engineering Research Foundation (CERF) and its Highway Innovative Technology Evaluation Center (HITEC) to examine the need for a national highway innovation clearinghouse. The need for such a clearinghouse was identified. However, as preliminary

planning began, it was recognized that creation of a physical center was not necessarily appropriate. Advanced communications and information management techniques offer greatly expanded options for virtual clearinghouse opportunities. HITEC organized a Steering Committee comprising representatives of key highway community stakeholders, and has issued a report reflecting the consensus of the Committee, which is enclosed.

Value of Information: The Volpe National Transportation Systems Center has issued a draft report on "The Value of Information and Information Services," which is enclosed. The report grew out of a 1994 workshop sponsored by the Transportation Research Board Committee on the Conduct of Research, which first recognized the need to improve recognition and awareness of the value of information. The report discusses the value of information and identifies strategies for promoting information programs. A national distribution of this report is planned.

By working together, partners in the transportation R&T community can develop a more comprehensive approach to achieving common goals through the innovative use of knowledge management and information technology. I would welcome your ideas regarding the next steps to be taken. Michael Halladay (Telephone 202-366-9210; e-mail michael.halladay@fhwa.dot.gov) in my office is coordinating OTA's activities. If you would like to identify a key person to work more closely with him, please do so.

I also would welcome any general comments or suggestions regarding the enclosed reports, or any other aspect of knowledge management for the transportation community. I would appreciate receiving any feedback as soon as practical, and no later than the end of July.

The possibility of a small national workshop, where key officials could brainstorm next steps, has been discussed. If you would be interested in working with us on such a session, which would probably be held in late August or early September, please let me know.

Sincerely yours,

Joseph S. Toole
Director, Office of Technology Applications

Enclosures
Transportation Knowledge Sharing Executive Summary
Highway Innovation Clearinghouse Study Draft Report
The Value of Information and Information Services Draft Report
List of others who received similar letters

List of others who received similar letters:

Robert E. Skinner, Jr., Executive Director
Transportation Research Board

Francis B. Francois, Executive Director
American Association of State Highway and Transportation Officials

E. Dean Carlson, Chairman
AASHTO Subcommittee on Information Systems

Allan L. Abbott, Chairman
AASHTO Standing Committee on Research

Larry Goode, Chairman
AASHTO Special Committee for International Activity Coordination

Antonio Mariano, Jr., Transportation Program Manager
American Public Works Association

Russel C. Jones, PE, Executive Director
The National Society of Professional Engineers

Henry R. Lambert, Chair
National Association of Transportation Technology Transfer Centers

Harvey M. Bernstein, President
Civil Engineering Research Foundation

cc
Highway Innovation Clearinghouse Study Committee
Thomas Brahms
William P. Carr
Mike Halladay
Chuck Kline
Ken Kobetsky
Richard A. McComb
Wayne McDaniel
Renee McHenry
Richard McReynolds
Terry Mitchell
Lisa Pogue
Larry Scofield
Robert E. Spicher
Ken Warren
Laura Whayne
Peter Kissinger

Value of Information Technical Panel
Nelda Bravo
William P. Carr
Claudia Devlin

Denis Donnelly
Barbara T. Harder
Kathryn Harrington-Hughes
Christopher Hedges
Robert J. Perry
Sandy Tucker
Robert Zarnetske

FHWA Transportation Knowledge Sharing

Executive Summary

Introduction

The wealth of technical information that resides within the Federal Highway Administration (FHWA) and the larger highway community is enormous. Within the organization, various offices have developed or evaluated new technologies and materials. At the same time, field offices have participated in technology development and implementation efforts. A number of innovations have been developed in cooperation with outside partners. Indeed FHWA's focus on partnership is a key characteristic of its technical program.

As a knowledge-based organization within the DOT, FHWA has a strategic imperative to capture its collective knowledge of transportation technology and deliver it to its customers so it can be put into immediate practice. FHWA is moving to meet this challenge by pursuing a Transportation Knowledge Sharing (TKS) initiative for collaboration and sharing innovation within the highway community. This initiative will leverage FHWA's most valuable asset – the expertise of its employees and partners – and make it accessible to its customers.

The most tangible product of the TKS will be a knowledge network that facilitates the electronic exchange of ideas and provides a knowledge repository of documentation of best practices, procedures, product evaluations and research reports. However, the overall TKS strategy must also focus on the organizational and management framework needed for successful knowledge sharing within FHWA and for expansion beyond FHWA to include outside partners.

Vision of Transportation Knowledge Sharing

During the past six months, FHWA has developed a vision of transportation knowledge sharing that:

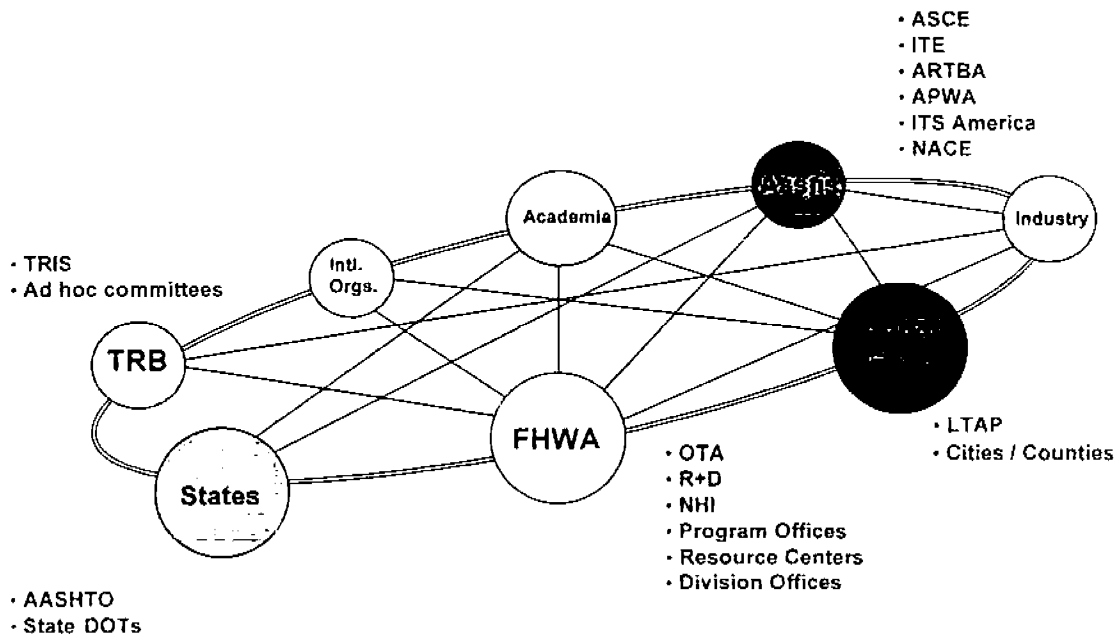
- **Serves the technology needs of its customers**. FHWA has a role to deliver transportation technology so it can be put into immediate practice.

- **Presents information according to the customer point of view,** not inside organizational walls. Customers want to access information according to transportation subject matter, regardless of which organization "owns" the information.

- **Facilitates knowledge capture and exchange** by creating Communities of Practice to capture, share, and build knowledge among transportation professionals.

- **Promotes technology sharing among transportation partners.** FHWA will act as a "node" on a transportation knowledge network. It will provide coordination, set protocols and standards, and the host server. Partners will provide adherence to protocols, additional infrastructure, and their content.

The following diagram depicts this envisioned transportation knowledge sharing structure, with FHWA as a single node in the partnership. Clearly, this diagram does not include all potential participants; for instance, other US DOT administrations and other associations would be valuable contributors.



Features of the Knowledge Network

FHWA envisions its transportation knowledge network as:

- **A forum for the highway community to share knowledge.** The knowledge network will create a collaborative space where technical experts from various organizations can exchange ideas, insights, and experience as well as share project specific schedules, meeting minutes, and works-in-progress.

- **A repository for valuable information about highway innovation.** The knowledge network will contain a widely accessible electronic library of project- and organization-related information, such as technical briefings, recommended best practices, and evaluation and research results.

- **A resource for training and education.** The knowledge network will provide a focal point for FHWA employees and other transportation professionals to access information about training resources and activities. It would include catalog of course offerings, on-line registration, and training and conference reviews.

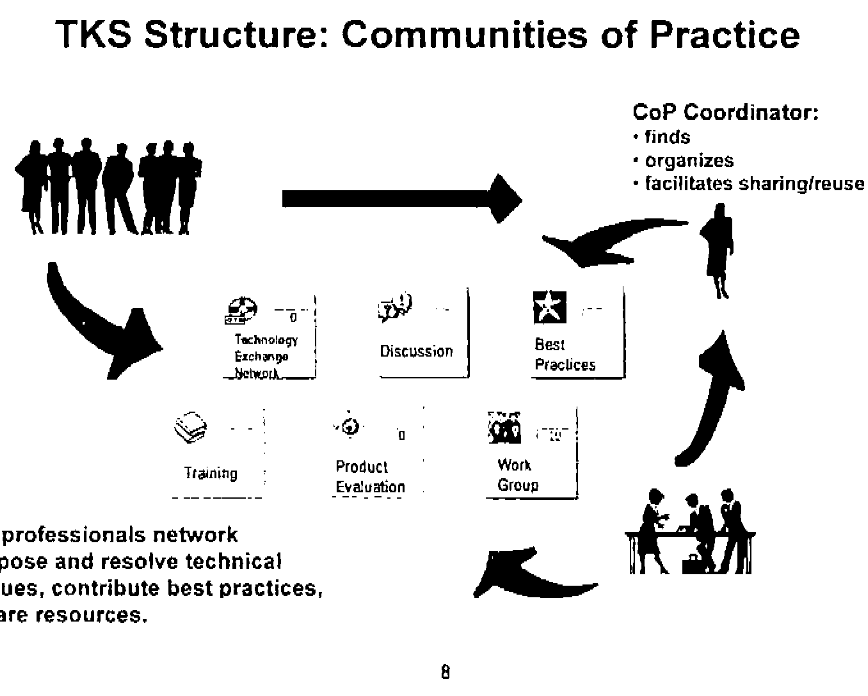
- **A means of accessing technical and industry developments.** The knowledge network would allow users to search for information from a variety of source databases as will as point to other sources of information. The knowledge network will incorporate a robust search engine that allows for full text searching as well as the controlled language of the Transportation Thesaurus developed for TRB.

The information in the Knowledge Network would be organized and presented according the customer perspective, not organizational boundaries. However, the search and indexing function will be sophisticated to enough to allow searches across multiple databases, so the user can find information on topics that crosses specialties.

Building Knowledge through Communities of Practice

In the course of developing the vision, FHWA recognized that knowledge management entails far more than databases and networks. Companies undertaking similar knowledge management initiatives have found that only 20% of their efforts involve technical issues; the remaining 80% is institutional. In fact, an Ernst and Young survey of U.S. and European executives found 54% citing organizational culture as the biggest impediment to knowledge transfer. FHWA's knowledge management initiative represents an opportunity for the transportation community to foster a culture that is more collaborative, open to innovation and knowledge sharing, and less divided by functional specialization.

A central principle of knowledge management is that organizations can best foster knowledge capture and exchange through Communities of Practice – professional networks to pose, share and resolve issues and publish the results. A Community of Practice is a "virtual community" of people throughout the highway community connected by interest and expertise in a specific discipline. Each community should be led by a team of Coordinators, recognized as leaders in their respective disciplines. In addition to contributing research papers, technical briefings, or other reports, the members of the community will make an effort to identify the best practices as well as the gaps in knowledge in their field. This information will then be recorded in the knowledge repository for the CoP.



Members of a Community of Practice are also committed to helping solve problems "in the moment" by responding to directed e-mail and voice mail messages from their peers. The individual posing the question has the responsibility to record the responses in the knowledge repository.

The idea of Community of Practices within the highway community is not new. There are already formal and informal networks of professionals who exchange information and assist each other on a regular basis. The real potential is to support customers by recording the essential information that the community knows and where gaps in knowledge exist. As they participate in CoPs, customers can become both users and producers of information.

TKS Objectives

Through its Transportation Knowledge Sharing initiative, FHWA seeks to achieve the following objectives:

- **Improve customer service** by speeding the delivery of transportation technology to FHWA's customers and partners. This will enable FHWA to fulfill its mission to provide proactive leadership, expertise, resources and information to improve the Nation's highway and intermodal connections

- **Leverage community-wide knowledge** by giving staff access to cumulative expertise on specific topics. Eventually the Transportation Knowledge Sharing network will create intelligent linkages to partners' databases, expanding the FHWA knowledge base.

- **Improve the knowledge base of the participating organizations** by encouraging individuals and groups to record their special knowledge. This is especially important as key staff members near retirement and the pace of technological innovation accelerates.

- **Extend information networks.** Long-term staff members have personal contacts, developed over many years that give them access to most of the information they need. Less tenured staff members have less extensive links. The Technology Resource Center is intended to provide access to these personal resource networks.

By giving each staff member the ability to increase effectiveness and make use of the organization's collective knowledge and experience, the Transportation Knowledge Sharing initiative has the potential to play a significant part in FHWA's continued success.

Timeframe for Achieving the Vision

A TKS of this scope should be implemented in phases over a period of three to five years, depending on the scope and complexity of the system. As a first step in achieving the TKS, FHWA is working to create a shared internal vision for the TKS. The next step is to share this vision with FHWA partners and begin inviting partners to further shape this vision and to participate as "nodes" on the knowledge network.

At the same time as FHWA communicates its TKS vision, FHWA / OTA should begin to pursue the development of internal TKS features and content. The Superpave Technology Delivery Team has been identified as the first project group to test a collaborative forum, and this effort is underway as of the spring of 1998. Once this effort is evaluated and a technical platform for the TKS is identified, components can be added or expanded as desired, as flexibility is a primary goal of the TKS. A suggested sequence for these activities is presented below:

- Create a working Community of Practice to model how knowledge sharing will operate in the future. This group should be educated in the goals and principles of the TKS project and guided towards becoming a cohesive working group that can help define TKS requirements.

- Begin to gather and organize existing best practices, working papers, research results, and other "state of the practice" materials in preparation for recording them in the knowledge repository.

- Extend the collaborative forum and knowledge repository components to key FHWA program offices and partners within the highway community.

- Organize and expand the knowledge repository component to make it available to the general public. This would involve developing an engine with the ability to search over multiple databases within FHWA and the transportation community.

- Expand the full capabilities of the TRC to the entire highway community.

Traveler Information Showcase
1996•Atlanta

Legacy Plan

Prepared by:

Battelle
505 King Avenue
Columbus, OH 43201

System Resources Corporation
400 Virginia Avenue, SW, Suite 460
Washington, DC 20024

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

Although the FES was designed to run in an automated mode, it is expected that operational and maintenance support will be required to keep data current and troubleshoot/diagnose problems. It will be necessary for a GDOT software and hardware support staff to become familiar with the physical connections and programs that interface with the various legacy TIS devices/systems.

In addition, if the FES is selected for retention, a support agreement with NavTech (mapping database) for future updates and maintenance must be initiated. The NavTech database is resident on the FES and provides routing information to the TIS devices/systems. It is also essential that support/maintenance agreements be established and or continued for all FES hardware and software.

In order to accommodate the potential for future growth possibilities, and to reduce the cost of operations and maintenance, consideration should be given to establishing a Landline Data System (LDS) dial-up capability to the FES. Although this may require some modification to current Interface Control Documents (ICDs), it will greatly simplify the maintainers role in providing information to the ISP. The FES architecture currently has seven (7) spare modems suitable for this dial-up access (phone lines are needed).

In order for the FES to be retained as legacy, the following must be considered:

- Maintenance/support of Hardware and Software.

- Training of GDOT Staff for System Administration and Call-Taker/Operator functions.

- Transfer of TIS radar site control/data acquisition software to ATMS Communications Server; along with necessary integration, testing, and evaluation.

- Transfer of TIS video control GUI to ATMS (integrate or link) along with necessary integration, testing, and evaluation.

3.2 Personal Communications Device - Envoy

3.2.1 TIS

The Envoy is a hand-held device with integrated communications capabilities that can graphically display a variety of ITS Atlanta TIS information. It has a built-in wireless packet radio modem compatible with the ARDIS wireless network, an additional circuit-switched fax/data modem, a serial port, an infrared transceiver, and two Personal Computer Memory Card International Association (PCMCIA) Type II card slots. In addition to providing the user with TIS-unique traffic and transit information, the Envoy also provides e-mail and fax capabilities as part of its baseline personal productivity functionality.

Information is exchanged between the PCD and FES via the ARDIS network, a two-way packet-data demand-driven communications path. Fastline developed the TIS unique custom software for the Envoy to control and display functions that require an interface exchange with the FES. The interface provides graphical icons that allow the user to navigate among the available functions. When a request is initiated by the user, the PCD connects to the server, retrieves the appropriate information, and displays the information on the PCD screen.

3.2.2 Legacy

The key to maintaining the Envoy PCD as legacy is the operational and maintenance support of the FES and the ARDIS server (currently located in the equipment room of the TMC). Fastline, the developer of the TIS software for the Envoy, has stated that they do not intend to pursue a market in the Atlanta area for the PCD. However, at the end of the TIS, FHWA will own approximately 115 Envoy devices. These devices have extensive inherent functionality as personal organizers and communications devices; in addition to static loads of TIS unique information (e.g., MARTA, CCT, etc.).

Retention of this device as legacy would require:

- Operational and maintenance support for the FES and ARDIS server.

- A support agreement with ARDIS to continue communications capabilities, would need to be established. The costs associated with maintaining communications are provided in paragraph 4 and Appendix A of this document.

- A support contract would need to be established with NETTECH for the RF Gate software used in the ARDIS server. Costs associated with this requirement are in paragraph 4 and Appendix A of this document.

3.3 Personal Communications Device - Hewlett Packard 200LX

3.3.1 TIS

The Hewlett Packard 200LX is a hand-held device capable of graphically displaying a variety of ITS Atlanta TIS information. The HP 200LX is a self contained IBM-compatible PC, with a communications application. It connects to the SkyTel network through a Personal Messaging Unit (PMU) (Pager) when connected to the HP 200LX with a special cable. A 20MB Flash memory card in a PCMCIA Type II format is included to hold the resident Traveler Database.

Information is received by the PCD from an ETAK Server via SkyTel. The ETAK communicates with the FES to receive updated traffic situations and route information. Hewlett Packard and ETAK developed the TIS unique custom software for the HP 200LX to control and display functions that require an interface exchange with the TIS server.

3.3.2 Legacy

Hewlett Packard has stated that they do not plan to retain operations in the Atlanta area after the TIS. Therefore, no attempt will be made to provide for a legacy of this system. The system was installed in Room 307 of the TMC to allow for easy removal of equipment after the TIS operational period. There are no unfunded costs anticipated with this transition.

3.4 In-Vehicle Navigation Device

3.4.1 TIS

The In-Vehicle Navigation device is capable of providing a variety of textual (instructions) and graphic (map) information, in addition to TIS traffic situation information. Navigation Technology (NavTech) provided the mapping program necessary for the device to provide built-in route guidance. This is a baseline feature of the In-Vehicle device and does not require a separate agreement. The device receives TIS traffic information from the FES, through a Frame Relay Access Device and a CSU/DSU, broadcast via an FM subcarrier to the vehicle. The information is received through a serial port that is connected to an FM receiver located in the vehicle, then processed by the CPU, and sent to the display unit. DCI has contracted with six radio stations in the Atlanta metro and surrounding areas (including Savannah, GA) to broadcast TIS information over their FM subcarrier. The following radio stations were active during the TIS period:

- WRFG Atlanta (89.3)
- WRAF Toccoa Falls (90.9)
- WSTH Columbus (106.1)
- WSKZ Chattanooga (106.5)
- WJTG Macon (91.3)
- WEAS Savannah (93.1)

Siemens developed the custom software to control and display broadcast speed and incident messages, and parking information from the FES. The device utilizes a Global Positioning System (GPS) to determine its initial location when the vehicle is started. Subsequently, the device navigates using a combination of dead reckoning, map matching, and an inertial gyroscope.

3.4.2 Legacy

The key to maintaining the In-Vehicle as legacy is the operational and maintenance support of the FES and the continuation of a service/support contract with DCI. The costs and operational considerations for maintaining this system in its current configuration, are discussed in detail in paragraph 4 and Appendix A of this document.

FHWA currently owns 20 In-Vehicle devices. These devices are installed in a variety of FHWA and other government agency vehicles. The devices can be operated without the TIS traffic data, but would be limited to their inherent baseline functionality of route guidance.

3.5 Cable TV System

3.5.1 TIS

CATV provides TIS traffic situation information in the form of graphic map images, audio (pre-recorded), live surveillance video, and traffic advisory information. An ETAK Transportation Workstation receives traffic situation information from the FES, processes the information, then pushes the information to a Multimedia Workstation. The Multimedia Workstation then scripts the data with live video broadcasts and prerecorded audio. An announcer, or GDOT staff, can provide live traffic information during peak traffic hours. Special traffic advisories and/or announcements are input into the system via one of four CATV bulletin Boards. Once information is processed and converted to the proper signal, it is broadcast to the Georgia Public Television (GPTV) system via a fiber optic connection. From the GPTV location the information is broadcast via satellite to subscribing cable companies. Alternatively, the same program (video/audio) is delivered via TMC-TCC fiber to the City of Atlanta, Clayton County, and Gwinnett County.

3.5.2 Legacy

The key to continuation of the CATV system is a fully operational FES environment. There two possible scenarios, besides discontinuing and removing the system.

Continue operations of the CATV System in Room 119 by GDOT and/or FHWA. Maintenance of the ETAK Traffic and the Multi-Media Work Stations hardware and software would be required. There must also be funding for repair and/or replacement of the audio and video equipment in the event of a failure. Maintenance of the software could be contracted with ETAK or another vendor with ETAK as an advisor. Operational support could be under an existing contract (ATMS, FES,....) or independent support contract. The existing public fiber cable TV transmission infrastructure could be used. The system would remain under government control.

Transition the CATV System component to a vendor/agency (i.e., Media One, Scripts Howard,.etc.). All CATV equipment would be transitioned to a vendor under a temporary or permanent agreement. The selected vendor could maintain the system for a set period of time with the agreement that GDOT would continue to provide the traffic information during that period. The agreement would be renegotiated at the end of the designated period. In this option, equipment would be transferred to the vendor's location. The vendor would arrange and coordinate the CATV operations, equipment and software maintenance, and TV signal transmission. In order for this option to work, supplemental agreements would have to be made with the selected vendor to provide traffic information to other cable systems (counties, City of Atlanta, etc.) if they choose to continue service.

3.6 Interactive TV System

3.6.1 TIS

The Interactive Television System is an on-demand system that provides; a highway speed map with color coded road segments to indicate traffic speed; incident information from an overview map. The user selects choices from pre-defined zones and selects the proper incident icon in the selected zone from a menu. This results in a more detailed street map and a textual description of the incident; a pre-canned direction service where the user can select from 100 pre-selected points of interest - each point of interest contains a color photograph, road map(s) indicating directions from the hotel, a brief textual description, and a pre-recorded narration; instructional information provides the user with slides, text, and voice narration on transportation options (e.g., MARTA rail, park-and-ride locations, and bus routes), transit schedules (static), and general information on traveling within the Atlanta metro area; and Yellow Pages, as well as route information which can either be displayed on screen or sent to a printer located at the front desk of the hotel.

IATV is a client/server application. The IATV system consists of a hotel resident head-end server which communicates with the TV set-top boxes in the hotel rooms. Hotel guests use a remote control device to request information and interact with the head-end server. The head-end server is connected to the ETAK Transportation Workstation via a leased modem line to receive current traffic data (e.g., traffic speed and incidents).

3.6.2 Legacy

IT Networks does not plan to continue operating the IATV system at the Crown Plaza Hotel. However, IT Networks has a two year contract to demonstrate a home based interactive TV system in an apartment complex in Atlanta. IT Networks could integrate the Traffic capabilities into this system, if the traffic information is available.

There are two scenarios if the transmission of the traffic data to the IATV is continued.

The IATV (ETAK) TWS would remain operational in the TMC. The support for the IATV (ETAK) TWS would be included as an extension of the ETAK CATV contract.

IT Networks and/or another vendor would take responsibility for the TWS off-site. It could remain as a stand alone system or the software could be incorporated into the IT Networks Head-End Server. The IATV communications with the FES would be via a dial-up line. IATV would operate independently of the (CATV) and make arrangements for a work station to receive the data.

3.7 On-Line System - Web Site

3.7.1 TIS

The Web Site is a 24-Hour, real-time, high speed system that provides TIS information to the public over the Internet. Anyone with Internet access via a modem or network (e.g., Prodigy, CompuServe, America On-Line; Mosaic, NetScape, etc.) is able to receive a full range of information including; traffic information, route planning guidance, yellow pages, wide-area travel, web pages (press releases, TIS information, Atlanta ITS projects), as well as links to other ITS and/or Atlanta web sites. Information from TIS sources are fed to a server workstation which utilizes a Maxwell Labs developed application software and the Netscape Communications Navigator/ Mosaic World Wide Web server software to make TIS information available to customers accessing it on the Internet.

3.7.2 Legacy

The key to retaining the Web Site is the retention of the FES and maintaining the Web server located in the TMC Equipment Room (124). Maxwell Labs has made a proposal for maintaining the web site; a copy can be provided under separate cover. The two main issues surrounding this support are outlined below.

Issue 1:

The web pages themselves do not have any "source code" in them. They are textual "html" pages. Maxwell Labs will provide these existing pages to GDOT free of charge. Once these pages are transitioned, GDOT can either hire their own Webmaster (possibly Georgia-Net) to maintain the html pages, or have Maxwell Labs maintain them at no cost to GDOT. However, if Maxwell Labs does maintain the html pages, they would want an agreement with GDOT to use the pages as "marketing tools".

Issue 2:

Included in the Georgia-Traveler web page is "source code" for accessing the FES when a route request or traffic update is performed. This "source code" is proprietary, and belongs to Maxwell Labs. Maxwell Labs can provide a license to GDOT for use of the executable files in the "source code" at no cost to GDOT. However, if any changes needed to be made to the interface between the FES and the web server (changes to "source code"), Maxwell Labs would then charge GDOT. A formal agreement would need to be worked out between Maxwell Labs and GDOT on this issue.

The Internet provider for the Georgia-Traveler web site is PeachNet. Cost for the T1 connection is $1,500 per month/$18,000 per year.

3.8 Surveillance

3.8.1 TIS

3.8.1.1 Automated Surveillance Sites:

The TIS has made a substantial investment installing 51 operational survey sites, 22 which have slow-scan Pan-Tilt-Zoom (PTZ) controllable color video. All are connected to the TMC by dial-up phone lines. Maps of Radar and Video Surveillance Sites are shown at Tables 3-2a and 3-2b. A typical TIS automated surveillance site consists of two Doppler radar detectors mounted near the top of a 45-foot wood pole. Every five minutes the FES calls each site and receives the current average speed. The FES can define the parameters of the speed collection; to call or not to call, how often, etc. If at any time during the averaging period, the RPU detects a significant change in average speeds across pre-defined boundaries (either up or down), an "exception" call is initiated (to the FES) to immediately report the new values. In addition, the ATMS can also call (poll) the site at predetermined intervals to receive average speed values.

At strategically selected sites, information reported by the radar units is supplemented by 22 slow-scan video images from full PTZ controllable color cameras. The environmentally protected cameras are attached to the same pole as the radar units. The video signals are digitized at the site by an encoder unit and transmitted back to the TMC through a 28.8 kbps modem over standard, dial-up phone lines. Unlike the radar installation, camera equipment does not initiate a call to the TMC. Instead, upon receiving an alert from the TIS server that speeds at a particular location have suddenly changed, (and assuming the location is equipped with a camera) an ATMS Zone Operator (Call Taker) can call the camera site to begin receiving the digitized video signal. A companion modem and decoder at the TMC converts the data back to a standard video image. The pictures received are routed through the ATMS video switch for display to the TMC operators for their use in situation verification.

3.8.1.2 Supplemental "Manual" Surveillance:

Manual, or spotter, surveillance is provided to supplement the surveillance information received from radar and camera sites. Metro Networks provides general information pertaining to the traffic flow conditions in addition to their normal surveillance areas. Information reported that relates to traffic conditions in the specific coverage areas includes traffic volumes (light, medium, or heavy), range of speeds, and current weather conditions. Information is updated every 15 minutes during the peak hour periods (6am to 9am and 4pm to 7pm), no less than every 30 minutes during off-peak hour periods (9am to 4pm and 7pm to 10pm). Conditions and incidents observed by aerial or ground-based spotters are transmitted to the Metro Networks display terminal at the TIS call-takers position.

TRAVELER INFORMATION SHOWCASE

RADAR & VIDEO SURVEILLANCE SITES

● RADAR & VIDEO SURVEILLANCE
○ RADAR ONLY

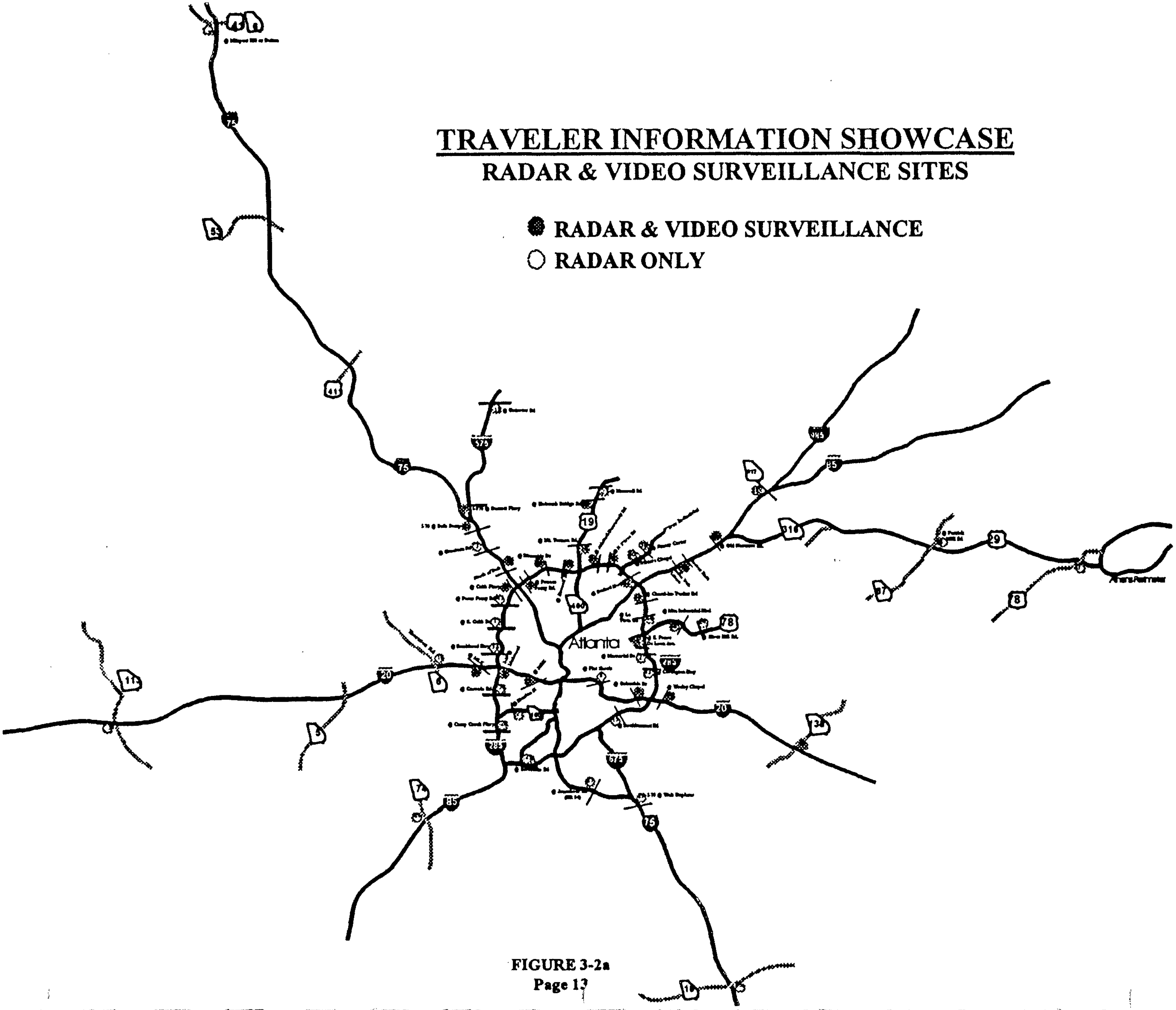


FIGURE 3-2a

TRAVELER INFORMATION SHOWCASE

RADAR & VIDEO SURVEILLANCE SITES
(CLOSE-UP) *

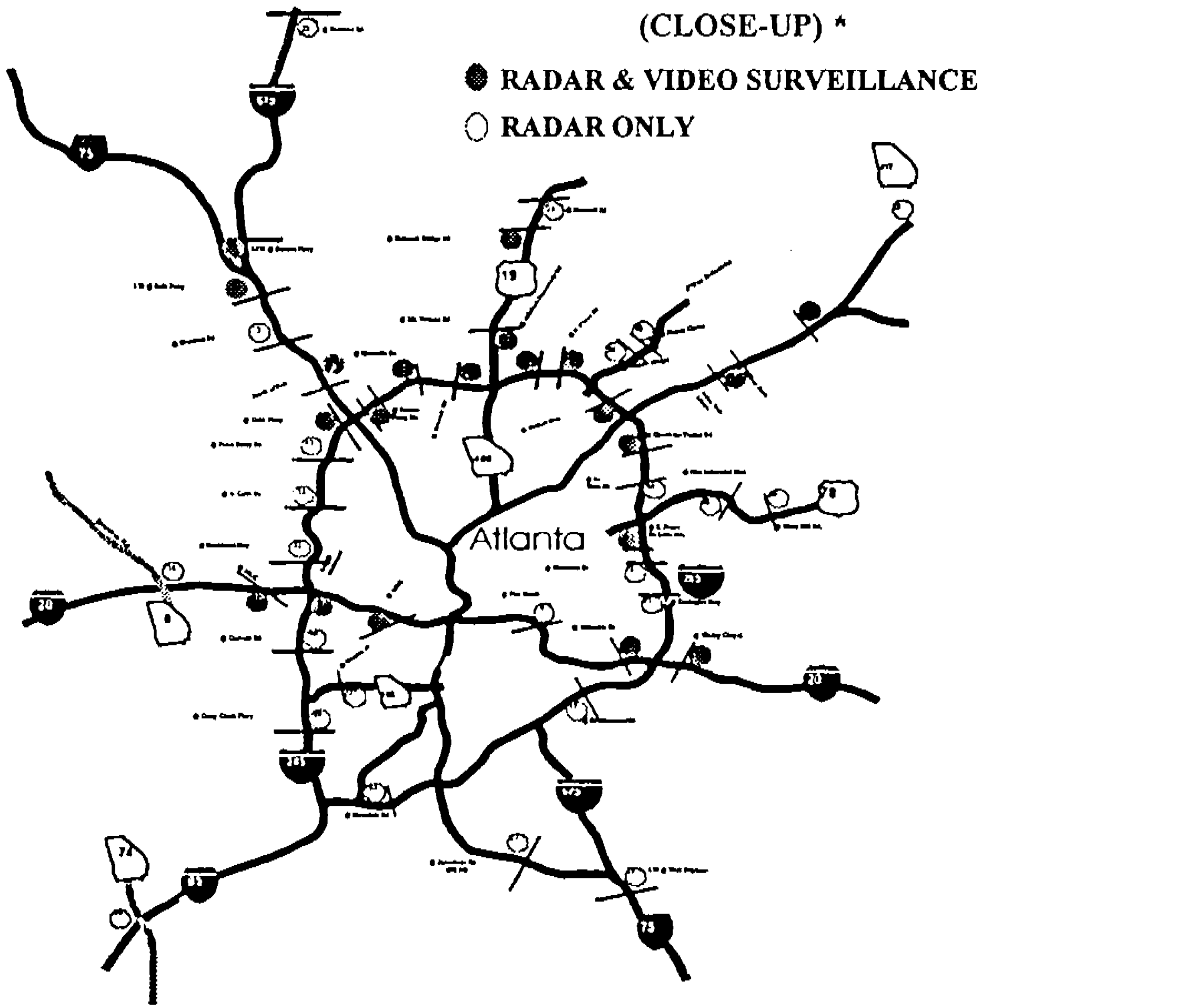


FIGURE 3-2b

* DISTANT SITES ARE SHOWN ON PREVIOUS MAP.

An operator reads the information from the terminal and then, after verification procedures have been followed, manually enters the information into the ATMS.

3.8.1.3 Spotter Sureveillance:

To supplement the Metro Networks surveillance information, JHK hired approximately 16 spotters to concentrate on the traffic activity around the park-n-ride lots identified by the Atlanta Committee for the Olympic Games (ACOG), as well as the access routes to the lots and the freeway interchanges along the routes. JHK spotters report on conditions every 15 minutes during peak hours (6am to 9am and 4pm to 7pm). The method of communication is by cellular phone directly to a TIS call-taker who manually enters reported information into the ATMS. In addition, JHK hired Showcase Surveillance supervisors. They are responsible for monitoring the TIS Call-Takers, the performance of mobile spotters, repositioning spotters, coordinating spotter operations with a Metro Networks liaison, and reporting equipment malfunctions to JHK personnel.

3.8.2 Legacy

The key to maintaining the TIS supplemental surveillance sites (51 radar and 22 video) would be the costs associated with the 73 phone lines to the surveillance sites. The FES would not necessarily have to be retained for the surveillance to operate, since in "normal" operations surveillance data is fed to the ATMS, stored in a database, where it is available for use (i.e., by the FES). However, the FES could be utilized as a surveillance server, when the ATMS is unavailable, and continue to feed surveillance data to the ATMS. Detailed equipment, communications, and operations information is located in Appendix A.

Continuation of supplemental traffic information from MetroNetworks would require a support contract to outline the extent and cost of the service. It is possible to receive MetroNetworks data without verification, via a terminal (with a printer) in the TMC, but details of this would need to be worked out.

4. Legacy Scenarios

Each of the scenarios outlined below describes the legacy possibilities for retention of TIS Legacy devices/systems. The retention of the HP 200LX is not included in the scenarios because Hewlett Packard has indicated that they do not intend continue operation after the TIS period.

4.1 Scenario 1 - Retain no TIS devices/systems

If the decision is made not to retain any TIS devices/systems, to include the FES, as legacy, the only cost incurred is for the removal of any equipment from the TMC and disposition of the equipment as directed by FHWA.

4.2 Scenario 2 - Retention of the TIS FES

The retention of the FES as a stand alone system, would or could have several uses:

- As a backup to the ATMS and as a repository for static information possibly needed for other ATIS systems.

- Dial-up access for LDS Interface. The system currently has seven (7) modems; phone lines would be needed.

- Use for collection of supplemental surveillance information from TIS sites and manual speed data.

- TRW support needed to either maintain or transition the FES.

4.3 Scenario 3 - Retention of TIS FES Plus

In this scenario, various combinations of TIS devices/systems could be retained. The following tables show detailed costs for retaining the system/device and an operations summary for legacy.

TIS FIXED-END SERVER (FES)

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
(Basic) Operational FES (ATMS, radar & video surveillance, manual interfaces only)	1. Communicate with ATMS via existing ATMS network. 2. Manual data entry from X-Terminals via subnet (10BaseT hub) or via ATMS network. 3. Surveillance site control or data acquisition via two banks of 10 modems each and up to 13 dedicated phone lines. 4. Requires use of existing network connection to MARTA for any client system that uses transit itinerary planning capability.	1. No additional equipment is needed. Maintenance or replacement as needed.	1. Automated interface for data collection from ATMS. 2. Supplemental data entry by Call Takers/Operators 3. Backup/Failover control and data acquisition from slow-scan video and radar sites. 4. System Administration.	1. Minimum configuration for FES functionality would enable ATMS and manual data entry interface; backup/failover control of video and radar sites; backup/failover radar site data acquisition, and necessary System Administration. 2. Basic FES relies on existing ATMS infrastructure for power, phone/PBX, dedicated external circuits and inter-networking connectivity to ATMS and MARTA.

Comments above apply to all enhanced FES systems in addition to those comments enumerated below:				
Operational FES with LDS Interface(s) **(HP 200LX PCD and CATV)**	1. Communicate with external clients using direct null modem serial interface or via modem and phone line. 2. Point of demark is serial port at FES. Media or phone costs are responsibility of client system/user (see Cable TV, Interactive TV or HP200LX sections). 3. MARTA network connection if client system has transit itinerary planning capability.	1. Additional modems or phone lines as needed. 2. Additional serial port concentrators (DigiBoards) as needed.	1. Periodic operational and maintenance checks to insure proper functions of all devices and media. 2. Periodic system administration tasks to insure data currency and stability.	1. Basic FES has two 16 port modem racks equipped with 10 modems each; basic FES uses 10 of 20 modems for radar site control/data access and 3 of 20 modems for video site control. There are currently 7 spare modems, 12 spare modem slots, and one spare phone line. 2. Basic FES has 2 16-port DigiBoards; basic FES uses 13 ports for control/data acquisition of video and radar data and 4 ports for existing TIS ISP systems. There are potentially 19 spare ports for use as LDS serial ports; each LDS port requires either a modem and a phone line or a dedicated serial line circuit (see above).
Operational FES with MSBC Interface (10BaseT/Character-Oriented) **(Web-Site)**	1. Communicate with external client web server using ATMS network or dedicated subnet (10BaseT hub). 2. Point of demark is 10BaseT port at FES hub. 3. MARTA network connection if client system has transit itinerary planning capability.	1. Additional network connectivity via hub, interface boards, etc. Responsibility of client/user system.	1. Periodic operational and maintenance checks to insure proper functions of network media. 2. Periodic system administration tasks to insure data currency and stability.	1. MSBC interface has a character-oriented (verbose) variant format for use via network or low-cost media.
Operational FES with MSBC Interface (Wireless/Bit-Oriented) **(Envoy PCD)**	1. Communicate with external clients using ARDIS PC with EICON board, ARDIS modem(s), dedicated circuit for ARDIS connectivity. 2. Point of demark is input/output port of EICON board. 3. MARTA network connection if client system has transit itinerary planning capability.	1. Additional or new wireless connectivity devices (e.g., DSU/CSU, modems, servers, etc.) And dedicated circuits. Responsibility of client/user system.	1. Periodic operational and maintenance checks to insure proper functions of all devices and wireless media. 2. Periodic system administration tasks to insure data currency and stability.	1. MSBC interface has a bit-oriented (terse/coded) variant format for use over wireless or more expensive usage fee-based media. 2. Use of existing ARDIS: all costs Associated with ARDIS modem(s), dedicated circuit for ARDIS connectivity, ARDIS connect costs, and ARDIS service fees are responsibility of user(s).

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
Operational FES with BAP Interface **(In-Vehicle)**	1. Communicate with external client broadcast system using serial data to FRAD and DSU/CSU via external dedicated circuit. 2. Communicate with multiple external broadcast systems (same media as above) using external software driven network (e.g., DCI).	1. Additional serial port concentrators (DigiBoards) as needed.	1. Periodic operational and maintenance checks to insure proper functions of all devices and media. 2. Periodic system administration tasks to insure data currency and stability.	1. Basic FES has 2 16-port DigiBoards; basic FES uses 13 ports for control/data acquisition of video and radar data. There are 19 spare ports for use as BAP interface serial ports.

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operational FES (Basic)				
System Turnover				
- Deliver system in place (TMC 124, 112, B-09, etc.)				
- Deliver System Documentation				
- Train Call Takers & Technical Support Staff				
System Operation				
- Establish/Transfer maintenance agreements				
-- Hardware (Sun, AdPro, HP, etc.)				
-- Software (Sun, Solaris, Sybase, etc.)				
System Technical Support				
- Establish on-call/resident technical support agreements (Basic FES)				
Options below include above list with changes as noted:				
Operational FES with LDS Interface				
System Technical Support				
- Establish on-call/resident technical support agreements (Basic FES & LDS Interface)				
Operational FES with MSBC Interface (10BaseT/Character-Oriented -or ARDIS Wireless/Bit-Oriented)				

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
System Technical Support				
- Establish on-call/resident technical support agreements (Basic FES & MSBC Interface)				
Operational FES with BAP Interface				
System Technical Support				
- Establish on-call/resident technical support agreements (Basic FES & MSBC Interface)				
DISCONTINUE OPERATION:				
System Removal				
- Remove system hardware and software	P		S	
- Transfer system hardware and software to ATMS (e.g., surveillance site control for radar and video, software for radar data processing, etc.)	P		S	
- Restore resulting infrastructure to "normal" for ATMS operations	P		S	
P: Primary Responsibility S: Secondary/Supporting Responsibility				

Table 4-1

CABLE TELEVISION

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
CABLE TV	Local connectivity 1. Serial interface between FES & TWS 2. Serial Interface between TWS & Multi-Media	1. Service Contract HP TWS Yearly $300 2. Maintenance fund for repair/replacement of audio & video equipment. Estimate $10,000 over a 3 year period.	1. Support contract with ETAK for Multi-Media WS & Traffic WS software communications, & operating environment Annual $35,000 2. Daily operations support to monitor CATV, coordination with TV stations/ Cable providers, etc... 3. Voice over GDOT personnel or contract with Metro Networks @ $60/hr - Metro Networks surveillance monitoring & printer in CATV room	1. The costs is based on a preliminary estimate from ETAK. 2. NOTE: The personal requirements could be combined with support for other TIS systems being transitioned for legacy.

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
Cable TV System Evolution (future)	1. Communications no charge in current configuration (in-house communications links)	1. Replacement of optical recoding equipment with digital technology. 2. Update the Multi-Media & TWS software to Windows NT operating system.		1. The costs is based on a preliminary estimate from ETAK. 2. NOTE: The personal requirements could be combined with support for other TIS systems being transitioned for legacy.

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operational FES with LDS Interface (reference FES Legacy Summary)				
Surveillance: **Video Camera Feeds** (reference Surveillance Legacy Summary) **Optional Surveillance Agreements** - Metro Networks helicopter monitoring - Metro Networks terminal & printer supplemental information system. - JHK roving spotters				
CATV System Turnover - Deliver TIS CATV hardware & software (Rm 119 & 124) - Deliver system documentation - Train operators & technical support staff				
CATV Operations - Operations plan (schedules & staffing) - Establish maintenance agreements - Hardware(ETAK & HP) - Software(ETAK) - Voice-over plan (schedule & staffing) - Recommendation: Purchase spare Traffic Work Station for backup & trouble shooting				
Technical Support (on-site) - Assist operations manager - Analyze and document problems - Coordinate with TV station, software, & hardware technical representatives				
Broadcast via Fiber: **Cobb, DeKalb, & Gwinnett** - Purchase & installation TIS audio equipment (DeKalb & Cobb) - Establish station broadcast agreements - Complete fiber implementation for CATV				

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
Interim Broadcast Agreement: Contract with GPTV to continue broadcast until fiber transition or other broadcast arrangement is completed.				
DISCONTINUE OPERATION:				
CATV System Termination - Disconnect & remove all TIS CATV equipment in the TMC - Deactivate ATMS camera connections - Terminate FES serial communications links - Disconnect audio equipment at TV stations - Inventory equipment & disperse as directed	P		S	

Table 4-2

ON-LINE SERVICES - WEB SITE

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
ON-LINE SVCS - WEB	Internet provider for Georgia-Traveler web site is PeachNet. The yearly cost is $18,000.		"html" - Can be maintained by GDOT or by Maxwell Labs (free) Web Page - Can be maintained by GDOT or by Maxwell Labs (free). If maintained by GDOT, Maxwell Labs retains proprietary rights to "source code" for any changes. See Appendix A Web Site for Maxwell Labs proposal.	

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operation FES with MSBC Interface (10BaseT/Character Oriented)				

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
OLS Operations - Establish maintenance agreements - Hardware (ETAK) - Software (Maxwell Labs, ETAK) - Maintain T1 Communications Link				
Technical Support - Establish web-site support agreement - Establish on-site/off-site support agreements				
DISCONTINUE OPERATION:				
Terminate Web-Site - Disconnect and transfer equipment in accordance with FHWA guidance.	P	S		

Table 4-3

IN-VEHICLE DEVICE

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
IN-VEHICLE DEVICE	Subscriptions for one Year = $200 ($100 for 6 months) - 20 Devices@$200= $4,000.	FRAD Monthly Cost $665 Yearly:$665 X 12 months = $7,980	Support contract with Seimens/DCI for FRAD and In-Vehicle Device comes with the yearly subscription cost.	In-Vehicle devices can be purchased after the TIS period for $1,000 if currently installed; $1,200 plus $170 installation, if installed in another vehicle. The extra $200 is approx cost for new wiring harness. DCI subscriptions cost $100 for 6 months.

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operational FES - FES interface with the Radio Broadcast Data System Bearer Application Protocol (RBDS-BAP).				
In-Vehicle System Operation - Fully functional in-vehicle device installed in a vehicle - DCI FM Subcarrier connectivity - Coordinate DCI subscription				
In-Vehicle Operational/Maintenance Support - System documentation & appropriate training - Operations monitoring & vendor coordination - Coordinate support and maintenance agreement – Hardware (Siemens for In-Vehicle device, and DCI for FM Receiver) – Software (Siemens)				
DISCONTINUE OPERATION:				
- Inventory equipment and return to appropriate vendor/agency. - FHWA will still own 20 In-Vehicle Devices but they will not have traffic situation display capability.	P	S		

Table 4-4

MOTOROLA ENVOY - PCD

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
MOTOROLA ENVOY	1. Monthly Service Charge: $2,300 (115 @ $20) - Yearly: $27,600 2. Monthly Leased Line Charges: $1,495 - Yearly: $17,940 3. Avg Traffic Update: $.40 ; Daily 6 per device: $2.40 ;115@$2.40 $276 per day. - Yearly: 260@ $276 = $71,760	1. The cost to replace an Envoy would be approx: $750 - $900. 2. 2MB PCMCIA cards are approx: $230.	1. Each additional Envoy would cost $65 to register with the ARDIS Network. 2. Spt contract with NETTECH for RF GATE software must be renewed. 3. At minimum one trained person would be needed to maintain ARDIS PC and FES Interface.	1. The costs are based on the number of Envoys owned by FHWA and current commo costs. 2. NOTE: The estimate for one trained person could be combined with support needed for other TIS systems being transitioned for legacy.

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
	4. Avg Route Request: $.44 ; Daily 2 per device: $.88 ; 115 @ $.88 $101.20 per day. - Yearly: 260@ $101.20=$26,312 5. Total commo costs per year: $143,612			

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operation FES with MSBC Interface (Wireless/Bit-Oriented) (Reference FES Legacy Summary)				
Connectivity between ARDIS PC/EICON Board/ FES				
Dedicated circuit for ARDIS Wireless Service connectivity				
System Turnover - Deliver system in place (TMC 124) - Deliver system documentation - Train Technical Support Staff **System Operation** - Establish /Transfer support agreements - Establish/Transfer communications accounts (ARDIS) **System Technical Support** - Establish on-call/resident technical support agreements (ARDIS PC, ARDIS Wireless)				
DISCONTINUE OPERATION:				
System Removel - Inventory system hardware/software - Remove system from TMC - FHWA will own 115 Envoy devices, a PC, and modems	P	S		

Table 4-5

TIS SURVEILLANCE

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
SURVEILLANCE	1. Monthly Service Charge: 73 phones @ $60 = $4,380 Yearly: $52,560 2. Cellular Phones: All Phones were received free of charge. 4 Phones were put into service in February and 28 in July. The monthly fee for each is approx $50. Each is on a 1 year/6 month minimum service contract. The buy out after 6 months is $120. - 32 Phones@$50 month=$1,600 Analysis: - 4 Phones are at 6 month point; buy out: - 4@$120=$480 or - 4@$50=$200 month X 6 months=$1,200 - 27 Phones (1 Phone was lost) are only 2 months into the contract period. - 27@$50 month= $1,350 X 4 months= $5,400. This amount would have to be paid until buy out. - 27@$120=$3,240 - 27@$50 month= $1,350 X 6 months= $8,100.	1. No additional equipment would be necessary. Normal wear and tear replacement. 2. JHK will need the Laptop PC (already paid for by TIS) through Jan 97 to perform diagnostics on RPU's.	1. A metro Networks terminal is located in the call takers room at the TMC. Continuation of this is a no cost option. 2. Continues coverage of traffic situations in the Metro Atlanta are, with verification would have to be renegotiated with MetroNetworks. Current charges for Metro Networks services are: - $50 per hour - 8 hours a day @$50 = $400. - 5 days a week @$400 = $2,000 week - 52 weeks a year @ $2,000 = $104,000 a year - $104,000 assumes either outside perimeter coverage or inside perimeter coverage. If both are needed, the cost would be approximately double ($208,000). 3. JHK has provided estimates of manpower to maintain radar and video sites. These estimates are provided in Appendix A in the surveillance legacy analysis.	1. There is one long distance phone line to Dalton. This phone does not call the TMC unless there is an exceptional occurrence in the traffic situation. Costs, other than the monthly service charge in column one, have not yet been identified by JHK. They will provide this information during their demobilization and transition period. The cost is expected to be minimal. 2. Cellular Phones: JHK will need 4 Phones through the end of the year for continued use monitoring surveillance sites. The other 27 Phones will be available at the end of August 1996.

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Radar Surveillance - Operational ATMS				

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
Video Surveillance Operation - TIS video surveillance sites can currently be viewed and controlled through the TIS system. The camera assignment to the AdPro is done through the TIS video controller screen. The ATMS GUI can select any of the three ADPros and perform PTZ functions for the video cameras. However, the ATMS cannot change the camera that the AdPro is using. - In order for the ATMS to have full functional control of TIS Video sites: -- ATMS GUIs would have to be modified and/or a new GUI created, and/or -- remotely access TIS video controller through the FES (If this is done Full Operation would require an Operational FES. -- If there is no FES, then ATMS would need to develop similar hardware connections to the AdPro (currently the ADPros are connected to the digiboards for TIS)				
System Turnover - Deliver system in place (all Radar and Video Surveillance site equipment) - Deliver system documentation (JHK will provide during their transition and demobilization phase) - Train Call Takers and Technical Support Staff (JHK will provide)				
System Operation - Establish/transfer maintenance agreements for hardware and software.				
System Technical Support - Establish on-call/resident technical support agreements (should be similar to ATMS operation)				
DISCONTINUE OPERATION:				
System Removal - Remove system hardware and software. If a decision is made to discontinue using TIS Radar and Video sites, a further decision would have to be made on whether to physically remove the equipment or leave it in place and turn it off at the TMC (this includes deactivating phone lines). - Inventory system hardware/software				

Table 4-6

INTERACTIVE TELEVISION

TIS SYSTEM/DEVICE	COSTS			COMMENTS
	COMMUNICATION	EQUIPMENT	OPERATIONS	
INTERACTIVE TELEVISION	Local connectivity 1. Serial interface between FES & TWS 2. Serial Interface between TWS & Multi-Media Remote-Dial 3. Dial Line IATV TWS to Head End Server. TMC local line	1. Purchase an HP TWS @ $2000 2. Service Contract HP TWS Monthly $_______ Yearly $_______	1. Support contract with ETAK for Multi-Media WS & Traffic WS software. Annual $_______ 2. Daily operations support to to monitor & coordinate IATV system	1. The costs is based on a preliminary estimate from ETAK. 2. NOTE: The personal requirements could be combined with support for other TIS systems being transitioned for legacy.

SUMMARY				
ACTION	RESPONSIBLE ORGANIZATION			
	TIS	FHWA	GDOT	OTHER
FULL OPERATION:				
Operational FES - Serial Interface Local/Remote to IATV TWS				

IATV TWS:
- System documentation & operators training
- Purchase IATV Traffic Work Station
- Establish maintenance agreements
  - Hardware(HP)
  - Software(ETAK)				

IATV Operational Support - Operations monitoring & vendor coordination				
IT Networks Agreement				
DISCONTINUE OPERATION:				
- Disconnect phone line to TWS in Room 119. - All equipment belongs to IT Networks.				

Table 4-7

5. Summary

The information in this document summarizes the critical items that are needed to identify the necessary requirements to operate and maintain the various devices/systems that make up the TIS as a legacy. Combined with the information in the attached Appendix A, all elements necessary to make a decision should be available. Once a decision is made on which devices/systems will be maintained beyond the TIS Showcase period, detailed legacy transition plans and schedules will be developed.

In preparation for the legacy, all TIS systems were designed, engineered, and developed to allow transfer of critical parts of the system to other supporting entities such as Georgia DOT and/or GerogiaNet. Systems were designed to be compatible with the strategies developed and implemented by the Georgia DOT ATMS. In an effort to minimize maintenance and support issues, TRW was selected as the development contractor for the Fixed End Server (FES).

Since the TIS has been operating in the ATMS environment, minimal changes would be necessary for legacy. However, the system will potentially require additional GDOT staffing for operational and maintenance support. NOTE: Georgia DOT has requested that the TIS surveillance equipment remain in place and that full operation of the hardware be transferred to the ATMS staff at the end of the TIS. This will be accomplished by the TIS team member JHK in late 1996.

APPENDIX A

LEGACY ANALYSIS
FIXED END SERVER

1. EQUIPMENT: Also see attached inventory sheet provided by TRW.

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
EQUIPMENT ROOM				
Vertical Equipment Rack(ICXFR-317819)	Emcor		Owned	2Ea
SPARC Station 20	SUN	$33,388	Owned	2 Ea ($16,694 each)
External Tap Unit (4mm) (411)	SUN	$2,178	Owned	2 Ea ($1,089 each)
External Disk Unit (2x2.1GB)	SUN	$3,828	Owned	2 Ea ($1,914 each)
20" Monitor (GDM-20D10)	SUN	Part of SPARC Sys	Owned	2 Ea
Serial Port Concentrator	DigiBoard	$837	Owned	2 Ea
Radar Site A/B Switch Unit	BlackBox	$1,110	Owned	2 Ea; #1:1-5, #2:6-10 ($555 each)
Video Site A/B Switch Unit	BlackBox	$302	Owned	
Ethernet Hub (LMR8T)	Lantronix		Owned	2 Ea (#1, #2)
CALL TAKER ROOM				
Envizex Xterminal (C2731A)	HP		Owned	5 Ea (1:SysOp, 3:Call Taker, 1:JHK Supervisor)
19" Monitor (HM-4020-D)	HP		Owned	5 Ea

2. COMMUNICATION:

A. ATMS Interface: The FES requires a network connection (minimum of 10BaseT Ethernet) for transfer of traffic situational data (e.g., incidents, speed). This connection is currently active and is part of the TMC ATMS infrastructure. Some housekeeping and re-wiring costs to sustain in operation for legacy.

B. MARTA Interface: The FES requires a network connection (minimum of 10BaseT Ethernet) for query/response of transit itinerary planning data (e.g., navigational maneuvers for use of MARTA bus and rail). This connection is currently active and is part of the TMC ATMS-MARTA infrastructure. No action or additional cost to sustain it in operation for legacy.

C. Other (External Devices/Systems): All other FES communications to/from existing or new external devices or systems (e.g., ARDIS, frame relay for BAP, LDS subscribers via dial-up access, Digital DJ, etc.) are fee or usage based and are the responsibility of that client subscriber device or system. Refer to Envoy, in-vehicle, or web site discussions for details of their communications requirements.

3. MAINTENANCE:

A. HARDWARE: See above table. Normal replacement maintenance.

B. SOFTWARE: Continue or establish maintenance and support agreements for:

(1) Operating System: Solaris 2.4

(2) Database System: Sybase 10.0

(3) Application(s):
(A) TransView Engine: TRW/Version 2.0
(B) Showcase Value-Added: TRW/Version(s)

(4) Third-Party Database(s):
(A) Mapping Data: NavTech (data and API code libraries), Yellow Pages.
(B) OAG Flight Schedules, Greyhound, AmTrak (Manually entered)

4. OTHER COSTS/CONSIDERATIONS:

A. TRAINING:

(1) Operators (Call Takers): GDOT staff will require training on basic FES functions and GUI operations. This will include: system operator terminal startup, navigation techniques, traffic information data entry and management procedures, surveillance site control (via terminal GUI and using manual control), and system shutdown.

(2) Systems Administration: GDOT staff will require training on the unique aspects of FES UNIX SysAdmin as it applies to the Solaris operating system, Sybase database engine, and the Showcase-unique application architecture (e.g., networking, data tables and elements, directories, etc.). This includes system initialization, main and cold boot/restart, troubleshooting, etc.

B. OPERATIONS:

(1) Normal Operations: the FES (Showcase) will operate in a hands-off or operator-assisted mode. In the hands-off mode, the FES will draw traffic situational information (incidents and speed) from the ATMS. This information is then disseminated to external systems

via dedicated interfaces. In the operator-assisted mode, supplementary information can be entered by the Operator/Call Taker to amplify the traffic-related situation in terms of information of use to the traveler.

(2) Failover Operations: the FES could be used as a limited backup for the ATMS in terms of surveillance site control and acquisition of radar data. This mode requires System Sdministration action to invoke "failover", and again to restore normal operations.

DRAFT

Project Number Showcase

Battelle
. . . Putting Technology To Work

Internal Distribution

Barbara Harrelson
Gary Seebode
Jerry Pittenger
Dave Williams
Mort Serrell
files

Date August 22, 1996

To Distribution

From Don Creighton

Subject Expansion Capabilities of Fixed-End Server (FES) to Accommodate Dial-Up Access to Landline Data System (LDS)

The following information is provided in response to a request to examine the expandability of the FES to allow dial-up access to the LDS interface.

The FES architecture currently has two modem racks with sixteen (16) slots each. There are ten (10) modems mounted in slots 1-10 in each of these two racks. From the outside world, each modem rack has a 25-pair TELCO cable connected to it. One of the racks is currently used for radar site control and data acquisition--all ten of these modems are dedicated to that purpose. In the other rack, three of the ten modems are in use for video site control and viewing. There are thirteen (13) dedicated phone lines assigned to the FES for this purpose--ten for the radars and three for the video. These thirteen lines are connected to the modem racks through the mentioned 25-pair TELCO cables. The serial connection from the modem to the FES is via a serial port concentrator (aka DigiBoard). Each of these DigiBoards has sixteen (16) ports, matching the capacity of the modem rack itself. These same DigiBoard ports are in use for purposes other than modem connections, so there is not a one-to-one correspondence in availability of DigiBoard ports to modem slots. Therefore, there are seven spare modems ready for use, an additional twelve spare modem rack slots and fifteen spare DigiBoard ports in the existing equipment suite.

The limitation in expansion of this interface to accept additional user dial-up ports is:

1. Telephone Line: can add seven (7) phone lines to existing suite. Cost: (none)
2. Modems: after adding seven phone lines, each new line (8, 9, ... 15) will require a new modem in one of the 12 spare modem rack slots. Cost: $135/modem
3. DigiBoard: after adding 15 phone lines, using the 7 spare and adding 8 new modems, the next phone line/modem pair will require a new DigiBoard with 16 ports. Cost: $135/modem + $837/DigiBoard
4. Modem Rack: after adding 19 phone lines, using the 7 spare and adding 12 new modems and a DigiBoard, the next line will require an additional modem rack with 16 slots and a 25-pair TELCO cable. Cost: $135/modem + $837/DigiBoard + $?/Modem Rack

... and why is that hot dogs come ten to a package and hot dog buns come eight to a package?

This expansion can occur with minimal impact on the performance of the FES.

DRAFT

P.O	Vendor	Description	Cost
EB5203	Hewlett Packard	16MB Memory Module	$ 2,049.60
EB5252	International Computer	Modem	$ 135.00
EB5256	Hewlett Packard	Compter	$ 2,553.00
	Hewlett Packard	Keyboard Unit	$ 67.20
	Hewlett Packard	16MB Memory Module	$ 716.80
EB5257	Hewlett Packard	System Support	$ 76.80
EB5264	Interface Electronics, Inc.	Cable	$ 10.36
	Interface Electronics, Inc.	Cable	$ 9.25
	Interface Electronics, Inc.	Cable	$ 4.50
EB5265	Crenlo, Inc.	Equipment Shelf	$ 67.95
EB5267	International Computer	Outlet	$ 8.00
	International Computer	Hub	$ 82.00
EB5271	Accu-Tech Corporation	DB9 to RJ45 Adapter Male	$ 20.00
	Accu-Tech Corporation	DB25 to RJ45 Adapter Male	$ 15.00
EB7836	Digi International	C/CON - 16 RJ45	$ 837.00
705009		24 Port TPM1M	$ 2,340.00
322239	Sun	4MM Dat Tape	$ 1,089.00
		SPARC 20 MP	$ 16,694.70
		64MB Expansio	$ 2,508.00
		1GB Internal	$ 528.00
		CD Internal	$ 264.00
		SCSI Card	$ 722.70
		US Country OP	$ -
		Solaris 2.X	$ 66.00
		System Docume	$ 148.50
		CTT Products	$ 6,828.60

P.O	Vendor	Description	Cost
322239		Solstice Back	$ 1,596.00
		Motif Tool Ki	$ 295.00
		4.2 GB Ext	$ 1,914.00
322241	Sun	4MM Dat Tape	$ 1,089.00
		SPARC 20 MP	$ 16,694.70
		64MB Expansio	$ 2,508.00
		1GB Internal	$ 528.00
		CD Internal	$ 264.00
		SCSI Card	$ 722.70
		US Country OP	$ -
		SOLARIS 2.X	$ 66.00
		4.2 GB Ext	$ 1,914.00
322244		10 Base T Cables	$ 105.00
402132		Open Client C	$ 477.00
		SMP Access Fee SQL	$ 3,750.00
		SQL Server Mgr	$ 600.00
		SA Companion Utility	$ -
		SYBASE SQL Server	$ 5,760.00
402133		DIGI EPC/X SY	$ 5,790.00
402137		Rack Box w/5 ABC Switches	$ 1,109.60
		Rack Box w/3 ABC Switches	$ 301.77
		RS 232 to Rs-485 Interface	$ 166.00
702597		ENV1ZCK Terminal	$ 13,072.80
		Keyboard	$ 348.00
			$ 96,913.53

APPENDIX A

LEGACY ANALYSIS

PCD - MOTOROLA ENVOY

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Personal Communications Device	Motorola	Range: $750 - $1,395	Owned	There are currently 115 Envoys on-hand that will be transitioned during the legacy period.
PCD - PCMCIA Card		$230	Owned	
Pavilion 7020 75MHz Multimedia PC	HP		Owned	ARDIS Server
Multiscan 14" Display	HP		Owned	
EICON Interface Board	EICON		Owned	
RF Gate License	NETTECH	$2,000		Support must be renewed
Magic Exchange (3 copies - 2 for PC and 1 for MAC)		$200		This software ports the TIS Software from PC or MAC to the Envoy.
Telebug Box	Metrowerks			Software to port TIS Software to MAC for debugging
Code Warrior	Metrowerks	$400		This s/w was used by Fastline to develop the TIS software

2. COMMUNICATION:

The Motorola Envoy PCD utilizes the ARDIS network to communicate. The costs for this service are currently:

DESCRIPTION	ITEM	COST	COMMENTS
Envoy Account Set-up Charge	One Envoy	$65.00	This is a one time charge to add an Envoy to the ARDIS Network.
Monthly Service Charge	One Envoy	$20.00 ($2.300)	This is a monthly charge for each Envoy registered with the network.
Monthly Phone Charges	Leased Line	$1,495	

Sample Charges for Envoy User Request. (Request is in two parts: Request and Response)	**Update:** - **Traffic Request** (1 Packet) -Parking (14 Char) -Congestion (24 Char) -Incident (24 Char) - **Traffic Response** -Parking (1 Packet + 194 Char) -Congestion (1 Packet + 64 Char) -Incident(s) (Avg 1 Packet + 200 Char [5 Incidents]) **TOTAL:**	 $.06 $.0042 $.0072 $.0072 $.1182 $.0792 $.12 $.396	These are average requests. - Cost of Packet=$.06 (Peak) - Cost of Packet=$.04(Off Peak) - Cost per Character=$.0003 (Char: Body-180, Header-14) (Char: Body-50, Header-14) (Char: Per Incident Body-26, Header-14)
	Route: - **Route Request** (1 Packet) - Address to Address (114 Char) - POI to POI (18 Char) - Address to POI (66 Char) - **Route Response** - Avg # Packets 3 - Char per Packet 198 Therefore Total Route Request Cost would be (average): - Add/Add: Request/Response - POI/POI: Request/Response - Add/POI: Request/Response	 $.06 $.0342 $.0054 $.0198 $.18 $.1782 $.4524 $.4236 $.438	Char: Header-14 Char: Address-50 Char: POI-2 Char: Long/Lat-8 (Not currently used)

3. MAINTENANCE:

A. HARDWARE: See above table, paragraph 1. Normal replacement maintenance. Manufacturers warranty will be transferred with the equipment.

B. SOFTWARE:

1. Envoy:

- TIS software (currently version .39) developed by Fastline is a deliverable along with applicable code. Support agreement, if applicable, would need to be worked out with Fastline.

2. ARDIS PC:

- TRW developed software, written in C++, to interface RF Gate with the FES. Source code is a deliverable from TRW.

- NET TECH software. RF Gate license has been purchased but support agreement, if applicable, would need to be worked out with NET TECH.

- Windows NT.

3. Other:

- Magic Exchange Software.

- Code Warrior Software from Metrowerks. Software has been paid for but support agreement, if applicable, would need to be worked out with Metrowerks.

4. OTHER CONSIDERATIONS:

A. TRAINING:

1. Training for ARDIS PC, and related interfaces to the FES, are a TRW deliverable.

2. Training on Envoy related equipment (Telebug box, Code Warrior, TIS Software) would need to be worked out with Fastline.

B. OPERATIONS:

1. All elements to support the current number of Envoys in use are in place. The addition of Envoy users/devices may require a system upgrade.

2. To date, neither Fastline nor any other ISP has request support for creating a legacy PCD market in Atlanta.

3. The DSU is supplied free of charge by ARDIS as long as the system remains active.

APPENDIX A

LEGACY ANALYSIS
PCD - HP 200LX

1. **EQUIPMENT:**

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
All equipment related to the operation of the HP 200LX (ETAK Transportation Work Station [TWS], Modem connected to a leased telephone line, and the SkyTel communications system), will be removed from the TMC at the conclusion of the TIS period.				

2. **COMMUNICATION:**

A. All communications utilized by the HP 200LX device will be discontinued at the end of the TIS. This includes connections from the TWS to the FES.

3. **MAINTENANCE:**

A. HARDWARE: See above table.

B. SOFWARE:

1. The application software (Travel Guide) in the HP 200LX is a deliverable from Hewlett Packard.

2. The software developed by ETAK/Hewlett Packard for the TWS is a deliverable at the conclusion of the TIS. This includes both any original software developed as well as any modified software. NOTE: Some of the software for the TWS was developed by Hewlett Packard for another project, and was modified to work with the TIS system.

4. **OTHER CONSIDERATIONS:**

A. TRAINING: No training requirements exist.

B. OPERATIONS: No requirements and/or operational considerations.

APPENDIX A

LEGACY ANALYSIS
IN-VEHICLE NAVIGATION DEVICE

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
In-Vehicle Device (20 plus 1 Bench Unit) Device includes: - Display Screen - Wiring Harness - CPU - DCI FM Receiver - Supplemental Antenna - GPS Antenna - Hard Disk - Electronic Interface for DCI Receiver to CPU	Siemens	 $1,000 $ 375* $ 30 $ 230 $ 100	20 Owned by FHWA 1 Bench Unit On Loan	Units are currently located in vehicles owned by: 6 - GDOT 9 - FHWA 1 - FTA 1 - FRA 1 - FAA 1 - MARTA 1 - NHTSA 1 - Bench Unit Room 307, TMC * TIS bought 20 Receivers for a total cost of: $7,500. The 20 In-Vehicle systems cost approximately $2,000 each for a total cost of $40,000. In-Vehicle devices can be purchased after the TIS period for $1,000 if currently installed; $1,200 plus $170 if installed in another vehicle. DCI subscriptions cost $100 for 6 months.
Excalibur DAP (DSU/CSU)	Racal	No Cost	On Loan	Comes with the system at no additional cost.
Frame Relay Access Device (FRAD)	Motorola	$1,500		
FRAD Installation		$1,200		One time cost.

2. COMMUNICATION:

- The In-Vehicle device receives traffic situation data via an FM Subcarrier. Four radio stations in Atlanta and the surrounding area (100 mile radius), as well as one station in Savannah, provide the means to broadcast the signal once received from the TMC.

- The following table shows the communications costs:

DESCRIPTION	ITEM	COST	COMMENTS
FRAD Monthly Cost	Service	$ 665	Yearly: $7,980
Subscriptions for one Year	DCI Service	$ 100 (See Note)	The TIS is currently paying for 100 devices. For legacy, 20 units are owned by FHWA. Yearly: 20 @ $100 = $2,000 NOTE: The additional charge of $100 per subscription for 100 mile radius vice the normal 50 mile radius, was waived by DCI for the TIS. Consequently, there could be an additional charge of $2,000 for a total of $4,000. After the TIS period DCI subscription costs will be $100 for six months. 20 @$200 per year = $4,000.
Software to Process Data Through Network		$4,000	One time cost.

3. MAINTENANCE:

A. HARDWARE:

1. See above table, paragraph 1. Normal replacement maintenance. Manufacturers warranty will be transferred with the equipment.

2. Support contact for maintenance on the FRAD (TMC), DCI Receivers, and CPU (mounted in the vehicle).

B. SOFTWARE:

1. Software developed by DCI to process data through the network.

4. OTHER COSTS/CONSIDERATIONS:

A. TRAINING:

- No training would be required for the In-Vehicle devices since they are currently being operated by the agencies listed in paragraph 1.

- Training may be required to troubleshoot the DSU/CSU, FRAD, and FES connection.

B. OPERATIONS:

- A support contract with DCI for the maintenance of the FRAD or CPU would need to be developed.

APPENDIX A

LEGACY ANALYSIS
CABLE TELEVISION

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Cable TV Equipment (Room 119)				
Vectra XM Desktop PC	HP	4080	Owned	Traffic Mgmt WS
Ultra VGA 1280 Monitor	HP	800	Owned	
Vectra XM Desktop PC	HP	5400	Owned	Multi-Media WS
Ultra VGA 1280 Monitor	HP	800	Owned	
TV Monitor 13" CT-1384YY	Panasonic	350	Owned	
TV Monitor 13" Trinitron PVM-1350	Sony	825	Owned	
Digital AV Mixer	Panasonic	6700	Owned	
Video Cassette Recorder	Panasonic	4800	Owned	
Rewrittable Optical Disk Recorder (LQ-4000)	Panasonic	10000	Owned	
Rewrittable Disk Cartridge (2 @ 1000 each)	Panasonic	2000	Owned	
Optical Disk Player (LQ-4002)	Panasonic	4500	Owned	
VLXi VLX-I-RM VLX-I-3	VideoMedia	4000	Owned	
VLAN PRO1	VideoMedia	4000	Owned	
Video Switch (8in/2out)	Serra Video	3300	Owned	Select from up to 8 video inputs
Titler w/Keyboard	FOR-A	1215	Owned	

Scan Do Pro	Communication Specialities, Inc	2100	Owned	VGA Capture
VLXi (2 in one box)	VideoMedia	600	Owned	

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Cable TV Transmission Equipment (TMC & TCCs)				
(2) Audio Distribution Amplifiers @ 250 each	Leitch	500	Owned	TMC Rm 124
Video Distribution Equalizing Amplifier	Leitch	250	Owned	TMC Rm 124
(3)Audio Encoder 4 Channel @ 2200 each	C-COR	6600	Owned	TMC Rm 124
Audio Decoder 4 Channel	C-COR	2200	Owned	Installed at Clayton TCC
Audio Decoder 4 Channel	C-COR	2200	Owned	Installed at City of Atlanta TCC
Audio Decoder 4 Channel	C-COR	2200	Owned	Installed at Gwinnett TCC
TOTAL		**13950**		

New equipment required to complete the CATV deployment to DeKalb and Cobb county over the Fiber Link:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Cable Television AudioTransmission Equipment:				
(2)Audio Encoder 4 Channel @ 2200 each	C-COR	4400		TMC
Audio Decoder 4 Channel	C-COR	2200		DeKalb TCC
Audio Decoder 4 Channel	C-COR	2200		Cobb TCC

TOTAL		8800		

2. COMMUNICATION:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
OZ -PCE Application	Video media	2000		
Serial Communications link from TWS to FES	In-house	0		If equipment is external to TMC, a modem & external phone line are required.
Serial Communications link from TWS to Multi media	In-house	0		If TWS WS is external to TM, a modem & external phone line are required.
TOTAL		2000		

3. MAINTENANCE:

A. HARDWARE: See Table 1.

Replacement cost.

B. SOFTWARE

We are in the process of reviewing an initial cost estimate provided by ETAK for maintaining and supporting the ETAK Traffic and Multi-Media work Stations software. This is off site support and does not include daily operational support and/or initial problem assessments by the on-site technical staff. All hardware and vendor operating system software would be placed under the vendors maintenance contract if available. Otherwise, ETAK would (under their support contract) assess the problems and coordinate the repair or replacement of the equipment to ensure continuous operations of the CATV system. Also, transitioning the system to Windows NT should be considered. Microsoft support for Windows 3.1 may not be available in the long term due to Windows NT & Windows 95 deployment.

1. ETAK Traffic Workstation

- Operating System: Microsoft Windows 3.1
- ETAK TWS Application: Receives, processes & distributes the traffic information over serial communications links.

2. Multimedia Workstation

- *Receiver Program*: Receives traffic data from the TWS
- Data is plotted on the speed and incident maps for the presentation
- *Script Player Program*: Controls the multimedia presentation and devices (mixer, laser disk player, video switch). The information from each devices is selected in a predetermined sequence for broadcast.

3. Video & Audio Presentations

Pre-Recorded video & audio presentation material is played on a laser disk player and incorporated into the TIS CATV. Changes to presentation material would require a contract to create and/or acquire new material.

4. OTHER COSTS/CONSIDERATIONS:

A. TRAINING:

1. Operational training for the ETAK TWS and the Multi-Media Work Station is part of the TIS deliverable.

B. OPERATIONS:

1. All elements to support the Cable TV system are installed and operational.

2. CATV should operate on a dedicated traffic work station to ensure timely transmission of data to the CATV multi-media work station.

3. If the CATV equipment is off site, a dial line or low speed dedicated circuit would be required to transmit data to the CATV TWS.

C. Future System Expansion Tasks:

Task that go beyond routine maintenance may to negotiated on a case-by-case basis. The following task could be considered:

1. Additional Live-Video Feeds: Expanding the video feed beyond the current 4 that are implemented. The hardware is in place to support 8 video feeds, but software revisions would be required.

2. System Hardware Upgrade: Implement new digital video technology to replace the video recording and playback analog hardware with digital hardware. This would improves reliability and the system would be less expensive to maintain and easier to use.

ETAK
The Digital Map Company

13 August 1996

Ms. Barbara Harrelson
System Resources Corporation
400 Virginia Av., S.W.
Washington, DC 20024

Dear Ms. Harrelson:

This letter is in response to your request regarding proposed terms from Etak to support and maintain the Atlanta Traveler Information Showcase Cable TV system beyond the present 30 September 1996 contract period. We propose to provide this support on a time-and-materials basis at Etak's standard engineering rate of $135 per hour, plus expenses. We would suggest a tasking agreement with the following components:

1. Maintenance -- An initial one-year "not-to-exceed" maintenance and support task of $35,000 that would include up to 200 hours of labor ($27,000), up to 2 person-trips to Atlanta ($6,000), and miscellaneous expenses ($2,000 allowance for parts, supplies, and outside repairs) for routine support and maintenance of the system. This effort would be billed on an "as-needed" basis with verbal and/or written concurrence from the customer for each expenditure. The work would cover bug fixes, minor enhancements, and needed repair and maintenance of the hardware and software systems. Hardware parts and repairs not covered by manufacturers warranties would be charged to the customer at cost. This maintenance contract would also cover standard upgrades when Etak releases new versions of the TrafficWorkStation software. The contract not-to-exceed amount could be increased by mutual agreement if the desired/required efforts turn out to be greater than anticipated. However, it is our belief at this time that the needed maintenance can be provided for $35,000 or less for the first year. This maintenance agreement could be extended on a similar basis for subsequent years by mutual agreement.

2. System Modification and Enhancement Tasks -- These tasks would be negotiated on a case-by-case basis for Cable TV system modifications and enhancements that go beyond routine maintenance. Examples include:

2.1 **More Live-Video Feeds** -- We understand that there is a desire to utilize more live-video feeds than the 4 presently implemented (for example, video from a helicopter-borne camera. The Etak-provided hardware can handle up to 8 video feeds, but some software revisions would be necessary. We estimate the cost of these revisions to be about $15,000 (80 hours of labor for $10,800, travel for $3,000, and miscellaneous parts and supplies for $1,200).

2.2 **Expanded Coverage** -- We also understand that there is a desire to increase the system display coverage to extend further beyond Atlanta, particularly to the north. We estimate the costs of doing so to be about $17,000 (100 hours of labor for $13,500 plus travel for $3,000 and miscellaneous for $500).

2.3 **System Hardware Upgrade** -- New digital video technology is now becoming available and affordable that will permit replacement of much of the video recording and playback analog hardware with digital hardware. We anticipate that this digital equipment will be easier to use, more reliable, and simpler and less expensive to maintain. We expect within the next year to develop CATV systems using this new hardware for at least two MDI projects (Seattle and Phoenix) and for at least one FOT (TravInfo). Hence, we recommend waiting for the digital CATV system development to be paid for by these other projects. However, once the development has been accomplished, the Atlanta CATV system could be upgraded for about $17,000 ($6,000 for a TARGA board, $1,500 for a SCSI hard drive, $5,400 for labor, $3,000 for travel, plus $1,100 for miscellaneous parts and materials).

2.4 **Other Upgrades and Enhancements** -- Additional tasks could be undertaken on a case-by-case basis as mutually agreed between the customer and Etak. Each task could be performed on a time-and-materials basis or on a fixed-price basis, whichever was mutually deemed most appropriate.

I hope this information will be satisfactory for your present planning purposes. Please contact me with any questions or for additional information.

Sincerely,

Lawrence E. Sweeney, Jr., Ph.D.
Vice President and General Manager
Intelligent Transportation Systems

APPENDIX A

LEGACY ANALYSIS
INTERACTIVE TELEVISION

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Vectra XM Desktop PC	HP	Included in CATV cost	Owned	Traffic Work Station - Serves CATV & IATV
Ultra VGA 1280 Monitor	HP	Included in CATV cost	Owned	
Sportster 14.4 Fax/Modem	US Robotics		Owned	
Dial Communications Line	TMC/Bell South			

2. COMMUNICATION:

Communications lines is dial line operating at 14.4 Kpbs.

3. MAINTENANCE:

A. HARDWARE:

It is recommended that the IATV operte on an independent work station. An additional system should be purchased for approximately $2000.

B. SOFTWARE:

We are in the process of reviewing an initial cost estimate provided by ETAK for maintaining and supporting the Traffic Work Station software. This is off site support and would not include daily operational support and/or initial problem assesssments. This would be accomplished by on-site technical staff. All hardware and vendor operating system software would be placed under the vendors maintenance contract if available. Otherwise, ETAK would (under their support contract) assess the problems and coordinate the repair or replacement of the equipment t oensure continuous opererations of the IATV system.

ETAK Traffic Workstation

- Operating System: Microsoft Windows 3.1
- TWS Application: Receives, processes & distributes the traffic information over serial communications links.

IATV Head End Server

The software and operating system on the Head End Server is the full responsiblity of the IATV System provider.

4. OTHER COSTS/CONSIDERATIONS:

A. TRAINING:

Training for the IATV Traffic Work Station located in the TMC Equipment Room (124), would be provided by ETAK.

B. OPERATIONS:

To provide traffic information to other vendors/cutomers/general public, dial-up ports to the FES using the LDS interface could be provided. The user systems would receive only traffic data in a "firehose" mode from the FES. The IATV TWS interface to the FES, is a serial direct interfaces and could transition to the dial-up if the IATV TWS is moved off site for a vendor.

APPENDIX A

LEGACY ANALYSIS
ON-LINE SYSTEM - WEB SITE

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Gateway 2000 Desktop PC	Gateway		Owned	
Gateway Vivitron 15" Monitor	Gateway		Owned	
Sporster 28.8 Fax/modem	US Robotics		Owned	
T1 DataSmart CSU/DSU Dual Port/V.35	ADC Kentrox		Owned	
Router	Bay Networks		Owned	
Network Hub	Baystack		Owned	Not currently used

2. COMMUNICATION: The Internet provider for the Georgia-Traveler web site is PeachNet. The cost of this connection (T1 line) is $18,000 per year.

3. MAINTENANCE:

A. HARDWARE: See above table. Normal replacement maintenance.

B. SOFTWARE:

- Operating System: Web Server NCSA
- Traffic Processing Application Software (Maxwell Labs)
- Netscape Communications Navigator/Mosaic World Wide Web server software.

4. OTHER COSTS/CONSIDERATIONS:

A. TRAINING: Training for the Web server located in the TMC Equipment Room (124), would be provided by Maxwell Labs.

B. OPERATIONS:

- The Web Site can be handled remotely, with back-up on site at the TMC.

- Maxwell Labs can maintain the "html" pages at no cost to GDOT. However, if Maxwell Labs does not maintain the "html" pages, they would want an agreement with GDOT to use the pages as "marketing tools".

- The web page for Georgia-Traveler includes "source code" for accessing the FES for route requests from user and for traffic updates. The "source code" is proprietary. Maxwell Labs can provide a license to GDOT to use the code at no cost. However, if any changes needed to be made to the "source code", Maxwell Labs would then charge GDOT.

- A formal agreement between GDOT and Maxwell Labs would need to be developed for the above mentioned items.

APPENDIX A

LEGACY ANALYSIS

SURVEILLANCE

1. EQUIPMENT:

DESCRIPTION	VENDOR	COST	STATUS	COMMENTS
Traffic Management Center				
VST 10CA XCVR(4)	ADPRO	$12,156		All equipment was purchased/owned by TIS project. A detailed cost sheet is attached. 4@$3,039
VM85 Keyboard	ADPRO	$ 1,296		
VMD Programmer	ADPRO	$ 217		
XMTR w/RS232 (25)	ADPRO	$54,810		25@$2,610
ABC DB9 Switch (3)	Black Box	$ 210		3@$70
ABCDE DB9	Black Box	$ 107		
15" SVGA Monitor	Magtronic	$ 310		For 486DX4 100 PC
486DX4 100 Laptop PC	Magtronic	$ 1,370		
486DX4 100 PC	Magtronic	$ 949		
Equipment Racks (2)		$ 2,534		2@$1,267
Protocol Converter	COHU	$ 200		
20" Video Monitor (3)		$ 3,481		3@1,160.50
Located On-Site				
Video Camera Assembly (25)	Burle	$82,101		21@$3,281 4@$3,300
Control Receiver (26)	COHU	$38,232		21@$1,482 5@$1,422

Protocol Switch (RPU) (58)	Z-World	$ 23,337		
Master Control Panel	COHU	$ 2,355		
Preset Panel	COHU	$ 650		
Construction Materials		$ 5,011		
Poles (Various Lengths) (59)		$ 38,092		
Equipment Cabinets (55)		$103,125		55@$1,875
28.8 Modem (Sportster) (88)	US Robotics	$ 15,894		55@$182 25@$181.70 8@$167.78
Radar Detector (116)	Wheelen	$107,685		110@$961 6@$1.130
On-Hand JHK				
Software for Local Control of MPC-D-111 Receivers		$ 495		
Spare Parts		$ 3,100		
Remote RS-232 Display (2)	Wheelen	$ 426		
Cellular Phones (32)		$ 1,483		3@$59.95 29@$44.95 Phones are for spotters.

NOTE: A comprehensive equipment listing, provided by JHK, of surveillance equipment is attached.

2. COMMUNICATION:

A. There are 73 phone lines utilized for communicating to TIS surveillance sites. The monthly charge for each line is $60.00 ($4,380). The TMC calls each radar site every 5 minutes to poll the site for speed data.

B. Only one of 73 phone lines, Dalton, is a long distance phone call from the TMC. This phone line does not call the TMC unless there is an exceptional occurrence (major change in the traffic situation). Therefore, the cost of this line is considered minimal. Exact charges will be available from JHK during their demobilization and transition period.

3. MAINTENANCE: A worksheet of resources for the surveillance system support is attached.

A. HARDWARE:

- See above table, paragraph 1. Normal replacement maintenance.

- JHK has provided estimates of manpoower and resources to maintain radar and video sites. These estimates are provided as an attachment to this Appendix.

B. SOFTWARE:

1. JHK developed firmware for Radar Processing Units (RPU). The source code will be provided by JHK.

2. MPC Receiver (COHU) software purchased by JHK provides for local control of cameras at the site cabinet. A PC can be connected to the cabinet for testing or monitoring activities at the site.

3. JHK developed software, to call out to the RPUs for operational checks, will be provided during the demobilization and transition period.

4. All other software is FES/ATMS resident and is deliverable by TRW.

4. OTHER CONSIDERATIONS:

A. TRAINING:

1. JHK will provide training materials and instruction during their demobilization and transition period.

B. OPERATIONS:

1. TIS surveillance sites have not interfaced with the ATMS to date. Additional training and/or testing support may be required once this connection is made.

2. JHK hired spotters to supplement TIS surveillance systems. The cost to JHK was $10.00 an hour plus overhead for each spotters, as well as reimbursement of $.25 per mile for their privately owned vehicles. Total costs for spotter support can be obtained from JHK at the conclusion of the TIS period.

3. Metro Networks was hired to cover the traffic situation outside the perimeter (plus Savannah in weeks 8 and 9) during the period 1 June 1996 through 28 August 1996. All reports had to be verified by either air or by vehicle. The cost

for this coverage was $29,200.

4. Metro Networks was also hired to cover inside the perimeter if the system was in the "failover mode" (no ATMS traffic data). This period was from 1 June 1996 to 25 August 1996. The following is a breakdown of this cost:

- 2 X 4 hours per day = 8 hours per day @ $50 per hour = $400 per day.

- 5 days per week = 40 hours per week @ $50 per hour = $2,000 per week.

- 13 weeks @ $2,000 = $26,000.

- Total for Metro Networks coverage = $55,200 (13 week period).

Surveillance Site Equipment Costs

Item Description	Unit	Qty.	Unit Price	Tot. Price
Adpro VST 10CA XCVR (Transmitter/Receiver)	ea	4	3,039.00	12,156.00
Adpro VM 85 Keyboard	ea	1	1,296.00	1,296.00
Adpro VMD Programmer	ea	1	217.00	217.00
Adpro XMTR with RS-232 (Transmitter)	ea	25	2,610.00	54,810.00
Black Box ABC DB9 Switch	ea	3	70.00	210.00
Black Box ABCDE DB9 Switch	ea	1	107.00	107.00
Burle Video Camera Assembly	ea	21	3,281.00	68,901.00
	ea	4	3,300.00	13,200.00
Cellular Phones	ea	3	59.95	179.85
	ea	1	44.95	44.95
	ea	28	44.95	1,258.60
Cohu Control Receiver	ea	21	1,482.00	31,122.00
	ea	5	1,422.00	7,110.00
Cohu Master Control Panel	ea	1	2,355.00	2,355.00
Cohu Preset Panel	ea	1	650.00	650.00
Cohu Protocol Converter	ea	1	200.00	200.00
Construction Materials				
7-Conductor, 18 AWG, Shielded Tray Cable	ft	5000		1,510.00
	ft	1000		294.11
9-Conductor, 18 AWG Unshielded Tray Cable	ft	1500		373.50
	ft	1000		329.50
12-Conductor, 18 AWG Shielded Cable	ft	1500		682.50
	ft	1000		447.05
Alpha 1855/19-1 AWG 22 (19), White	ft	100	0.17	17.00
Alpha 1855/19-3 AWG 22 (19), Red	ft	100	0.17	17.00
Alpha FIT-22IV-3/32 Shrink Tubing	ft	16	0.00	0.00
AMP 413589-9 BNC Plug	ea	85	2.28	193.08
AMP 58531-1 BNC Connectors	ea	1	91.18	91.18
AMP 605980-2 1" Cold Shrink Wrap	ea	30	6.31	189.30
AMP 66103-2 CPC PINS Type III	ea	100	0.11	10.60
Belden 8920-9 22 AWG wire, White	ft	100		8.00
Belden 8920-2 22 AWG wire, Red	ft	100		8.00
Belden 9659/RG-59 Coax Cable	ft	1500		361.50
	ft	1000		319.00
CINCH 142J-2 Jumpers	ea	400	0.15	60.00
ECN04X EIA Cable 4-Conductor Cable	ea	4	21.82	87.20
GE RTV-103 Black, In Caulking Gun Tube	ea	2	6.26	12.52
Equipment Cabinets	ea	55	1,875.00	103,125.00
Equipment Racks	ea	2	1,267.25	2,534.50
Magitronic 15" SVGA Monitor	ea	1	310.00	310.00
Magitronic 486DX4 100 Laptop PC	ea	1	1,370.00	1,370.00
Magitronic PC 486DX4 100	ea	1	949.00	949.00
Poles				
25 ft Steel Pole	ea	1	2,950.00	2,950.00
30 ft Wooden Pole	ea	37	435.00	16,095.00
55 ft Wooden Pole	ea	21	907.00	19,047.00
Software for Local Control of MPC-D-111 Receivers	ea	1	495.00	495.00
Sony 20" Video Monitor	ea	3	1,160.50	3,481.50
Spare Parts				
C Interface Board	ea	1	200.00	200.00
CX06-BNCY	ea	10	41.59	415.90
Dynamic C (Win) Deluxe	ea	1	395.00	395.00
PC-642 C-015	ea	10	34.41	344.10
PC-642 C-020	ea	10	34.41	344.10
PC-642 C-200	ea	10	34.41	344.10
PC-642 C-232	ea	20	34.41	688.20
P264-130/RMS	ea	10	37.06	370.60
Z-World Protocol Switch (RPU)	ea	2	580.00	1,160.00
US Robotics Sportster 28.8 Modem	ea	55	182.00	10,010.00
	ea	25	181.70	4,542.50
	ea	8	167.78	1,342.24
Wheelen Radar Detector	ea	110	961.00	100,905.00
	ea	6	1,130.00	6,780.00
Wheelen Remote RS-232 Display	ea	2	213.00	426.00
Z-World Protocol Switch (RPU)	ea	55	399.50	21,972.50
	ea	3	454.00	1,365.00

Total: 499,779.78

RESOURCES FOR SURVEILLANCE SYSTEM SUPPORT

Slow-Scan Video Cameras

Phone Lines:
- 22 sites @ $64.00 / month .... $1,408 / month

Repair Maintenance:
- 2 technicians for 20 hours / month .... 40 man-hours / month
- 2 pick-up trucks .... 24 truck-hours / month
- 1 bucket truck (Hi-Ranger) .... 8 truck-hours / month

Preventive Maintenance:
- 2 technicians for 7 hours / month .... 14 man-hours / month
- 1 bucket truck (Hi-Ranger) .... 7 hours / month

Factory Repairs:
- 0.5 / month @ $150.00 / repair .... $75.00 / month

Doppler Radars

Phone Lines:
- 51 sites @ $64.00 / month .... $3,264 / month

Repair Maintenance:
- 2 technicians for 40 hours / month .... 80 man-hours / month
- 2 pick-up trucks .... 48 truck-hours / month
- 1 bucket truck .... 16 truck-hours / month

Preventive Maintenance:
- 2 technicians for 7 hours / month .... 14 man-hours / month
- 1 bucket truck (Hi-Ranger) .... 7 hours / month

Factory Repairs:
- 3 / month @ $120.00 / repair .... $360.00 / month

Electrical Power

Camera & Radar Sites:
- 22 sites @ $33.00 / month .... $726.00 / month

Radar Only Sites:
- 29 sites @ $21.00 / month .... $638.00 / month

Miscellaneous Spare Parts

Surge Suppressors:
5 / month @ $35.00 .... $175.00 / month

Solid State Relays:
2 / month @ $5.00 .... $10.00 / month

NUCLEAR RADIATION HAZARDS TO HIGHWAY TRANSPORTATION

BPR

MAY 1967—DRAFT

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Bureau of Public Roads

NUCLEAR RADIATION HAZARDS TO HIGHWAY TRANSPORTATION*

Background

Highway traffic regulation in an emergency may be instituted for several reasons. One of the reasons is the presence of radioactive fallout which would cover vast areas of the United States, including highways, in the event of an all-out nuclear attack on this country.

Radioactive fallout emits dangerous nuclear radiations, which cannot be detected by the five human senses, but can be injurious or fatal to all living things. Radiation emitted by fallout would be most dangerous within the first several hours after the explosion of a nuclear weapon. As time passes, the radioactivity becomes less intense and in time would be at a level low enough to permit normal movement in most areas. Some areas would be dangerous for human resettlement for many years.

Because this situation may exist after an attack, the system of highway traffic regulation being devised and organized on a nationwide basis should be used to protect the highway user from unnecessary exposure to radiation.

Fallout Pattern Study

A nuclear attack on the United States could take many forms. In addition, the pattern of fallout contamination would be affected by weather conditions and wind directions and velocities at various levels in the atmosphere. When the cloud of radioactive matter is formed after a surface nuclear burst, the larger particles fall more rapidly and, since they generally carry a large part of the radioactivity, the downwind area nearer ground zero (the point of explosion) is likely to be more highly contaminated than areas farther away.

Smaller particles, on the other hand, require many hours to fall to earth. During this time, they may be

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*This document received review and comments by the Office of Civil Defense carried hundreds of miles from the point of explosion and widely distributed by prevailing winds. Moreover, a surface burst, in the megaton range, would produce a quantity of contaminated matter so large that fallout may continue to be deposited in hazardous concentrations up to perhaps 24 hours after the burst.

Changing wind patterns from the ground to the top of the cloud, the effect of rain and irregularities in terrain, and the irregular distribution of radioactivity in the cloud would contribute to the development of small areas ("hot spots") that have a much higher radioactivity than the surrounding area.

In many areas of the earth's surface, fallout from one nuclear burst would overlap the fallout from other nuclear bursts. Even though large areas of the country could be covered by the fallout of strategically exploded weapons, there would be other areas in which fallout would be relatively negligible.

Figure 1 illustrates the irregular distribution of fallout that could be expected.

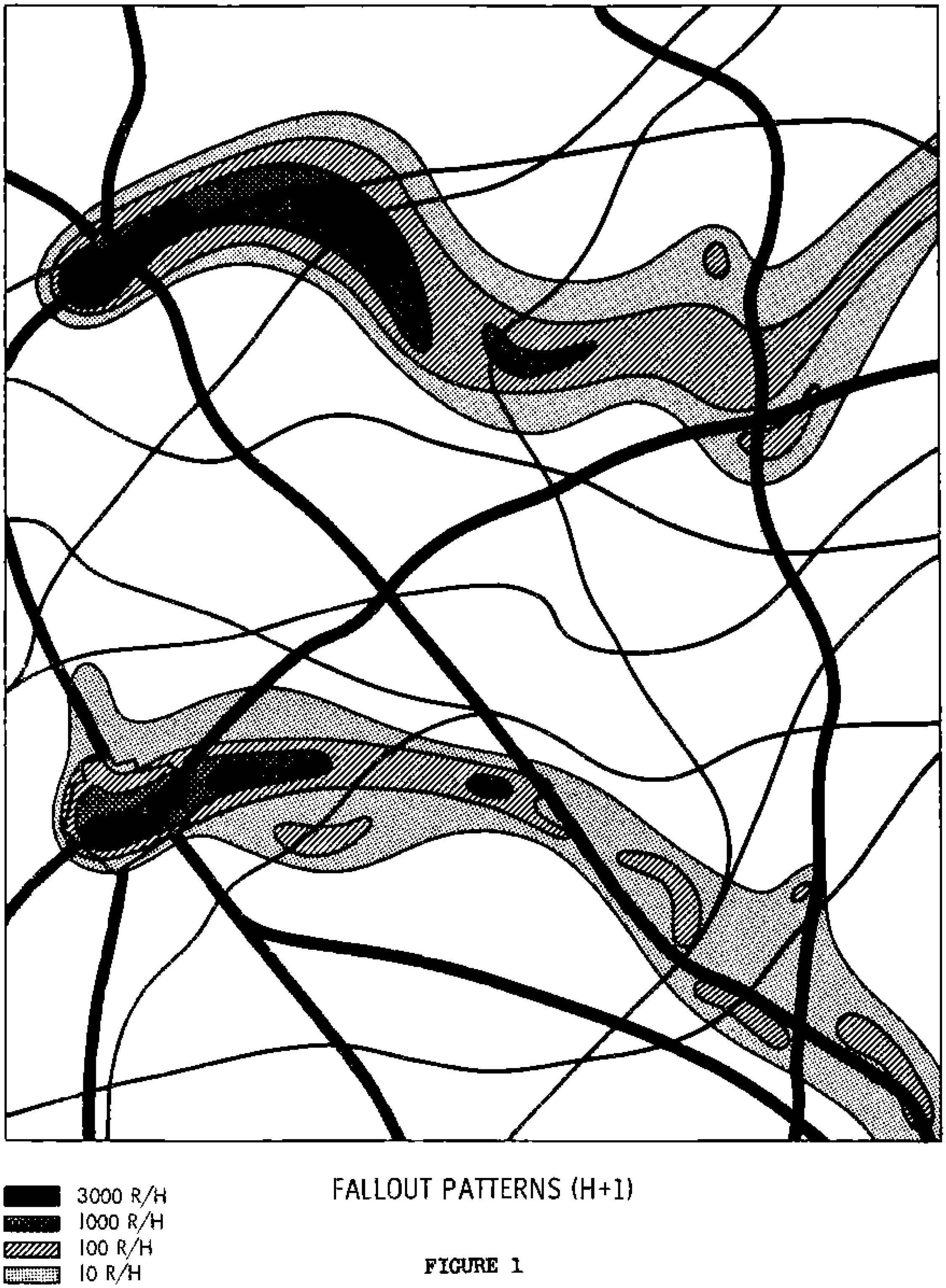
Fallout on Highways

Crisscrossing the United States are roughly 3½ million miles of highways that are used by the drivers of some 90,000,000 cars, trucks and buses.

The fallout from a nuclear attack would also fall on these highways and the highway users, being unaware of its presence could, unknowingly, expose themselves to lethal doses of radiation.

Even though traffic or changing weather conditions could blow or wash the fallout from the surface, the radiation hazard could still be significant, since gamma rays, given off by the fallout, can penetrate many feet of air without great loss in energy.

Unless the user had specially designed instruments to detect the presence of radiation, he would not know whether a road was safe or unsafe for travel. He, therefore, must rely upon, and be guided by, those persons who are specifically trained and equipped to conduct radiological monitoring.



FALLOUT PATTERNS (H+1)

FIGURE 1

Areas of Unrestricted Travel

Referring again to Figure 1, one can see that some areas are relatively free of fallout. These are called "areas of unrestricted travel."

In an emergency, these areas would be defined by barricading and signing the limits beyond which unrestricted travel would be hazardous.

At specific periods of time, as radioactivity decays, barricades and signs would be moved forward, expanding the areas of unrestricted travel. The point to which barricades and signs are moved should be consistent with established criteria for human exposure for permanent resettlement and unrestricted travel.

Travel Through Restricted Areas

Highway travel would be restricted in those areas in which the levels of radiation intensity would not permit permanent resettlement of people without subjecting them to serious biological consequences.

There may be many miles of highways covered by fallout within these areas, and travel would only be permitted on certain regulated routes. Transportation benefits from the use of these routes would have to be weighed against the dangers of radiation exposure to drivers, policing personnel and highway maintenance personnel.

Certain routes extending into or through restricted areas would be open for emergency movement of equipment, supplies, manpower, or evacuation of people. Movements on such routes would be strictly regulated to keep radiation exposure of participating personnel to a practicable minimum.

The Equivalent Residual Dose (ERD)

The reading of a personnel dosimeter gives the dose to which the wearer is exposed, in roentgens or milliroentgens, for the period of time it is worn. It would be convenient to assume that the accumulated exposure dose and the dose received or absorbed by an individual are identical; but such is not the case. The exposure dose in roentgens should be converted into absorbed or tissue dose in Rads. However, this is not practical in an emergency.

To simplify matters, it is assumed that in the case of brief exposure lasting up to 4 days, the extent of the radiation injury is dependent on the total dose. In protracted exposure, over 4 days, recovery from injury leads to an increasing disproportion between the size of the accumulated dose and the extent of radiation injury. In this situation, the equivalent residual dose (ERD) is more useful than the accumulated dose for predicting the possibility of illness and the chances of survival.

The National Committee on Radiation Protection and Measurement (NCRP) states in Report No. 29:

"ERD is a concept that permits a more reliable prediction of the biological and medical consequences of exposures to radiation than is possible on the basis of the accumulated dose alone.

"The decision to use ERD to evaluate radiation exposure in an emergency is based on the following considerations: (1) it is not possible to predict the immediate effect of any amount of radiation unless one knows the manner and duration of the exposure; (2) the body can repair a substantial fraction of the injury responsible for such immediate effects as acute radiation sickness; (3) recovery requires time; (4) what injury cannot be repaired persists, and successive increments of the irreparable injury are cumulative."

Animal experimentation resulted in establishing the following assumptions as a basis for the ERD concept:

1. Ten percent of the total injury is irreparable.
2. The body can repair 90 percent of the total injury.
3. Recovery after a brief dose (i.e., delivered over a period of a few seconds to 4 days) begins on the 5th day after the onset of exposure. The remaining reparable injury is reparable at the rate of 2½ percent per day.

4. The process of recovery is continuous in the case of protracted exposure.

5. The equivalent residual dose (ERD) at any point in time after the onset of exposure is equal to the irreparable 10 percent of the accumulated dose plus the fraction of the balance of the accumulated dose which has not yet been repaired.

Several curves (Figures 2, 3, 4 and 5) show the relationship between the accumulated dose, the ERD with the passage of time, and the 10 percent dose which is never repaired.

An examination of the curves will show that after the maximum ERD has been reached the body repairs the injury faster than it accumulates the daily dose.[1/]

Radiological Exposure Criteria

The National Committee on Radiation Protection and Measurements (NCRP) issued, in January 1962, Report 29 on "Exposure to Radiation in an Emergency."

The report discusses current scientific knowledge of the effects of radiation; decision-making problems in a nuclear war emergency; the equivalent residual dose concept and its use in an emergency; and numerous recommendations.

The Office of Civil Defense (OCD), basing its policy on the NCRP Report, states that, in a nuclear war emergency, peacetime standards must be replaced by the principle of limiting the exposure of our people: first, to protect them from radiation injury; second, to protect them from radiation injury severe enough to require medical care; and third; to minimize the long-range effects of radiation.

The OCD has established specific guidelines based on the Equivalent Residual Dose Concept (ERD). The OCD states in the Federal Civil Defense Guide, June 15, 1963, Part E, Chapter 5, Appendix 1:

"In most areas, after nuclear attack, the ERD of the general public can be controlled to less than 100R by the application of countermeasures such as optimum utilization of shelters, remedial movement and decontamination.

1/ Based on the recipient remaining in the area that received the indicated initial intensity of fallout.

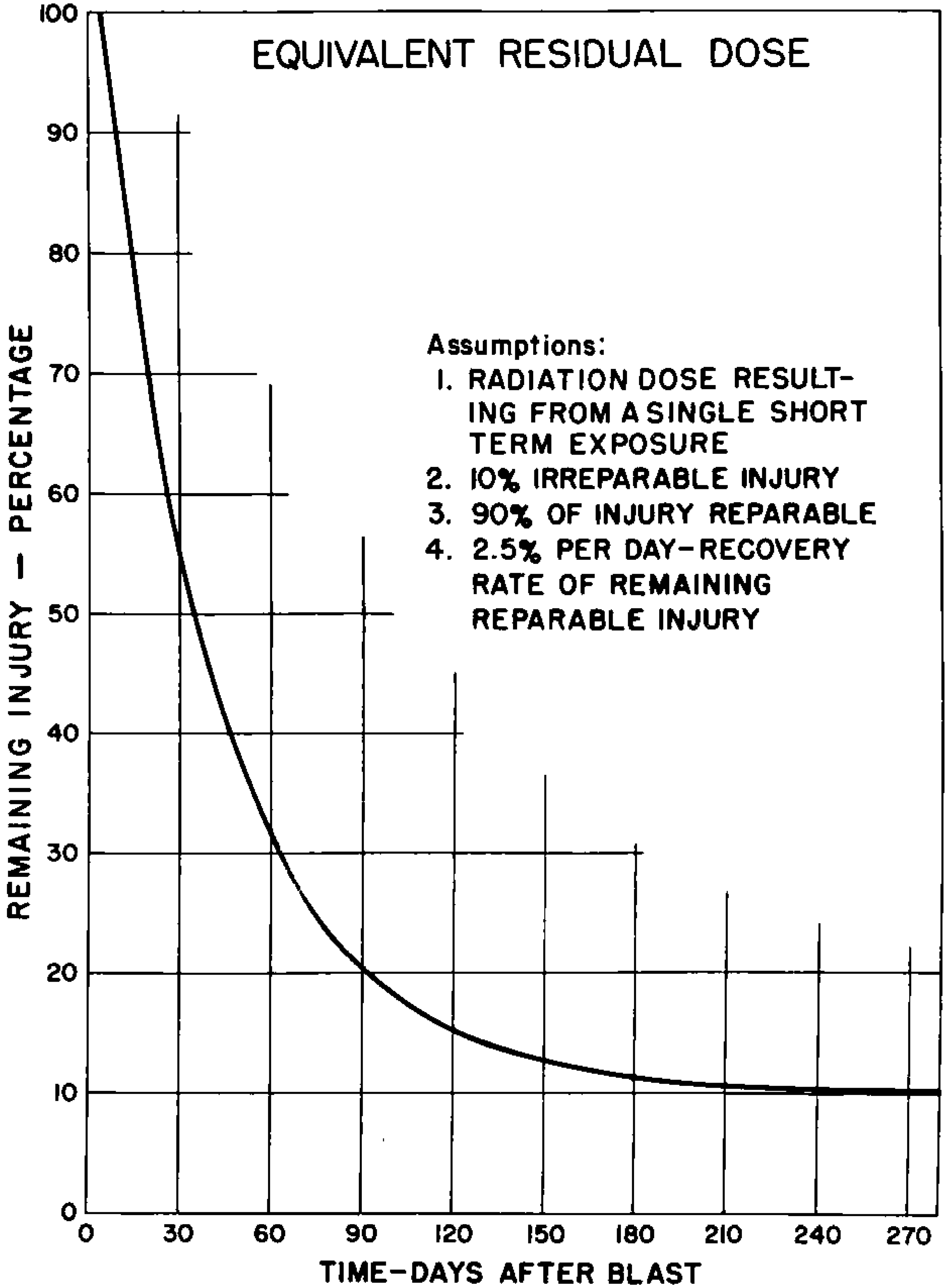

EQUIVALENT RESIDUAL DOSE
Assumptions:
1. RADIATION DOSE RESULTING FROM A SINGLE SHORT TERM EXPOSURE
2. 10% IRREPARABLE INJURY
3. 90% OF INJURY REPARABLE
4. 2.5% PER DAY-RECOVERY RATE OF REMAINING REPARABLE INJURY
REMAINING INJURY - PERCENTAGE
TIME-DAYS AFTER BLAST
100
90
80
70
60
50
40
30
20
10
0
0
30
60
90
120
150
180
210
240
270

FIGURE 2

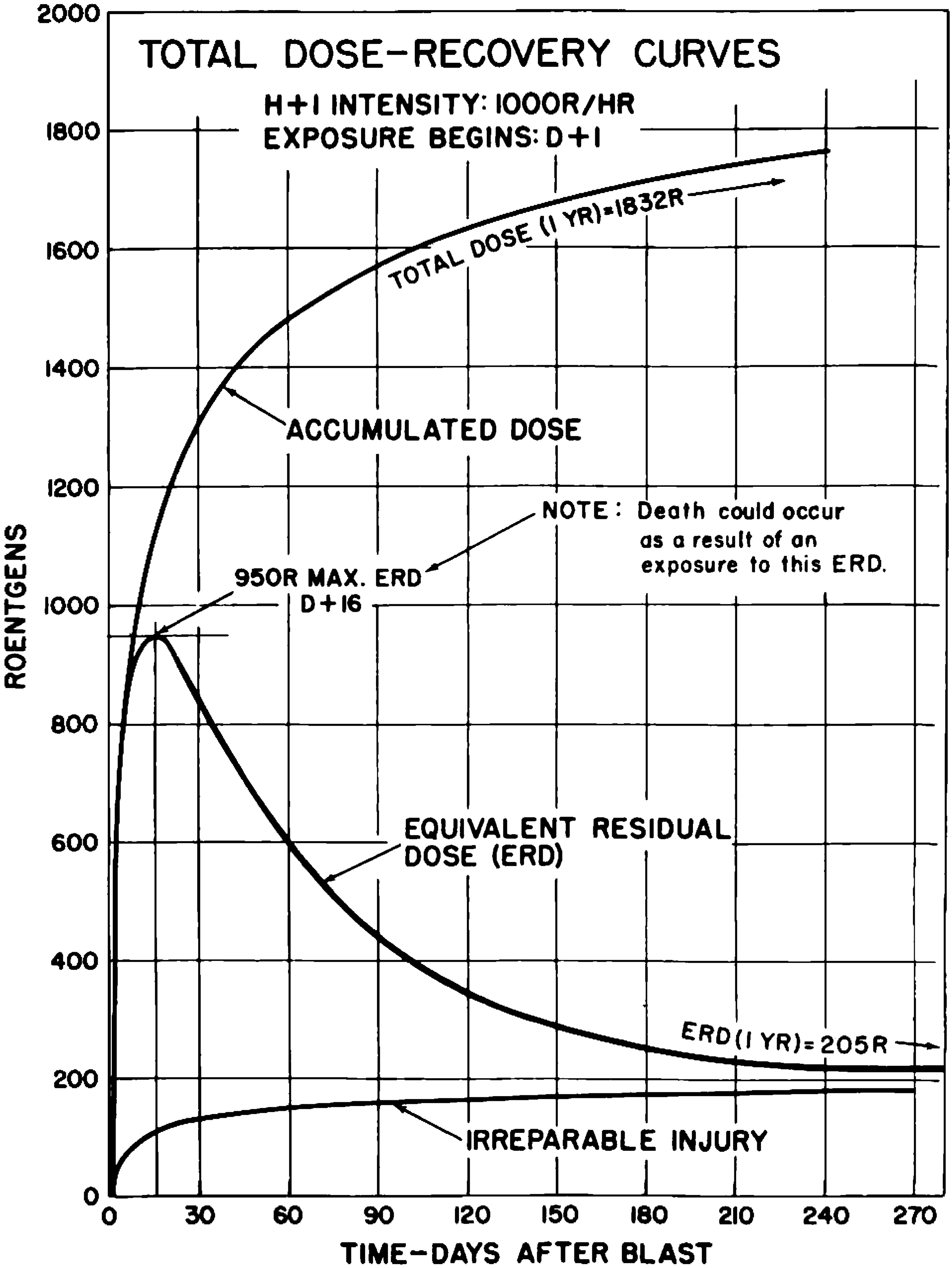

TOTAL DOSE-RECOVERY CURVES
H+1 INTENSITY: 1000R/HR
EXPOSURE BEGINS: D+1
TOTAL DOSE (1 YR)=1832R
ACCUMULATED DOSE
NOTE: Death could occur as a result of an exposure to this ERD.
950R MAX. ERD D+16
EQUIVALENT RESIDUAL DOSE (ERD)
ERD (1 YR)= 205R
IRREPARABLE INJURY
ROENTGENS
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
30
60
90
120
150
180
210
240
270
TIME-DAYS AFTER BLAST

FIGURE 3

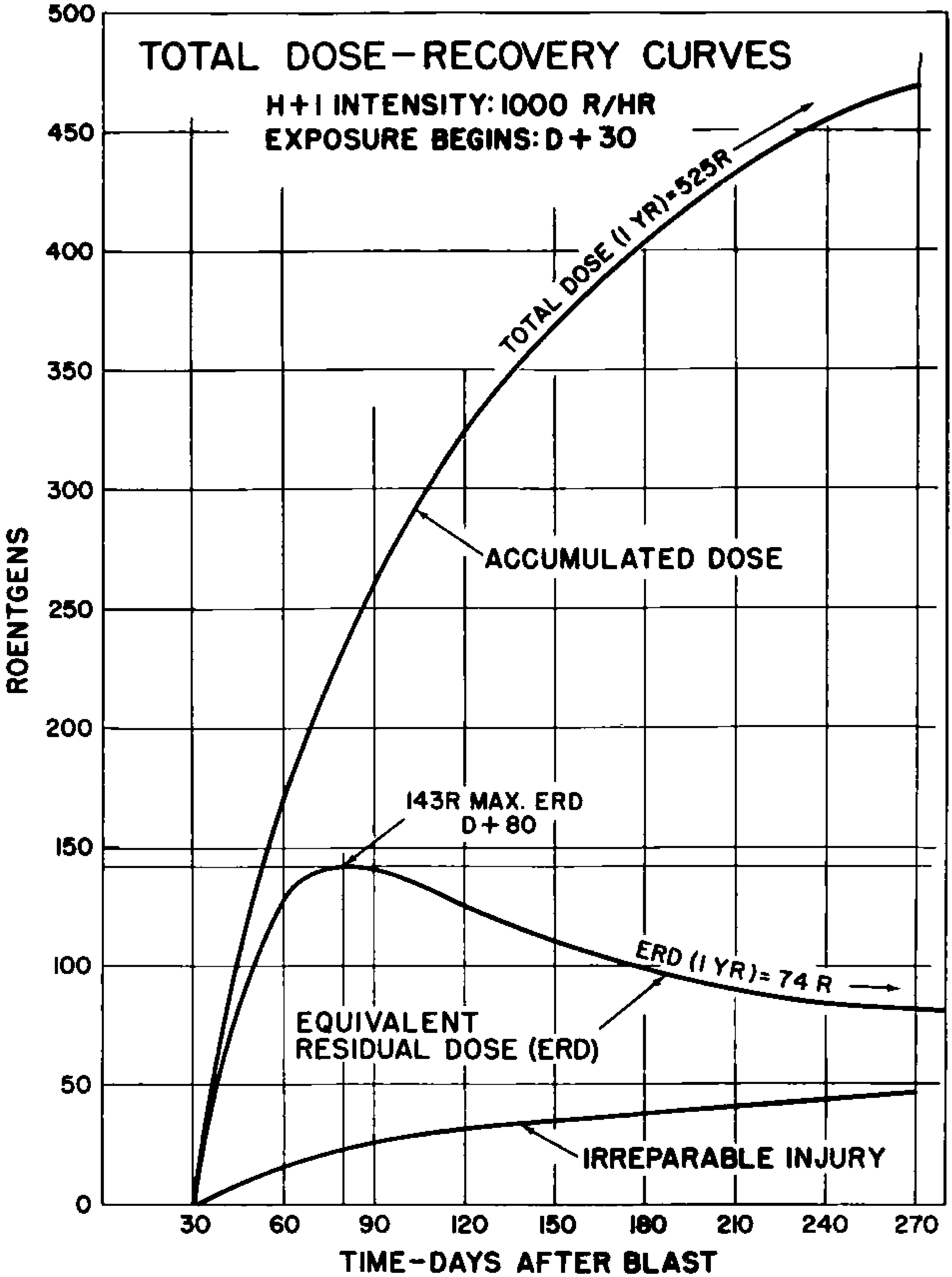

TOTAL DOSE-RECOVERY CURVES
H+1 INTENSITY: 1000 R/HR
EXPOSURE BEGINS: D+30
TOTAL DOSE (1 YR)=525R
ACCUMULATED DOSE
143R MAX. ERD
D+80
ERD (1 YR)= 74 R
EQUIVALENT
RESIDUAL DOSE (ERD)
IRREPARABLE INJURY
ROENTGENS
TIME-DAYS AFTER BLAST
0
50
100
150
200
250
300
350
400
450
500
30
60
90
120
150
180
210
240
270

FIGURE 4

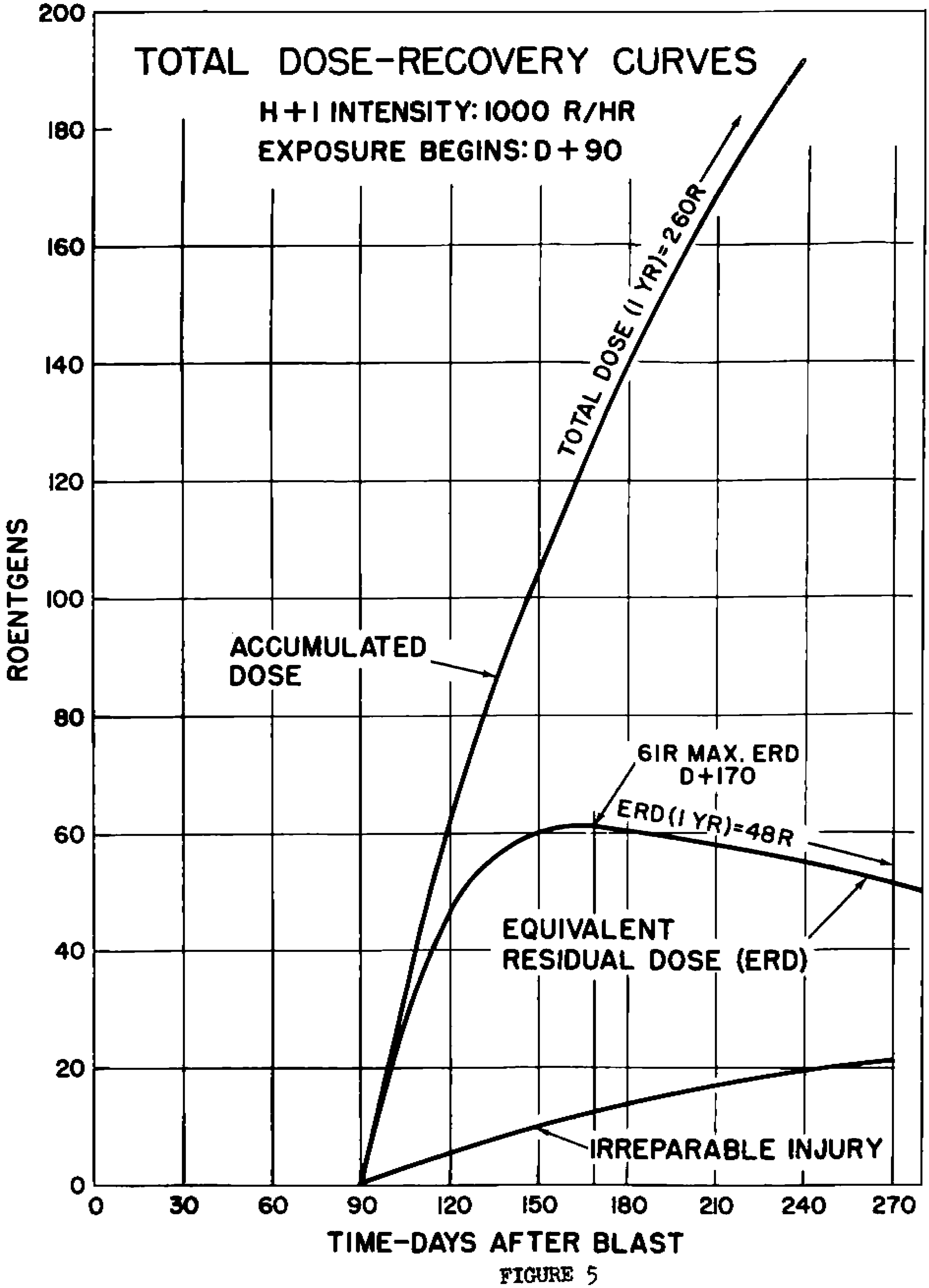

TOTAL DOSE-RECOVERY CURVES
H+1 INTENSITY: 1000 R/HR
EXPOSURE BEGINS: D+90
TOTAL DOSE (1 YR)=260R
ACCUMULATED DOSE
61R MAX. ERD D+170
ERD (1 YR)=48R
EQUIVALENT RESIDUAL DOSE (ERD)
IRREPARABLE INJURY
ROENTGENS
TIME-DAYS AFTER BLAST
0
20
40
60
80
100
120
140
160
180
200
0
30
60
90
120
150
180
210
240
270

FIGURE 5

"In no instance should the ERD of emergency personnel exceed 200R, except on a command decision basis where such exposure of a few individuals might be instrumental in the saving of hundreds of lives or in the saving of a highly essential facility."

The National Committee on Radiological Protection and Measurements states:

"The acceptance of any radiation exposure is warranted only when there is no practical or reasonable alternative way to achieve the required goal."

Everyone may be exposed to some radiation hazard after a nuclear attack. Unless the general public was equipped with reliable dosimeters, it would be impossible to determine how much radiation was absorbed except through clinical studies of, and symptoms displayed by, those exposed.

As stated above, it is the objective of the OCD to maintain exposure of the general public below an ERD of 100R by the application of certain countermeasures. Conforming to this objective, the following assumptions were made:

1. There may be millions of people in travel status after a nuclear attack.

2. A large percentage of these travelers would be using the highway network.

3. Thousands would be located in areas low in fallout contamination and would desire to return to their homes.

4. The location of fallout, and its degree of hazard, may be unknown to the traveling public.

5. The traveling public must be protected immediately after the attack and during the long-range recovery.

6. Flexible guidelines for exposure of the traveling public are necessary.

Neither the Office of Civil Defense nor the National Committee on Radiation Protection and Measurement have issued specific guidelines for radiation exposure of the traveling public.

The guidelines set forth in Table 1 are calculated and based on the $t^{-1.2}$ theoretical decay scheme for a nuclear detonation of known time. However, in a real emergency, fallout from several weapons, which may be detonated at substantially different times, would result in a radiation field with a decay scheme other than that used for calculation of the guidelines.

Field radiological data would have to be evaluated and interpreted by specialized technical personnel who would advise decision-making officials in charge.

With a view to anticipating confusion and the probable lack of an orderly procedure in the early stages, State highway department personnel, located in relatively uncontaminated areas, should begin monitoring as soon as fallout has settled, using the guidelines in Table 1 and Table 2 for setting barricades and signs on highways.

Adjustments in the tables, monitoring operations and setting of barricades and signs may be necessary as measured radiological data is interpreted, and general weapons effect on the populace and economy are evaluated.

Until circumstances and official decisions require that adjustments be made, the present guidelines for setting limits of unrestricted travel are as shown in the following table. These limits of unrestricted travel are being reexamined. Revised criteria will be issued as soon as it is available.

TABLE 1

ENTRY	BPR CRITERIA FOR LIMITS OF UNRESTRICTED TRAVEL				
TIME	Actual R/HR	H+1 Intensity	Max. ERD	Day of Max. ERD	ERD At End of 1st year
D+1	2.2	100r/hr	95r	D+16	21r
D+30	.14	375r/hr	54r	D+80	28r
D+90	.08	750r/hr	46r	D+170	26r

In the last two columns of the table, the "end of the 1st year" means one year after H+1 (one hour after the bomb exploded).

If the same maximum ERD were used for each of the entry times shown, people resettling at D+90 would receive more than double the irreparable dose of those resettling at D+1.

Emergency Exposure Criteria

Where possible, monitoring will begin at H+24 hours, assuming that all fallout is down. At D+1 (H+24) a monitor would find the limit of unrestricted travel by finding the actual on the ground meter reading of 2.2r/hr. This would indicate the area where the initial intensity was 100r/hr. Likewise, at D+30, the actual meter reading would be .14r/hr and at D+90 it would be .08r/hr establishing the limits of unrestricted travel and indicating the areas where the initial intensities were 375r/hr and 750r/hr respectively.

Table 2 shows the H+1 intensities for various intensity readings at various entry times.

The above criteria has been established from curves using a decay rate of $t^{-1.2}$. The rate of decay can change in an actual attack requiring some modification in criteria, meter readings, H+1 intensity lines, etc.

In routine emergency work, monitors and other highway personnel should not expose themselves to more than 5r in any single day nor more than a total of 10r during the first week.

Where an Extreme Emergency exists, such as the saving of many lives or an essential facility, it may be necessary for the monitor, construction or maintenance worker to accept a brief exposure of up to 200r.

Decision Making

After a nuclear attack, a major objective in the support of survival is maintenance of the economy and reconstruction. One of the prime elements in accomplishing this objective is the decisions made by officials in charge, in respect to radiation exposure of individuals, in relation to all other elements of the situation.

TABLE 2

Time after Blast	METER READINGS (r/hr.)						
H + 1	100	202	267	320	375	565	750
H + 2	43.5	87.8	116	139	163	246	326
H + 4	18.9	38.1	50.4	60.4	70.8	106	142
H + 6	11.6	23.4	30.9	37.1	[illegible]	65.5	87
H + 8	8.2	16.5	21.9	26.2	30.7	46.3	61.5
H + 10	6.3	12.7	16.8	[illegible]	23.6	35.6	47.2
H + 12	5.1	10.3	13.6	[illegible]	19.1	28.8	38.2
H + 14	4.2	8.48	11.2	[illegible]	15.7	23.7	31.5
H + 16	3.6	7.27	9.6	[illegible]	13.5	20.3	27
H + 18	3.1	6.26	8.28	9.[illegible]	11.6	17.5	23.2
H + 20	2.7	5.42	7.20	8.6[illegible]	10.1	15.2	20.2
D + 1	2.2	4.84	5.87	7.0[illegible]	8.25	12.4	16.5
D + 2	.98	1.98	2.62	[illegible]	3.67	5.54	7.32
D + 3	.59	1.19	1.57	[illegible]	2.21	3.33	4.42
D + 4	.42	.85	1.12	[illegible]	1.57	2.37	3.15
D + 5	.32	.646	.854	1.02	1.20	1.81	2.40
D + 6	.26	.572	.694	.832	.975	1.47	1.95
D + 7	.215	.434	.572	.688	.806	1.21	1.61
D + 14	.093	.188	.248	.297	.348	.525	.697
D + 21	.057	.115	.152	.182	.214	.322	.427
D + 30	.037	.075	.099	.118	.139	.209	.277
D + 60	.016	.032	.043	.051	.060	.091	.120
D + 90	.01	.02	.027	.032	.038	.057	.076

Note: Inside heavy lines are readings which are safe for unrestricted travel, for those people who have not experienced previous heavy exposure.

Officials who have the responsibility for making command decisions which will expose persons to additional radiation must understand, first, the biological and medical consequences of exposure (NCRP, report No. 29). Secondly, they must have essential materials readily available for reference in planning movements and/or controlling exposures.

Charts and Nomograms for Operational Planning and Controlling Exposures

The curves and nomograms (figures 6 through 9) are based on the $t^{-1.2}$ decay law and can be used for planning operations and controlling exposures in a real emergency, subject to adjustments in the decay rate.

(a) Decay Law or Curve (Figure 6).

In view of the rather large variability in the rate of decay of fallout, attempts to predict the decay of actual fallout on the basis of any given decay law or curve are almost certain to be inaccurate.

In an actual emergency, decay characteristics can be determined by measuring dose rates at specific time intervals in an area where fallout is not subject to weathering. By making a logorithmic plot with the measured dose rate (r/hr) as the vertical axis and time as the horizontal axis, the decay slope, can be computed.

In Figure 6, three slopes have been plotted to represent decay characteristics. To find the slope or exponent of (t), divide the measured length of vertical line ab by the length of horizontal line bc. In this case ab=27/16 inches and bc=20/16 inches which divided equals 1.35.

The $t^{-1.2}$ decay law and the equations derived from it have been used in the preparation of many types of charts, graphs, nomograms and calculations. Most of these devices are being used for planning purposes and in forecasting the probable effects of fallout in the preparation of tests, exercises and problem studies likely to be encountered in a postattack situation. However, in an actual emergency, a Radiological Defense Officer would have to adjust any recommended remedial action to reflect variations from the $t^{-1.2}$ decay characteristics. It should be noted that when the minus exponent is large, e.g. -1.35, the dose rate decreases more rapidly than when it is small, e.g. -1.05.

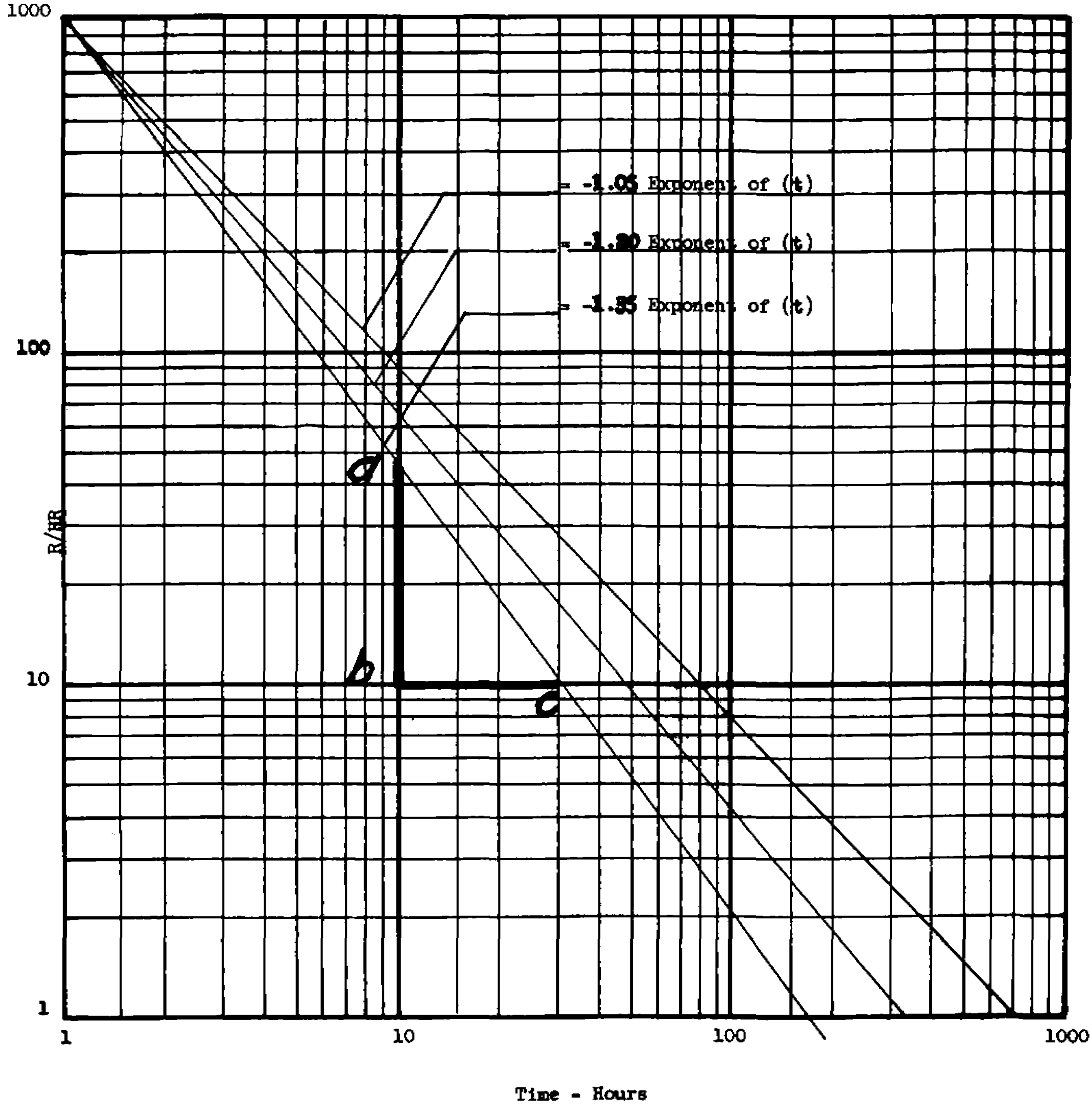

1000
100
10
1
R/HR
= -1.05 Exponent of (t)
= -1.20 Exponent of (t)
= -1.35 Exponent of (t)
a
b
c
1
10
100
1000
Time - Hours

FIGURE 6

(b) Equivalent Residual Dose (ERD) (Figure 7).

Figure 7 is a nomogram which can be used for rapid computation of the (ERD). The scale at the bottom is laid out in "time in days" after exposure. The scale on the right represents a brief, initial dose (shock dose or dose spread over one to four days.) The scale on the left shows daily exposures in r/day which occur after the brief dose. The curved, quasi-horizontal lines drawn from left to right represent the Equivalent Residual Dose.

On the nomogram, a line has been drawn from 50r on the right vertical scale to 5r/day on the left vertical scale. The line shows that an individual was exposed to a brief dose of 50r and thereafter to daily doses of 5r/day. If the line is followed, one can pick off the ERD on any day up to 400 days. For instance, at 10 days the ERD is 70r; and at 50 days it is 150r.

If an individual did not experience a brief dose but was exposed to daily doses of 5r/day, a line would be drawn from zero on the right to 5r/day on the left. The ERD could then be read for various times in the future. With an initial brief dose of 150r and no subsequent exposure, a line would be drawn from 150r on the right to zero on the left.

The nomogram can be used to find the ERD at a future time for each group (not exceeding 7 days per group) of daily exposures. For example, an individual is exposed for seven days as follows: The first day 50r, then 30r, 20r, 10r, 15r, 10r, and 5r. Find the ERD at 30 days from the first day of exposure. By laying a straight edge from 50r on the right to zero on the left, read the ERD at 30 days (28r); for the second day, from 30r on the right to zero on the left, read the ERD at 29 days (17r); from 20r on the right to zero on the left, read 12r at 28 days; 10r to 0, read 6r at 27 days; 15r to 0, read 9r at 26 days; 10r to 0, read 7r at 25 days; and 5r to 0, read 3r at 24 days. The total ERD at the end of 30 days would be 28r+17r+12r+6r+9r+7r+3r=82r.

A more simplified and faster method is as follows: The total dose for the seven day period is 140r. Note that more than half, or 80r, was received at the end of the second day. From D+2, the end of the second day to D+30,

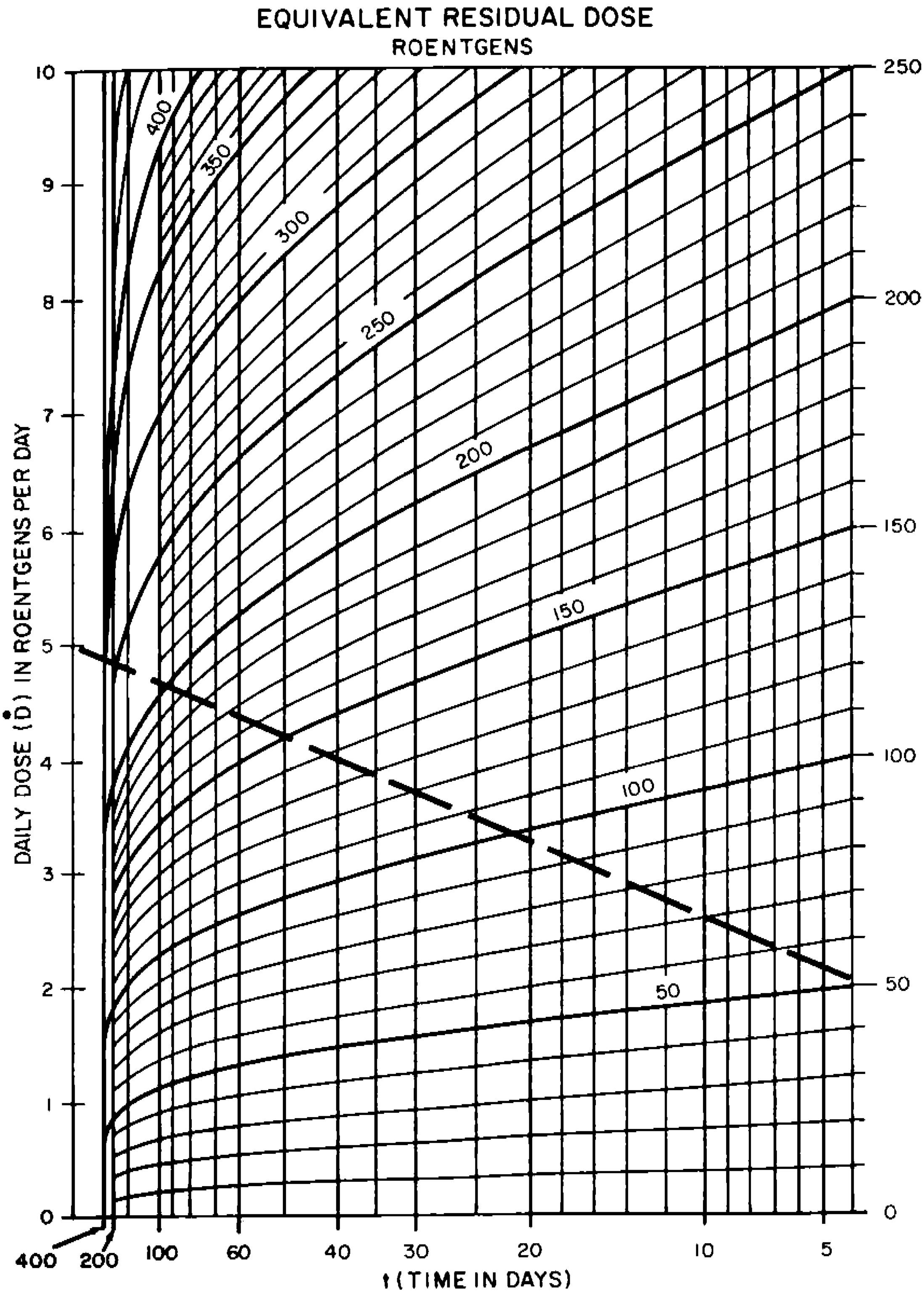

EQUIVALENT RESIDUAL DOSE
ROENTGENS
400
350
300
250
200
150
100
50
DAILY DOSE (Ḋ) IN ROENTGENS PER DAY
BRIEF DOSE (D_0) IN ROENTGENS
0
1
2
3
4
5
6
7
8
9
10
0
50
100
150
200
250
400
200
100
60
40
30
20
10
5
t (TIME IN DAYS)

FIGURE 7

the day on which you wish to find the ERD, is 28 days. Lay a straight edge from 140r on the right to zero on the left and read the ERD at 28 days. This will read about 82r.

The ERD's for each group of seven-day exposures can be added to give the total ERD on a future day.

(c) Dose Rate Nomogram (Figure 8).

Figure 8 is a nomogram which can be used to estimate, at any specific time after the explosion of a nuclear weapon, the dose rate as of H+1 and any future dose rate at that same location.

Example:

The dose rate at H+12 hours was 50r/hr. What is the dose rate at H+1 and D+2?

Under the column "Dose Rate at H+T" on the left, find 50r; and under the column "Time After Burst" in the center, find 12 hours. Lay a straight edge on the line from 50 to 12 and read the "Dose Rate at H+1" where the straight edge intersects the column on the right (about 970r/hr).

To find the dose rate at D+2, hold the straight edge on 970r/hr and pivot to D+2 on the center column "Time after Burst" and read 9.2r/hr on the left column "Dose Rate at H+T."

(d) Total Dose - Stay time - Entry time - Nomogram (Figure 9).

Figure 9 is a nomogram which can be used to determine when to enter a radioactive contaminated area, how long to stay in the area, and the total dose absorbed while in the area.

Example:

The dose rate in an area is 10r/hr at H+24 hours. What would the total dose be if a person entered the area at D+2 days and remained for 8 hours?

Referring back to Figure 8 find the dose rate at H+1 as described in Section (c). This will be 450r/hr. Then in Figure 9 lay a straight edge from D+2 on the "Entry Time" column through 8 hours on the "Stay Time" column and read

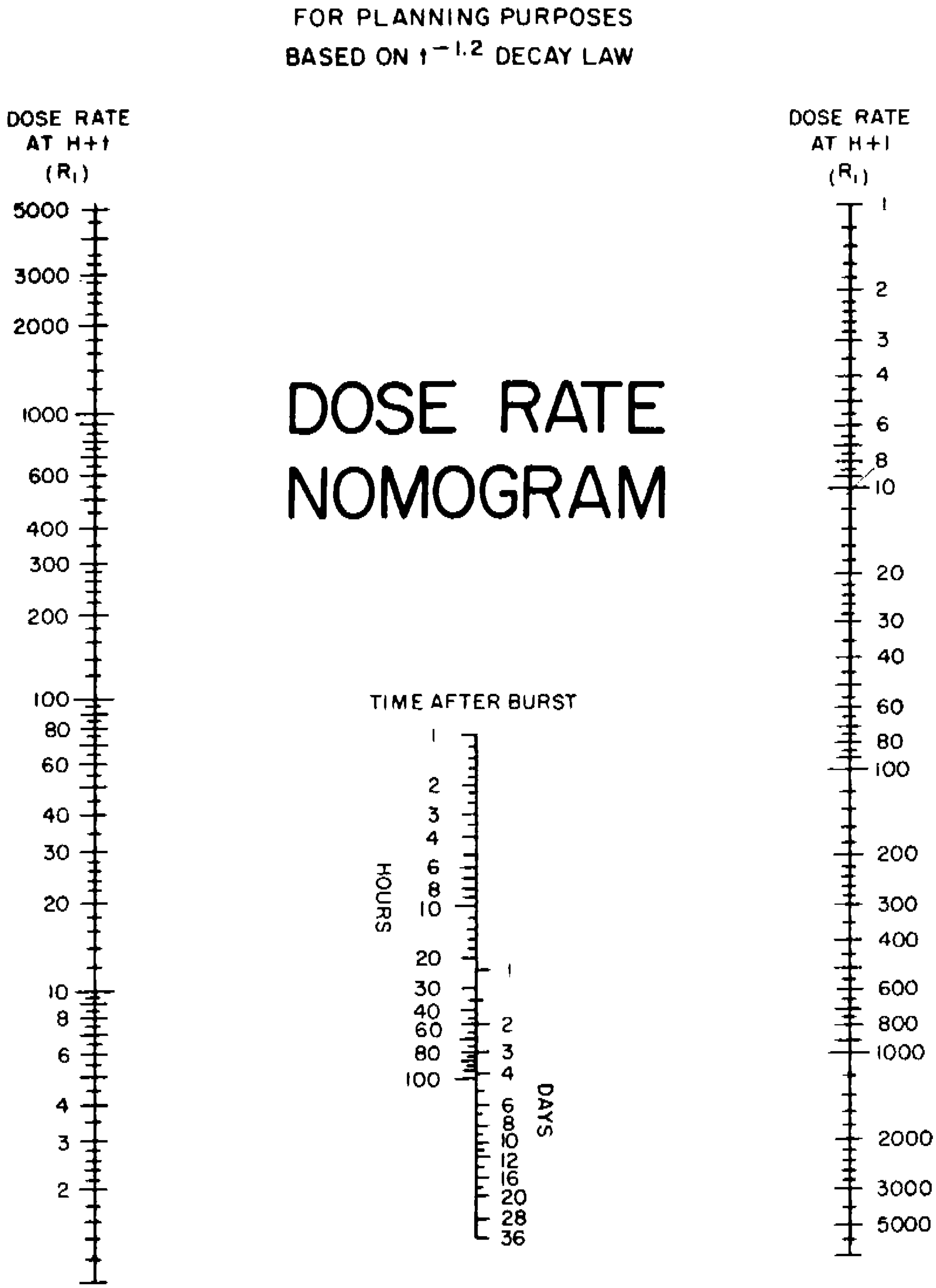

FOR PLANNING PURPOSES
BASED ON $t^{-1.2}$ DECAY LAW
DOSE RATE AT H+t (R_t)
5000
3000
2000
1000
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
DOSE RATE NOMOGRAM
TIME AFTER BURST
HOURS
1
2
3
4
6
8
10
20
30
40
60
80
100
DAYS
1
2
3
4
6
8
10
12
16
20
28
36
DOSE RATE AT H+1 (R_1)
1
2
3
4
6
8
10
20
30
40
60
80
100
200
300
400
600
800
1000
2000
3000
5000

FIGURE 8

ENTRY TIME - STAY TIME TOTAL DOSE NOMOGRAM

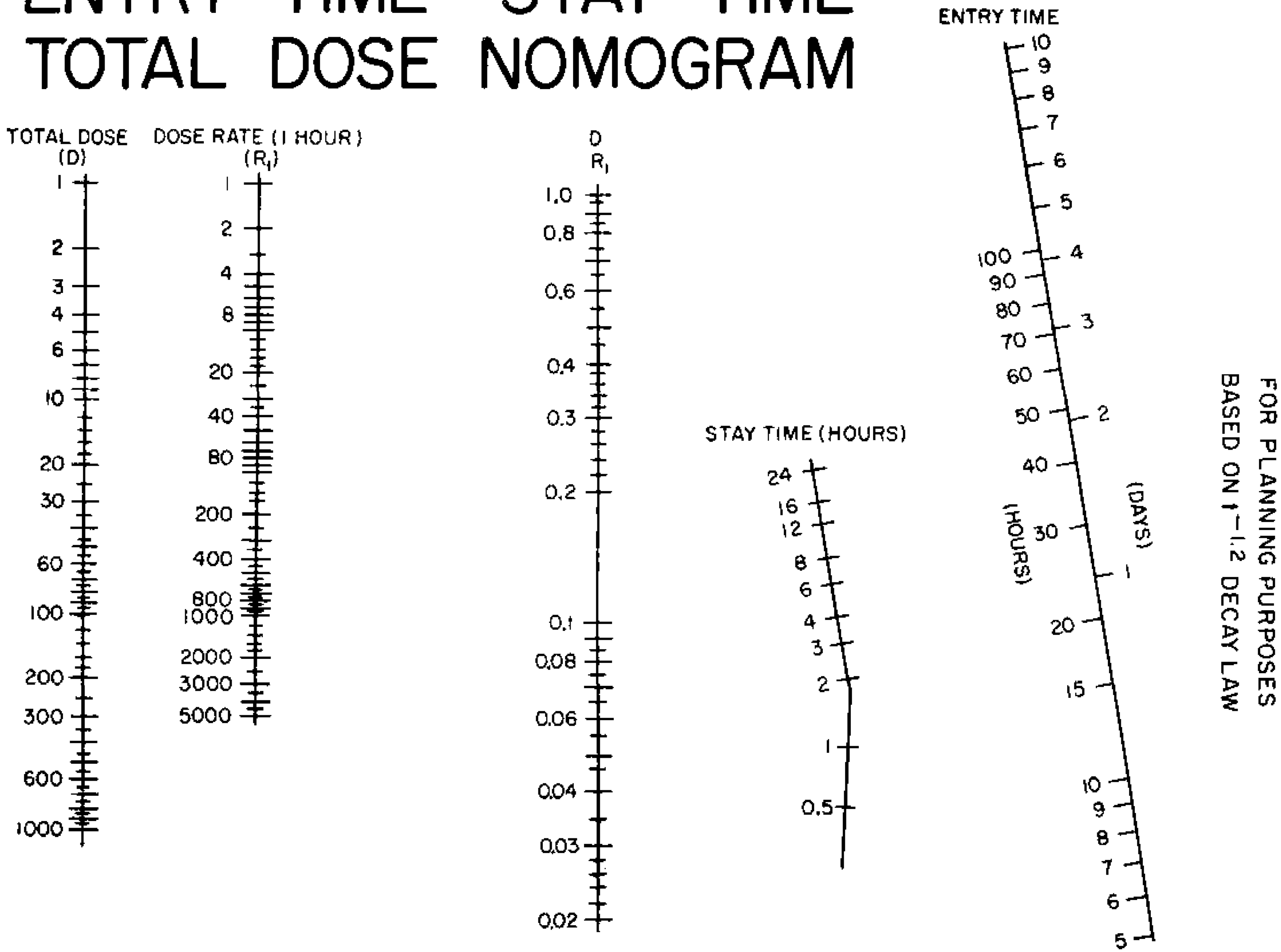


FIGURE 9

about .07 on the D/r reference line. Next lay the straight edge from the .07 point on the D/r line through 450r/hr on the "Dose Rate at H+1" column and read about 31r on the Total Dose Column.

The nomograms, Figures 8 and 9, can be applied to movements on highways or to specific missions to be accomplished by truckers, construction and maintenance crews or others, while maintaining control of exposure to radiation.

Example:

Given: A trucker must leave his sheltered area to accomplish a mission in an area where the measured dose rate is 20r/hr at D+2. The stay time outside the shelter is 6 hours. The total dose allowable to accomplish the mission is 50r.

Find: The earliest day the trucker can leave the shelter and perform the mission.

Solution: Using Figure 8 (Dose Rate Nomogram) find 20r/hr in the "Dose Rate at H+t" column and D+2 in the "Time after Burst" column, and connect these two points with a straight edge extending it on the same line and read 2100r/hr in the "Dose Rate at H+1" column. Then using Figure 9 (Entry Time - Stay Time nomogram) connect 50r total dose with 2100r/hr and mark D/r reference line. Pivot straight edge at D/r reference line through 6 hours stay time and read about 3.4 days entry time.

Example:

Given: The average dose rate through an area 400 miles long is 15r/hr at D+2. A one-way mission by truck is to be carried out through the area at D+7. The protection factor of the truck is 1.5. The maximum permissible mission dose is 10r.

Find: (a) Allowable travel time (Stay time) at D+7.

(b) The average speed required so that the mission dose is not exceeded.

Solution: To get the actual average dose rate the driver would be exposed to in the protected truck, divide 15r/hr by the 1.5 protection factor which equals 10r/hr. Then using Figure 8 (Dose Rate Nomogram) find 10r/hr under the column "Dose Rate at H+t" and connect this point with a straight edge to D+2 under the column "Time after Burst." Extend the line between these two points until it intersects the column "Dose Rate at H+1" and read about 1050r/hr.

In Figure 9 "Entry Time - Stay Time Nomogram" find the mission dose 10r under the column "Total Dose" and connect a line between this point and 1050 r/hr under the "Dose Rate (1 hour)" column. Extend this line to intersect the D/R reference line. Connect the point of intersection on the D/R reference line with 7 in the "Entry Time" column and read 8 hours in the "Stay Time" column.

To get the average speed of the truck, divide the distance (400) miles by the stay time (8 hours) which equals 50 miles per hour.

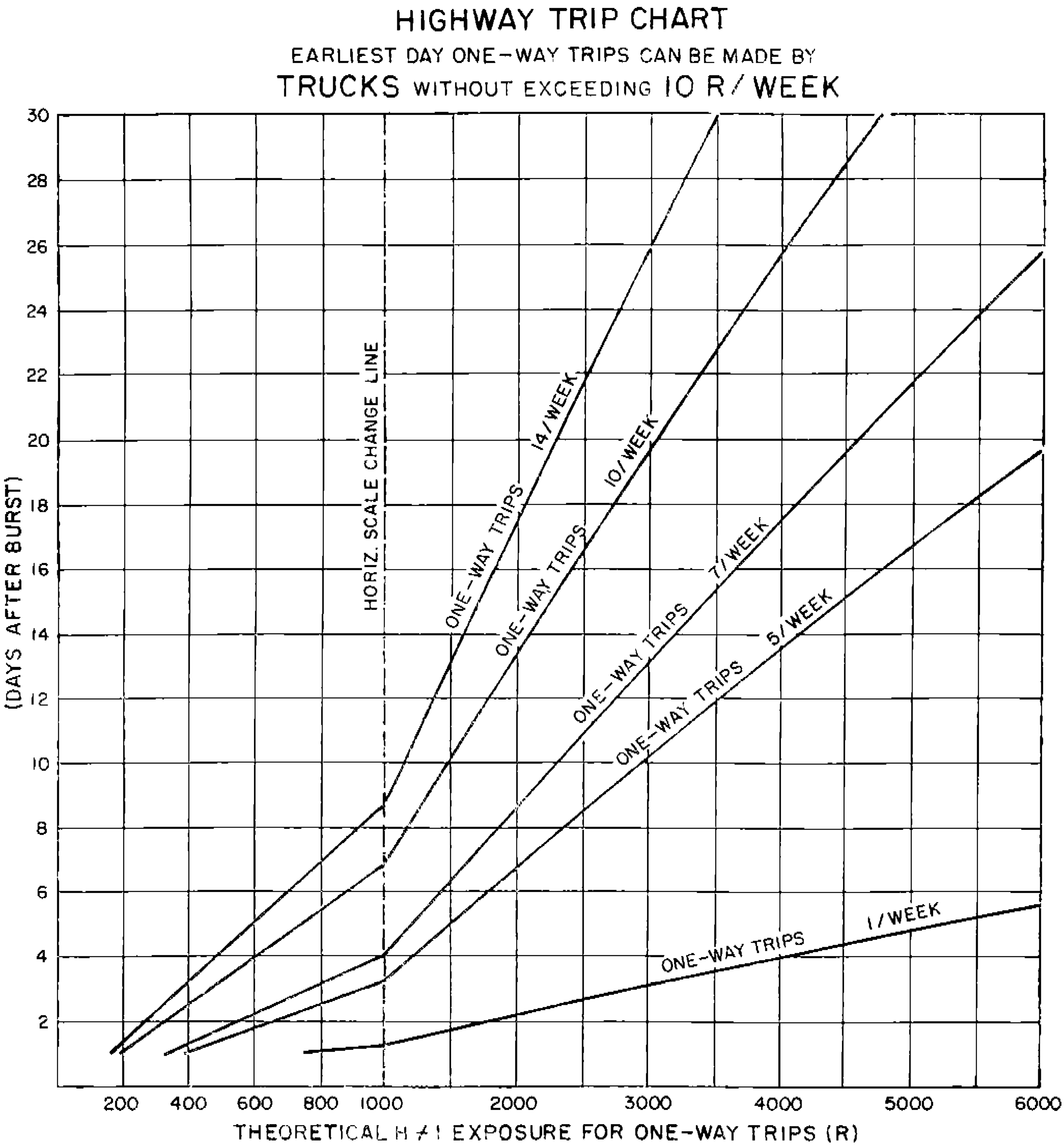
(d) Highway Trip Chart (Figures 10, 11, 12, and 13).

Figures 10, 11, 12, and 13 are charts designed for the control of the exposure of the drivers of trucks, buses, cars and maintenance crews. The drivers of the vehicles are in the class of emergency personnel and are expected to accept a minimum exposure of up to 2r/week or a total of up to 100r in one year. This would be in addition to that to which they would be exposed during normal day-to-day living during the remaining non-working year. The maximum exposure in any one week should not exceed 10r.

Protection factors of 1.25 for cars and 1.7 for trucks were incorporated in the computations of the curves.

On the charts, the vertical scale is the "Entry Time" in days after a nuclear burst. The horizontal scale is the "Theoretical Exposure at H+1", and shows two separate scales which distorts the curves at the dividing line. The curves show the number of one-way trips which can be made in one week.

To become familiar with the use of these charts, a theoretical problem and solution is worked out below:



HIGHWAY TRIP CHART
EARLIEST DAY ONE-WAY TRIPS CAN BE MADE BY
TRUCKS WITHOUT EXCEEDING 10 R/WEEK
(DAYS AFTER BURST)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
HORIZ. SCALE CHANGE LINE
ONE-WAY TRIPS 14/WEEK
ONE-WAY TRIPS 10/WEEK
ONE-WAY TRIPS 7/WEEK
ONE-WAY TRIPS 5/WEEK
ONE-WAY TRIPS 1/WEEK
200
400
600
800
1000
2000
3000
4000
5000
6000
THEORETICAL H + 1 EXPOSURE FOR ONE-WAY TRIPS (R)

FIGURE 10

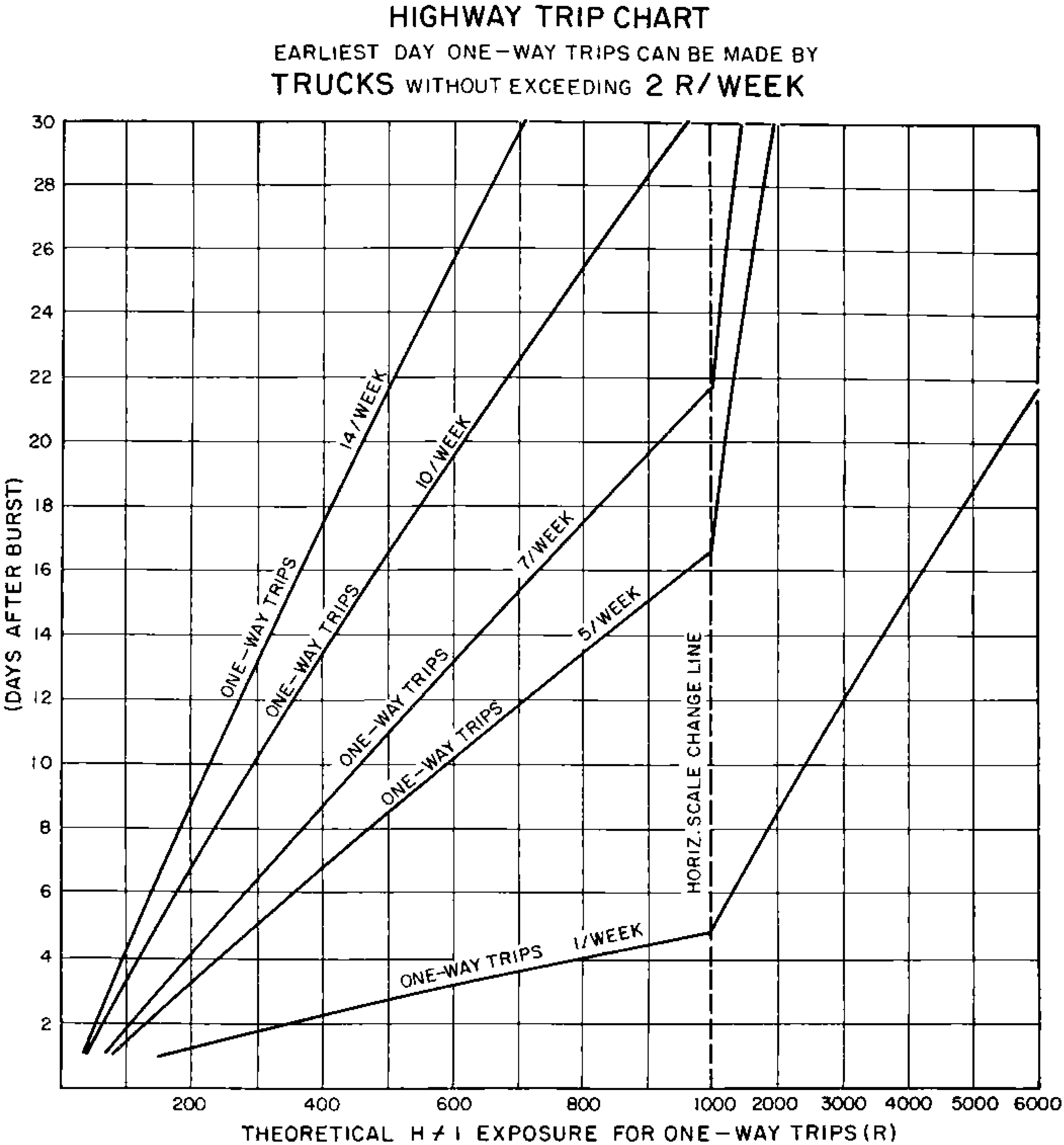

HIGHWAY TRIP CHART
EARLIEST DAY ONE-WAY TRIPS CAN BE MADE BY
TRUCKS WITHOUT EXCEEDING 2 R/WEEK
(DAYS AFTER BURST)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
ONE-WAY TRIPS 14/WEEK
ONE-WAY TRIPS 10/WEEK
ONE-WAY TRIPS 7/WEEK
ONE-WAY TRIPS 5/WEEK
ONE-WAY TRIPS 1/WEEK
HORIZ. SCALE CHANGE LINE
200
400
600
800
1000
2000
3000
4000
5000
6000
THEORETICAL H + 1 EXPOSURE FOR ONE-WAY TRIPS (R)

FIGURE 11

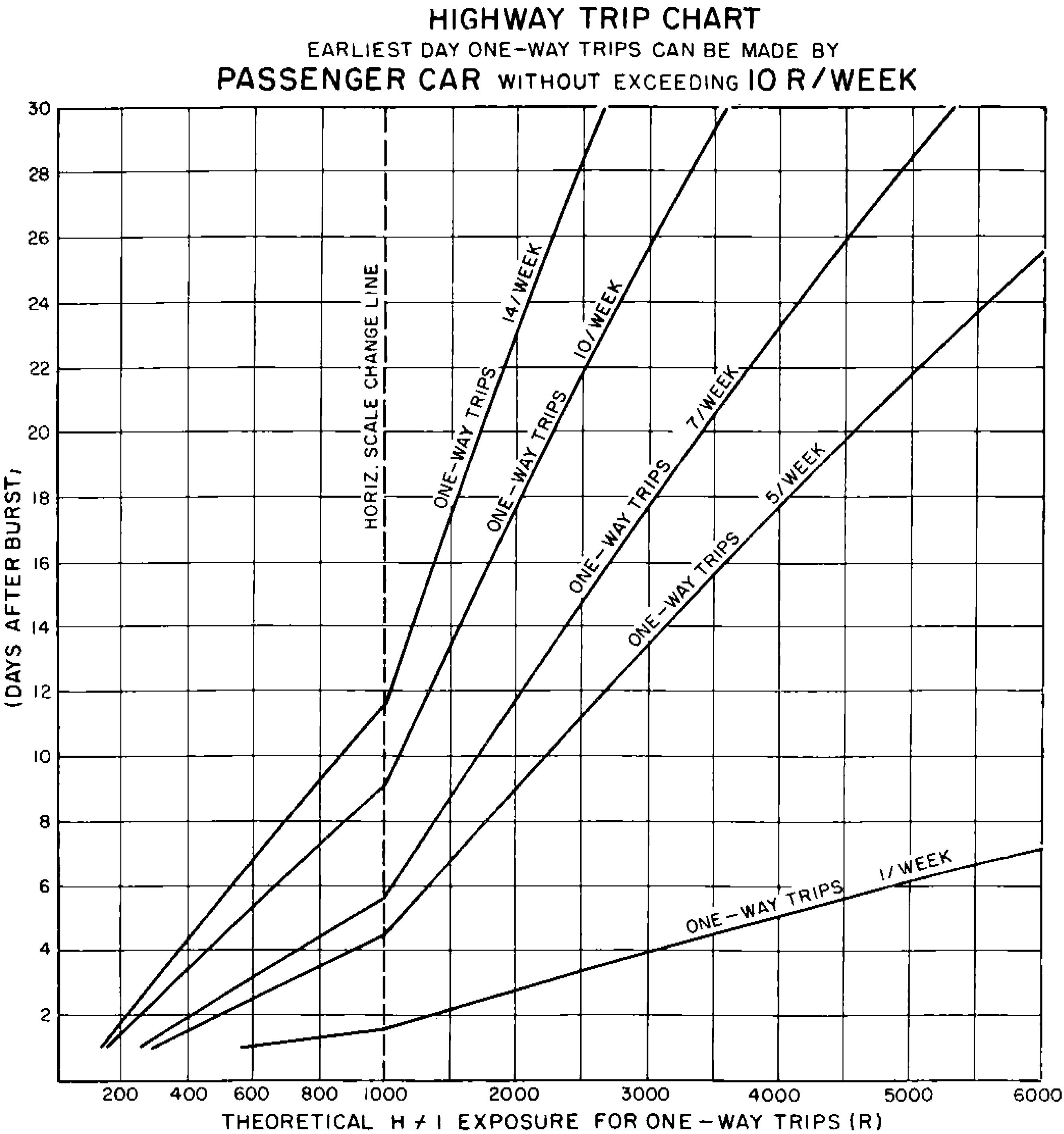
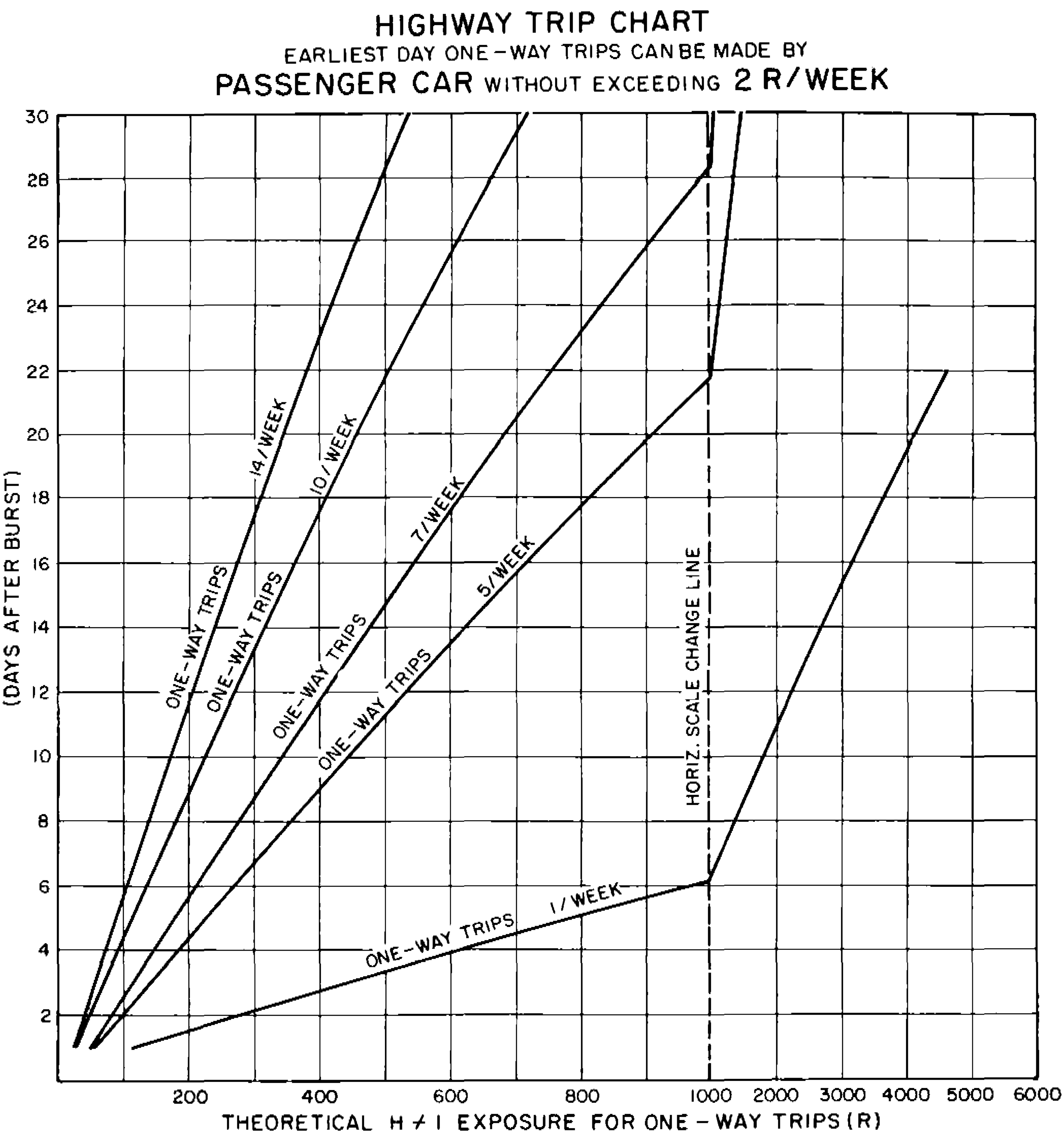

HIGHWAY TRIP CHART
EARLIEST DAY ONE-WAY TRIPS CAN BE MADE BY
PASSENGER CAR WITHOUT EXCEEDING 10 R/WEEK
(DAYS AFTER BURST)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
200
400
600
800
1000
2000
3000
4000
5000
6000
THEORETICAL H + 1 EXPOSURE FOR ONE-WAY TRIPS (R)
HORIZ. SCALE CHANGE LINE
14/WEEK
ONE-WAY TRIPS
10/WEEK
ONE-WAY TRIPS
7/WEEK
ONE-WAY TRIPS
5/WEEK
ONE-WAY TRIPS
1/WEEK
ONE-WAY TRIPS

FIGURE 12



HIGHWAY TRIP CHART
EARLIEST DAY ONE-WAY TRIPS CAN BE MADE BY
PASSENGER CAR WITHOUT EXCEEDING 2 R/WEEK
(DAYS AFTER BURST)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
ONE-WAY TRIPS 14/WEEK
ONE-WAY TRIPS 10/WEEK
ONE-WAY TRIPS 7/WEEK
ONE-WAY TRIPS 5/WEEK
ONE-WAY TRIPS 1/WEEK
HORIZ. SCALE CHANGE LINE
200
400
600
800
1000
2000
3000
4000
5000
6000
THEORETICAL H + 1 EXPOSURE FOR ONE-WAY TRIPS (R)

FIGURE 13

Problem: At D+2, officials at Oklahoma City, which survived the greater hazards of blast and fallout, decided to ship several truckloads of urgently needed supplies to Fort Worth. A fallout map showing approximate radiation intensity lines in the Oklahoma-Texas area was available and the decay rate was found to be generally $t^{-1.2}$.

It was estimated that the trucks could travel the 200 miles, in a most direct route, at an average speed of 50 miles per hour.

Officials had to determine what day the truck movement could begin without exposing the driver to more than 10 roentgens of radiation in one week, and on what days more than one trip per week could be made.

Solution: The problem was worked out by making a chart in table form, Table 3. The table shows the towns encountered between Oklahoma City and Fort Worth, the distance in miles between these towns, the average r/hr at H+1 on each section, the travel time from one town to the other and the theoretical dose received at H+1.

By using the Highway Trip Chart titled "Trucks Without Exceeding 10r Per Week," find 4170r (rounded off) on the horizontal scale and read the one-way trips at D+4, 1 per week; at D+7, 2 per week; and at D+14, 5 per week.

To find the number of round trips which could be made, one could interpolate between curves. For instance, at about D+7, 2 trips per week or one round trip per week; at D+16, 6 per week or 3 round trips per week.

GPO 924-389

TABLE 3

Map Problems

Solutions

From	To	Dist. Miles	H+1 R/HR.	Ave. H+1 R/HR	Travel Time Dist. /50	Theoretical Dose H+1
Oklahoma City	Norman	15	500 1000	750	3/10 hrs.	225R
Norman	Pauls Valley	45	1000 2750 1000	1580	9/10 hrs.	1422R
Pauls Valley	Denton	110	1000 500 1000	833	11/5 hrs.	1832R
Denton	Ft. Worth	30	1000 1300	1150	3/5 hrs.	690R
					4 hrs.	4170R

Use Truck Chart 10R/week

Find 4170 and read one way trips
at D+4, 1/wk
at D+14, 5/wk
at D+18, 7/wk

EHTR

THE POLICE FUNCTION
IN
HIGHWAY TRAFFIC REGULATION IN AN EMERGENCY

BPR

1967—DRAFT

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Bureau of Public Roads

THE ROLE OF THE POLICE IN EMERGENCY HIGHWAY TRAFFIC REGULATION*

Chapter I.---INTRODUCTION

Traffic supervision has always been a basic responsibility of various police agencies and so a call for police traffic services, even in unusual emergencies, generally is classed as routine. However, emergency highway traffic regulation poses unique problems and responsibilities for the police as it does for all those charged with official obligations.

Since this country has never experienced an enemy attack in modern times, much less one involving the use of nuclear weapons, it is necessary to preface this chapter largely on assumptions. These assumptions will be repeated where applicable in this text for purposes of understanding. New assumptions will be interjected where necessary as an introduction to potential police problems and subsequent guidelines as to how to cope with the problems thus raised.

Although it is recognized that police duties, before, during and after an enemy attack, conceivably would run the gamut of police responsibilities, it is the purpose here to limit or confine attention solely to the role of police as one of a large team of many officials and agencies concerned with emergency traffic regulation following a nuclear attack.

The restoration and regulation of traffic in a national emergency is the responsibility of each State. Since a Governor has the prerogative of designating which agency will be delegated the authority to direct emergency traffic supervision, the police responsibility may vary from State to State.

Whether police have full or only partial responsibility for emergency highway traffic regulation, the magnitude of the problems involved will require the full

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*This text was prepared by the International Association of Chiefs of Police.

cooperation and coordinated efforts of many agencies and individuals. Besides the police, other chief participants in this team operation are representatives of the U. S. Bureau of Public Roads, the State highway departments, the military and the organized highway user groups.

Chapter II.---ASSUMPTIONS

1. An attack on the United States would employ predominantly nuclear weapons of multimegation yeild.

2. Little warning of attack can be expected with the advent of long-range supersonic missiles with nuclear warheads.

3. Roads, bridges and tunnels within a blast area will be unusable in varying degrees.

4. Many miles of highways throughout the Nation will be denied to use for varying periods of time of destruction or radioactive fallout.

5. Routes in and about blast areas must be utilized where available or where they can be speedily developed.

6. Unaffected routes may need to be fully utilized, some probably on a regulated basis.

7. Routes through radioactive areas, which can be traversed without serious peril to the occupants of the vehicle, must be opened to essential travel on a regulated basis.

8. Routes so highly contaminated as to be dangerous to the traveling public must be so marked and with the decay of contamination, the markers must be moved to permit less restricted travel.

9. Since target areas would be damaged or destroyed, police facilities, equipment and personnel would suffer similarly.

10. Widespread devastation and fallout will result in the involvement of many political subdivisions at the municipal, county, and State levels, including their respective police representatives.

Chapter III.---DEFINITIONS

Emergency Highway Traffic Regulation is a system which facilitates orderly flow of traffic under a national emergency situation including but not limited to postattack evacuation, regulation of movement through dangerous areas and clearance of priority traffic over routes of limited capacity.[1]

Clear Routes* are highway routes or sections without any restriction of use.

Regulated Routes* are highways selected for control by the EHTR organization because of hazardous conditions, special uses or limited capacity. There are three classes of such routes: A, B, and C.

Regulated Routes Class A* are those highway sections that lie within a radioactive contaminated or other dangerous area and which must be identified and used with special precaution and practice.

Regulated Routes Class B* are highway sections which are temporarily reserved for a special purpose such as civil defense and/or military movements.

Regulated Routes Class C* are highway sections on which all traffic is rigidly controlled by official road space permit at specified times because of critical capacity restrictions or volume demands.

Highway is any roadway, thoroughfare, street, alley, toll road, boulevard, expressway, parkway.

EHTR Road Space Permit[2] is a form issued to identify and recognize vehicles having priority missions on routes subject to regulation.

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[1] Policy and Procedure Memorandum 50-7, Bureau of Public Roads, June 25, 1962

*Instructional Memorandum 50-4-63, Bureau of Public Roads, September 25, 1963

[2] Policy and Procedure Memorandum 50-7, Bureau of Public Roads, June 25, 1962

Special Size and Weight Permits[3] are issued to identify and recognize vehicles which exceed ordinary size and/or weight limitations.

Police refers to any duly constituted peace officer engaged in law enforcement at the State, county or parish, or municipal level.

State Police also refers to highway patrol, State patrol, State highway police, and State troopers.

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[3] Ibid

Chapter IV.---

ORGANIZATION FOR EMERGENCY HIGHWAY TRAFFIC REGULATION (EHTR)

The organizational structure which has been designed for highway traffic regulation purposes is illustrated in Chart No. 1. The State Highway Traffic Regulation Center will be activated immediately. It will be located near the State emergency operating center for purposes of communication and coordination with other emergency operating agencies. The EHTR Center will be the focal point in the State to direct the emergency highway traffic regulation effort.

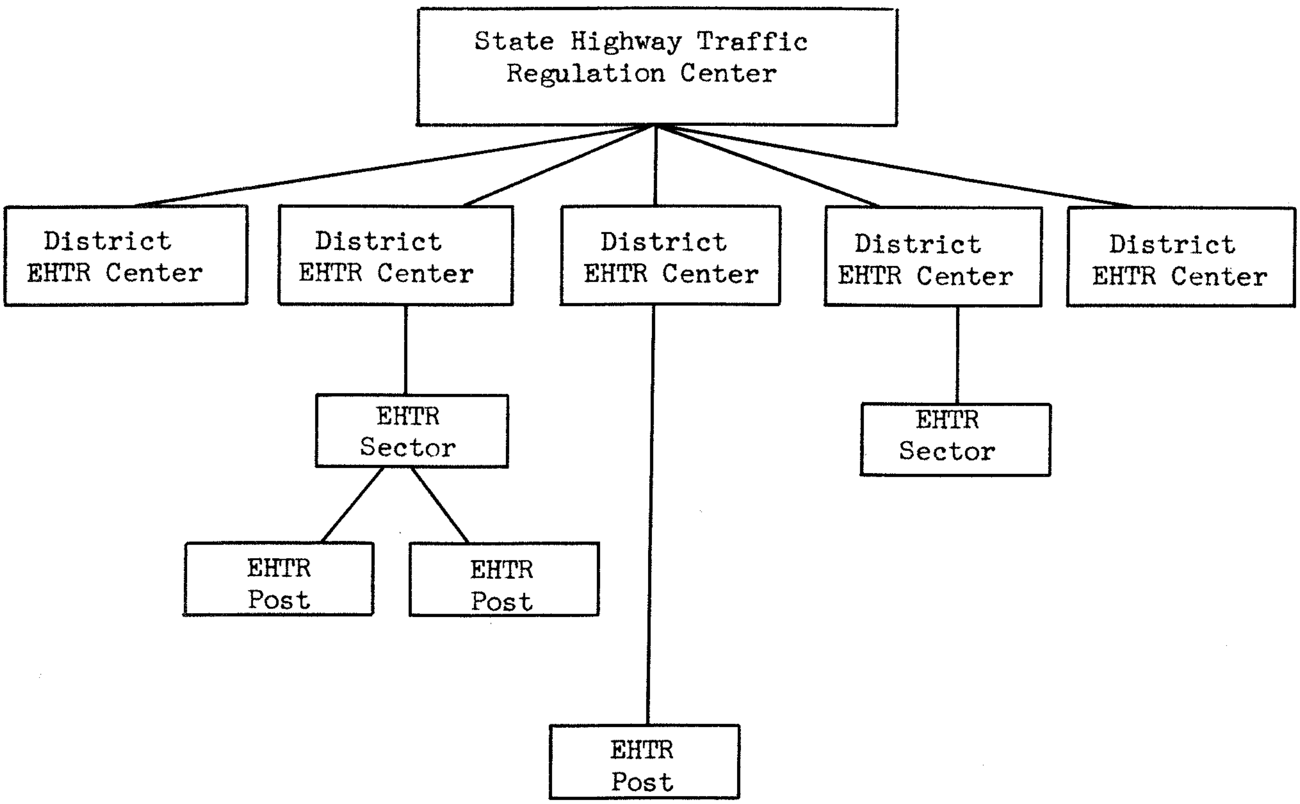

Chart No. 1 - Basic Organization for Highway Traffic Regulation

The District Highway Traffic Regulation Centers will most often be located at district or division State highway offices and garages because of their capability to provide personnel and equipment resources. In addition most district offices are equipped with radio, connected to their state-wide radio network as well as to mobile units in automobiles and trucks used in their local operations. Their capability is further enhanced in some States where district State police or highway patrol headquarters are located in or near the highway offices.

Even though field or decentralized police offices may not be a part of a district highway complex, police should be prepared to make their facilities available as district or sector headquarters or as highway traffic regulation posts because of their communications and, in many States, their housing, feeding, and garage facilities.

Highway traffic regulation sectors, subordinate to the district centers, are to be established and will function at the county, city or metropolitan level as required.

Highway traffic regulation posts will be established along regulated highways to assist, protect, and expedite traffic. The number of posts, and their locations will be determined by the district traffic regulation center, or by the sector.

Chart No. 2 illustrates the police "chain of command" for purposes of assigning responsibility, delegating authority and establishing lines of communication. The Governor, as the State's chief executive, is ultimately responsible for the State's emergency effort including highway traffic regulation. The Governor will normally delegate the authority for state-wide police emergency operations to the commanding officer of the State police agency. Since highway traffic regulation is but one task encompassed by his duties, the State police commander will usually designate another high ranking State police officer to represent and direct police operations from the State Highway Traffic Regulation Center.

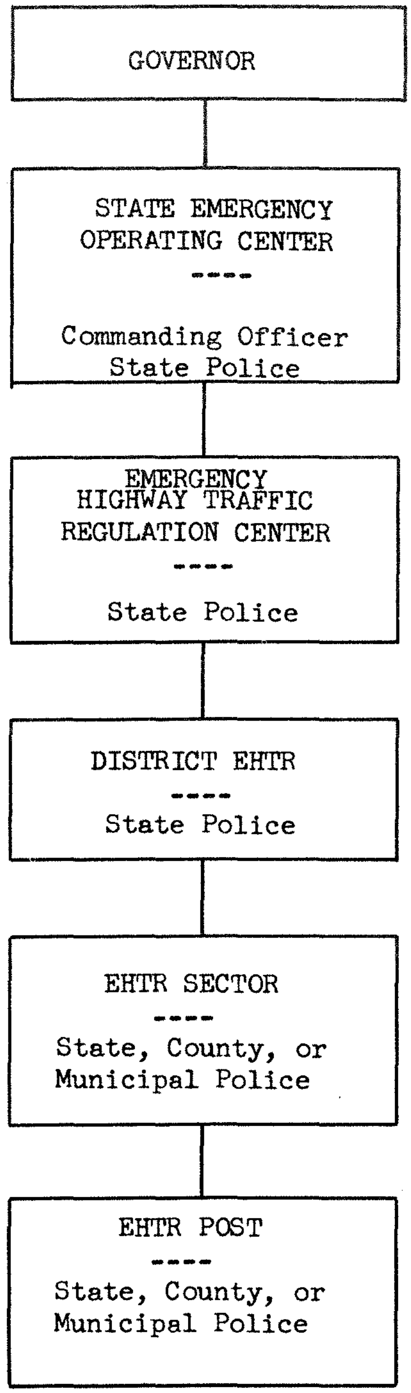

Chart No. 2 - Police "Chain of Command" for Highway Traffic Regulation

The very decentralized nature of State police operations, their communications capability, proximity in some cases to State highway offices and garages, familiarity with routes throughout the State and their experience in handling area-wide situations which frequently cross jurisdictional lines makes them best adaptable to assume responsibility for police highway traffic regulation command at the HTR District level. Below this echelon, command responsibility may be assigned to State, county or municipal police depending upon the availability of police and the location of the HTR Sectors and Posts. Police command of a sector established in or near a metropolitan area will normally be delegated to a county or municipal officer. This will also be applicable to HTR Posts serving the sector area. This situation does not preclude the probability that State police or officers of other jurisdictions will be subordinate to such a command.

It is important to note the implications of Chart 2. Although it represents the most logical approach to performance of the police role, the success of the mission is solely dependent upon the complete devotion of all police agencies involved to a singular purpose. There must be a coordination and cooperation among State, county and municipal police. Each must make his plans so as to mesh with the total effort. All officers need to be well trained in emergency highway traffic regulation, and to be uniformly trained. Police have many responsibilities. A chief must pre-determine what portion of his force will be assigned to highway traffic regulation duties and decide in conjunction with HTR officials just what those duties are to be. A well-coordinated organizational, planning, training and operating effort may be enhanced by using already existing groups such as State associations of chiefs of police or the enforcement committee of a State safety council.

Manning of HTR Offices

A major police responsibility is to provide one or more persons as a member of the team needed to properly activate and maintain EHTR offices.

A high ranking officer - a captain or above - should be assigned to the State EHTR center. He should be an experienced officer. He should be answerable to the top police official assigned to the State Emergency Operating Center. This officer will either be immediately subordinate to the official in charge of the State EHTR center or he may actually be in charge, depending upon to whom the Governor delegates this authority.

A commissioned officer or supervisory officer should be the police representative and local spokesman in both district and sector EHTR's.

If available and needed, police should provide technical and clerical personnel at the various EHTR offices. This is particularly true of dispatchers, lab technicians, and garage mechanics as well as public information and clerical personnel, such as stenographers and typists.

Highway Traffic Regulation Posts

Police have the primary responsibility for the establishment, staffing and operation of EHTR Posts in order to maintain the integrity of regulated routes.

HTR Posts should be strategically located on regulated routes at: (1) State lines; (2) intersections where potential of unauthorized infiltration is probable and could not be effectively controlled through other means; (3) at the start and end of a regulated route; and (4) at sufficiently close intervals to assure adequate regulatory controls on all regulated routes.

Following are some considerations in establishing HTR Posts:

(1) Sufficient space for holding unauthorized vehicles or convoys, and temporarily holding movements off schedule.

(2) Communications capability to and from HTR Center.

(3) Availability of such emergency equipment as tow vehicles, ambulances, highway maintenance equipment, gasoline, and supplies.

(4) Level or threat of radioactivity.

EHTR Posts shall check rapidly all vehicles and convoys for their road space permits. If the movement is authorized and on the proper time schedule, allow them to proceed. If the movement is authorized but not on the proper time schedule, direct it into the holding area and advise the EHTR Center. The EHTR Center will advise the permit issuing authority and request a new time schedule. The EHTR Post will then be advised of the new time schedule and the vehicle or convoy will be allowed to proceed after noting new time on the road space permit.

Police Patrol of Regulated Routes

One of the major functions of patrol is police traffic supervision which ordinarily consists of (1) traffic accident investigation, (2) traffic direction and control, and (3) traffic law enforcement. These same three basic component elements would still be applicable with some modifications in emergency highway traffic regulation.

Accident Investigation. If at all possible a report should be made of all accidents, particularly injury and fatals. Although the report may be abbreviated, it should at least contain basic information, the names of persons involved, addresses, age, sex, race, location of accident, time and date, investigating officer's name and department, description of vehicle(s) and a resume of the circumstances. A standard accident report form can be used. Besides getting the basic information, the officer will also be responsible for treating the injured, preventing other vehicles from becoming involved, and clearing the roadway. All pertinent information should be transmitted to his headquarters.

Direction and Control. The patrol officer is responsible for keeping the roadway clear of stalled and abandoned vehicles and other impediments. It may be necessary to change or modify signing; erect barriers; perform point control; divert traffic; keep pedestrians off the trafficway; set out fusees and flares; provide directional and other information.

Enforcement. Police are responsible for the enforcement of emergency traffic regulations. They will detect and remove unauthorized vehicles, convoys and pedestrians; require adherence to any emergency prompted regulation such as minimum speed limits; prevent unnecessary parking or stopping on the highway; protect lives and property of highway users; enforce the proper use of road space permits; detect and restrain anyone who threatens the route by an act of sabotage.

Other Related Patrol Duties. These will include:

(1) Cargo Protection. Security of classified or high-priority movements will be provided by shippers or carriers.

(2) Reporting. A very important phase of police responsibility will be to report all pertinent information to an EHTR office, generally the nearest one.

Although other agencies and individuals will also be reporting information to EHTR offices, some of it duplicating that which police may report, police are, by the very nature of their responsibility, assignment, training, communications and other resources, and experience the most competent and capable of relaying the best information possible relative to weather, traffic, damage, highway, and radiological conditions.

Communications

Police have the best emergency communications experience, equipment and facilities. Therefore, whether they are called upon to establish or assist in the operating of an emergency communications center at an EHTR office, or they provide supplemental and relay service, police must be ready to assume a leading role in this vital function.

Emergency Medical Assistance

Emergency first aid is a routine police duty, but in times of war this duty and the skills attendant to the task would receive its greatest challenge. The police must be prepared, both in the skill and with the equipment. It is also conceivable that police and EHTR offices will be required to act concurrently as a first aid station until victims can receive professional medical assistance.

Public Information

One of the most difficult and yet most important functions to be performed by EHTR personnel is to acquire, assimilate, and appropriately disseminate the best information possible for public consumption as it relates to highway traffic. One of the real tests of our postattack recovery ability rests with the effectiveness of our communication with the surviving population. To get compliance with EHTR Center policy and directives; to facilitate the safe and efficient evacuation of goods and people as well as the prompt and orderly ingress to disaster areas; to lift the spirit of a shocked and terrified people; to minimize further injury and loss of life and property - all are to a considerable extent dependent upon our public information capability. Police are responsible for relaying information to the EHTR Center and to assist in its dissemination.

Develop Plans

A major purpose of this text is to provide a guide for police planning for emergency highway traffic regulation. It is also a stimulus to thinking and planning for the many other aspects of the police role in such an emergency. The next section is devoted to planning as a means of providing for maximum police preparedness.

Chapter VI.---

POLICE PLANNING FOR HIGHWAY TRAFFIC REGULATION

Good planning is an essential prerequisite to maximum police operational capability and execution.

Planning requisites involve an appreciation of the following principles. Plans must

a. Be made in advance, and constantly updated to assure their currentness. Where no planning has taken place or is only partially completed, every effort should be made <u>now</u> to draw plans.

b. Be flexible and provide for alternatives. This was never so true as in planning for emergency highway traffic regulation. The inherent devastation of one nuclear device coupled with a lack of human experience following its use makes flexibility of plans imperative. Also remember, no plans can be devised which can eliminate the many occasions when a police officer must exercise his best judgment to meet a situation.

c. Keep in mind the human element. Plans must recognize human limitations; the need to provide for basic wants; the necessity of protecting personnel from excessive radioactive fallout. A crisis such as is involved in this particular event requires the greatest challenge yet conceived of an officer's devotion to service to mankind. It would be folly not to consider that some surviving personnel strength may not be available because of an overwhelming personal concern for the welfare of family.

d. Be drawn so as to be easily understood. Plans must be as simple and free of superlatives as possible. The methods and techniques of implementation should be regulated to training.

e. Be realistic so as to appear capable of accomplishment. Such plans are much easier to sell to all personnel and their acceptance is, of course, of paramount importance to the success of our mission. Plans will be more practical, more realistic, more saleable if they reflect the thinking and suggestions of subordinates. Another means of gauging the practicability of plans is to test them in mock exercises.

f. Be documented. This is fundamental, but a rudiment in planning too frequently overlooked. Ease of distribution is also facilitated.

g. Be disseminated to police and other appropriate agencies and individuals. Training and informational programs are two vehicles by which widespread and accurate dissemination can best be effected. More emphasis on police training will be found later in this chapter.

h. Be coordinated and correlated with the overall mission. Police are not singularly responsible for either normal or emergency highway traffic regulation. They are an important part of a team effort. Concurrent jurisdictions and the multiplicity of agencies demands the highest degree of cooperativeness and coordination among the police themselves.

Specific Planning for Highway Traffic Regulation

Highway traffic regulation following a nuclear attack will demand police planning in several specific areas. Following are those areas which can readily be identified. In addition, observations and suggestions are made relative to planning details.

1. Organization. An organization chart should be prepared reflecting not only the highway traffic regulation structure, but also the HTR position in and relationship to the whole emergency operating structure. A police "chain of command" is an inherent part of this structure.

2. Manpower Assignments. Written descriptions of responsibility should be drawn for each police task to be performed. Specific individual assignments should be made where feasible, particularly for positions of command authority. Other assignments for each officer and police department employee will be dependent upon orders given by superior police personnel at the time his services are needed and available for use. Plans should also include a list of especially qualified young officers who could temporarily assume various command positions.

3. Alerting Personnel. A standardized set of procedures should govern the alerting of personnel. A personnel roster listing name, rank, address and phone number should be currently maintained in each department. At least one State* has established a series of four (4) readiness conditions. Each condition requires an increased state of preparedness on the part of personnel to meet an increasingly serious or imminent situation. It is vitally important that proper police action be taken immediately in an emergency. Such action must be correct, prompt and decisive.

4. Maps. Planning must include the acquisition of current maps and the preparing of overlays. Maps should be obtained depicting the United States, the State, major metropolitan areas, and counties. Maps and overlays can be used to plot radioactive fallout patterns, identify clear and regulated routes, locate EHTR offices and posts, and pinpoint areas of damage. They are also an invaluable training aid. Maps may further be of use in showing vulnerable points such as bridges, tunnels, powerhouses, armories, telephone and communications centers, subway and elevated stations, interchanges, and railroad crossings.

5. Take Inventory of Resources. Police should determine now and periodically in the future just what resources are potentially available. This would include manpower, both sworn and civilian, in respect to rank or classification, skills, present assignment, physical location and duty hours. Do not fail to include any police cadets, recruits and reserves.

*California Highway Patrol Disaster Plan

All existing police equipment should be inventoried with respect to location, type of equipment, condition, and accessibility. This includes first aid materials, vehicles, weapons, ammunition and parts, uniforms, towing equipment, radiological monitoring equipment, badges, fusees and flares, signs, office equipment, communications equipment and parts, report forms, cameras and supplies, bull horns, public address systems, fire extinguishers, axes and wrecking bars, rope and/or cable, flashlights and batteries, aircraft, gas equipment and masks.

All police facilities should be inspected and listed according to how each could be used as an EHTR center, district, sector or post headquarters; a first aid station; a communications center; an informational office; a garage; or other appropriate facility. Considerations such as emergency power, kitchen and feeding facilities, housing, parking, fallout shelter protection, location, access routes, fuel storage and supplies on hand would be valuable information for further planning and future reference.

Non-police resources useful in an emergency should be itemized as to type, location, how contacted, possible use, limitation, accessibility, and other pertinent information. Examples of such resources would be:

. . . wreckers
. . . ambulances
. . . hospitals
. . . other law enforcement agencies
. . . fire departments
. . . police, fire and military reserve units
. . . fallout shelters
. . . heavy construction equipment and operators
. . . physicians
. . . vehicle fuel and service outlets
. . . equipment service centers
. . . engineers
. . . communications technicians
. . . motor fleet operators
. . . members of military veterans' organizations

As the inventory is being conducted, notations should be made as to deficiencies and inadequacies so that action can be taken to better meet the anticipated needs. Such an inventory, if thoroughly and properly made, will reveal more than resource strengths and weaknesses. Undoubtedly you will find gaps in training which must be filled; new plans and policies will have to be formulated; new lines of communications will have to be established; new equipment will be tested and other specifications re-written.

Police may have or should at least know how to acquire such special equipment as inhalators, jacks, small tools, acetylene cutting units, wrecking and digging tools, chain and handsaws, grappling equipment and portable 100 volt generators. Lists of such equipment and how and where obtainable should be compiled for future reference. This list, like others, must be kept current.

An adjunct of the inventory process should be the determination as to where, what, and how much emergency equipment and material should be stockpiled. With the possibility of total or partial destruction of much of our "in use" recources, it is quite clear that provision should be made for accumulating, locating, maintaining and protecting emergency supplies. This stockpile should include essential items only. Examples might be a vehicle(s); food and water; radiological monitoring equipment; fuel; emergency radio and power equipment; clothing; hand tools; emergency or blank traffic signs. Stockpile sites should be carefully selected keeping in mind their proximity to personnel; accessibility; security and maintanance features.

6. Police Reserves or Auxiliaries. When taking inventory, it will be immediately apparent that manpower resources are grossly inadequate to meet unusual emergency needs. Although police cannot justify nor can public funds afford the maintenance of a full-time task force solely for EHTR and other wartime emergencies, many police agencies have already established a reserve unit which can be of immense value as supernumeraries. Plans should be drawn to create a reserve unit now or to expand an existing unit. Reserve programs involve comparatively little cost. Every community has citizens who can be recruited or will

volunteer for a public service activity. Recruitment, selection and training can be handled by appropriate existing police functions. The man-hours expended and relatively small outlay of supplies and equipment can return big dividends, particularly in times of emergency. In many communities, the reserve purchases his own equipment. Reserves also generally serve without remuneration and other benefits which usually accrue to regular police officers. One exception is the necessity and equity of providing some form of insurance coverage to protect both the reserve and the employer.

The use of police reserves requires at least two important considerations. First, recruitment should be oriented away from those persons who hold reserve positions in the military, are employed by public utilities, possess highly critical skills such as engineers and physicians, or are otherwise committed to performing necessary emergency duties following an enemy attack making them unavailable for police use. Secondly, the fact that these personnel are volunteers who have assumed their police reserve capacity only on a part-time basis and as a secondary vocational choice, it is obligatory that police manpower plans discount their full response accordingly.

7. Legal Problems and Implications. Planning must include a thorough review of laws and ordinances to determine those statutes which may apply to anticipated situations. Study should include applicable Federal, as well as State and local laws. Clearly defined laws should be delineated from those where opinion only is the basis for possible action. Police authority should be made clear. Admittedly, not all emergency situations may permit the exercise of police authority within clearly defined limits. Some need for new legislation or revisions of the old may be necessary. "Battlefield" judgments may be unavoidable. However, police must use the law as the basis for their actions, and recognize the continuous need for the exercise of sound judgment, particularly in the so-called "gray" areas of jurisprudence. Martial law and its ramifications should be thoroughly understood as should police authority to deputize. A list of legal questions should be made and researched.

8. Detention Facilities. Arrests will be inevitable. Jails and/or prisons may be damaged or destroyed. Sites and facilities for detention should be provided for in good planning. Officers making arrests should report to their headquarters all pertinent information. There an arrest log should be maintained with captions for name, sex, race, location of arrest, date and time of arrest, charge, and name and department of arresting officer. Space for additional comment is advisable.

9. Police Emergency Communications System. Generally, police have the best existing emergency communication system. Therefore, with some modifications the system can be used to maximum advantage for EHTR operations. Plans should be developed which will provide emergency adaption. The inventory of communications equipment, personnel, and facilities will reveal needs. Alternate communications plans should be drawn where possible. Plans should include emphasis on abbreviated or minimal messages and transmission discipline. Acquisition of pack sets and walkie-talkies is recommended. The great importance of emergency communications demands that greater impetus be given now to increasing communications contact, particularly voice radio, between all police agencies. Although some destruction of teletype circuits and micro-wave systems can be expected, use of unaffected facilities can be continued to real advantage. Repairs to damaged systems and replacement of destroyed ones can eventually be made. Therefore, plans to install or extend these excellent police communications media should be expedited.

10. Reporting. Standard or existing report forms and reporting procedures should be used where possible. However, EHTR will require some revised or new reporting systems and report forms. Reporting methods for traffic accidents and incidents must be determined. Report flow must be established.

11. Police Uniforms. State-wide plans and specifications should be drawn to assure that some semblance of uniformity exists in the display and design of symbols of authority (badges, uniforms, etc.). The ready identification of authorized persons and the enhancement of their appearance are two important objectives.

Chapter VII.---

TRAINING FOR EMERGENCY HIGHWAY TRAFFIC REGULATION

Of vital importance to police preparedness in performing emergency highway traffic regulation is a training program for police personnel.

A training program should consist of at least four types: (1) basic course; (2) mock exercises; (3) specialist training; and (4) supplemental training.

Basic Course

The basic course should be a well-rounded program covering generally all aspects of emergency highway traffic regulation, and some attention to detail as an aspect particularly relates to police duties. The "Guide for Highway Traffic Regulation in an Emergency" is suggested as one text for this portion of the training program. All sworn and civilian personnel should attend. Such a course would be extended to include local and State plans where applicable and necessary to the full understanding of each employee's role.

Specialist Training

Specialist training should be designed for further educating the various technicians in their particular skill so that they may be more adept and suitably oriented in their responsibility in emergency highway traffic regulation. The extent of such specialized training will depend upon the numbers of personnel involved, present level of skill, and whether additional instrumentation is anticipated.

Supplemental Training

Supplemental training should be offered continuously in order to keep all personnel current and to act as a reminder of their individual responsibilities. Such training can and should take several forms: (1) attendance at other related training programs; (2) training bulletins;

(3) department newsletters or house organs; (4) films; (5) expert speakers; (6) distribution of appropriate literature; (7) refresher courses; (8) staff meetings; (9) use of library. Such training also draws the employee's attention to the fact that the department places emphasis on EHTR as a very important police function. This in turn will stimulate personnel to take a more personal interest in the total program.

Mock Exercises and Demonstrations

Wherever possible all personnel should be involved in mock exercises and demonstrations. Such exercises should be a part of the basic course as well as a technique to be employed in supplemental training.

Instructors

All police department instructors should be carefully selected and well-oriented themselves before being assigned to the program. They should be thoroughly familiar with the subject, their own State and local plans, the various publications emanating from the U. S. Bureau of Public Roads, Office of Emergency Planning and other pertinent materials. Planned visitations to other States or cities which are further advanced in their training efforts may well be advisable. As in any training program, the instructors should not only be excellent teachers but also exude enthusiasm reflecting a genuine belief in their subject area.

Many knowledgeable and capable instructors are available from other agencies at little or no expense. They should be employed where appropriate.

Should Emergency Highway Traffic Regulation Be Integrated With Other Training Programs?

This question can be answered both negatively and affirmatively. EHTR should be made a part of police recruit training and new employee orientation but only in a limited sense. It would certainly be appropriate to refer briefly to EHTR while recruits are being exposed generally to emergency police traffic supervision. Distribution of literature and other materials relative to EHTR should be a part of a package of materials provided a new civilian employee. Obviously, these methods of teaching are extremely limited.

Aside from some superficial disadvantages, EHTR training should be presented as a separate and distinct program. This does not, however, exempt it from being considered as a part of an overall training effort to meet emergency needs in a postattack period. Training in emergency highway traffic regulation must be provided with a cognizance of the total spectrum of police responsibilities. There must be a balanced relationship.

All police personnel are not uniformly trained in basics or fundamentals. We cannot assume that all police are equally capable of assimilating instruction due to wide variations in selection standards. As an aside, therefore, in making our plans, every consideration should be given to a continuous effort designed toward up-grading selection and training standards.

Whose Responsibility Is EHTR Training?

This question can best be answered by another question: Who is in the best position to provide training? It is the obligation of the State police to provide much of this training. State police staff, equipment, and facilities can be augmented by support from other police departments, particularly in large metropolitan areas, other State agencies, and the Federal Government.

Where Can Training Be Given?

Existing police academies at the State, county and municipal level are best suited because of their size, staff and experience in handling numerous large and small classes alike, both in basic and specialized instruction. Although, as mentioned earlier, the State police have primary responsibility for EHTR training, every consideration should be given to decentralizing the training so as to make it available to as many police agencies as possible. Training plans should include a curriculum so fully developed that one of the inherent disadvantages of decentralization--the tendency toward lack of uniformity--is greatly reduced. A team of trained instructors, circulating throughout a State, can also do much to insure a standardized program.

Curriculum of Basic Course

Suggested topics for inclusion in the EHTR basic training program are as follows:

1. Definition and purpose of EHTR.

2. Organizational structure for EHTR.
   a. Its relationship to the State emergency operating center.

3. State and local EHTR plans.

4. Police chain of command in EHTR.

5. Police responsibilities for EHTR.

6. Specific duties - e.g., manning EHTR centers, districts, sectors, and posts; reporting highway conditions; accident investigation.

7. Familiarization with emergency routes signing.

8. Radiation
   a. Monitoring devices, techniques and reporting
   b. Human tolerance and necessary safeguards.

9. Familiarization with various reporting forms and symbols used in EHTR.

10. Familiarization with a glossary of terms peculiar to EHTR.

11. Legal aspects of EHTR.

12. Police personnel alerting procedures.

13. Familiarization with road space permits, special permits for excessive size and/or weight.

14. Use of special equipment.

15. Communications procedures.

16. Mock exercises and demonstrations.

17. Role of civilian personnel, including reserves and recruits.

18. First aid.

VIII.---SUMMARY

Since police have the responsibility for the handling of all types of emergency situations, it should be emphasized that planning for emergency highway traffic regulation is not a substitute for well-developed plans dealing with pre-attack, attack and immediate postattack phases. Rather, EHTR is only a part of postattack planning. It is a vital part, however, because so much of our postattack survival and recovery depends upon the prompt and efficient flow of people and goods over a disrupted but functioning highway system.

The need for active police participation in the early planning stages is essential. Lacking informed guidance from police executives, non-police planners--unfamiliar with police resources and capabilities--may cast the police in a rôle which is unrealistic. Adequate, workable plans can be structured only on a base of intelligent effort and not on one of ignorance.

The police role in emergency highway traffic regulation can only be met through a recognition and identification of responsibilities, well-coordinated planning, uniform and continuous personnel training and a growing spirit of interagency cooperation. Altruistic as it may sound, preparedness is the strength of our Nation. Are you ready to assume your role in her defense?

☆ U.S. GOVERNMENT PRINTING OFFICE: 1967—251-025/89

POTENTIAL ADVANCEMENTS IN FREEWAY SURVEILLANCE AND CONTROL TECHNIQUES

-A Technical Report-

June 1970

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Prepared for the
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TABLE OF CONTENTS

Section 1

INTRODUCTION AND SUMMARY

Section 1

INTRODUCTION AND SUMMARY

1.1 Introduction

The nation's freeway system has proven to be one of its most important transportation resources. Like all transportation facilities, however, it is not entirely free of operational problems. Considerable attention has been devoted to these problems in the past, and several approaches have been investigated.

One such approach lies in making the most efficient use of the traffic carrying capabilities of the present system through electronic surveillance and control. While this approach offers no real alternative to the development of an expanded and "balanced" transportation system, it does offer some tangible short-term benefits, in the improvement of freeway operations and safety. In many respects, it provides a stop-gap measure pending the development of more adequate facilities. In another sense, however, it is definitely a part of the long-term solution to transportation problems since it promises to be the logical ancestor of many of the futuristic traffic control concepts now on the drawing boards.

This report deals with four separate topics in freeway surveillance and control:

- The use of traffic density as a control parameter, is discussed in Section 2, which deals with the various types of density-based models, and the techniques by which density may be measured.

- The subject of entrance ramp control is treated in Section 3. Two specific topics are explored, including the evaluation of the motorists response to the "green-band" display, and the "open-loop" pacer concept.

- Section 4 deals with the advisory and control messages which may be presented to drivers already on the freeway approaching critical sections which are subject to "bottleneck" operation.

- The final section discusses the concept of the automatic detection of capacity reducing incidents by a freeway surveillance system. The subjects which are presented include the characteristics of highway incidents, a functional analysis of an incident detection system, and the information processing logic by which these incidents may be identified.

The material presented herein was originated in a number of technical analyses performed for the Federal Highway Administration by the Kelly Scientific Corporation under Contract No. FH-11-6373.

Section 2

THE USE OF TRAFFIC DENSITY AS A CONTROL PARAMETER

Section 2

THE USE OF TRAFFIC DENSITY AS A CONTROL PARAMETER

2.1 Introduction

The macroscopic variables which describe the state of a traffic stream are:

- Flow Rate, (Q) vehicles/hour
- Density, (K) vehicles/mile
- Speed, (U) miles/hour

These three variables are related by definition such that any one of them may be expressed in terms of the other two, according to the basic relationship:

$$Q = KU$$

In addition, a number of emperical models have been formulated which relate these quantities internally such that only one of the three need be measured accurately to provide a statistical basis for a complete description of the state of the stream.

It is essential to note at this point the differences between "point" and "area" measurements. Point measurements such as flow rate and speed describe the conditions which exist at a point in space taken over a finite time interval. Area measurements represent the converse situation - i.e., they are taken at a point in time and measured over a finite distance interval.

Thus, an area oriented measurement, such as density, can only be expressed accurately in terms of point oriented measurements, such as speed and flow, when the facility in question is operating in a homogeneous manner - i.e., when all vehicles are travelling at the same speed and with the same spacing. Most traffic sensors are of the point-measurement type, and it is extremely difficult to obtain true density measurements for on-line control purposes. However, in many real-time applications, the actual number of vehicles in a given section of roadway is generally accepted as the most meaningful piece of information which the highway has to offer. Some success has been obtained in the measurement of density in tunnels by close surveillance of the traffic flow at frequent intervals,[(1)] however, in the less constrained traffic movement observed on multi-lane freeways, the required density values have been approximated by point measurements for purposes of real time surveillance and control. The usual method of approximation lies in the measurement of detector occupancy, which is defined as the percentage of the total time in a given sampling interval during which a presence detector is occupied by a vehicle. This quantity has been shown to be related to the equiv-

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[(1)] Cunningham, Ronald F. and White, Carroll F., "Vehicular Tunnel Traffic-Flow Control", Vehicular Technology, February 1970.

alent density at the point of measurement and it has been found experimentally that the occupancy values are strongly correlated with figures obtained by dividing measured flow rate by measured speed[1] (which, by our previous definition, yields a calculated value for density). Occupancy inputs have been used, therefore, in past freeway surveillance and control activities for such purposes as prediction of travel times, determination of metering rates, and location of highway incidents. The conclusions drawn from all three of these experimental applications suggested that occupancy alone left much to be desired and that actual measured densities could have been used more effectively had they been available.

2.2 Application of Density Models

There are four main areas in which reliable real-time density information could be used effectively in freeway surveillance and control applications. These include:

- Prediction of travel time: since traffic density is a measure of the number of vehicles which must be served at a freeway bottleneck of (more or less) known capacity, it provides the basis for a realistic estimate of waiting time during periods of congested operation.

- Bottleneck density controls: density is also accepted as the most reliable predictor of congestion resulting from the breakdown of traffic flow at a bottleneck. Under stable

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(1) Courage, K.G., Some Electronic Measurements of Macroscopic Characteristics on a Multi'Lane Freeway, Highway Research Record No. 279, 1969

flow conditions, bottleneck density may be controlled to some extent by restricting the input of vehicles at upstream entrance ramps. Therefore, with accurate density information, it is reasonable to expect that many of the current real time freeway metering schemes could be significantly improved.

- Section Density Controls: when congestion does develop in spite of bottleneck controls, it becomes necessary to optimize the upstream inputs on a different basis - i.e., optimal distribution of delay between the freeway and adjacent surface streets. This requires an adaptive system model which relies heavily on the density of traffic in individual section of the freeway.

- Incident Detection: the occurrence of an incident on a freeway tends to create "pockets" of density which may not become detectable by point measurements until considerable time has elapsed. Therefore, a knowledge of individual section densities can prove especially valuable in the detection of such incidents.

2.3 Measurement of Density

2.3.1 Input-Output Methods

If the number of vehicles within a highway section at t = o is defined as N_o then the number remaining in the section at a later time, $t = \tau$ may be calculated by

$$N_\tau = N_o + \sum_{t=o}^{\tau} Q_i - \sum_{t=o}^{\tau} Q_o$$

Where: Q_i denotes the flow of vehicles into the section

Q_o denotes the flow of vehicles out of the section

Simply stated, this means that the number remaining in the system is just the algebraic sum of the initial number plus the net change.

The initial number may be approximated under very light flow conditions by observing the flow over a suitable period and assuming an average value for "free" speed. This number may then be used as a basis for subsequent density estimates during periods of more congested operation. As an alternative, a reference value may be established periodically using a moving vehicle technique, with the position of the vehicle communicated to the central location at key points in the system. This technique has been used successfully in short term experimental studies for the evaluation of control algorithms, but is likely to be too costly and cumbersome for operational purposes.

Assuming that the initial storage can be determined reliably, there still exists the problem of an accurate accounting of inputs and outputs. The first requirement, of course, is that detectors be installed at the boundaries of the chosen freeway sections and on all entrance and exit ramps within the study area. Experience has shown that accurate counts can generally be obtained on the single-lane ramps, but significant errors can creep in on the mainline where multi-lane operation is involved. Furthermore, these errors are accumulated in the subsequent calculation of storage and in many cases calculated values bear little relationship to reality after a very short time.

It is interesting to note, however, that a direct input-output method is currently used in Chicago with some success. The subsystem accumulations, referenced to a point of very low density prior to the peak period are printed out on a five minute basis and used on-line by the system operator in assessing current conditions. The figures so obtained are not used in connection with the metering algorithms, however, the project staff has expressed a general confidence in the validity of the figures, particularly as tempered by human judgement to account for detector failures, etc.

An important consideration in the counting accuracy of a multi-lane sensor station is the placement of the detectors where the vehicle paths are predictable. Current models of loop detectors, and their equivalents can provide an accurate count of vehicle passage over a fairly wide speed range provided that the vehicles occupy a reasonably constant portion of the detection area. Where excessive lane changing takes place, there is a tendency to either over-count, by recognizing the same vehicle in two adjacent lanes, or to under-count by missing lane changing vehicles completely. Furthermore, in freeway surveillance applications, it is often desirable to place the detectors quite close to bottleneck areas, such as entrance ramp locations where lane changes are frequent, to increase the sensitivity of the system to breakdowns in traffic flow. Thus, some measures must be sought to improve traffic counting accuracy if input-output studies are to provide useful density information.

One such method, tested in Detroit in 1968, utilized additional detectors located between lanes, combined with special processing logic to eliminate possible miscounting due to lane changing vehicles.[1] This technique was not formally evaluated, however, it appeared that within the depth of the studies carried out, accuracy improvements in the order of three to four percent were obtained. Another possible technique, which has not been implemented, uses two detectors per lane, i.e., one detector more per station than the Detroit system (which used 2N-1 detectors for N lanes). The advantage of the proposed system is that it also provides accurate speed measurements on all lanes. This scheme uses a different detection area for the two detectors in each lane (upstream and downstream). The basic detector con-

(1) Paesani, G.F., Software Methodology: Appendix C of Texas Transportation Inst. Report 488-6 (NCHRP Project 20-3), 1968.

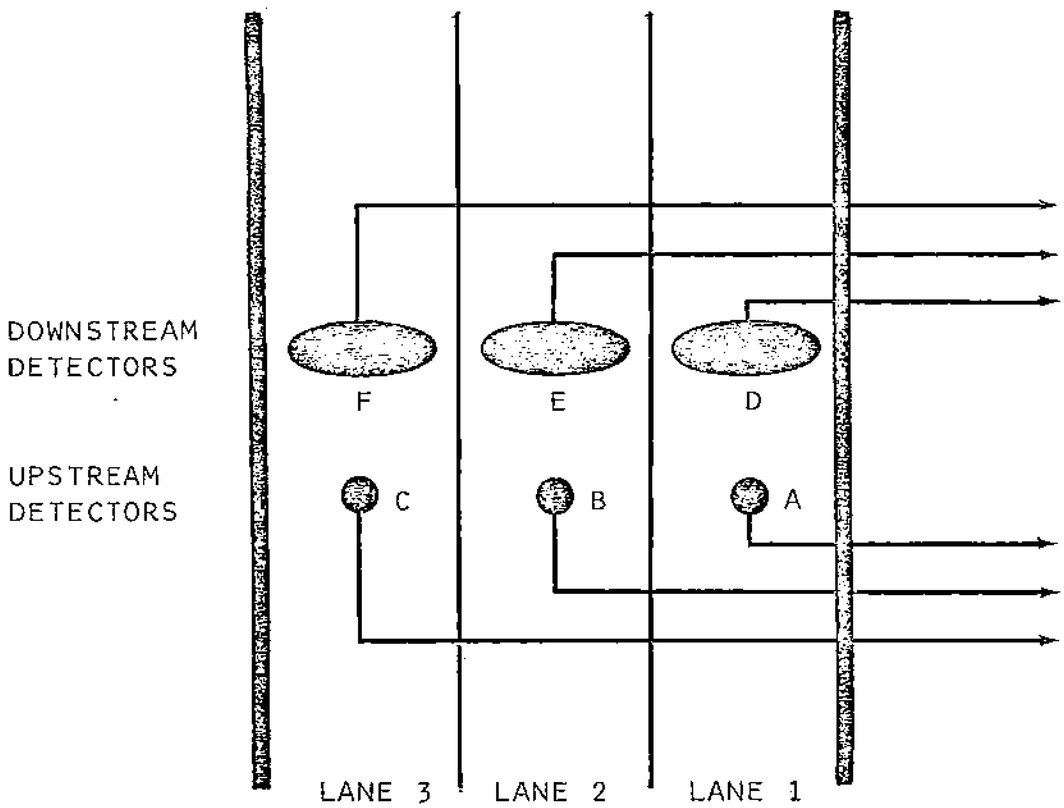
figuration is shown in Figure 2-1. The processing logic, shown in Figures 2-2 to 2-5 inclusive, is based on the following assumptions:

- Upstream detector lateral spacing such that one vehicle can miss both, but can not double-count.
- Downstream detector lateral spacing such that one vehicle can double-count, but not miss both.
- A vehicle passing over an upstream detector cannot pass over the downstream detector in the adjacent lane without activating the downstream detector in the same lane.
- Detector spacing (longitudinal) is short enough that a vehicle must actuate the downstream detector in a given lane before it leaves the upstream detector.

It is felt that this detection scheme may be worthy of implementation and evaluation where adequate processing facilities exist and where there is a need for accurate flow and speed data.

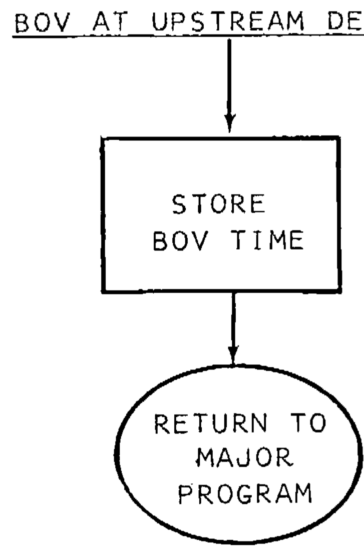
2.3.2 Extrapolation of Point Measurements

The storage of vehicles within a roadway of length l may be expressed as the amount of travel time expended by all of the vehicles on the roadway per unit of time. Therefore, if the total travel time can be calculated, the number of vehicles on the roadway may be estimated. Now, the total travel time (TTT) may be expressed in terms of total travel (TT) and average speed



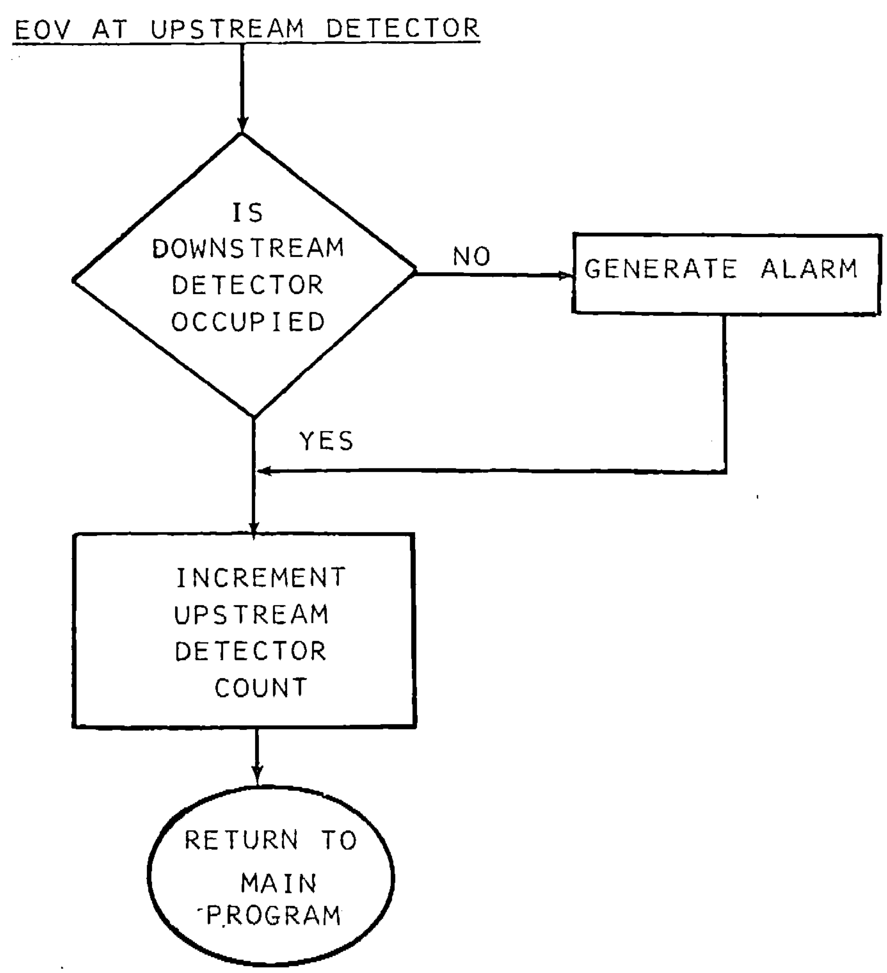
DETECTOR CONFIGURATION

FIGURE 2-1



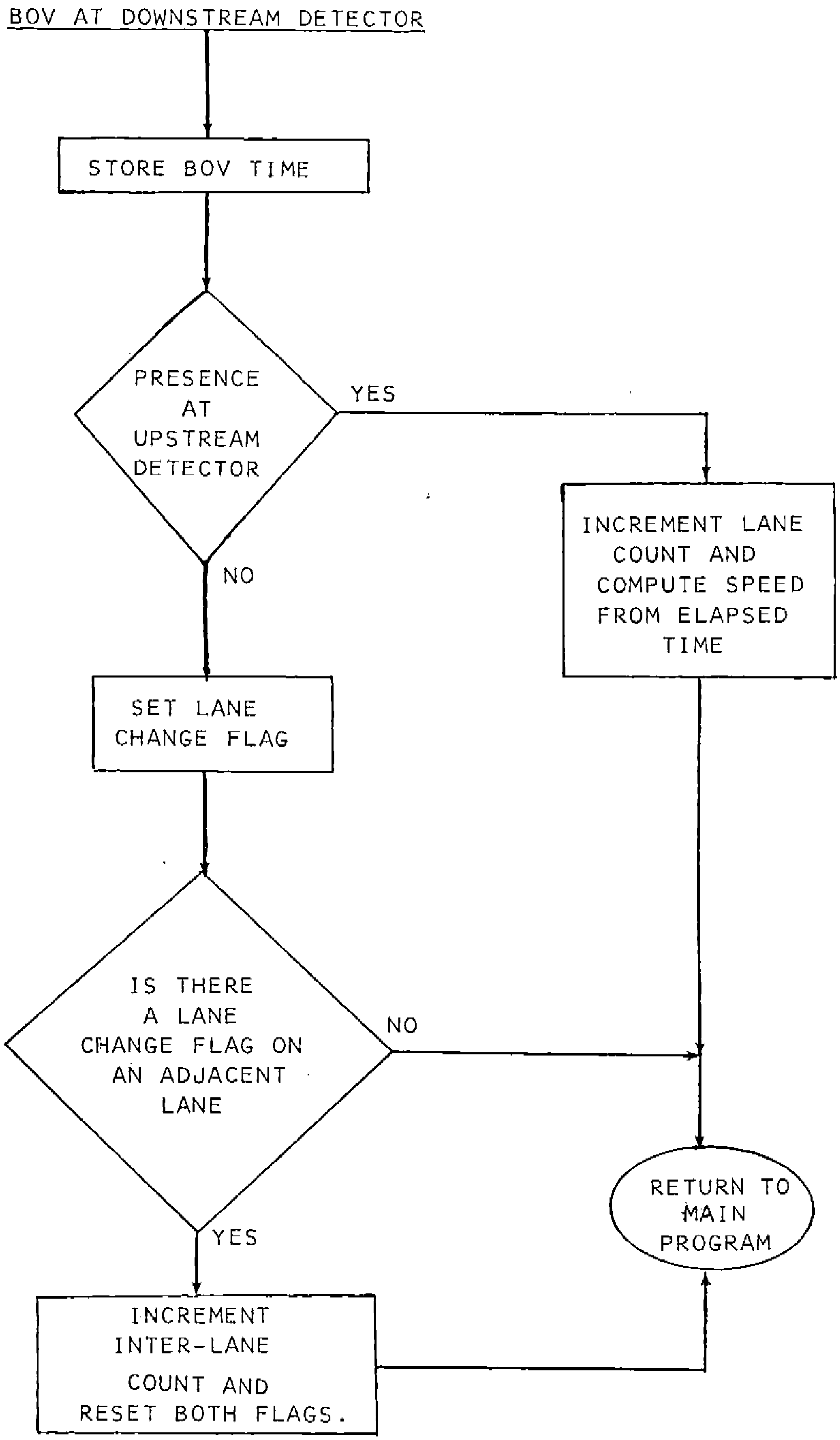
PROCESSING LOGIC FOR BEGINNING OF VEHICLE AT UPSTREAM DETECTOR

FIGURE 2-2



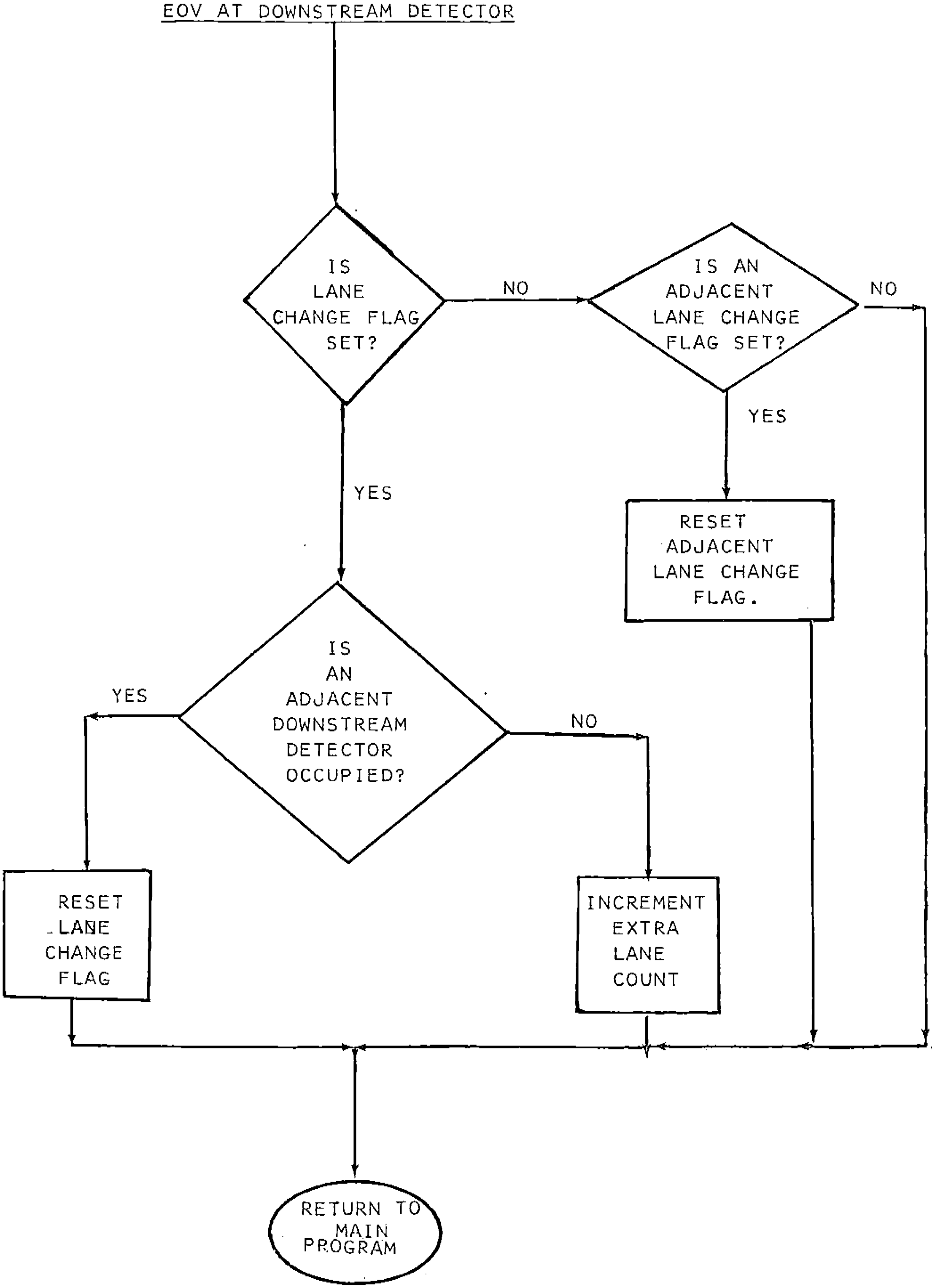
PROCESSING LOGIC FOR END OF VEHICLE AT UPSTREAM DETECTOR

FIGURE 2-3



PROCESSING LOGIC FOR BEGINNING OF VEHICLE AT DOWNSTREAM DETECTOR

FIGURE 2-4



PROCESSING LOGIC FOR END OF VEHICLE AT DOWNSTREAM DETECTOR

FIGURE 2-5

($\bar{u}$) as follows:

$$TTT = \frac{TT}{\bar{u}}$$

Each of these quantities may, in turn, be approximated using real-time inputs from automatic presence detectors.

- The total travel per unit of time may be approximated by the relationship:

$$tt = (Q_u + Q_d)\ \frac{\ell}{2}$$

where:

Q_u is the measured flow at the upstream detector

Q_d is the measured flow at the downstream detector

ℓ is the spacing between detectors

- The average speed may be approximated by the relationship

$$\bar{u} = 1/2 \left(K_u \frac{Q_u}{O_u} + K_d \frac{Q_d}{O_d} \right)$$

where:

O_u and O_d are the occupancy values for the upstream and downstream detectors, respectively, taken over the sampling interval and K_u and K_d are constants of proportionality which must be emperically determined.

Note:

The quantity Q/O has been shown to give reasonable estimates of speed over a 1 minute sampling period.[1]

Then:

$$TTT = \frac{1/2\ (Q_u \ell + Q_d \ell)}{1/2\ \left(\frac{K_u\ Q_u}{O_u} + \frac{K_d\ Q_d}{O_d}\right)}$$

$$= \ell \left\{ \frac{Q_u O_u O_d + Q_d O_u O_d}{K_u Q_u O_d + K_d Q_d O_u} \right\}$$

This approximation is, of course, only valid under conditions of homogeneous flow between the upstream and downstream detectors. In practical terms, this requires:

- Close detector spacing
- Low or medium density operation.

These approximations could be checked for validity by comparing upstream and downstream values of flow and occupancy and resorting to an input - output accumulation only when these values show large discrepancies. A composite technique of this type could probably produce better results over a full peak period than either approach when used alone.

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(1) Courage, K. G., op. cit.

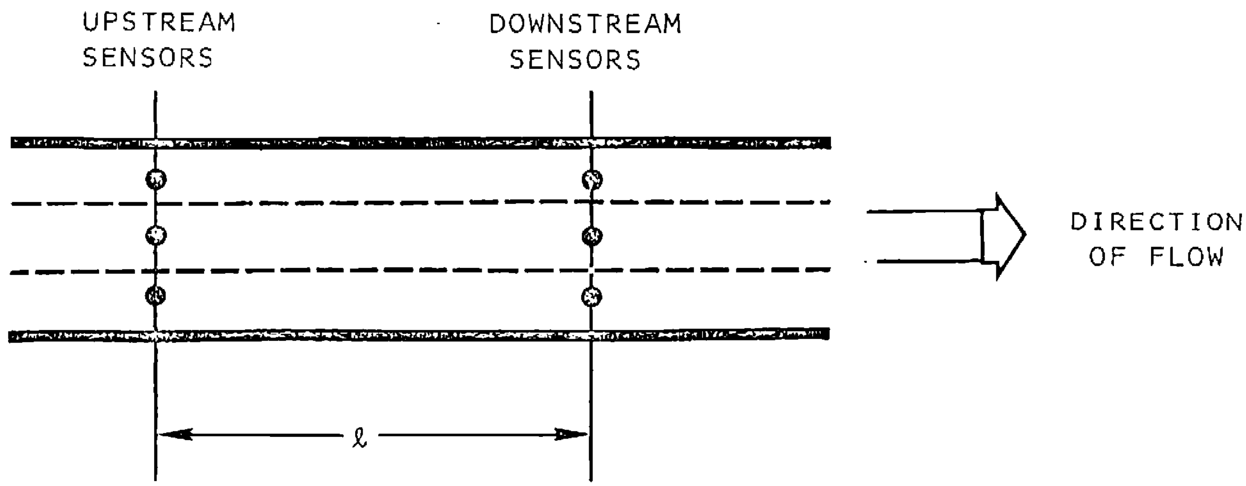
2.3.3 Time Series Analysis

This technique offers a more accurate method of determining speed under stable flow conditions. It's major shortcoming is likely to be excessive computation requirements for both time and memory storage. For this reason, it will not be explored in depth, however, it is considered to be worthy of some further consideration.

Referring to Figure 2.6, two sensor stations separated by a distance ℓ, will each generate time series measurements, designated as M_u and M_d for the upstream and downstream stations respectively. The dimensions of these measurements could take several forms such as moving averages of speed, energy, etc. Now, M_u and M_d will be separated by a time interval, τ, depending on the separation, ℓ, and the speed of the traffic. As the separation is increased, two effects will be noticed.

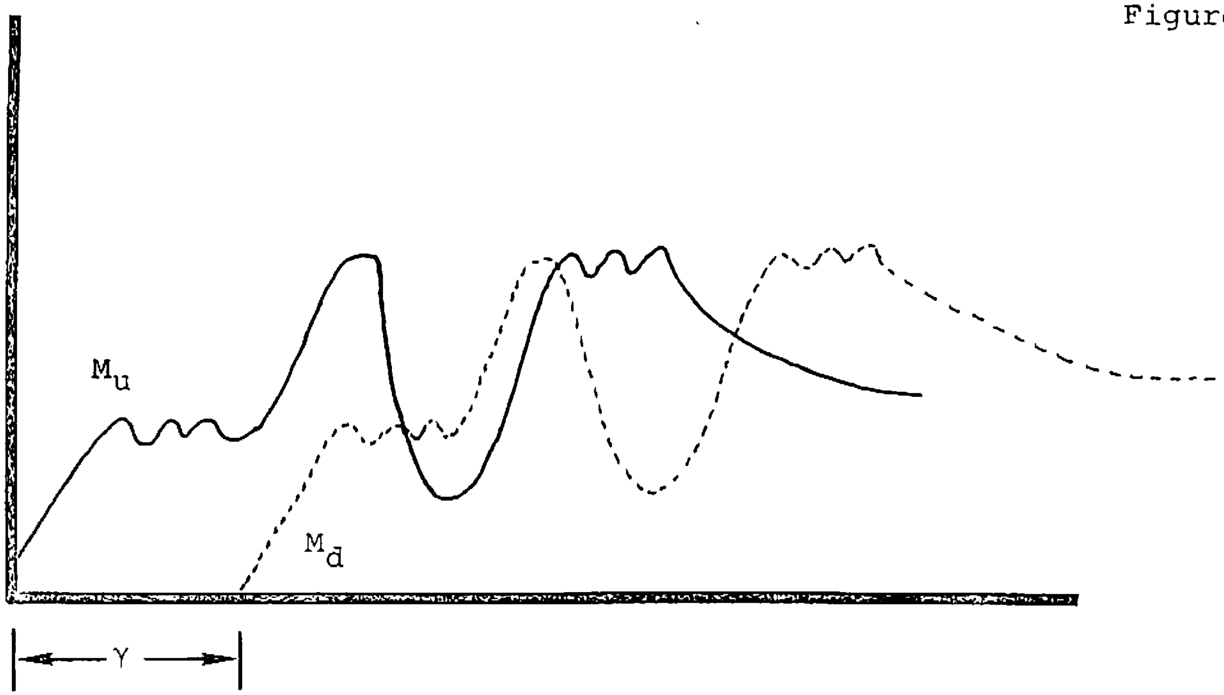
- The degree of correlation between M_u and M_d will drop; and,
- The value of τ at which maximum correlation is observed will increase.

Thus, providing the separation is kept short enough to retain a reasonable degree of correlation, the correlation index may be calculated for different values of τ and the value which gives the highest correlation index will correspond to the true space



TYPICAL TIME SERIES MEASUREMENTS AT TWO DETECTOR STATIONS

Figure 2.6



mean speed for the traffic stream. This estimate of the space mean speed may be used in the density calculations as described in Section 2.3.2.

Section 3

RAMP CONTROL TECHNIQUES

Section 3

RAMP CONTROL TECHNIQUES

3.1 Driver Display Interaction in the Green Band System

One of the current activities of the BPR's merging control system program is the development of hardware and software for the "green band" display. This effort is now being carried out by the Raytheon Company in Boston. An experimental installation, shown photographically in Figure 3-1, uses a pacer-typce display to guide the motorist into gaps in the traffic stream. The present display is generated on a "closed loop" basis - i.e., the position and speed of the ramp vehicle are sampled frequently and these data are used in real time in conjunction with freeway operational data to determine the desired position and speed of the pacer signal. A previous KSC report, prepared under the current contract presented an analysis of this system from the point of view of a simple feedback control system and developed a recommended method for evaluating the parameters of the control equations.[1] The green band system, on the other hand, is basically an "open-loop" system, in which an illuminated dis-

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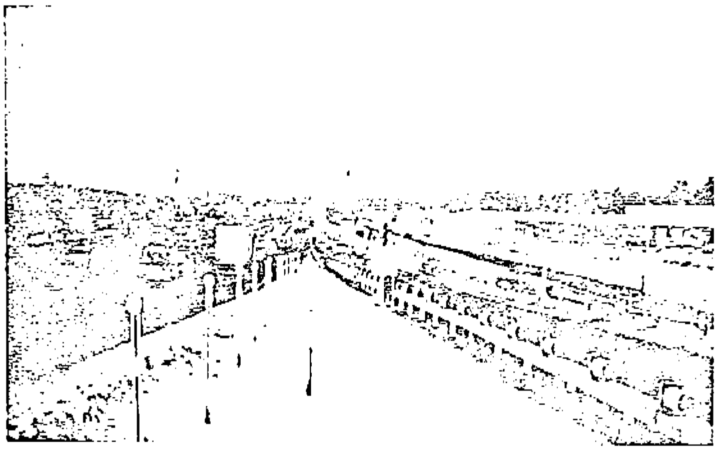
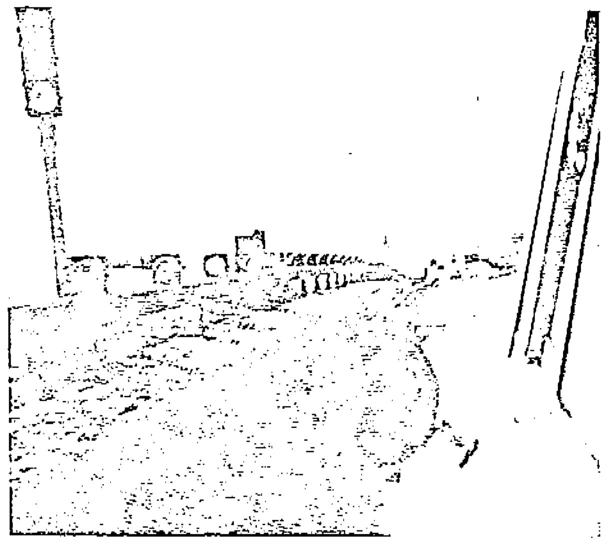
(1) Haavik, S., "Driver Display Interactions in a Single Ramp Merging Control System", KSC Technical Report, 1970.



ENTRANCE RAMP
WITH DISPLAY

THE PACER
IN OPERATION



ON-SITE
SITUATION DISPLAY

THE SINGLE RAMP MERGING CONTROL SYSTEM

Route 128 and 38, Boston

Figure 3-1

play is generated in response to a gap in the freeway traffic (rather than an individual ramp vehicle as in the pacer system). The characteristics of the display, i.e., length and propagation velocity, are simply a mapping of the corresponding characteristics of the freeway gap. Thus, the driver-display interactions may not readily be described by the second order differential equation approach suggested for use in analyzing the pacer system.

Nevertheless, it is important to know how well the driver follows the instructions of the green band display if this concept is to be evaluated objectively. One of the advantages of this particular display technique is that it is not as demanding upon the attention of the ramp vehicle driver, since he is not expected to follow a moving point at a prescribed distance, but simply to stay within a general domain on the time-space plane. It must be realized, therefore, that the degree of motorist conformance will be somewhat more difficult to express as a numerical quantity.

The relationship between the driver and the display falls into three distinct categories.

- Driver within the green band;
- Driver following a green band at a distance which makes it practical for him to accelerate and "join" the green band; and,

- Driver unable to locate an acceptable green band.

It is assumed in the above description that the driver is not expected to react to a green band travelling behind his vehicle.

The effectiveness of the man-machine interface (response of the driver to the display) may be assessed to some extent by observing the behavior of the driver and comparing these observations to the required behavior, upon which the ability of the system to improve merging operations is based. The two most significant behavioral variables (of those which can be readily measured) are the speed and acceleration of the ramp vehicle as a function of distance from the merge point. The speed in this case could be computed from the ramp sensor data, and the acceleration could be obtained by comparison of speeds at adjacent sensors. The latter quantity may have to be "smoothed", using appropriate techniques of numerical analysis[1]. Table 3-1 summarizes the expected characteristics of speed and acceleration for the three separate categories of driver-display relationship.

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(1) McCormick, John M. and Salvadori, Mario G., Numerical Methods in Fortran, 1964.

Table 3-1

CONFORMANCE CRITERIA FOR DRIVERS USING THE GREEN BAND DISPLAY

Relationship to Display	Criteria for Conformance	
	Speed	Acceleration
Driver within Green Band	Should not depart Significantly from displayed speed.	Should be close to zero
Driver following Green Band	Should be greater than displayed speed.	Should be positive as long as speed remains below a reasonable maximum.
No acceptable Green Band	Should be lower than displayed speed.	Should be negative as long as speed remains above a reasonable minimum.

The recommended procedure for evaluating the driver's conformance to the green-band display is as follows:

- Obtain the required data describing the vehicle kinematics and green band characteristics under operational conditions. An on-line data output to the existing magnetic tape unit would probably be best suited to this purpose.

- Adjust the data off-line to smooth the acceleration curves and to interpolate the position of the ends of the green band, if necessary.

- For each sensor crossing, determine the appropriate category of driver display relationship, and associate the speed and acceleration of the vehicle with the category.

When the above calculations have been completed, a series of statistical analyses may be performed on the results. The main purpose of these analyses will be to test the hypothesis that the speed and acceleration are influenced by the category of operation. If it can be proven that the speeds and acceleration are significantly different under the three categories of operation, then it may be concluded that the system has, in fact, influenced the drivers behavior on the ramp.

3.2 The Open-Loop Pacer Concept

The idea of the "moving merge" is a logical estension of the ramp control techniques developed in connection with past freeway surveillance and control projects. The purpose of moving-merge control is to guide the entrance ramp vehicles into gaps in the freeway traffic stream by controlling their speed along the entire length of the ramp, rather than by simply releasing them one at a time from a stopped position and leaving the drivers to seek their own space-time trajectories. The experimental installation in Boston described in the previous section is the first major effort aimed at developing and testing the various schemes which may be used for this purpose.

The alternative means of controlling a moving merge differ mainly in the type of display presented to the ramp driver. The two schemes presently under consideration are the "pacer" and "green-band" systems which are discussed briefly in Section 3.1. Both systems present the driver with a display of illiminated signals covering about 600 feet adjacent to the entrance ramp. The sequential activation of the individual display segments creates a sense of motion which the driver is expected to follow. There is no reason, however, to limit future display designs to a rigid choice between the two which are presently under consideration. In fact, it is quite logical to expect some evolution in this area as more information becomes available. The concept of the "open-loop pacer" is an example of such an alternative scheme. This concept is explored in a preliminary manner in the following discussion. The depth of the exploration is not considered sufficient at this point to warrant any basic changes in the BPR's current research and development program. It is felt, however, that since this program is still in an early stage of growth, all promising alternatives should be considered in connection with future plans.

The distinguishing features of the open loop pacer are summarized in Table 3-2 and compared with the two other schemes presently under consideration. It is noticed that, in many respects, the open loop pacer represents a hybrid, or compromise, between its predecessors. In this sense, it is an evolutionary, rather than a revolutionary concept and its intent is to capture the best features of each.

This scheme is based on the selection of three speeds which represent:

- The desired speed of the ramp drivers;
- The maximum speed which the ramp driver could be expected to maintain; and,

Table 3-2

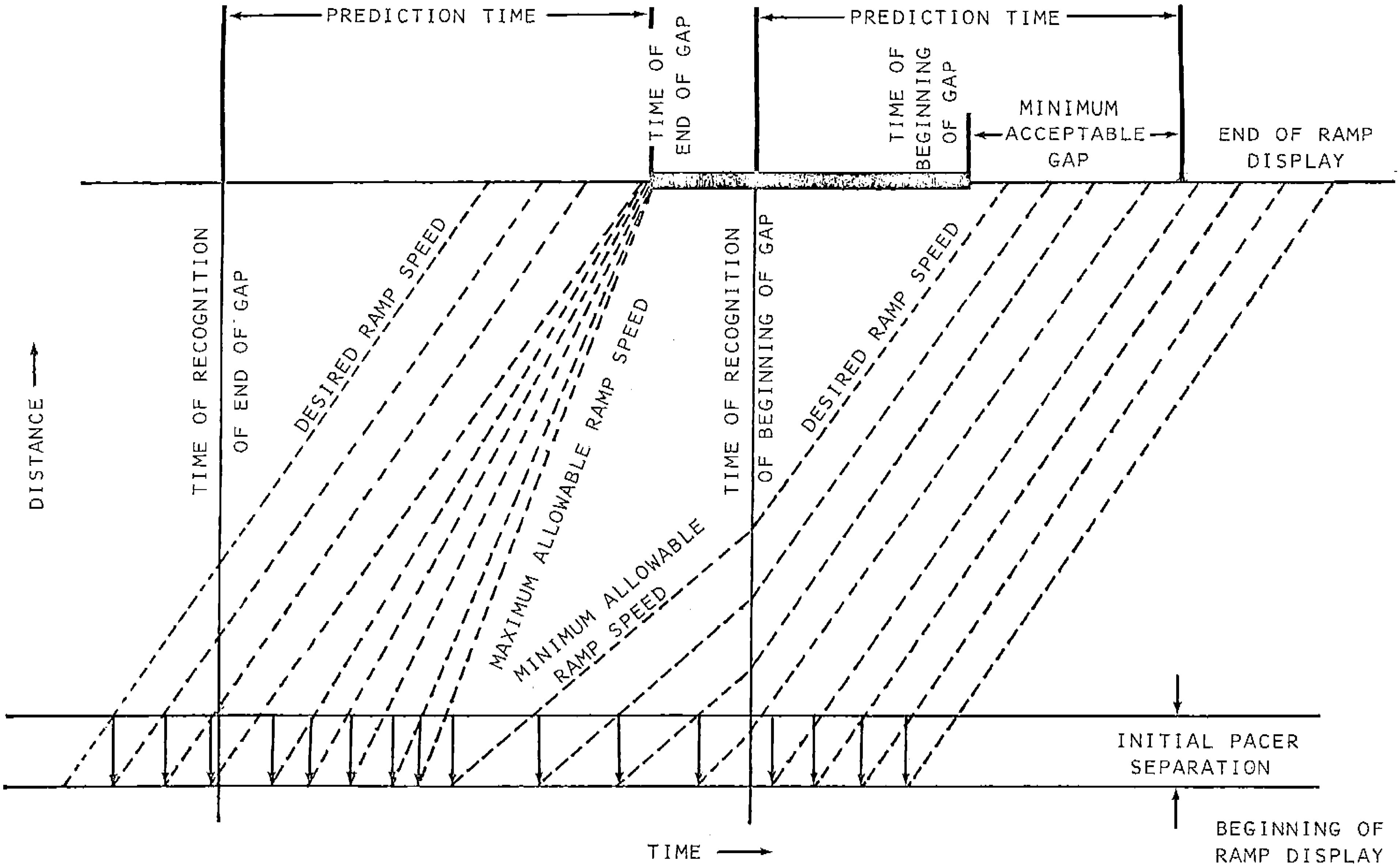
OPERATING FEATURES OF MOVING MERGE CONTROL SYSTEMS

Feature	Open Loop Pacer	Closed Loop Pacer	Green Band
Primary Generator (Stimulus)	Freeway Traffic	Ramp Vehicle	Freeway traffic
Type of Display	Series of moving points (Pacers)	Single moving point (Pacer)	Moving band of finite length
Required Driver Action	Travel at same speed as moving pacers	Follow moving pacer at a constant distance	Stay within moving band
Controlled Variables	Speed of propagation of moving pacers.	Position and speed of moving pacer.	Length of band plus speed of leading and trailing edges.
Response to closely following ramp vehicles	Terminate pacer between vehicles travelling at close headways	Attempt to maintain minimum headway through control of second pacer	No response
Response to lack of gap on Freeway	Set pacers to minimum allowable speed until a new gap is detected	Attempt to find another suitable gap; terminate pacer and stop ramp vehicle if unsuccessful	Do not generate green band until new gap appears
Response to sudden loss of gap on Freeway	Several options exist	Terminate pacer	Interrupt green band

- The minimum speed which the ramp driver could be expected to maintain.

Now, if two successive pacers travel the length of the ramp at the maximum and minimum speeds, respectively, then a "gap" will be created on the ramp, the length of which is proportional to the difference between the two speeds. Thus, if vehicles can be made to follow the movements of these pacers, their arrival time at the merge point can be controlled to a large extent. Furthermore, if this control is coordinated with the predicted conditions (gap or no gap) on the freeway, then the matching of ramp vehicles with freeway gaps can be accomplished. The time space relationships for this system are shown in Figure 3-2. It is seen that the pacers travel, whenever possible, at the desired speed seperated by a prescribed distance which remains constant. When the end of a gap is projected, the speed of successive pacers is increased until the maximum speed is reached at which point the minimum speed governs until a new gap is located. The desired speed is restored when this takes place. The operating parameters will vary from ramp to ramp. As an example, assuming 20 and 45 mph minimum and maximum speeds, respectively, a "no gap" length of 15 seconds on the freeway may be accommodated.

The major difference in philosophy compared to the existing



TIME-SPACE RELATIONSHIPS FOR THE OPEN LOOP PACER

FIGURE 3-2

schemes, as seen in Table 3-2, is the response to the lack of gap on the freeway. Both existing schemes, it is felt, have some potential for driver confusion, since the pacer system may stop the vehicle at a mid-ramp traffic signal and the green band display may leave the driver without any form of guidance under this condition. This should present no particular problem to drivers who are thoroughly familiar with the systems and able to interpret such actions as an indication of a "no-gap" situation. However, to the driver who is not adequately experienced, a reasonable interpretation would be that the system has done something which he does not understand, and for no apparent reason (since the freeway is not usually visible). Looking now at the other side of the argument, the open loop pacer provides the motorist with a display which remains with him throughout the ramp length, and without any disruptive changes to confuse him, however, it does not guarantee him an acceptable gap when he reaches the merge point. The ideal ramp display should neither be subject to disruptive changes, nor should it guide vehicles into anything but an acceptable freeway gap, however, these two objectives are mutually exclusive and some judgement must therefore be applied. The arguments in favor of the present methods are that guiding a a vehicle into a "no gap" situation is more dangerous than requiring him to alter his course for no apparent reason on the ramp, and that the same is true for the possible detrimental effect on the drivers confidence in the system. Should these arguments be borne out, then the open loop pacer has very little to offer the motoring public, at least in the form presented herein. There are, however, a number of counter-arguments which tend to favor this approach:

- Even though the ramp motorist would be guided into a "no gap" situation, his speed would be reduced to the minimum which the system allows. This is probably the most desirable way for the driver to enter the merge area when gaps are not available.

- Because of the stochastic nature of the merging process, there is no guarantee, in the existing system, that the driver will accept the gap chosen for him. In other words, the methods presently employed can still guide the driver into what he considers to be a "no gap" situation.

- The motorist has become well accustomed to merging onto a freeway. He has not acquired the same experience with following potentially confusing ramp displays, or with stopping at mid-ramp signals.

- The display, at least in the present experimental installation, ends well before the merge area, and the motorist is "on his own" after that point.

- The "merge with caution" sign used in the present installation can be activated whenever adequate gaps do not exist on the freeway.

Apart from this one potentially controversial point, there are other advantages which clearly favor the open loop pacer. Most of these advantages stem from the reduction in the complexity of the processing logic. It is suggested, for example, that this system would be less sensitive to detector ambiguities which can cause frequent and undesirable "reinitialization" of the control process. It is also felt that an open-loop system could be made operational with fewer detectors (e.g., wider spacing, and replacement of multiple sensors with single detectors). This would reduce the hardware cost as well as the other problems inherent in the system complexity.

Thus, there appears to be some merit in considering the open-loop pacer concept in further detail. This concept is not proposed, however, as a specific alternative to the present techniques, but rather as a collection of ideas which may be used to deal with some of their potential weaknesses which may appear during the implementation and evaluation phases of the program. Since most of these ideas were generated in retrospect, they should not be contrued as a criticism of the present design; they are intended instead to provide constructive suggestions to further the efforts of the merge control program.

Section 4

ON-FREEWAY CONTROL AT BOTTLENECKS

Section 4

ON-FREEWAY CONTROL AT BOTTLENECKS

4.1 Introduction

Most specialists in the freeway operations area tend to favor direct control of entrance ramp access over other forms of "on-freeway" control.

It is important, however, that the potential benefits of the latter technique not be overlooked, especially in view of the advanced detection capability which current surveillance projects have developed. These techniques generally take the form of advisory messages which prepare the motorist for a downstream situation. Their regulatory influence depends on their acceptance by the motorist which, in turn, depends on several factors, including the motorists understanding of the message and the degree of confidence which he places on the information received. Based on the assumption that the driver will respond to a message which he clearly understands and which he respects as valid information, the concept of on-freeway control offers some potential at certain types of recurring bottlenecks. These bottlenecks are normally characterized by an upstream demand which approaches, and may slightly exceed the capacity for short periods of time. In such cases, it is essential to maintain maximum throughput to prevent congestion from forming.

Assuming that the motorist has already committed himself to driving through a bottleneck, (i.e., he has elected not to leave the freeway at an upstream exit) he faces two decisions:

- how fast to drive; and,
- which lane to use.

These two decisions are faced throughout the entire length of his trip, however, they become especially critical as he approaches an area of reduced capacity. At present, he bases these decisions on such factors as desired speed, vehicle performance characteristics and observation of traffic conditions. He may usually be observed to accelerate, decelerate and change lanes frequently throughout the course of his trip, in an attempt to optimize the driving process.

The crude information available to the motorist through visual observation may be refined considerably using state-of-the-art detection and information processing equipment and techniques. This refined information may be transmitted to the motorist through standard types of variable message signs. Thus, the motorist may be presented with information which is potentially useful to his decision making process and which (if utilized) could demonstrate improved traffic operations at freeway bottleneck locations.

4.2 Advisory Speed Messages

Current and proposed entrance ramp control algorithms use measured speed of freeway vehicles for such purposes as projecting gaps, calculating available capacity, etc. This information could also be used effectively in determining the optimal speed for vehicles entering a bottleneck area. By displaying the optimal speed some distance upstream, the motorist could be encouraged to improve the operation of the facility. The main problem with operating a freeway at or near capacity is the occurrence of shock waves which eventually deteriorate into sustained congestion under prolonged periods of high demand. These shock waves can be dissipated to some extent by controlling the speed of traffic approaching the disturbance. Thus, an effective speed control system could increase the maximum throughput which could be accommodated under conditions of stable flow.

The computation of the optimal speed could be approached in two ways:

- The actual speed at the bottleneck could be calculated over a short sampling interval and displayed directly.
- The projected travel time to clear the bottleneck could be computed using an algorithm of the type described by Weinberg et al[1] and the corresponding speed displayed.

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(1) Weinberg, Morton I., Et Al, Surveillance Methods and Ways and Means of Communicating With Drivers, 1966.

It was suggested earlier that the prerequisites for successful advisory speed control are understanding and confidence on the part of the motorist. The display of actual bottleneck speed would probably be preferable from an "understanding" point of view since it is conceptually simpler and easier to explain to the driver. The projected speed, on the other hand, better satisfies the "confidence" criterion since it takes into account the conditions between the display and the bottleneck.

Standard variable matrix signs are available for speed displays. One possible type, illustrated in Figure 4-1, is similar to the unit which was used experimentally in Detroit for several years.(1) Recent studies showed that its value was questionable in that particular application(2), however, it should not be inferred from these studies that the concept is unsound, particularly in view of the state-of-the-art advancements which have been made since the Detroit system was originally installed. The advisory speed control system discussed herein differs from its predecessor in several important ways:

(1) Wattleworth, Dr. Joseph A., et. al., "NCHRP Project 20-3", June, 1967.

(2) Wattleworth, Dr. Joseph A., et. al., "An Evaluation of Two Types of Freeway Control Systems", April, 1968.

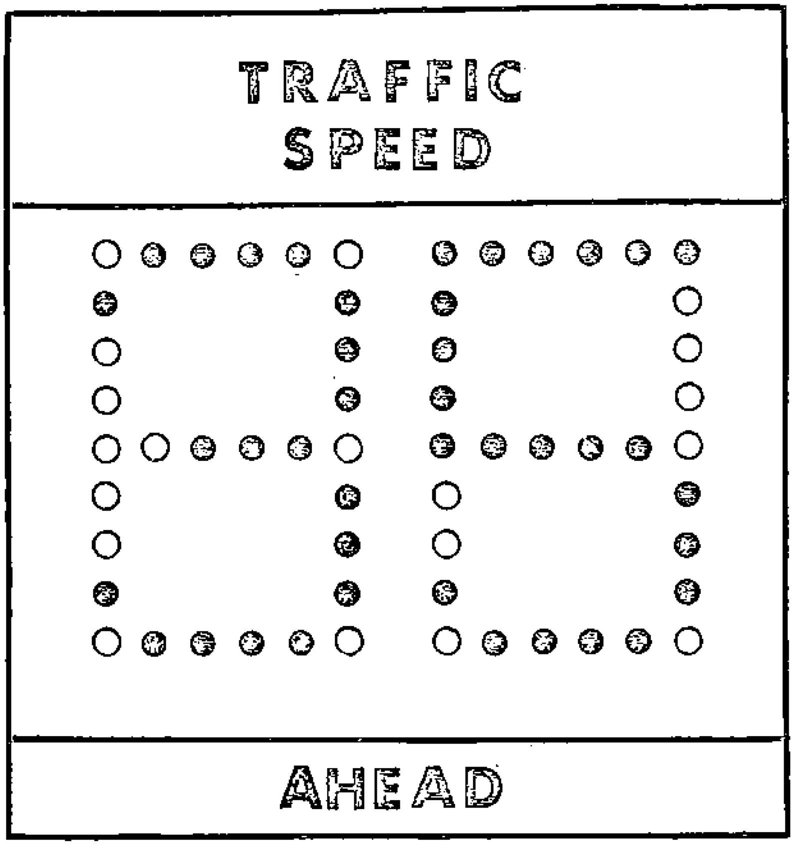


Figure 4-1

POSSIBLE ADVISORY SPEED MESSAGE

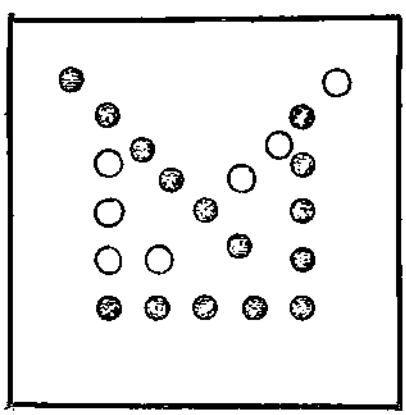


Figure 4-2

POSSIBLE ADVISORY LANE

CHANGE MESSAGE

- Actual speed measurements would be used in the determination of the speed to be displayed, as opposed to human judgement, based on the observation of television monitors.

- Smaller increments of speed could be displayed. The Detroit system provided a choice of 3 speeds at 25, 40 & 55 mph. This was particularly undesirable from the standpoint of motorist confidence when extremely low speeds prevailed.

- The proposed scheme would concentrate the information at a small number of critical locations rather than attempting to cover the entire freeway. This should reduce the overall demand on the motorists attention and focus it where it is needed most.

4.3 Advisory Lane Use Signals

The second decision facing the motorist is the choice of lanes. There is some evidence that the motorist attempts, in a crude way, to optimize this choice based on his own observation. For example, the distribution of individual lane volumes tends to become more uniform with increasing flow, indicating at least some desire for optimal utilization of the available capacity. Further subjective evidence of this desire may be obtained by casual observation of the lane changing activities which take place within the traffic stream. It is suggested, therefore, that optimal lane usage information would be welcomed by many drivers and could promote improved traffic operations at critical points by balancing the demand and capacity on individual lanes. This assumes, of course, that the required information could be presented in a manner which satisfies the two criteria of understanding and confidence discussed previously.

The necessary computations for such a system may be performed readily using available equipment and techniques. On the other hand, the display of this information presents a more challenging problem. Whereas optimal speed can be transmitted in the form of a simple numerical speed message, the optimal lane distribution is a much more complicated piece of information.

The specific purpose of the display must be to encourage drivers in a lane, known to be too heavily travelled, to change to another lane known to be too sparsely travelled (i.e., one where available capacity exists). The design of the display requires significant effort outside of the limited scope of this discussion, which will include only a brief description of two of the more promising techniques, including:

- Display of a separate "optimal" speed for each lane; and,
- Display of separate messages recommending specific lane changes.

Display of individual lane speeds could promote lane changing from low speed lanes to lanes showing a higher speed. Other advantages include:

- Minimal requirement for motorist education since in this case "the medium is the message".

- The ability to transmit both speed and lane use information with a single, standard type of sign unit.

The shortcomings of this technique include:

- The requirement for the motorist to assimilate a large amount of information at one time.

- The success of the system could be self-defeating, i.e., a strong response to a displayed speed differential could compromise the accuracy of the original information and produce an unstable operation.

The alternative of providing direct lane change recommendations offers, on the other hand, a more stable operation through the ability to suppress the display until a high degree of differential has been reached, and to limit the displayed message to a single recommended lane change. An example of the type of arrow-matrix sign which could be used for this purpose is shown in Figure 4-2.

Section 5

INCIDENT DETECTION

Section 5

AUTOMATED DETECTION OF HIGHWAY INCIDENTS

5.1 Types of Highway Incidents

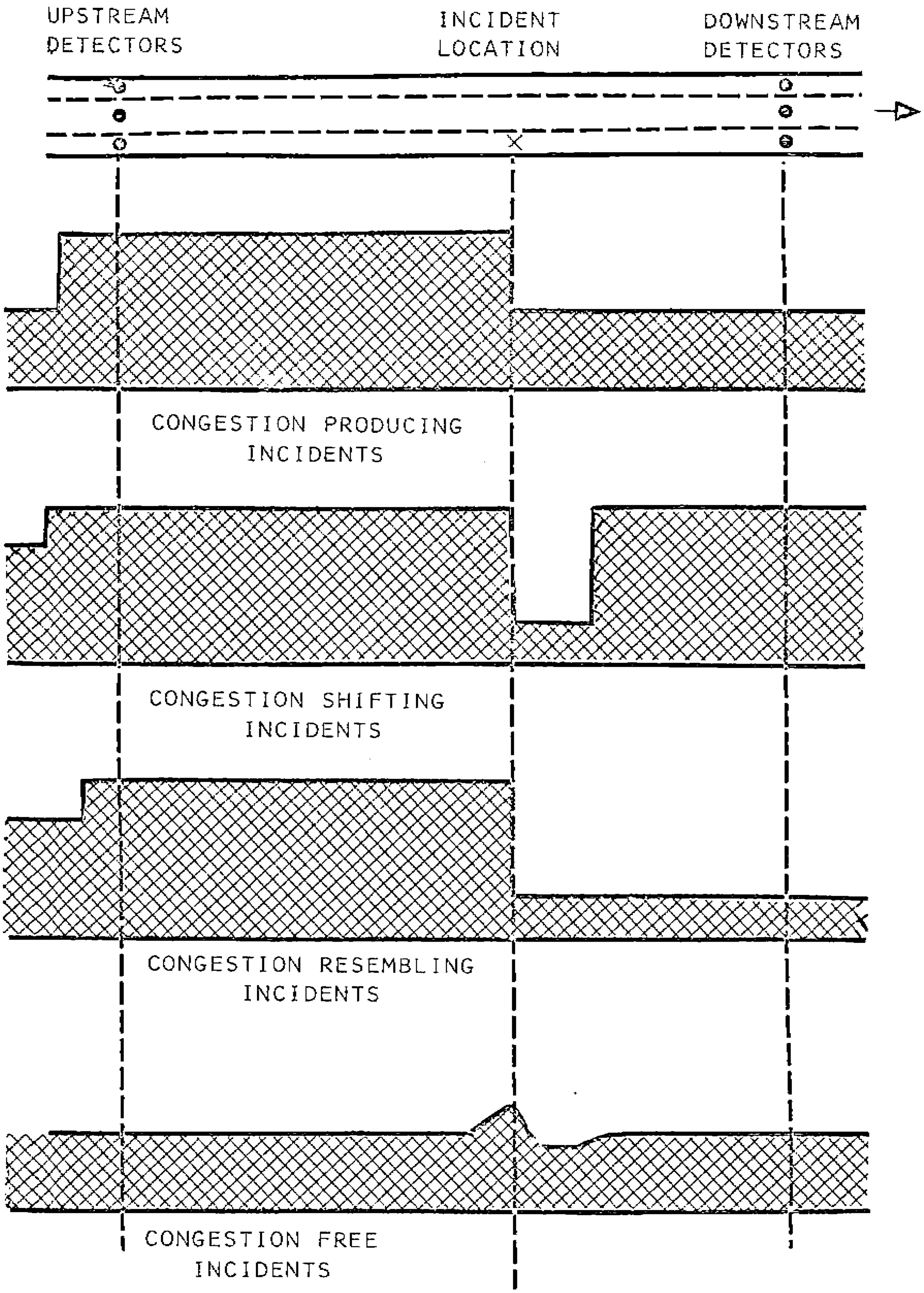
5.1.1 Introduction

Another useful function of a discrete-sensor highway surveillance system is the automatic location of capacity reducing incidents. The purpose of this function would, of course, be to promote the rapid restoration of "normal" conditions by expediting whatever assistance is required, and by activating control and information systems to minimize the effect of the incident on operations and safety. It must be realized, however, that such a system is not capable of detecting the incident per se, but only the various symptoms which the incident generates. It is necessary, therefore, to examine these symptoms as a preliminary step, and to identify the symptoms associated with different types of incidents, before proceeding with the development of detection techniques.

Four such incident categories may be readily identified and are labeled as follows:

- Congestion-producing incidents;
- Congestion-shifting incidents;
- Congestion-resembling incidents; and,
- Congestion-free incidents.

Typical density profiles for each of these incident categories are illustrated in Figure 5-1.



TYPICAL DENSITY PROFILES FOR VARIOUS INCIDENT CATEGORIES

Figure 5-1

It will become increasingly obvious as this discussion progresses, that these categories must, in fact, be treated much differently in an incident detection scheme and the need for an appropriate terminology will become correspondingly apparent. The above terminology was, therefore, developed with this in mind.

5.1.2 Congestion-Producing Incidents

These are the most common types of highway incident and are certainly the easiest category to detect. They are characterized by a capacity reduction at one point on the freeway, which produces high-density, low-speed operation upstream, accompanied by the converse situation on the downstream side. This condition is relatively easy to identify, and several simple detection algorithms may be formulated to identify this type of incident. The problem is, therefore, to select the techniques which demonstrates a fast response, low false alarm rates, and high immunity to error in the presence of one of the other three incident categories.

5.1.3 Congestion-Shifting Incidents

When an incident occurs within an already heavily congested area, the symptoms of discontinuity in the speed-density characteristics are very slow to appear and, especially in the case of minor incidents, may not appear at all. The effect of the incident in this case is merely to "shift" the congestion slightly upstream. A much more complex stochastic model would be required to identify this condition. Several approaches to the development of such a model may be explored, including:

- Keeping a close watch on the progress of minor shock waves within the congested area. Repeated origin or termination of a shock wave at a given point may be evidence of a congestion shifting incident. This requires the development of measures for quantifying intensity and speed of shock waves with a minimum of computation time and storage.

- Comparison of the measured position of the "tail-end" of the queue with the number of vehicles known to be in the queue. An unexpectedly long queue may be an indication of a "dead spot" in the middle caused by a congestion shifting incident.

- Comparison of the computed values of detector occupancy within the queue with the known speed and/or density of the queue. An unexpectedly low total occupancy measurement may indicate a similar condition.

- Combinations of the above approaches could be incorporated into a composite model.

5.1.4 Congestion-Resembling Incidents

The detection algorithm for the most common incident type (congestion producing) must make provision for the recurring bottleneck conditions which are observed almost daily on many freeways. Failure to recognize these "normal" bottlenecks as such could generate a perpetual false alarm lasting for the duration of the peak period. In other words, the occurrence of high density upstream and low density downstream of a given location cannot be automatically proclaimed as an incident without first checking on the possibility that this condition might be attributable to the breakdown of traffic flow due to an excess of demand over capacity. A simpler check would be to establish whether or not the anticipated throughput of vehicles was maintained, however, bottleneck throughput is subject to a wide variation over short sampling periods and must be considered as a distant second choice to the demand vs capacity prediction.

In any event, if it is concluded that the breakdown of flow could be attributed to a cause other than an incident, the decision to proclaim an incident must be delayed pending the analysis of data from subsequent sampling periods. This is a case of a possible "congestion-resembling" incident. At the time of its original detection, it is an ambiguous case - i.e., there is reason to believe that the observed breakdown of flow has been due to internal, rather than external causes, however, the possibility of a congestion-resembling incident at the bottleneck or at the tail end of a shock-wave cannot be entirely dismissed as long as the congestion prevails.

If, during the next few sampling periods, the congestion dissipates at the location in question, then it may be concluded that no incident has occurred. If the congestion remains, and the original suspicion was that a shock wave had passed through the area, then the problem must be re-identified as a congestion resembling incident. As a third possibility, the condition will remain ambiguous as long as the congestion lasts if the suspected cause is a recurring bottleneck condition. In this case, the flow rate should probably be monitored frequently, looking for signs of a capacity reduction. It should be kept in mind, however, that wide fluctuations in flow are to be expected under these conditions, and the sampling period (and hence the speed of response to the incident) should be adjusted accordingly. Another factor which must be considered is the possibility of a congestion-resembling incident happening at the bottleneck at a future time during the peak period. Hence, the possibility of an incident cannot be dismissed at any time during the period of congested operation even though an acceptable throughput has already been measured.

5.1.5 Congestion-Free Incidents

Some congestion, as evidenced by high detector occupancies, low speeds, etc., has been associated with all three of the incident categories discussed to this point. There exists, however, a fourth category termed, logically enough, as a congestion-free incident. Congestion free incidents may be defined as those in which the remaining roadway capacity is sufficient to accommodate the current traffic demand. Thus, there will be no measurable symptoms of high density, low speeds, etc. observed in connection with this type of incident.

It is quite probable, therefore, that congestion free incidents will be, at best, difficult and at worst, impossible to detect with a discrete sensor system. The most promising avenue of approach, from a conceptual point of view, appears to be in a time series analysis technique, the details of which are discussed briefly in Section 2.3.3.

5.2 Functional Analysis of an Incident Detection System

5.2.1 System Goals

An incident detection system must be treated as a subsystem of an overall freeway corridor surveillance, communications and control system, the goals of which are to optimize the utilization of the available roadways by the motorist. The mission of this particular subsystem may be stated simply as the provision of information regarding the probable location of highway incidents to other subsystems whose functions are to minimize the effects of these incidents on traffic operations and safety.

5.2.2 Inputs

The inputs available to the system include traffic data recorded in real-time by electronic vehicle presence sensors, in addition to a selection of historically derived operating parameters which provide an a priori basis for predictions concerning the state of the system as a function of time. The scope of this discussion has restricted the input information to the essentially "blind" forms of purely quantitative data and the state of the art in traffic detection has further constrained the analysis to consider vehicle presence sensing as the only means of data acquisition.

5.2.3 Outputs

The outputs are very difficult to define in detail at this time, since they are strongly influenced by the type of corrective action to be taken by the other elements of the system. It is suggested, however, that the outputs should take the form of statements indicating:

- The possible location of an incident;
- The estimated degree of capacity reduction attributed to the incident;
- The degree of confidence which the system places on its own assessment; and,

- The recommended corrective action which should be taken to minimize the effect of the incident on traffic operations and safety.

5.2.4 System Configuration

The generalized system configuration for an automatic incident detection system is shown in the functional block diagram of Figure 5-2. The major system elements are seen to include:

- Automatic vehicle presence sensors, which form the primary input to the system.

- A data link which transmits the sensor information to a central location for processing.

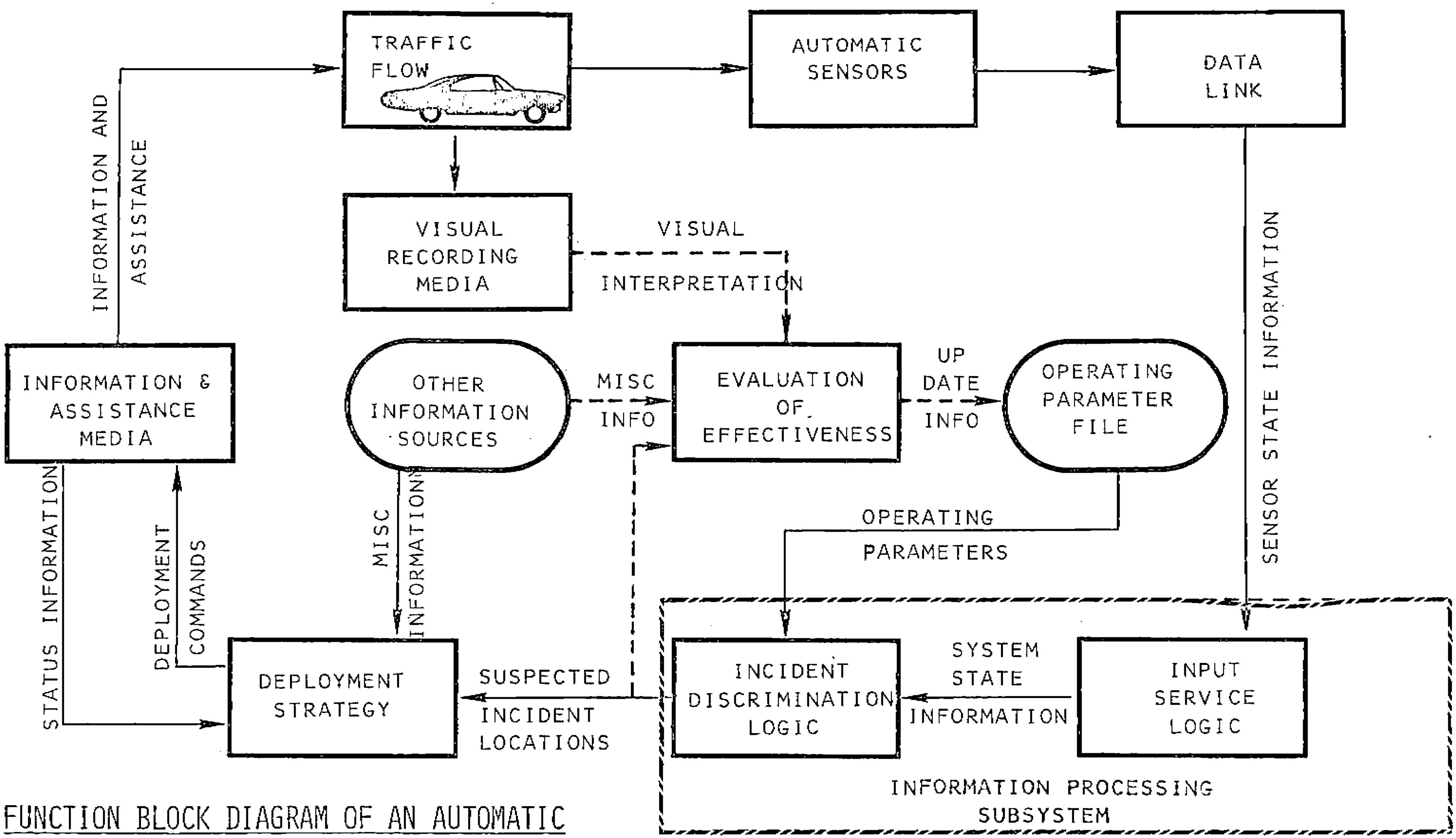
- An information processing subsystem which, in a practical system, will involve a process control computer of the type used to operate the other elements of the surveillance and control system. This subsystem will also provide for the storage of operating parameters upon which many of the system calculations will be based, and for the implementation of appropriate strategies for dealing with suspected incident locations.

- Information and assistance media whose function may include removal of disabled vehicles, display of advanced warning to the motorist, etc.

5.3 Information Flow

5.3.1 On-Line Information Flow

The on-line information flow deals with the real-time



FUNCTION BLOCK DIAGRAM OF AN AUTOMATIC INCIDENT DETECTOR SYSTEM

Figure 5-2

function of the incident detection system. It involves a closed loop process whose major features, as shown in Figure 5-2 include:

- Input of sensor state information to the information processing subsystem.
- Input of system state information generated by the input service logic and operating parameters, stored in the operating parameter file into the incident discrimination logic.
- Transfer of information regarding suspected incident locations from the incident discrimination logic, through a deployment strategy, where deployment commands are generated.
- Provision of appropriate information, assistance, etc., to the disabled motorist and to other motorists affected by the incident.

5.3.2 Off-Line Information Flow

The off-line information flow is intended to provide an evaluation of the effectiveness of the incident discrimination logic on an open-loop basis. It is also intended to provide, by a closed-loop process, a continuing improvement of the reliability of the system by updating the operating parameter file to reflect current information and by suggesting possible changes in the incident discrimination logic to minimize the errors which this logic generates. The evaluation of effectiveness is based primarily on a comparison of known conditions obtained through some form of visual record and the suspected conditions which are recorded by the incident detection system.

5.4 Incident Detection Logic

5.4.1 Macroscopic Variables

Flow and occupancy data are the two forms which are most readily obtainable from the type of discrete sensor system commonly used in freeway surveillance and control. Flow (Q) is defined as the number of vehicles which pass a given point during a finite time interval and is obtained by simply summing the output pulses received from the detectors. The other variable, occupancy, (O) is defined as the proportion of time in which a given detection area is occupied by a vehicle. It has been shown to be related to the equivalent traffic density at the point of measurement.

The basic unit of measurement of macroscopic flow models may be expressed as:

$$\frac{Q^a}{O^b}$$

where: a and b are intergers.

Specified values of a and b give the following measurements:

a	b	Measurement
0	-1	Occupancy
1	0	Flow
1	1	Speed
2	1	Kinetic Energy

Only those examples with simple conceptual significance are summarized above, however, it may be desirable to test parameters which result from other combination of a and b in an incident detection model to choose the most appropriate combination.

The macroscopic variables may appear in the incident detection logic in any of four ways:

- Absolute value;
- Time rate of change, d/dt;
- Space rate of change, d/ds; and,
- Distribution by lane.

The time rate of change would be determined by comparison with data obtained from the previous sampling period. Similarly, the space rate of change would be determined by comparison with current data from the adjacent detector station.

Macroscopic models considered in Detroit under NCHRP project 20-3 were based on:

- Flow $\frac{d^2Q}{dsdt}$
- Energy (absolute value)
- Energy (d/ds)
- Energy Lane distribution
- Composite Speed-density Function

$$\sqrt{\frac{d}{ds}\left(\frac{Q}{O}\right)^2 + \left(\frac{dO}{dS}\right)^2}$$

the value of which is related to the degree of "shift" in the operating point on the speed-density plane between two freeway locations.

All of these models demonstrated some ability to detect incidents and may therefore merit further consideration. They did, however, exhibit a high false alarm rate, and it is felt that considerable refinement would be required to produce an operational incident detection scheme.[(1)]

5.4.2 Microscopic Variables

Microscopic models deal with the position, velocity and acceleration of individual vehicles within the traffic stream, and with the headway relationships between successive vehicles.

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(1) Courage, K.G. and Levin, M., "A Freeway Corridor Surveillance Information and Control System", Texas Transportation Institute Report 488-8, 1968.

Their application to automatic incident detection may be somewhat limited by the fact that they tend to focus on a single point in space and time, whereas the objective is to cover a large area continuously in time.

There are, therefore, a number of obstacles to the development of a practical detection system based on microscopic concepts:

- Kinematic measurements such as speed and acceleration are difficult (or at least costly) to obtain for individual vehicles;

- Close spacing of sensors would probably be required to obtain the desired area of coverage; and,

- Central processing time and storage requirements would be greatly increased by the need to perform operations on individual measurements rather than the accumulated values used in macroscopic models.

On the other hand, the microscopic approach, by its nature, offers a more rapid response to a highway incident, and for this reason, it may deserve further attention. It is suggested that headway should be the basic variable used in the model due to the difficulty of measuring individual vehicle speeds, etc., in a microscopic sense.

An example of a microscopic model which may merit further attention is one which has been used successfully in the Lincoln Tunnel. This model generates an alarm when headways become excessive, with respect to the measured traffic volume.(1)

5.4.3 Basic Processing Logic for Incident Detection

This final section deals with what may be considered as a basic program structure for the development of an incident detection system. It utilizes many of the concepts developed previously in this report in formulating a scheme by which all four of the incident categories discussed earlier may be treated.

Figure 5-3 shows the suggested program structure, and indicates the conditions necessary to generate the various incident messages. The essential features are as follows:

- A congestion free incident is identified when traffic flow is known to be very light and when a correlation analysis on the time series outputs of two adjacent sensor stations fails to meet the established criteria. This concept was discussed in Section 2.3.3.

- A congestion producing incident is identified when a significant difference is noted between the occupancy (or some other macroscopic variable) at two adjacent sensor stations, provided that the area is not the site of a known bottleneck, and provided also that no "shock waves" are calculated to be passing through the area. If a known bottleneck does exist in the area, a further check is made to determine whether the projected demand is at or above capacity. If this demand is noted to be well below the capacity, a congestion producing incident is also declared to have occurred.

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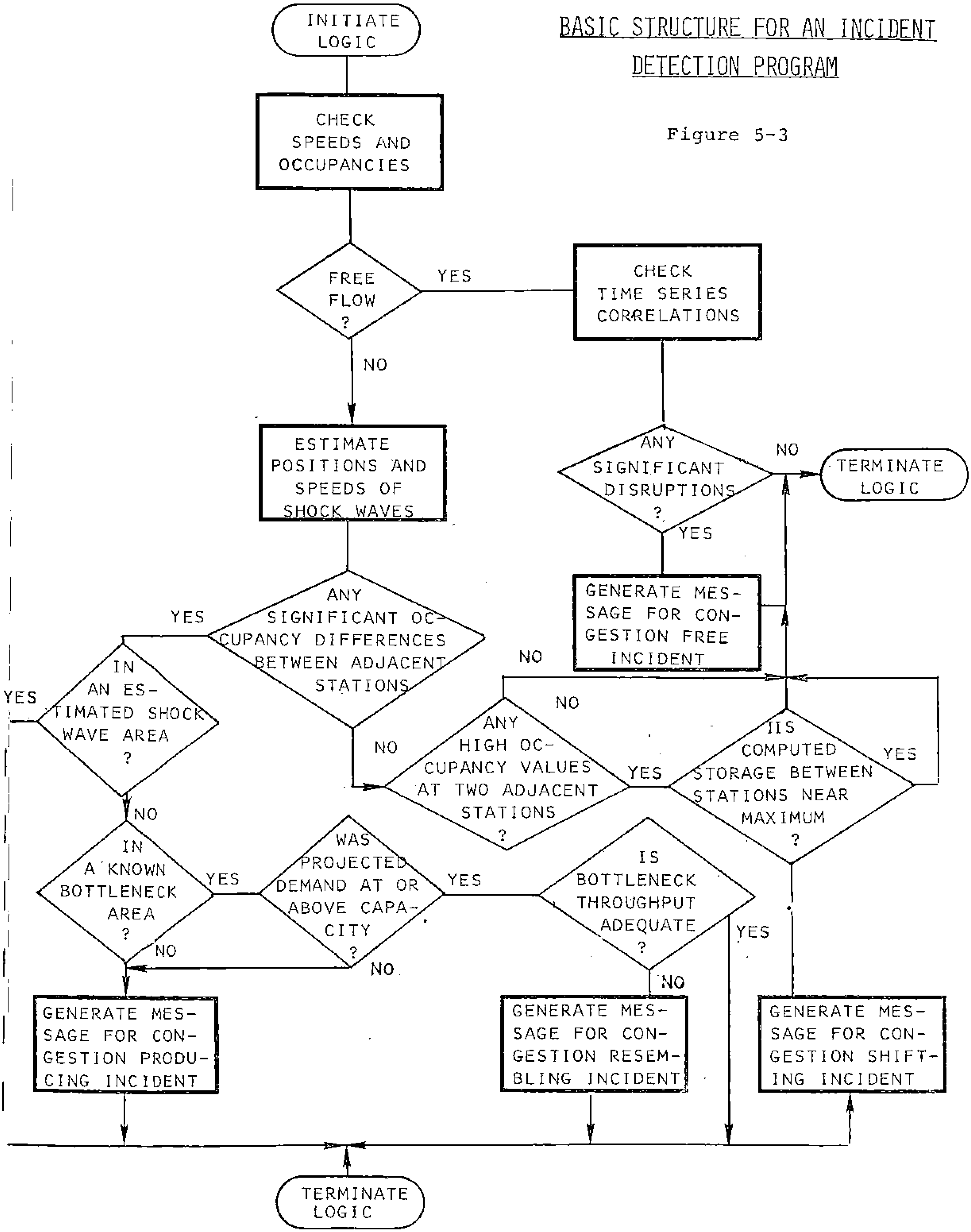
(1) Port of New York Authority, "Review Comments on TTI Final Report - NCHRP Project 20-3", 1969.

BASIC STRUCTURE FOR AN INCIDENT DETECTION PROGRAM

Figure 5-3



- A congestion resembling incident is identified only in bottleneck areas when the demand is known to be at or above capacity, and the throughput at the bottleneck is significantly lower than anticipated.

- A congestion shifting incident is identified only when two adjacent sensor stations register high values of occupancy, or some other indication of congestion, and when the computed value of storage between the two detectors falls below an established level. It is assumed that the storage value would be calculated by one of the methods discussed in Section 2.3, or by some other appropriate means.

It is felt that this overall structure provides a worthwhile basis for further investigation, however, it is realized that considerable effort would be required to develop an operational system of the type discussed herein. It is further recognized that the feasibility of many of the computational procedures has not yet been established, and that this, in itself, constitutes a major undertaking.