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16. Abstract
This report presents an executive summary and level of service concept for Urban Freeway Guide Signing. This report is the final report for Research Project 2-18-77-220 entitled, "Evaluating Urban Freeway Guide Signing".

The scope of this project was to isolate problem areas with Urban Freeway Guide Signing, develop alternative solutions to these problems, and determine the best solution in laboratory and field studies.

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EVALUATING URBAN FREEWAY GUIDE SIGNING -
EXECUTIVE SUMMARY AND LEVEL OF SERVICE

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Final
Research Report 220-4F

Research Study Number 2-18-77-220

Sponsored by the Texas
State Department of Highways and Public Transportation
In Cooperation with
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Federal Highway Administration

Texas Transportation Institute
Texas A&M University
College Station, Texas

August 1981

SUMMARY

This is the final report in a series which documents research conducted on various aspects of urban freeway guide signing in Texas. This report contains an executive summary, a level of service methodology, diagnostic freeway guide signing evaluation and freeway guide signing references.

- The executive summary documents the research performed during the study. Significant research findings developed during the project are also included. A unique advance guide sign recommended to be used along urban freeways is also presented.

- The Level of Service methodology presented in this report will aid traffic engineers in evaluating proposed or existing urban freeway guide signing systems. It provides a detailed evaluation procedure. It evaluates each sign in the areas of navigation, workload and response.

- The diagnostic freeway guide signing evaluation is a diagnostic tool that traffic engineers should be familiar with. For several broad problem areas, this approach presents the probable cause of the problem and then provides references to project reports where problem solutions are described.

- And finally, a definitive signing reference list is presented. These references contain the major signing reports published to date.

Implementation

This project addressed many complex urban freeway guide signing problems in the state. The findings presented in this report and all previous reports contain procedures and guidelines for improving a significant portion of these problems so that a safer and more efficient transportation system may be provided. Some of these research findings are already being implemented.
As future sign modification programs are implemented, opportunities for applying other research findings will arise. The Level of Service methodology presented in this report should prove an invaluable aid to the traffic engineer in identifying freeway guide signing problems and developing improved cost-effective solutions.

Disclaimer

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

METRIC CONVERSION FACTORS

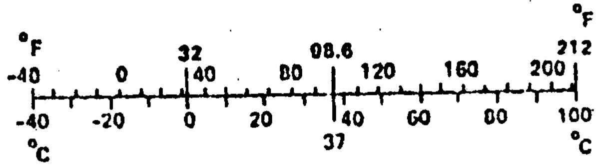
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Overview

This report presents an executive summary and level of service concept for urban freeway guide signing. This report is the final report for research project 2-18-77-220 entitled "Evaluating Urban Freeway Guide Signing".

The scope of this study was to isolate problem areas with urban freeway guide signing, develop alternative solutions to these problems, and determine the best solution in laboratory and field studies.

Research Methodology

Ten study areas were investigated using laboratory studies. Approximately 100 subjects participated in these studies. The research methodology required the subjects to respond to 35 mm slides of alternative sign designs. Manual recording of subject preferences and response times were recorded. In two exit signing system experiments, a 16 mm film together with 35 mm slides were used. The results of the laboratory studies were documented in Research Report 220-3, "Evaluating Urban Freeway Guide Signing - Laboratory Studies".

Background operational studies conducted within the project were documented in Research Report 220-2, "Operational Studies of Urban Freeway Guide Signing Systems". Operational studies conducted in Houston and Dallas used the field study technique. Operational data were collected for lane volumes, lane changes and erratic manuevers. An accident study was conducted in conjunction with an Astro-Bluebonnet Bowl football game. Accident data collected on freeways in Dallas and Houston indicated no out-of-state motorist attending the game had a recorded accident. A physical signing inventory was conducted in ten major cities, both in and out of state.

This inventory determined how other major cities, similar to those in Texas, signed their freeways.

Significant Results

The following section describes the significant results obtained from this research project. These results are given in sequence as published.

I. The significant results from Research Report 220-2:

A) The I-30 Dallas Operational Study

Traffic operations through the westbound section of I-30 from I-45 to I-35 improved in 1979 as compared to 1977. The reasons likely are due to 1) improved route design of I-30 through Dallas and 2) the new freeway route guide signing system installed.

B) The I-10 Houston Operational Study

The elimination of the assignment of specific lanes to the freeway motorists traveling on a nominal tangent section of an 8-lane urban freeway resulted in a very slight change toward a less controlled roadway. For all practical purposes, the effect was negligible. Most motorists do not follow pull-thru signs with lane assignment arrows. This could be a serious problem unless lane assignments are used only when necessary to communicate unexpected information needs approaching complex interchanges, such as splits and at left-hand exits.

C) The Astro-Bluebonnet Bowl Study

A study of 1,500 out-of-state drivers from Nebraska revealed that they experienced no reported accidents while driving on Dallas or Houston freeways while attending a recent Astro-Bluebonnet Bowl football game.

D) The Physical Inventory of Urban Freeway Guide Signing System

The physical inventory taken in six out-of-state cities and compared to the signing in four Texas cities showed that Texas had a higher density of signs than most out-of-state motorists would expect. The amount of information on each panel and number of panels per sign bridge also were higher in the Texas cities than in the out-of-state cities. Texas has many more concurrent routes than do the other states. Detailed results of all the aforementioned studies are found in Research Report 220-2.

II. The laboratory studies covering ten items are presented in Research Report 220-3. The ten topic areas are:

Designation of Routes to the Downtown Area

Formatting and Method of Presenting Route Transfer Information

Reading Times of Freeway Guide Signs

Target Value of Different Types of Route Guidance Shields

Concurrent Signing - Motorist Understanding

Concurrent Signing - Route Number Reduction

Control City Information

Suburb City Information

Right-Hand Interchanges Exiting System

Left-Hand Exit Signing Study

Recommendations

The following recommendations were developed as a consequence of this research project.

1. Desirable and maximum amounts of sign messages per sign were defined. A desirable maximum level of 16 bits per sign structure is recommended together with an absolute maximum level of 20 bits per sign.

2. A systemmatic elimination of redundant U.S. numbered routes from the Interstate freeways of Texas should be implemented.
3. Signing along urban freeways of Texas that have signing attributes which are unexpected by out-of-state motorists should be eliminated.
4. Unfamiliar motorists currently are forced to read almost all overhead freeway guide signs as they travel through large cities. With the increase in the number of guide signs and volume of traffic approaching and traveling within Texas cities, freeway navigation is becoming increasingly difficult. Advance Sequence Guide Signs like the one shown in Figure 1 should be placed a few miles in advance of the first major interchange (the loop). In this way, unfamiliar motorists are informed of critical distances to major route junctions.
5. It is recommended that 1) as motorists approach the city limits, the appropriate guide sign destination should be the name of the major metropolitan area, 2) after motorists pass the loop (or major arterial) where they are approximately 5 miles away from the downtown area, the proper destination would be Downtown, and 3) major arterial names should be used to sign exits throughout the downtown area.
6. It is recommended that all state shields should be one size smaller than any Interstate or U.S. numbered shields on the same panel.
7. The next control city for Interstate signing should have a total population of at least 300,000 and should be located no further than 300 miles away. Consider using the adjacent state name if this criterion cannot be satisfied.
8. The name of a suburb is sufficient to guide motorists to the downtown area of the suburb. Motorists associate the term "Downtown" with the major metropolitan area and not with the suburb. The use of "Downtown" with the suburb's name on the same signs is not appropriate.

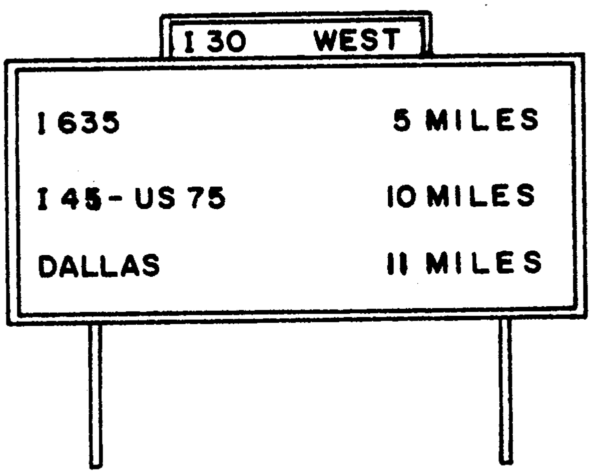

Figure 1. Advance Sequence Guide Sign.

9. For both the right-hand and left-hand exit studies, when the subjects chose a diagrammatic sign, an alternative verbal sign was also provided because of the economics involved with using diagrammatic signs.

Future Research Areas

It was discovered that motorists from the West Coast were not familiar with U.S. Business Routes leaving the Interstate systems, going through a small town and then returning to the Interstate, as presently signed on many Texas freeways. In the West, the Interstate Business Loop is used for this purpose. Therefore, many businesses along these U.S. routes in Texas may be losing business because motorists are not leaving the Interstate for fear of getting lost or having to backtrack to the Interstate. A pilot study should be initiated between El Paso and Fort Worth to study the effects the use of Interstate Business Loops would have on 1) traffic operations and 2) the economics associated with the small businesses along these routes.

Pavement markings were taken into consideration in this study only as they affect the signing system. A similar project should be undertaken to isolate the problems currently associated with pavement markings and possible solutions to these problems and to develop guidelines with respect to alternative pavement markings at selected geometrics and/or interchanges where the pavement markings may serve a dual role.

EVALUATING URBAN FREEWAY GUIDE SIGNING - LEVEL OF SERVICE

INTRODUCTION

The development of guide signing plans for urban freeways is a complex and challenging engineering problem. It often demands all the wisdom and perseverance one can muster. Many decisions have to be made based on experience and interpretations of state and national signing manuals. Even though most previous signing plans have been developed after the freeway geometrics were "cast in concrete", severly limiting the range of available signing options, a good signing system has been provided along most urban freeways in Texas. Given more financial resources, time, and earlier consideration of the signing demands during the preliminary (schematic) stage of the freeway design process, an even better guide signing system would exist today. Solution constraints, not technical expertise, has limited the features of numerous urban freeway guide signing systems installed around the U. S. as well as in Texas.

The opportunity now exists to critically examine the urban freeway guide signing systems in Texas, and to improve those areas found deficient. To make optimum use of existing resources, a proficient evaluation procedure needs to be utilized which identifies probable trouble spots without requiring an excessive amount of staff time or data collection. The evaluation methodology presented herein was developed to satisfy this need.

Cornerstone of Methodology

The Manual on Uniform Traffic Control Devices (MUTCD) provides a good set of freeway guide signing principles (1) which forms the cornerstone of this evaluation procedure. Our research has attempted to add specificity to those principles and an evaluation system. The following paragraphs paraphrase the principles of freeway guide signing presented in the MUTCD (1).

MUTCD Freeway Guide Signing Principles

The MUTCD states that the development of freeway guide signing systems must be approached on the premise that the guide signing is primarily for the benefit and direction of drivers who are not familiar with the route or area. The signing must furnish drivers with clear instructions for orderly progress to their destinations. The course of the freeway route and the major destinations or "control cities" along it must always be clearly identified. Continuity in successive sign messages and consistency with available highway maps are essential.

Unfamiliar drivers should not be overloaded or confused by the signing. The amount of destination names and directional information must not exceed the amount of copy that most drivers will be able to readily comprehend. The Manual (1) provides guidelines regarding the maximum amount of directional copy a sign should contain.

The major signs at freeway interchanges and on their approaches are 1) advance guide signs and 2) exit direction signs. It is essential that the same destination messages be displayed on these signs. New destination information should not be introduced into the major sign sequence, nor should information be dropped. At any given decision point, a given destination shall be indicated over only one route.

Potential driver expectancy problems at interchanges should be recognized. At bifurcations or freeway splits where the off-route movement is to the left or where there is an optional lane split, driver expectancy problems (delayed reactions and/or incorrect decisions) usually result. Two-lane exits with an optional through/exit lane can cause driver confusion. Some two-lane exits with an optional lane carry the through route on the exiting lanes. These interchanges create serious expectancy problems for all drivers.

Methodology Evaluation Premise

The evaluation methodology is formed around the MUTCD signing principles (1). Unfamiliar motorists are assumed and have the capabilities of about 80 licensed drivers observed in supporting laboratory studies (2). The unfamiliar motorists are assumed to be from out-of-state, and to be experienced with urban freeway signing such as found in Los Angeles, Chicago or Atlanta.

The methodology has one basic premise - that the quality of freeway guide signs can be measured by numerically evaluating selected design parameters. The parameters selected are thought to be principal contributors to the overall quality of freeway guide signing in urban areas.

Certain assumptions are built into the procedures. For example, it is assumed that the MUTCD (1) is followed, that the unfamiliar motorists can read English, decode the messages, and control their vehicles in a normal manner. Likewise, it is assumed that the signs are bright, clean, and free from sun glare or nighttime blackouts.

Background

This methodology for evaluating the level of service of urban freeway guide signing culminates 4 1/2 years of research by the Texas Transportation Institute in cooperation with the State Department of Highways and Public Transportation and Federal Highway Administration. Almost every urban freeway guide sign in Texas has been observed and recorded by the research staff since 1976. In addition, over 1,000 freeway guide signs in six major cities in other states have been inventoried. Ten laboratories dealing with urban freeway signing issues have been conducted and evaluated. In addition, several operational studies were also conducted in Houston and Dallas. Research reports describing these supporting research efforts are described elsewhere (2, 3, 4).

LEVEL OF SERVICE CRITERIA

The criteria used to evaluate the level of service of urban freeway guide signing include specifications of the design driver, the satisfaction of navigational information needs, the time rate that signs must be read, and the distance provided to respond to the messages. An introductory discussion of these criteria follows. A detailed discussion of the evaluation procedures will be presented in subsequent sections.

Design Driver

The "design driver" is assumed to be from out-of-state and reasonably experienced with urban freeway signing. The ability of these motorists to read and respond to guide signing affects the quality of the signing system. Generally speaking, the ability of unfamiliar motorists to recognize the information content of a sign message depends on the visibility, legibility (or letter design) and readability of the message (5). The legibility of a given sign's copy depends on the letter height, strokewidth and contrast of the alphanumeric characters used (the federal sign alphabet) together with the visual acuity of individual drivers.

Visual acuity is a laboratory measurement of the ability of people to see clearly (fine detail of objects). It is often said that an average person's vision is "20/20". Exceptionally good eyesight is near 20/10. The minimum legal visual acuity for getting a driver's license without the aid of glasses is often set at 20/40 (6). The literature (7) indicates that the median (50%-ile) visual acuity is about 20/17. Ascending cumulative percentile visual acuities of the national driving population were reported (7) to be 60% (20/19), 70% (20/21), 80% (20/24), and 90% (20/30). A visual acuity of 20/24 (80%-ile value) was selected as the typical driver's visual acuity for evaluating levels of service of freeway guide signing.

Navigation

The development of a guide signing system for freeways must be approached on the premise that the signing is primarily for the benefit and direction of drivers who are not familiar with the route or area. The signing must furnish drivers with clear navigation instructions for orderly progress toward their destination. Laboratory studies conducted in support of this methodology indicates that motorists use (and read) destination, designation, direction and distance information, but the relative priorities depend on the individual driver (and possibly the familiarity of the name or number)(2).

The navigational level of service of a particular guide sign on an urban freeway is determined from a consideration of several principal navigational related factors. Engineering guidelines and accepted practice will be used as criteria for judging the quality of the individual factors. A numerical score is selected for each factor depending on how well the analyst believes the sign satisfies the navigational requirements. The basis and guidelines for using this navigational evaluation procedure will be presented in detail in a later section. A route is evaluated sequentially from a point outside of the city until it leaves on the other side of town. All intermediate destinations are identified and evaluated each in turn.

Four information system factors are considered in the navigational evaluation process for each sign are

Navigation Factors	Acceptance Score		
	Good	Fair	Poor
1. Sufficiency	1	(3)	10
2. Consistency	1	2	(5)
3. Expectancy	(1)	3	10
4. Relatability	1	(2)	5

Total Score, T = 11

The next step is to convert the total score into a level of service grade for navigational requirements. This is accomplished using the following conversion scale, reading a navigational level of service of E for T equal 11.

Navigational Level of Service

A	B	C	D	E	F
4	5,6	7,8	9,10	11,12	>12

Navigational Total Score, T

Workload

Workload is one criterion used to evaluate the quality, or level of service, of freeway guide signing. Workload is a time based measure of the rate that the design driver would have to acquire information from a given sign according to the models of information processing and driving tasks postulated in the methodology. Workload is described by the ratio of time needed to acquire selected navigational information from freeway guide signs divided by the time available to acquire the information. That is, the workload (W) of a sign is defined as the ratio

$$W = \frac{\text{Time Needed}}{\text{Time Available}}$$

A numerical scale selected for describing the resulting level of service "grade" based solely on a consideration of driver workload W is as follows:

Workload Level of Service Grade

	A		B		C		D		E		F	
0.0		0.5		0.8		1.0		1.2		1.5		or more

Workload Ratio, W

The scale was subjectively specified based on the research available and the ramifications of W exceeding unity. It is known for example, that human subjects can perform at workload rates exceeding unity in a stressed condition for brief periods of time. However, driver errors would be expected to increase under these conditions.

Response

Guide signs should be located so that the requested traffic maneuver can be made within the time and space provided. Time and related distance traveled should be available to read the messages, make the necessary lane changes, preview the interchange geometry and exit at the natural departure station.

Two types of freeway guide signing are considered: 1) advance guide signs and 2) exit direction signs. The MUTCD (1) provides detailed descriptions of these signs and recommended placement. While the procedure assumes that the MUTCD is being followed, it is the placement of the signs on the freeway that is to be evaluated and not the Manual.

A grading scale is used for estimating the level of service provided. The grading scale is based on the ratio of the estimated travel distance needed to comfortably perform the driving tasks (identified in the modeling of advanced guide or exit direction signs) divided by the distance provided by the design and placement of the sign relative to the exiting station. The response ratio, R, is defined as

$$R = \frac{\text{Travel Distance Needed}}{\text{Physical Distance Provided}}$$

The numerical grading scale for estimating the level of service for driver response to the guidance messages is defined as follows

Response Level of Service Grade

A	B	C	D	E	F
0.0 – 0.5	0.5 – 0.8	0.8 – 1.0	1.0 – 1.2	1.2 – 1.5	1.5 or more

Response Ratio, R

As in the workload scale, it is assumed that motorists could work above their normal capacity levels under stress for a brief period, although this is undesirable and subject to the occurrence of more driving errors.

SUMMARY

An introductory discussion of the criteria used to evaluate the level of service of urban freeway guide signing has been presented as an overview of the level of service methodology. The criteria described included: navigation - the satisfaction of information needed by unfamiliar motorists for their orderly progress to their destination, workload - the time rate that drivers must work to acquire the total guidance information presented, and response - the time and distance necessary to safely perform the necessary traffic maneuvers.

Evaluation procedures will be presented in the following sections that describe in detail the methodology recommended for determining the level of service based on each of the three criteria. A separate section is devoted to each criterion, beginning with navigation. Subsequent sections will cover workload and response.

NAVIGATION

INTRODUCTION

The MUTCD describes the types of navigational information that must be on the various types of freeway guide signs. The information and layout are specified for advance guide signs, exit direction signs, and exit gore signs (among others). Signing requirements are identified by class of interchange being signed, (major, intermediate, minor) by type of interchange, and by type of exit. Signing for closely spaced interchanges is also given.

The evaluation of the navigational aspects of urban freeway guide signing evaluates the signing essentially from a consideration of two points of view. The MUTCD obviously provides useful and desirable standards from which to measure the quality of the guide signing. The methodology simply tries to provide specificity and a numerical scaling of satisfaction for some MUTCD standards. Secondly, the Manual recommends and permits optional signing in some cases, depending on the circumstances, and in other cases only describes guidance concepts in general terms. The methodology attempts to specifically address many of these important navigational needs in light of previous research findings (2).

It is recognized that many aspects of the quality of freeway guide signing cannot be evaluated by a numerical procedure. Many perceptual and cognitive activities of motorists cannot be measured by a continuous scale even though it is apparent that differences in quality exist. Certain sign layouts and configurations are easier to perceive and understand than others. For example, the relative performance of a diagrammatic sign as compared to a conventional alphanumeric sign can be demonstrated in the laboratory. However, no numerical evaluation system is known to exist which could predict beforehand the performance of each type of sign for a specific case. Meaningfulness of message groupings also is difficult to predict, although accepted guidelines for visual display are known to yield better results than a randomly designed one. Engineering insight and experience still are important to the development of successful freeway guide signing. With these caveats offered, the following approach is offered to evaluate principal aspects of the navigational features of urban freeway guide signing.

LEVEL OF SERVICE EVALUATION

The navigational level of service of a particular guide sign on an urban freeway is determined from a consideration of several principal navigational related factors. Engineering guidelines and accepted practice will be used as criteria for judging the quality (good, fair, poor) of the individual factors. A numerical score is selected for each factor depending on how well the analyst believes the sign satisfies the navigational requirements. Four information system factors considered in the evaluation process for each guide sign are as follows:

Navigation Factors	Acceptance Score		
	Good	Fair	Poor
1. Sufficiency	1	(3)	10
2. Consistency	1	2	(5)
3. Expectancy	(1)	3	10
4. Relatability	1	(2)	5
Total Score, T = 11			

The next step is to convert the total score into a level of service grade for navigational requirements. This is accomplished using the following conversion scale, reading a navigational level of service of E for T equal 11.

Navigational Level of Service

A	B	C	D	E	F
4	5,6	7,8	9,10	11,12	>12

Navigational Total Score, T

Each advance guide sign and exit direction sign along a route is evaluated sequentially from a point outside the metropolitan area, progressing through the city to the other side of town. All intermediate exiting roadways are first identified. The desired guidance information and location for each exit are recorded for subsequent evaluation. Evaluation then begins for the first exit, the second, and so forth, ending with the mainline route guide signing. The following evaluation guidelines are provided for consideration when rating each of the four navigational factors previously noted.

Sufficiency

Sufficiency is a term used to denote whether the information presented on each guide sign should be sufficient to satisfy an unfamiliar motorists navigational information needs. The basic issues here are whether the guide signing elements believed necessary are present and in accordance with accepted national guide signing principles. The MUTCD (1) is used as the chief yardstick of sufficiency. It is assumed that the analyst is familiar with sections D, E and F of the MUTCD (1).

Five types of urban freeway guide signs may be used. These guide signs and their MUTCD section locations are as follows:

1. Advance Guide 2E-26
2. Exit Direction 2E-29
3. Pull Thru 2E-31
4. Interchange Sequence Series 2E-34
5. Gore 2E-30

Examples of each of these five types of signs taken from the MUTCD are presented in Figure 2. An overhead guide sign structure commonly found on an urban freeway may contain a pull thru sign, an advance guide sign and an exit direction sign, but never an interchange sequence sign or a gore sign. Diagrammatic signs may be used to replace the conventional signing for advance guide and pull thru signs, but not exit direction or gore signs. Specific guidelines which may be used to evaluate the sufficiency of advance guide, exit direction and pull thru signs follows.

Advance Guide Signs. Seven signing elements should be considered in determining the sufficiency of an urban freeway advance guide sign. These signing elements are presented in Table 1. Usage requirements and guidelines as described in the MUTCD (1) also are given in Table 1 for each element. The analyst should check the existence, selection and format of each element on each sign regarding the recommended application guidelines and usage requirements.

The seven signing elements deal primarily with route descriptors and exit descriptors. Route descriptors include the route's destination (name), designation (number) and direction (heading). Exit descriptors include the exit's distance (from sign), exit number, lane configuration (exit only) and lateral position (lane assignment) as needed.

Exit Direction Signs. The exit direction sign generally repeats the route and destination information that was shown on the advance guide sign(s) for the next exit, and thereby assures the driver of the destination served and indicates whether he leaves on the right or on the left side of the freeway for that destination.

Table 2 presents usage requirements and guidelines for six guide signing elements which are used (always, in most cases) on urban freeway exit direction

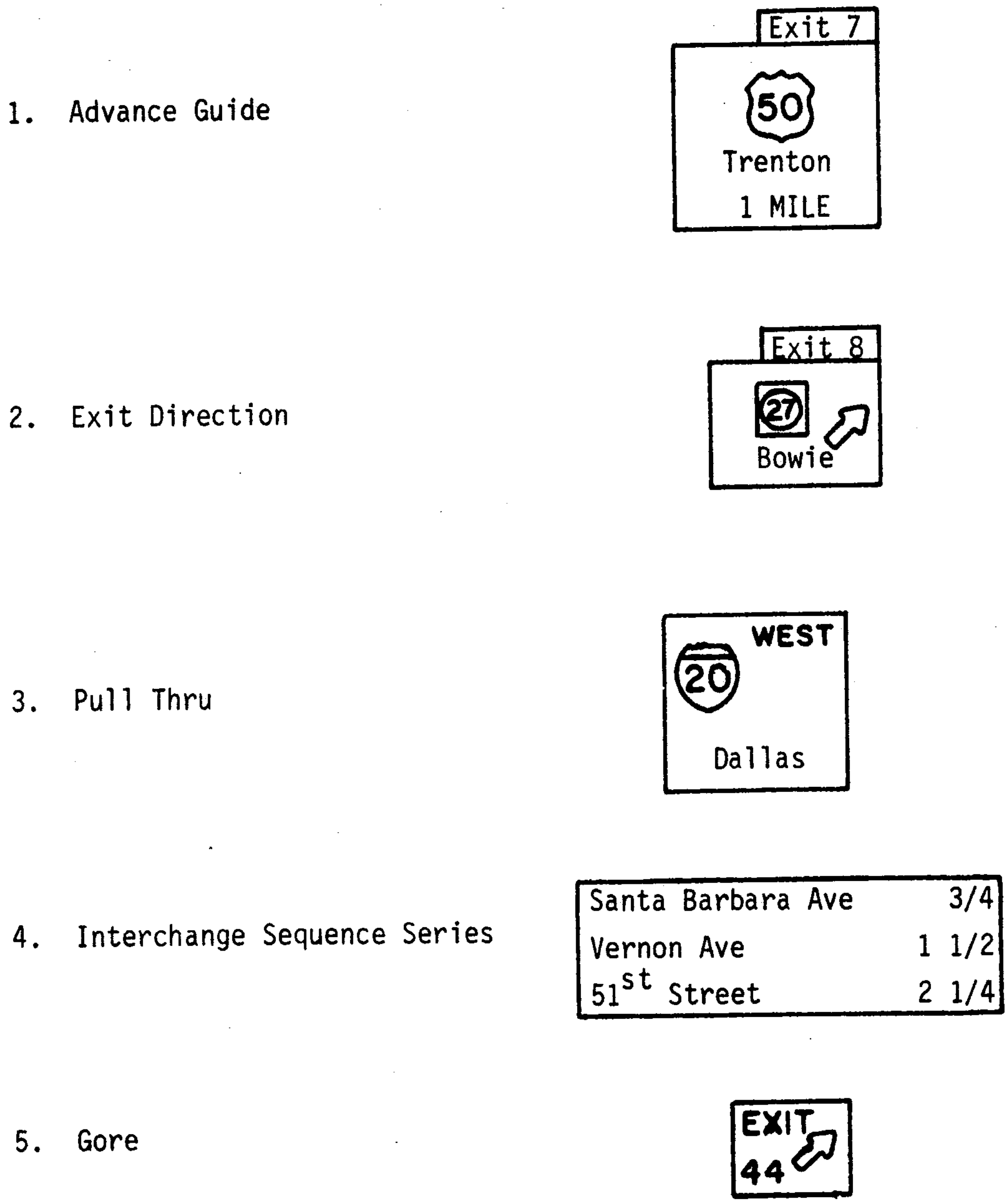

Figure 2. Five Types of Freeway Guide Signs.

Table 1. Conventional Advance Guide Signs

Sign Element	Usage Requirements and Guidelines
1. Route Destination	Control city if exit is to another through freeway. Destination if U.S. or lower class highway. Official name of city street. See Appendices 1-D and 1-E in SDHPT manual. Not normally needed if outbound exit to urban loop freeway, but may be used as auxiliary route signing for inbound traffic.
2. Route Designation	All route numbers required in priority.
3. Route Direction	Cardinal direction of numbered route to single direction from single-route exit.
4. Exit Distance	Shall use nearest 1/4 mile, except at lane drop within one mile of interchange. Shall use 1/4 mile at first exit to cloverleaf; no distance used on C-D roads. Do not need word Exit if exit numbers are used.
5. Exit Number	At top of sign flush with exit side. Not used on multilane exit of single exit, dual-route gore split, nor on cloverleaf C-D gore.
6. Exit Only	Use Exit ↓ Only overhead and in advance of lane drop where through route is carried on as mainline roadway. Not used with multilane exit. Use Exit Only with left hand lane drop diagrammtic sign.
7. Lane Arrow	Should be used when geometrics (alignment and number lanes) of through roadway are not readily evident at interchange since Pull Thru sign should be used, as at a multilane exit.

Table 2. Conventional Exit Direction Signs

Sign Element	Usage Requirements and Guidelines
1. Route Destination	Repeats advance guide sign for exit except use only single destination where single direction, single-route exit arises.
2. Route Designation	Repeats advance guide sign for exit except use only unique designation where single direction, single-route exit arises.
3. Route Direction	Cardinal direction of numbered route to single direction from single-route exit.
4. Exit Number	At top of sign flush with exit side. Not used on multilane exit of single exit, dual-route gore split, nor on cloverleaf C-D gore.
5. Exit Only	Use Exit Only overhead at lane drop.
6. Exit Arrow	Use ↗ where ramp is leaving the mainline lanes. The arrow shall point upward at an angle representative of the alignment of the exit roadway. Use ↓ overhead where it is desired to indicate a mainline lane(s) to be followed splitting from the through lanes at a major interchange. Arrows shall point downward toward center of lane(s) where only these lanes (but all that do go) are restricted to and go to the destination. Should be used when geometrics (alignment and number of lanes) of through roadway are not readily evident at interchange since Pull Thru sign should be used as at multilane exit.

signs. Some variation in the echo of the advance guide sign information exists, according to the MUTCD, depending on the type of interchange being signed. These variations are noted in the usage guidelines presented in Table 2.

Pull Thru Signs. Pull thru signs should be recognized as being distinctly different from advance guide signs and exit directions signs while providing guidance information similar to both but referring only to the mainline freeway route. Pull thru signs should be used when (and only when) the alignment and number of mainline through lanes of the freeway are not readily evident at an interchange. Multilane exiting roadways at a major interchance should be considered as candidates for using pull thru signs, especially where the through lanes do not proceed straight-ahead. Pull thru signs should be used anytime multiple lane assignment arrows are used on an overhead exit direction sign.

Consistency

Destination names are a principal navigational and information source. As many as one-half of the unfamiliar motorists may be guiding only on destination names. Thus it is imperative that consistent usage of destination names be achieved.

Three criteria have been identified as impacting the consistency of destination names. These destination name evaluation criteria are as follows:

1. Name familiarity consistent with route priority
2. Number of names consistent with number of exits
3. Names of route destinations consistent area-wide

It is reasonable to presume that motorists associate major city (or state) names with the Interstate highway system since the Interstate is the highest priority highway system in the U. S. Motorists driving experience would naturally associate the priority of highway facilities such as Interstate, urban freeway, arterial highway, and city street with the familiarity of destination names such as Houston, Hondo, and Hereford. The consistent usage of destination names on an overhead sign structure would call for the Interstate freeway system to have the more familiar names on the sign structure.

Familiarity. The following guidelines are presented to assist in rating the consistency of an urban freeway guide sign with respect to name familiarity.

An Interstate urban freeway should be signed with a destination name that is very familiar to out-of-state motorists. As a guide, cities with a population of over 300,000, state capitols, or state names are likely to be "good" names. Cities with a population between 100,000 and 300,000 are likely to be only "fair" destination names. Distance to the familiar city name is not as important as familiarity, although distances beyond 300 miles would have to be considered uncommon and should be considered to reduce the rating value by one category.

A federally marked route (i.e. U. S. route) that traverses an urban area as a freeway and which serves "interstate" motorists mostly as a freeway should be signed to the same standards within the urban area as an Interstate. Otherwise, cities with a population of at least 100,000 are classified as "good" destination names; whereas, cities with a population of at least 25,000 rate as a "fair" city. Street names should not be used to designate any urban freeway, or used as a destination name for any exit that also has a named city destination.

In a related area, the name "Downtown", when used on an overhead urban freeway guide sign, should only be used to mean the central core or downtown section of the major city of the urban area in which the sign is located.

Downtown may be combined with the name of the major city for emphasis, but Downtown should never be used in combination with any other town name.

Exit Consistency. Consistent usage calls for one destination name per exit. Some interchange designs are inherently inconsistent in this regard and cannot be modified in practice. Multilevel, single-exit interchanges and cloverleafs are examples. Rate these accordingly regardless of the flexibility for modification. In other cases, however, inconsistent usage has crept into the signing plans.

Area Wide-Consistency. Consistent usage also calls for the same destination name to be used for the same highway direction over the entire urban area. This calls for an urban wide review of the destination names used to refer to each highway departing an urban area. Inconsistent usage of control city and/or destination names may have likewise crept into the signing system, probably for a good reason at one time. For example, U.S. 61 may be shown on one freeway as going to Hondo and, on another route, U.S. 61 may be shown as going to Hereford. This inconsistent destination signing may confuse a tourist who is visiting several attractions in the metropolitan area and observes both signing alternatives for U.S. 61. This situation could result in the driver confusion and unsafe traffic operations.

Expectancy

Expectancy evaluations address guide signing problems which may occur within the signing sequence for a particular freeway exit. Violation of short-term memory is the primary consideration. Consideration of long-term expectancy built-up from driving experience and observation are considered elsewhere in other evaluation factors. Very few short-term expectancy problems are observed to occur in practice because thier severity is usually noticed and corrected immediately. The MUTCD (1) addresses this factor, however, with the following guidelines:

1. A route diverging from a freeway should not be signed with any of the same destination names as (or similar names) are shown at that point for any other route. The following examples illustrate what is desired. Assume the "control city" destination is "Denver". Then "Denver" should not appear on any other overhead sign panel at the location except the principal route to Denver. Another undesirable example causing expectancy problems is the use of the same "front name" with only a "tack-on" distinction at the end as "St., Blvd., or Business".
2. New destination information should not be added or dropped from the advance guide, exit direction sign sequence for an exit.

A third expectancy consideration deals with the placement of the individual overhead guide sign panels in the signing sequence approaching an interchange. The third evaluation guideline is as follows:

3. Overhead signs for an exit should not laterally move away from the exit side as the signing sequence approaches the exit.

Downstream exit route signing should always be placed over a lane which is the same lane or a lane nearer to the exit side when compared to the previous advance guide sign for the exit.

Relatability

Relatability describes the general ease of determining the correct exit directions, exit destinations and lane position from the associated cardinal directions, destinations, and lane use (assignment) arrows. The analyst must judge the collective effects of all factors regarding the appropriate relatability score.

Regarding spatial orientation from cardinal directions presented on overhead guide signs, it is presumed that motorists tend to read cardinal directions from left-to-right across the entire overhead sign structure. To maximize the relatability of signing directions with compass directions, interruptions to the natural clockwise progression of compass headings are undesirable. The natural sequence is: ... north, east, south, west ... with only one cycle per sign structure, beginning at any point. Inversion of the cardinal direction sequence on the overhead sign structure results in a "fair" rating. Multiple inversions result in a "poor" rating. The following cardinal direction sequence presents a "good" relatability rating:

Sign No. 1	Sign No. 2	Sign No. 3
South	West	East

The following cardinal direction sequence on an overhead sign structure has a "fair" sequence:

Sign No. 1	Sign No. 2	Sign No. 3
South	East	West

The following sequence would be rated as "poor":

Sign No. 1	Sign No. 2	Sign No. 3
West South	North	West

Concurrently numbered routes splitting at a major interchange may yield extremely poor relatability scores. Any sign panel which has opposite cardinal directions shown on it should be rated as "poor".

Motorists tend to read multiple route numbers of an overhead advance guide sign from left-to-right and associate with them multiple destination names read from top-to-bottom. If this visual arrangement is broken on a subsequent sign at a major interchange split, then the left route numbers and first destination name should be together on the same sign which should be left of the other sign containing the remaining route numbers and destination name.

The first destination name in a name list is also associated with the first (next) exit downstream, or the first (next) event to occur. At a freeway split, the first of two names on a prior advance guide sign goes with the left rather than the right sign at the split; whereas, at the first single-route exit ramp of a two-exit interchange, the first name goes with the first event to occur (the right-side exit direction sign).

Relatability problems also arise due to difficulties in associating lane assignments of overhead "down" arrows when the overhead sign structure is located on or very near the end of a horizontal curve. Message content is only slightly disrupted due to horizontal curvature, but lane assignment may be rendered indistinguishable. Signs located on horizontal curves of 1° to 3° are rated "fair"; whereas, signs located on curves of more than 3° are rated "poor".

WORKLOAD

INTRODUCTION

The concept of "workload" is used to describe the time rate that an unfamiliar "design driver" is presumed to work while acquiring all of the freeway guidance information needed to navigate a planned route toward his ultimate destination. Sufficient guidance information is assumed to be provided. However, all guide signing presented on a freeway sign structure is not needed by a particular motorist and he must therefore search through the signing to find the relevant information.

Critical Parameters

The time required to acquire relevant navigational information for various signing configuations has been determined from previous laboratory studies (2). The driver must acquire the navigational information within a reasonable time frame considering all of the driving tasks a motorists must routinely perform: i.e., control, guidance and navigation.

While the time required to acquire the information is presumed to be a constant value for a given signing configuration, the time avialable to read the sign depends on the sign design, operating speed and the freeway's horizontal curvature. As the horizontal curvature increases, the available reading time decreases thereby increasing the workload on the motorist.

Workload Ratio

A measure of the quality of service afforded urban freeway motorists by the design of the freeway guide signing as related to the associated geometrics and operating conditions is provided by the workload reading ratio, or simply, the "Workload Ratio". The Workload Ratio is defined as:

$$W = \frac{T_r}{T_a}$$

where

W = Workload Ratio

T_r = Time required to read sign, sec.

T_a = Time available to read sign, sec.

The Workload Ratio may be used to establish a level of service rating scale since it is apparent that a Workload Ratio value greater than 1.0 is undesirable. The numerical scale selected for describing the resulting level of service "grade" based solely on a consideration of driver workload W is as follows:

Workload Level of Service Grade

	A		B		C		D		E		F	
0.0		0.5		0.8		1.0		1.2		1.5		or more

Workload Ratio, W

The scale was subjectively specified based on the research available and the ramifications of W exceeding unity. It is known for example, that human subjects can perform at workload rates exceeding unity in a stressed condition for brief periods of time. However, driver errors would be expected to increase under these conditions.

A detailed development of the workload evaluation parameters follows beginning with the rather complex modeling of the driving task used for estimating the available reading time of a given freeway guide sign. Reading time requirements for various sizes of freeway guide signs will then be described followed by two application examples.

TIME AVAILABLE

The time motorists have available to read overhead freeway guide signs depends on many design, operational and human factors. Some of the more important design factors include the type of sign lettering (alphabet), brightness and contrast of the lettering, familiarity of message, sign density, competing sign messages, and location of the sign. Critical operational factors include operating speed and traffic density of surrounding vehicles. Principal human factors deal with the perception, comprehension, decision and response of the drivers to the information provided on the sign.

It is very difficult to estimate response conditions to such a complex perceptual situation like urban freeway guide signing due to the number of factors impacting the time motorists have available to read the signs. Rather than try to enumerate and evaluate all possible conditions that can be identified, standard conditions will be defined based on available data and/or research documentation. Some engineering judgment was required to fill gaps in the existing technology in a few cases.

Standard Conditions

Standard conditions for designing and/or evaluating urban freeway guide signing in Texas follows. Standard conditions may be thought of as describing the criteria and parameters for systems design and analysis. Basic criteria will be identified, parameters established and the basis for each selection noted. System variables include legibility, visibility constraints and operating speed among others. It is also very important to identify all assumptions made in developing the system parameters. For example, the standard conditions assume that the Manual on Uniform Traffic Control Devices (1) applies and is used; that external lighting of the signs is used to maintain general sign visibility; and that regular sign maintenance insures continuous high-quality sign brightness and uniformity. The following discussion presents the development of other system criteria and parameters for standard conditions.

Maximum Horizontal Reading Angle

Good sign design practice should reflect the fact that motorists cannot (should not be required to) effectively read signing at typical freeway speeds when the horizontal angle from the driver's vehicle control heading to the sign exceeds 10°(6, 8, 9), or outside the normal clear field of vision. The 10° value is now generally accepted in Great Britian (10) as well as in the United States (11). Most urban freeway guide signing placed along the roadside according to MUTCD (1) standards fulfill this requirement. The 10° horizontal angle is assumed to define when drivers no longer can read a roadside sign while driving by it without losing sight of the roadway ahead.

Overhead freeway guide signs also can be affected by this readability criterion in that some horizontal curvature may be so sharp that the roadway ahead gets outside of the 10° cone of clear vision even when reasonable allowances are made for average anticipation headings for negotiating the curve. Human factors research (12, 13) suggest that, when possible, motorists attempt to maintain and average preview distance of about 3.0 seconds while driving horizontal curves at relatively high speeds (60 mph). That is, drivers tend to look around the curve somewhat. It seems reasonable to assume that this action permits overhead guide sign reading to begin (if basically legible) at horizontal angles to the curve's tangent somewhat in excess of 10°. Note that the maximum horizontal reading angle constraint may affect the beginning of sign reading of overhead signs.

Maximum Vertical Reading Angle

As drivers approach an overhead freeway guide sign on a tangent or curve section, sign readability becomes restricted by the vertical cut-off angle of the vehicle's windshield. The vertical angle lies between the driver's normal horizontal line of sight and the center of the sign. Also, a motorist's natural field of clear vision in the vertical axis has about the same limiting vertical angle (9) as a windshield's vertical cut-off angle. Recent traffic engineering publications (14) recommended a vertical cut-off angle of 7.5°, which is assumed herein. Earlier researchers have used a value of 6° (9). The effect of selecting 7.5° rather than 6° will be discussed later.

The maximum vertical reading angle is used in conjunction with assumed values for the driver's eye height and the center of the overhead sign height to define lost legibility distance.

Lost Legibility Distance

This distance should be subtracted from all basic legibility distances (effects of vertical curvature are neglected) for either ground mounted guide signs along the roadside or for overhead guide signs. The value subtracted depends on the situation.

For overhead freeway guide signing, an average height to the center of the sign is conveniently assumed to be 23.75 feet and the driver's eye height 3.75 feet (9). Observations of Texas freeway signing plans reveal that these assumptions are reasonable. Thus, a vertical displacement of 20 feet results. The lost legibility distance to overhead signs due to the limiting 7.5° vertical reading angle is 150 feet. At the standard operating speed of 60 mph, this results in a loss of 1.7 seconds of reading time. Had a 6° vertical reading angle been assumed (9), a lost time of 2.6 seconds would have resulted yielding about a one second reduction in reading time from that obtained using the 7.5° reading angle.

While the focus of this development is on evaluating the more critical overhead guide signing system, roadside signing on tangent sections lose legibility distance as motorists pass by them, although in Texas this does not generally appear to be a problem since most roadside guide signing on urban freeways in Texas are exit direction or exit gore signs and user motorists are likely to be on the side of the freeway nearest the exit signing. Speeds and information density levels are also relatively low.

Basic Legibility Distance

This distance is the maximum distance from overhead freeway guide signs where the design driver can be assumed to start reading the information used to navigate along the freeway. The design driver is assumed to be unfamiliar with the specific freeway but alert and knowledgeable of freeway signing. The driver also is assumed to be destination oriented since this research (2) as well as other work (15) have shown that almost half of the unfamiliar motorists navigate primarily according to destination names rather than route numbers. This is important to the specification of basic legibility distance because place names on freeway guide signs are slightly smaller than route shield numerals.

The basic legibility distance then depends on the assumed legibility of the letter series used to construct place names and the height of letters used. Since Interstate and other freeway guide signing practice for place names uses an upper-case letter for the first letter of the place name which is 1 1/3 times the loop height of the remaining lower-case letters, it appears that many motorists usually recognize (or figure out) familiar destination names by reading the first letter together with a generalized perception of the name's form and length. Thus, it seems reasonable to assume that the basic legibility distance can be estimated from the legibility of the intial upper-case letter and its letter height.

While the Series E (M) upper-case letter may suggest that a legibility of 60 feet per inch of letter height is appropriate (at 20/20 visual acuity) under near ideal conditions (16), a lower value is usually recommended for design evaluation purposes. The most common value used is the 50 feet per inch rule-of-thumb (or 20/24 visual acuity of Series E(M) letter series) (9, 17). An argument could be made for using a lower legibility rate for several reasons including the fact that it is legal to drive with a lower effective visual acuity. However, it is believed that motorists usually learn to compensate for their long-term physical disabilities by driving slower, being more alert and avoiding routine situations they believe to be unsafe. A legibility distance is therefore calculated from the legibility rate of 50 feet/inch multiplied by the letter height of the initial upper-case letter of the destination name. In Texas, most destination names on urban freeway signs are composed of 16 inch upper-case letters and 12 inch lower-case letters which is the assumed standard. The resulting basic legibility distance is 800 feet (16 x 50) (17). Where the larger (but less common) 20 inch upper-case and 15 inch lower-case letters are used, the legibility distance would be 1000 feet (20 x 50).

Effective Legibility Distance

The effective legibility distance for overhead freeway guide signs under standard conditions is the basic legibility distance minus the lost legibility distance due to the maximum vertical cut-off angle of 7.5°. Therefore, the effective legibility distance is 650 feet (800-150) for the 16"/12" letter height standard. For the 20"/15" design, the related distance would be 850 feet (1000-150).

Note that further reductions in effective legibility may be necessary if the signing is located on a horizontal or vertical curve. The effect of horizontal curvature on reductions in legibility distance is presented in Table 3. Vertical curvature further reduces legibility distance only when the line of sight is disrupted. Examples are crest vertical curves, structures, and truck blockage.

Operating Speed

The average operating speed on urban freeways in Texas as of October 1978 was reported to be 58.9 mph with a median (50th %-tile) speed of 60.0 mph. It is assumed that the unfamiliar motorists drive responsibly and would not be driving much (if any) faster than the median speed. Thus, the standard operating speed on a tangent freeway section is assumed to be 60 mph. Research has shown that motorists slow down some on horizontal curves. This rate of speed reduction has been estimated at 0.866 mph per degree increase in curvature (18). Using the previous information as a basis, the standard operating speed for evaluating urban freeway signing systems in Texas under off-peak traffic conditions is estimated to be as follows:

$$S = 60 - 0.866\ D$$

where S is the speed in mph and D is the degree of horizontal curvature.

Navigational Time Availability

Motorists driving along an urban freeway perform three basic driving tasks: control, guidance and navigation (19). The control and guidance tasks include: operating the vehicle, maintaining lane tracking, maintaining a safe speed and headway, and avoiding hazardous traffic situations.

Table 3. Estimated Time Available for Reading Overhead Freeway Guide Signing Under Conditions As Related to Horizontal Curvature.

Analysis Step	Degree of Horizontal Curvature								
	0°	1°	2°	3°	4°	5°	6°	7°	8°
Basic leg., ft. 16"/12" letters	800	800	800	800	800	800	800	800	800
Max. leg., ft. 10° horz. angle	-	-	-	920	750	650	570	520	480
Eff. leg., ft. 7.5° vert. angle	650	650	650	650	600	500	420	370	330
Speed, mph	60	59	58	57	57	56	55	54	53
Max. Time, sec. 100% Available	7.4	7.5	7.6	7.7	7.2	6.1	5.3	4.7	4.3
% of Motorist Time Available, P	56	53	49	46	42	39	35	32	28
Available Reading Time, sec.	4.1	3.9	3.7	3.5	3.0	2.4	1.9	1.5	1.2

Motorists become more occupied with the control and guidance tasks as the complexity of alignment and traffic volumes increase. Motorists time-share among control, guidance and navigational tasks as the need arises and as tasks demands permit. Safety considerations dictate, and driver behavior usually confirms, that motorists must satisfy current control and guidance task demands before attending to navigational demands, for example, reading guide signs (19). As will be discussed subsequently, motorists may require 25% to 50% of the total time available to perform the control and guidance tasks. Research also has indicated that at the higher driving stress levels, the driver acts as a single channel processor and effectively performs only one task at a time (13).

Some research has been conducted to determine the percent of time drivers use to maintain vehicle control while driving various horizontal alignment conditions. Other research, conducted in driver behavior and actions while reading freeway guide signing, is available to support some assumptions necessary to bridge gaps in the existing technology since no study is known to have specifically studied all levels of the driving tasks on high-speed urban freeways.

McDonald conducted an elaborate instrumented vehicle study (20) to determine the percent of time drivers needed (percent occupied) to drive the vehicle along tangent and curve sections of a highway. Subject motorists drove a test track at various speed levels. No other vehicles were present. Upon reaching the test section, subject drivers were not required to maintain the initial speed. McDonald (20) found that drivers traveling about 60 mph are about 22% occupied when driving a tangent section and are 30% occupied when driving a 4.6° horizontal curve. It was also determined that driver workload and the percent of time drivers were occupied when driving a curve increased almost linearly with curvature for curves up to 15° for a given speed.

Some extrapolation and assumptions are necessary to use McDonald's findings. Basically, it is necessary to extrapolate test track data to freeway driving conditions. Further, since the test data neither required speed control (to maintain a safe car following headway) nor required additional driver workload (to search for and possible avoid vehicles in adjacent lanes) some additional increases in workload and percent of the time drivers are occupied while performing these additional urban freeway driving tasks are appropriate. Assuming that speed control and traffic surveillance are equal to the basic lane tracking task, then the net time drivers are occupied while performing control and guidance tasks on normal freeway tangent sections would be 44% occupied (2 x 22%) and 60% occupied (2 x 30%) on a 4.6° horizontal curve. The remainder of the time would be available for reading signs.

Other research conducted along Ohio freeways by experienced researchers using the eye-marker camera system (21) indicates the reasonableness of the adjusted time occupancy estimates for combined control and guidance tasks. In one case the Ohio resarchers seem to indicate (by our calculations) that motorists driving in moderate to heavy freeway traffic begin reading freeway guide signing on the average as if motorists were "occupied" on control and guidance tasks 45% of the time. In another case, the Ohio researchers suggest (again, by our calculations) that unfamiliar motorists read freeway signs under the highest information need levels at control and guidance occupancy levels not less than 50%.

The previous development can be used to estimate the percent of time (P) motorists have available to read urban freeway guide signing as a function of horizontal alignment conditions. The greater the horizontal curvature, the smaller the percent of time available to read signs. Using McDonald's driver workload study (20) results as a baseline, and the Ohio study (21) to support the assumption that the total control and guidance task requirements is about twice (2.0 times) the baseline value, then the percent of time (P) available for reading guide signs (or other navigational information) would be:

$$P = 100\% - \text{control and guidance requirements}, \%$$

$$P = 100\% - 2.0\,(22\% + 1.74\,D^{o}), \%$$

$$P = 56\% - 2.5\,D^{o}, \%\ \text{of time available} \qquad (1)$$

where D is the degree of horizontal curvature. The model predicts that drivers on a tangent freeway section ($D^{o} = 0$) have about 56% of their driving time available for reading navigational signing (as provided by the legibility distance of the signing for a given operating speed); 44% of the total time is needed to perform the control and guidance tasks. On a 4^{o} horizontal curve, only about 42% of the total time is available for reading signs.

Available Reading Time

The amount of time (in seconds) motorists are estimated to have available to read overhead urban freeway guide signing under standard conditions is presented on the bottom row of Table 3. The estimated times are based on the previous standard conditions, assumptions, and analytical development. Summary calculations leading up to the determination of the available reading times are presented in earlier rows of Table 3. The estimated time available on a tangent urban freeway section (0^{o}) for reading signing is 4.1 seconds for the 16"/12" letter size.

TIME REQUIRED

The times drivers require to read overhead freeway signs have been estimated based on considerable laboratory study data at the Texas Transportation Institute of high-quality simulated freeway guide signs under moderate display rates. The subjects were not task loaded. This research is fully documented in a companion research report (2). Required reading times were determined for overhead freeway guide signs having various levels of total information load on the sign and by the number of sign panels used to display the information.

Information Load

The unit used to measure information load on a freeway guide sign is conveniently called a "bit". This term has been selected to promote understanding of the concept but is being loosely used from a strictly theoretical viewpoint based on information theory (22). Other researchers have used similar descriptions to describe information such as "familiar words" (9) or "units of information" (23). A bit of information is defined herein as the existence, on a freeway guide sign, of each and every one of the following items:

Route Number
  "I-30"
Cardinal Direction
  "North"
Destination Name
  "Miami"
Route Name (1 or 2 bits)
  "Central Expressway"
Street Name
  "Park Street"
Next Right (Left)

Junction, To, Next

Exit Number
  (or exit number panel)
Command
  "Exit", "Use"
Exit Mileage
  "1¼ Miles"
Exit Only
  "Exit Only"
Mileage
  "2 Miles"
All Lane Use Arrows
  (To same route)
Business

Some variation in results may be expected in application of this measurement scheme, although good consistency was obtained after only modest instructions were given to users. Some discretion is also provided particularly on route and street names. Excessively long or possibly confusing route names such as Santa Barbara Freeway or Central Expressway may be considered two (2) bits of information (or load) as far as estimating the degree of difficulty in the reading task.

Reading Time

The time assumed to be required by the design motorist to read overhead freeway guide sign information based on the laboratory study data is presented in Figure 3 as the family of four curves for 2, 3, 4 and 5 panel overhead guide signs. No variation of reading time by sign panel position was determined and thus all values are average conditions. All panels would therefore require the same reading time and the same rating. Total amount of information load in bits on all sign panels is a primary input variable in using the curves. For example, a five (5) panel overhead freeway guide sign having a total of 20 bits of information on the sign would require 4.1 seconds reading time. Signs having more than 20 bits of information are undesirable (2) and the reading time curves are shown as broken above the 20-bit level. Score all signs having more that 20 bits of information as level of service F. Freeway guide sign structures having two sign panels require about 2.8 seconds to read for typical urban freeway applications (2).

LEVEL OF SERVICE EVALUATION

The following two example problems will be evaluated to illustrate the calculation procedures and determination of the level of service of urban freeway guide signing form a consideration of workload. As discussed previously, Workload Ratio is used to estimate the level of service. See page 20.

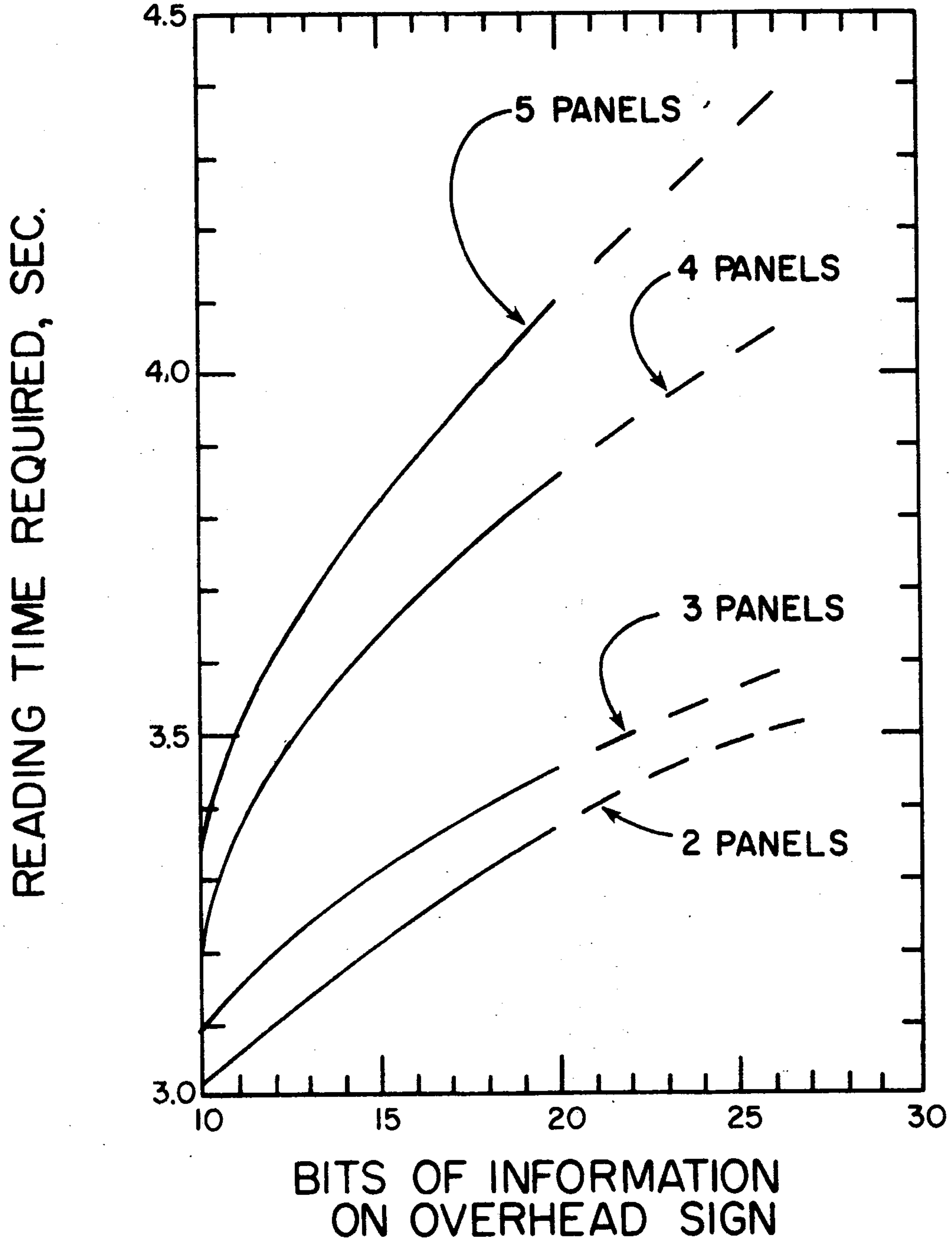

Figure 3. Reading Time Needed to Acquire Information as Related to Bits of Information on Overhead Sign.

Example No. 1

Problem. A large overhead freeway guide sign structure is located on a tangent section of a six-lane urban freeway. The sign structure contains four sign panels, including the exit direction sign. A total of 16 bits of information are present on the sign structure. Otherwise, standard conditions are assumed. The problem is to determine the Workload level of service for each sign.

Solution. The first step in the solution process is to determine the reading time required. Since the sign is located on a tangent (straight) freeway section, the available reading time is 4.1 seconds, from Table 3 on page 36.

The second step is to determine the time required to acquire the information from the sign structure. Since there are 16 bits of information on the sign, a time of 3.7 seconds is obtained from Figure 3 as the time required to read the four-panel sign. Note that the time is assumed to be the same regardless of which sign panel is being considered.

The final step is to calculate the Workload Ratio (W) and to read the resulting level of service from the scale presented at the bottom of this page. The Workload Ratio W is

$$W = \frac{\text{time required}}{\text{time available}} = \frac{3.7 \text{ sec.}}{4.1 \text{ sec.}} = 0.90$$

and the level of service for each sign is noted to be C using the Workload level of service scale, as shown below.

Workload Level of Service Grade

A	B	"C"	D	E	F
0.0 – 0.5	0.5 – 0.8	0.8 – 0.9	1.0 – 1.2	1.2 – 1.5	1.5 or more

Workload Ratio, W

Example No. 2

Problem. Another large overhead freeway guide sign structure is located on a 5° horizontal curve. The sign structure contains five panels, including the exit direction sign. A total of 20 bits of guide sign information are used on the structure. Standard conditions are assumed. It is desired to determine the Workload level of service for each sign.

Solution. Again, the initial step is to determine the time required to read the sign. Since the sign is located on a 5° horizontal curve, the available reading time is 2.4 seconds, from Table 3.

The next step is to determine the time needed to read the sign messages. Since there are 20 bits of information on the sign, a reading time of 4.1 seconds is needed to read the five-panel sign as determined from Figure 2.

The final step is to calculate the Workload Ratio (W) and to read the resulting level of service from the scale. The Workload Ratio W is

$$W = \frac{\text{time required}}{\text{time available}} = \frac{4.1 \text{ sec.}}{2.4 \text{ sec.}} = 1.70$$

and the level of service for each sign is observed on the scale to be F, a totally undesirable situation. This illustrates the need to consider free-

Workload Level of Service Grade

	A	B	C	D	E	"F"	
0.0	0.5	0.8	1.0	1.2	1.5	1.7	or more

Workload Ratio, W

way signing requirements early in the freeway design process.

RESPONSE

INTRODUCTION

Freeway guide signs should be placed such that the requested traffic maneuver on the freeway can be made within the space and time provided. Travel time and the related distance traveled should be provided for the driver to read the messages, make the necessary lane changes, preview the interchange geometry, and then exit at the natural departure point.

Response to two types of freeway guide signs are considered. Both advance guide signs to an exit and exit direction signs are evaluated. The MUTCD (1) provides detailed descriptions and recommended placement of these signs. While these procedures generally assume that the MUTCD is being followed, the placement of the signs on the freeway is evaluated and not whether the Manual has been followed.

LEVEL OF SERVICE EVALUATION

A grading scale is used to estimate the response level of service. The grading scale is based on the calculation of the ratio of the estimated travel distance needed to comfortably perform the driving tasks identified in the modeling process divided by the travel distance provided by the placement of the sign relative to the existing station. The Response Ratio, R, is defined as follows:

$$R = \frac{\text{Travel Distance Needed}}{\text{Physical Distance Provided}}$$

The numerical grading scale for estimating the level of service for potential driver response to the guidance messages is defined to be

Response Level of Service Grade

A	B	C	D	E	F
0.0 – 0.5	0.5 – 0.8	0.8 – 1.0	1.0 – 1.2	1.2 – 1.5	1.5 or more

Response Ratio, R

As in the Workload scale, motorists are assumed to be able to work above their normal capacity levels for brief periods under stress, although, this is undesirable and likely to result in more frequent driving errors.

ADVANCE GUIDE SIGNS

Advance guide signs give notice of the principal destinations served by the next interchange's exits. Approximate distance to the exit also is provided. It is important to note that the advance guide sign evaluated is the first advance guide sign that clearly indicates on which side of the freeway the exit is located. This may not be the first advance guide sign.

Driver Actions Evaluated

Advance guide signing should be placed far enough in advance of the exit point to permit a driver to comfortably perform the following actions:

1. Detect advance guide sign
2. Read advance guide sign
3. Perform necessary lane changes
4. Repeat 1 and 2 for subsequent advance guide sign
5. Detect exit direction sign
6. Read exit direction sign
7. Perform exit preview
8. Exit

The travel times and distances needed to perform each of these operational activities will be presented in the following sections. The analyst should assume that the motorist is unfamiliar with the freeway and is initially located in the median lane of the freeway.

Sign Detection

In the normal routine of reading overhead freeway guide signs, motorists can see the signs a considerable distance before they can read them and, therefore, there is very little detection time, per se. Roadway design conditions do occur, however, where the view of an overhead (or ground-mounted) guide sign is routinely blocked or limited by an obstruction until the motorist is less than 1,000 feet from the sign structure. In this case, the motorist must detect and recognize the sign, before reading can begin. A 1.0 to 1.5 second detection time is thought to be satisfactory based on existing literature sources (6, 9). Thus, if the sign view is restricted to less than 1,000 feet, then

$$T_d = 1.0 \text{ to } 1.5 \text{ seconds}$$

otherwise,

$$T_d = 0.3 \text{ seconds}$$

The longitudinal freeway distance in feet (D_d) traveled (required) by an unfamiliar motorist while detecting the sign would be

$$D_d = 1.47 \cdot V \cdot T_d$$

where V is the motorist's speed in mph and T_d is the sign detection time in seconds. At 50 mph, the travel distance would be 110 feet when T_d is 1.5 seconds due to a blockage. If T_d were 1.0 seconds, then at 60 mph D_d would be 88 feet. It seems reasonable to assume that D_d is 100 feet for all cases where a separate detection distance is necessary. When the sign view is unrestricted, the 0.3 second detection time results in a D_d of 26 feet at 60 mph. It would seem reasonable to use a detection distance of 0 feet when visibility of the sign exceeds 1,000 feet.

Sign Reading

The time a motorist uses while reading overhead freeway guide signs should account for the desired operating condition of providing a motorist sufficient space while routinely reading signs to maintain safe vehicle control and avoid traffic hazards (19). The percent of time the design motorist has available for sign reading previously was defined as equation 1 on page 47 and given in Table 3 as related to horizontal curvature. Using this conceptual specification, the travel time in seconds a motorist would use while reading guide signs of a given information bit rate is estimated as:

$$T_s = \frac{T_r}{\frac{P}{100}} = \frac{T_r}{0.56 - 0.035\ D^o} \qquad (2)$$

where T_s is the travel time while reading signs which have an "unloaded" sign reading time determined as T_r in the laboratory. T_r was given in Figure 2 for various sign configurations. Resulting travel times of T_s as related to total information load on guide sign and degree of horizontal curvature may be read from the nomograph presented in Figure 4 which solves equation 2 (above). T_s given T_r and D^o. As an example, an overhead guide sign containing a total of 15 bits of information on 4 panels located on a 2^o (degree) horizontal would result in an estimated sign reading travel time of

$$T_s = \frac{3.7}{0.56 - 0.035 \cdot 2} = 7.5 \text{ seconds}$$

as can be determined from the nomograph in Figure 4.

The solution procedure of Figure 4 is as follows: Trace vertically from "15 bits" on the x-axis to the "4 panels" curve. Next, trace horizontally to the turning line; the vertically upward to the given degree of curvature (here 2^o). From this point, move horizontally left to the time scale on the y-axis, reading the travel time, T_s of 7.5 seconds.

The distance traveled during the sign reading travel time should be calculated next. This distance is determined from

$$D_r = 1.47 \cdot V \cdot T_s$$

where D_r is the sign reading travel distance (in feet), V is the freeway speed (in mph), and T_s is the sign reading travel time (in seconds) as determined

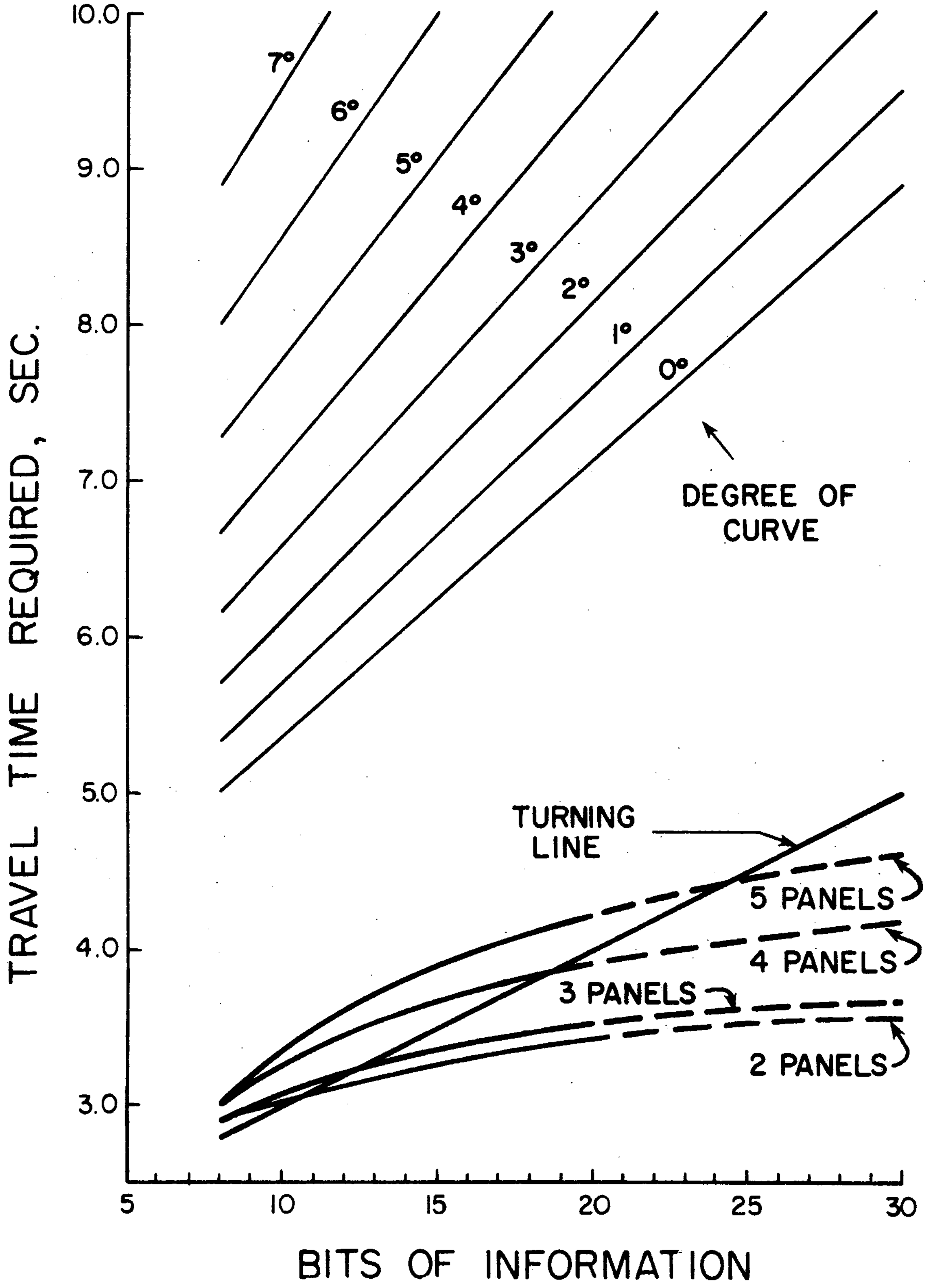

Figure 4. Nomograph for solving reading travel time.

from Figure 3. A motorist traveling 60 mph would travel about 660 feet while reading the 15-bit, 4 panel sign if it were located on a 2° horizontal curve.

The following simplified procedure may be used to expedite the analysis procedure. It results in satisfactory approximations for freeways not located on sharp horizontal curves (say less than 2°) and typical freeway guide signs. Under these conditions and assumptions, the average travel time ranges from about 6.5 - 7.5 seconds, with a mid-point of 7.0 seconds. The following travel distances would result for a 7.0 second travel time:

Speed	Travel Distance, D_r
40 mph	410 feet
50 mph	513 feet
60 mph	616 feet

Approximations for the nearest 100 feet should suffice, or

Speed	Approximate Travel Distance, D_r
40 mph	400 feet
50 mph	500 feet
60 mph	600 feet

Lane Changing

Lane changing between freeway mainlanes is frequently necessary to follow a route through an urban freeway system. One and probably more lane changes in succession may be required, or at least suggested by the overhead freeway guide signing. While research has indicated that most familiar motorists probably don't literally follow the positioning of each and every overhead freeway guide sign (4), this same study did demonstrate that a number of motorists (presumably mostly unfamiliar ones) were responding to the sign positioning over the freeway lanes. This latter situation should be the guiding premise for evaluation of advance guide signs. In any event, the first advance guide sign for a right-hand exit should be analyzed as if the motorist were in the median lane. The number of required lane changes would then be the number of mainline lanes in one direction minus one, or $n = \frac{N}{2} - 1$ where n is the number of required lane changes for a N-lane freeway.

The lane changing distance is the total distance traveled along the freeway while making lane changes of one or more lanes. It is the distance traveled after the decision has been made to begin making a lane change. The distance depends on traffic conditions, increasing with increasing traffic volumes.

Empirical evidence supported by traffic flow theory will be utilized to develop recommended lane change distance requirements. Two doctoral dissertations have been conducted at Texas A&M University on lane change characteristics. One study was mostly empirical in nature (24), whereas the other was more theoretical (25).

McNees in 1976 used 13 male and 7 female subject drivers from the Houston area to conduct lane changing studies along the inbound freeway surveillance and control system of the 6-lane Gulf Freeway in Houston (24). Ten of the drivers, or 50%, were in the 18-34 age group. An instrumented vehicle was used as the test vehicle. Data were collected of the "total" lane changing distance of two consecutive lane changes made to change from the median lane to the shoulder lane or vice versa. Four traffic flow conditions were studied: 1) light, 2) medium, 3) heavy with speeds above 35 mph, and 4) heavy with speeds below 35 mph. Light traffic could not have a traffic flow rate of more than an average of 725 vehicles per hour per lane (vphl), medium traffic conditions ranged from 725 to 1225 vphl, and heavy conditions were assumed to be greater than 1225 vphl. Computer printouts of lane volumes and speeds during the day were available to the researcher. Light traffic generally was found to exist from 3:00 a.m. to 5:30 a.m., and after 8:00 p.m. on weekdays. Since "heavy traffic" included levels of service C, D, and E, these conditions often were observed from 6:30 a.m. to 9:00 a.m. and from 3:00 p.m. to 6:00 p.m. At times, heavy traffic also was observed during the midday lunch break. It is to be noted that "heavy traffic" was not synonymous with rush hour only conditions, but included rush hour traffic within the range.

McNees' lane changing results (24) are presented in Table 4 for total lane change distance (of two lane changes across three lanes) and average distance per lane change for the four previously described traffic conditions. Also presented in Table 4 are median (50%-ile) and 85%-ile lane change distances. All distances are in feet. Average lane change distances increased as traffic volumes increased toward the capacity of the freeway.

Table 4. Lane Changing Distances Measured on Six-Lane Gulf Freeway for Various Traffic Conditions. (24)

Statistical Performance Measurement	Lane Changing Distance in Feet Traffic Conditions			
	Light	Medium	Heavy > 35	Heavy < 35
Total				
Mean	931	1007	1164	809
Median	877	973	1046	666
85%-tile	1105	1354	1346	1131
Per Change				
Mean	466	504	582	405
Median	439	487	525	333
85%-tile	553	667	673	566
Sample Size	56	56	32	27

One may speculate that had a large sample set been collected only at or near the extremum (capacity) condition then a longer lane change distance would have been observed. In the heavy traffic region with speeds less than 35 mph (the actual average speed measured was 19 mph), the stop-and-go traffic resulted in a shorter lane change distance. The 85%-ile distances, on the whole, were about 25% longer than the mean (average) distances.

Since it is desired to provide some margin of safety, McNees' 85%-ile data may be used as a guide for estimating the average lane change distance per lane change. It is recommended that a lane change distance of 700 feet per lane change be used. Total lane change distances in feet for 4, 6, 8 and 10-lane freeways are presented below:

Number of Freeway Lanes N	Total Lane Change Distance, feet
4-lane	700'
6-lane	1400'
8-lane	2100'
10-lane	2800'

Detect Exit Direction Sign

When evaluating the placement of any advance guide sign, time (and distance) should be provided to detect the sign structure containing the exit direction sign. A detection time of 1.0 to 1.5 seconds should suffice (9), which results in a travel distance of about 100 feet for common urban freeway speeds during free-flow conditions. Assume a detection travel distance D_r of 100 feet for every overhead freeway guide sign downstream to the exit from the advance guide sign being evaluated.

Read Exit Direction Sign

The travel time used while reading freeway guide signs (at least one of which is the exit direction sign) may be obtained from Figure 3. Input variables to Figure 3 include the total bits of information on the sign structure and horizontal curvature, if any. One-half of the time required obtained from Figure 3 should be used since the motorist is not time sharing between navigation and control. Approximate travel distances for "typical signing conditions" with little or no horizontal curvature (say less than 2°) give travel distances for various freeway speeds of

Speed, V	Travel Distance, D_r
40 mph	200 feet
50 mph	250 feet
60 mph	300 feet

which should be acceptable. If more detail is desired use

$$D_r = 1.47 \cdot V \cdot (T_s/2)$$

where D_r is the sign reading travel distance (in feet), V is the freeway speed (in mph), and T_s is the time (in seconds) required to read the guide signs containing the exit direction sign, as given in Figure 3.

Preview Exit

Upon reaching the freeway exit, or an interchange split, the unfamiliar freeway motorist will require additional time and related travel distance to obtain a visual preview of the geometrics, then identify the appropriate departure path, and determine a safe exit speed. This exit preview time has been assumed to be 3.0 seconds by AASHTO for the design of intersections and freeway deceleration lanes (26). In a FHWA publication (27) on decision sight distance, a similar time variable for detection and recognition of potential geometric hazards is used. A minimum of 1.5 seconds was recommended in the

FHWA publication for situations with moderate complexity and visual clutter, while 3.0 seconds was thought to be required for more complex situations or where the geometric feature is particularly difficult to detect, or where driver expectancies are violated.

The following exit preview times are recommended for two all-inclusive cases. An exit preview time of 1.5 seconds is recommended for use when <u>all</u> of the following conditions exist:

1) the exit is a nominal single lane, single exit ramp
2) the exit is located on the right-hand side of the freeway
3) the adjacent through lane continues
4) the ramp nose is readily visible to oncoming traffic
5) the freeway has a horizontal curvature of no greater than 2°

Otherwise, an exit preview time of 3.0 seconds should be used. This would encompass all other situations including the following exiting conditions:

1) all interchange splits
2) all multiple lane exits
3) all lane-drop (exit only) exits
4) all exits qualifying for diagrammatic signing
5) all left-hand exits

An additional brief period of time should be added to either exit preview time to account for the time needed by the driver to implement exiting vehicular control response (principally steering). A response time of 1.0 seconds is appropriate (<u>26</u>).

The distance traveled while the motorist is making his exit preview and exiting response can be calculated from the following equation:

$$D_e = 1.47 \cdot V \cdot (T_e + T_x)$$

where D_e is the necessary exit preview distance (in feet), V is the freeway speed (in mph), T_e is the appropriate exit preview time (1.5 or 3.0 seconds), and T_x is the exiting steering response (1.0 seconds). Table 5 summarizes the distances required for various freeway speeds.

Table 5. Exit Preview and Response Travel Distances for 1.5 and 3.0 Second Exit Preview Times.

Freeway Operating Speed, mph	Exit Preview Time, sec. 1.5	3.0
40	150	240
50	180	290
60	220	350

Exiting response time equals 1.0 seconds.

Exit Maneuver

An exit maneuver is defined as being any traffic maneuver that departs from the main freeway route. An exit maneuver would occur: 1) at a common freeway exit ramp to the frontage road or cross-street diamond interchange, 2) at major interchange-to-interchange ramp connections, or 3) at a freeway split. From the viewpoint of evaluating freeway guide signing, only one critical item needs to be identified - the departure location from the freeway mainlane which is closest to the departure ramp.

To determine the departure location, a natural direct departure path from the freeway should be assumed. If one lane of the freeway splits onto two downstream roadways, the departure location would be positioned on the diverge point of the paths of the center of vehicles taking the two possible routes from the common lane. This location is about 100 feet upstream of the physical gore station.

EXIT DIRECTION SIGNS

This section will be used for exit direction signals which are evaluated concurrently with the advance guide sign system. The driver actions to be determined are:

1. Detect Exit Direction Sign
2. Read Exit Direction Sign
3. Preview Exit

These signs usually provide a very short response distance to the driver. The exit direction sign should be placed far enough in advance of the exit to permit the driver to perform the above three actions.

Detect Exit Direction Sign

When evaluating the placement of any advance guide sign, time (and distance) should be provided to detect the sign structure containing the exit direction sign. A detection time of 1.0 to 1.5 seconds should suffice (9), which results in a travel distance of about 100 feet for common urban freeway speeds during free-flow conditions. Assume a detection travel distance D_r of 100 feet for every overhead freeway guide sign downstream to the exit from the advance guide sign being evaluated. As stated earlier, a 0.3 second detection time should be provided for signs with unrestricted sight distances. However, since we cannot determine when a particular signs sight distance will be restricted, a good rule of thumb will be to allow 100 feet for detection distance for all signs.

Read Exit Direction Sign

The travel time used while reading exit direction signs may be obtained from Figure 3. Input variables to Figure 3 include the total bits of information on the sign structure and horizontal curvature, if any. One-half of the time required obtained from Figure 3 should be used since the motorist is not time sharing between navigation and control. Approximate travel distances for "typical signing conditions" with little or no horizontal curvature (say less than 2°) gave travel distances for various freeway speeds of

Speed, V	Travel Distance, D_r
40 mph	200 feet
50 mph	250 feet
60 mph	300 feet

which should be acceptable for use in Response evaluations. If more detail is desired, then

$$D_r = 1.47 \cdot V \cdot (T_s/2)$$

where D_r is the sign reading travel distance (in feet), V is the freeway speed (in mph), and T_s is the time (in seconds) required to read the guide signs containing the exit direction, as given in Figure 3.

Preview Exit

Upon reaching the freeway exit, or an interchange split, the unfamiliar freeway motorist will require additional time and related travel distance to obtain a visual preview of the geometrics, then identify the appropriate departure path, and determine a safe exit speed. This exit preview time has been assumed to be 3.0 seconds by AASHTO for the design of intersections and freeway deceleration lanes (26). In a FHWA publication (27) on decision sight distance, a similar time variable for detection and recognition of potential geometric hazards is used. A minimum of 1.5 seconds was recommended in the FHWA publication for situations with moderate complexity and visual clutter, while 3.0 seconds was thought to be required for more complex situations or where the geometric feature is particularly difficult to detect, or where driver expectancies are violated.

The following exit preview times are recommended for two all-inclusive cases. An exit preview time of 1.5 seconds is recommended for use when all of the following conditions are present:

1) the exit is a nominal single lane, single exit ramp

2) the exit is located on the right-hand side of the freeway

3) the adjacent through lane continues

4) the ramp nose is readily visible to oncoming traffic

5) the freeway has a horizontal curvature of no greater than 2°

Otherwise, an exit preview time of 3.0 seconds should be used. This would encompass all other situations including the following exiting conditions:

1) all interchange splits

2) all multiple lane exits

3) all lane-drop (exit only) exits

4) all exits qualifying for diagrammatic signing

5) all left-hand exits

An additional brief period of time should be added to either exit preview time to account for the time needed by the driver to implement exiting vehicular control response (principally steering). A response time of 1.0 seconds is appropriate (26).

The distance traveled while the motorist is making his exit preview and exiting response can be calculated from the following equation:

$$D_e = 1.47 \cdot V \cdot (T_e + T_x)$$

where D_e is the necessary exit preview distance (in feet), V is the freeway speed (in mph), T_e is the appropriate exit preview time (1.5 or 3.0 seconds), and T_x is the exiting steering response (1.0 seconds). Table 6 summarizes the distances required for various freeway speeds.

Table 6. Exit Preview and Response Travel Distances for 1.5 and 3.0 Second Exit Preview Times.

Freeway Operating Speed, mph	Exit Preview Time, sec. 1.5	Exit Preview Time, sec. 3.0
40	150	240
50	180	290
60	220	350

Exit response time equals 1.0 seconds.

Exit Maneuver

An exit maneuver is defined as being any traffic maneuver that departs from the main freeway route. An exit maneuver would occur: 1) at a common freeway exit ramp to the frontage road or cross-street diamond interchange, 2) at major interchange-to-interchange ramp connections, or 3) at a freeway split. From the viewpoint of evaluating freeway guide signing, only one critical item needs to be identified - the departure location from the freeway mainlane which is closest to the departure ramp.

To determine the departure location, a natural direct departure path from the freeway should be assumed. If one lane of the freeway splits onto two downstream roadways, the departure location would be positioned at the diverge point of the paths of the center of vehicles taking the two possible routes from the common lane. This location is about 100 feet upstream of the physical gore station.

OVERALL LEVEL OF SERVICE

After the level of service has been determined for navigation, workload and response for a particular sign, an overall level of service characterizing the sign must also be determined. The overall level of service will be the worst level of service associated with each of the three prior levels of service.

<u>Example of the Overall Level of Service</u>

To show how the overall level of service is developed, an example will be provided. The following example illustrates how the overall level of service is determined. Navigation, Workload and Response are assumed to be as follows:

Navigation Level of Service

	A	B	"C"	D	E	F
0.0	4	5.6	7.8	9.10	11.12	>12

Workload Level of Service

	A		"B"		C		D		E		F	
0.0		0.5		0.8		1.0		1.2		1.5		or more

Response Level of Service

	A		B		C		D		"E"		F	
0.0		0.5		0.8		1.0		1.2		1.5		or more

In this example, the Navigation Level of Service is a C, the Workload Level of Service is a B and the Response Level of Service is an E. The overall level of service for this sign would be E since the overall level of service is equal to the worst level of service of all three.

LEVEL OF SERVICE REFERENCES

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URBAN FREEWAY GUIDE SIGNING

LEVEL OF SERVICE

Evaluation Worksheet

Freeway________________ Sign Type________________

Sign Location________________ Level of Service________________

Total Number of Panels on Sign Structure________________

Total Bits of Information on all Sign Panels________________

Degree of Horizontal Curvature________________

Comments:________________

____

____

1. Navigation Level of Service:
   - A. Sufficiency Rating of Sign________________
   - B. Consistency Rating of Sign________________
   - C. Expectancy Rating of Sign________________
   - D. Relatability Rating of Sign________________
   - E. Subtotal of Navigational Ratings________________ (Add A + B + C + D)
   - F. Navigational Level of Service (Read Scale on Page 17) ________________

2. Workload Level of Service
   - A. Number of Overhead Sign Panels________________
   - B. Total Bits of Info. on all Panels________________ (See page 40)
   - C. Degree of Horizontal Curvature________________
   - D. Determine Required Reading Time________________ (Figure 3, page 42)
   - E. Determine Available Reading Time________________ (Table 3, page 36)
   - F. Calculate Workload Ratio________________ (Divide D by E)
   - G. Determine Workload Level of Service (Read Scale on page 29) ________________

3A. Response Level of Service (Advance Guide Signs)

A. Number of Overhead Sign Panels ________

B. Total Bits of Info. on all Panels ________

C. Degree of Horizontal Curvature ________

D. Number of Freeway Lanes ________

E. Distance to Exit Theoretical Gore (ft.) ________ * (See Below)

F. Determine Sign Detection Distance (ft.) 100 feet
(See Page 46)

G. Determine Sign Reading Distance (ft.) ________
(See Figure 4, page 49)
(Use A, B and C above in Figure 4)

H. Determine Lane Change Distance (ft.) ________
(See Table 4 on page 52)
(Use D above in Table)

I. Calculate Subtotal Travel Distance (ft.) ________
(Add F + G + H)

Preliminary Analysis of Subsequent Advance Guide Sign

J. Number of Overhead Sign Panels ________

K. Total Bits of Info. on all Panels ________

L. Degree of Horizontal Curvature ________

M. Determine Sign Detection Distance (ft.) 100 feet
(See Page 46)

N. Determine Sign Reading Distance (ft.) ________
(See Figure 4, page 49)
(Use J, K and L above)

O. Calculate Subtotal Travel Distance (ft.) ________
(Add M + N)

Preliminary Analysis of Exit Direction Sign for Advance Guide Sign

P. Number of Overhead Sign Panels ________

Q. Total Bits of Info. on all Panels ________

R. Degree of Horizontal Curvature ________

S. Determine Detection Distance (ft.) 100 feet
(See Page 46)

T. Determine Sign Reading Distance (ft.) ________
(See Figure 4, page 49)
(Use P, Q ana R above)

U. Determine Exit Preview Distance (ft.) ________
(See Table 5, page 56)

V. Natural Direct Departure Path (ft.) 100 feet
(See Page 56)

*Distance from sign to Exit Theoretical Gore + line 3 of Table 3 (p. 36) + 150'.

W. Calculate Subtotal Travel Distance (ft.)________
(Add S + T + U + V)

X. Calculate Total Travel Distance (ft.)___________
(Add I + O + W)

Y. Calculate Response Ratio___________________________
(Divide X by E)

Z. Determine Response Level of Service ____________________
(Read Scale on page 43)

3B. Response Level of Service (Exit Direction Sign Only)

A. Number of Overhead Sign Panels____________________

B. Total Bits of Info. on all Panels_________________

C. Degree of Horizontal Curvature____________________

D. Distance to Exit Theoretical Gore (ft.)__________ * (See Below)

E. Determine Detection Distance (ft.) 100 feet
(See Page 57)

F. Determine Sign Reading Distance (ft.)___________
(See Page 58)
(See A, B and C above)

G. Determine Exit Preview Distance (ft.)___________
(See Table 6, page 60)

H. Natural Direct Departure Path (ft.) 100 feet
(See Page 60)

I. Calculate Subtotal Travel Distance (ft.)________
(Add E + F + G + H)

J. Calculate Response Ratio___________________________
(Divide H by D)

K. Determine Response Level of Service______________ ____________________
(Read Scale on page 43)

4. Overall Level of Service

A. Navigation Level of Service_______________________
(Refer to 1F)

B. Workload Level of Service_________________________
(Refer to 2G)

C. Response Level of Service_________________________
(Refer to 3A(Z) or 3B(K))

D. Determine the Overall Level of Service ____________________
(Worst Level of Service of A, B or C)

*Distance from Sign to Exit Theoretical Gore + line 3 of Table 3 (p. 36) + 150'.

DIAGNOSTIC FREEWAY GUIDE SIGNING EVALUATIONS

This section will present specific problem areas that most traffic and design engineers face on a daily basis and present possible causes and in which report and chapter a solution could be found. The problem areas presented in this report do not by any means constitute all of the problems. They do represent typical problems, from which a major portion of the engineer problems may be solved. Table 7 presents the problems, possible causes and locations where the solution may be found.

Table 7. Diagnostic Analysis and Cross-Referencing of Pertinent Sections of the Other Research Reports.

Problem	Possible Cause	Solution
1. Erratic manuevers	1. Inconsistent route guidance information	220-3, Chapters 3, 10, 11
	2. Too much information on the route guidance sign	220-3, Chapter 4
	3. Improper information to either a downtown area or a suburb	220-3, Chapters 2, 9
	4. Confusion to destination route	220-3, Chapters 5, 6
	5. General erratic manuever study	220-2, Chapters 1, 2
2. Erratic manuevers along main lanes	1. Too much information on the route guidance signs	220-3, Chapter 4
	2. Improper destination information	220-3, Chapters 2, 8, 9
	3. Confusion about route motorist is currently on	220-3, Chapters 5, 6
	4. General erratic manuever study	220-2, Chapters 1, 2
3. Increased number of accidents at or near exit gore	1. Improper information to downtown or suburbs	220-3, Chapters 2, 9
	2. Improper presentation of route transfer information	220-3, Chapters 3, 10, 11
	3. Insufficient reading time available	220-3, Chapter 4
	4. Confusion of route destination	220-3, Chapters 5, 6
	5. Unfamiliar driver, accident study	220-2, Chapter 3
4. Severe speed variations approaching major splits	1. Misleading or improper route transfer information	220-3, Chapters 3, 10, 11
	2. Confusion of which route the motorist should take	220-3, Chapters 5, 6

Table 7. Continued.

Problem	Possible Cause	Solution
5. Severe speed variation along main lane	1. Too much information on the route guidance sign	220-3, Chapter 3
	2. Confusing or misleading route designation or destination names to either the downtown area or to the suburbs	220-3, Chapters 2, 8
6. Increased useage of exit ramp after a major arterial exit ramp or major split	1. Confusing or misleading route transfer information	220-3, Chapters 3, 10, 11
	2. Misunderstanding of destination route information	220-3, Chapters 5, 6, 7
7. Non-specific route guidance signing problems	1. Cannot determine specific cause of problem	220-2, Section B

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