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Level of Service Evaluation of Freeway Guide Signing

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ABSTRACT

The methodological basis for a freeway guide signing level of service evaluation is presented. This level of service evaluation was developed using the level of service concept in the Highway Capacity Manual as the prototype. The level of service evaluation can be performed in the engineer's office on all types of signs, both overhead and ground mounted, either individually, in a series, or sequentially along a freeway. The methodology is divided into four sections: (a) navigational, (b) work load, (c) response, and (d) overall level of service.

The opportunity now exists to critically examine the urban freeway guide signing system and to improve those areas found deficient. To make optimum use of existing resources, a proficient evaluation procedure has been developed that identifies probable trouble areas without requiring an excessive amount of staff time or data collection. The various techniques used in the past (1-5) will still be used to study the effects of signing changes, but they will not be used to evaluate probable problems in freeway signing.

LEVEL OF SERVICE CRITERIA

The criteria used to evaluate the level of service of urban freeway guide signing include the navigational information needs of the motorist, the motorists work load, and the response distance provided to the motorist. The level of service concept developed in this paper was designed by using the same format as the level of service of freeway operations contained in the Highway Capacity Manual. This continuous scale signing level of service may be performed in the engineer's office on a single sign or on a series of signs along a particular freeway.

Motorists Navigational Information Needs

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. These factors are (a) sufficiency, (b) consistency, (c) expectancy, and (d) relatability. These four factors all relate to separate concepts that are embodied in the navigational task. As pointed out in the following discussion of each factor, a certain amount of overlap exists among these factors, but they are separate as they relate to the navigational task. The degree to which these factors contribute to the task of navigation has not been field tested.

Sufficiency

Sufficiency is a term used to denote whether the information presented on each guide sign should be sufficient to satisfy an unfamiliar motorist's navigational information needs. The basic issues are whether the guide signing elements believed necessary are present and in accordance with accepted national guide signing principles. The Manual on Uniform Traffic Control Devices (MUTCD) is used as the chief yardstick of sufficiency. As the number of manual violations increase, the poorer the rating for sufficiency.

Consistency

Destination names are a principal navigational information source; therefore, it is imperative that consistent use of destination names be achieved. Three criteria have been identified as affecting the consistency of destination names:

1. Name familiarity consistent with route priority,
2. Number of names consistent with number of exits, and
3. Names of route destinations consistent areawide.

As the number of violations of these three criteria increase, the poorer the rating for consistency.

Expectancy

Expectancy evaluation addresses guide signing problems that may occur within the signing sequence for a particular freeway exit. Violation of short-term expectancy is the primary consideration. The number of violations or the severity of the violations would be used by the evaluator in determining whether the system rates good, fair, or poor with regard to motorist expectancy.

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). Inversion of the cardinal direction sequence on the overhead sign structure results in a "fair" rating. Multiple inversions result in a "poor" rating. Concurrently numbered routes splitting at a major interchange may yield extremely poor relatability scores. Signs located on horizontal curves of 1 or 3 degrees are rated "fair", whereas signs located on curves of more than 3 degrees are rated "poor."

Navigational Level of Service

To determine the level of service, a numerical score is determined for each of the four informational system factors previously described in the evaluation process. Table 1 contains these four factors along with their associated numerical score.

TABLE 1 Numerical Score for Each of the Four Navigational Factors

Factor	Good[a]	Fair[a]	Poor[a]
Sufficiency	1	*3*	10
Consistency	1	2	*5*
Expectancy	*1*	3	10
Relatability	1	*2*	5
Numerical score, T = *11*			

[a]The relative weight of each factor is based on the author's estimation of the relative consequences for violations of good signing principles.

The numerical score is then converted into a level of service grade for navigational requirements. This is accomplished by using the following level of service scale.

Navigational Level of Service

	A	B	C	D	"E"	F
0	4	6	8	10	12	Or more

Navigational Numerical Score, T

Motorists Work Load

A measure of the quality of service afforded freeway motorists by the design of the freeway guide signing system is determined by use of a concept known as the driver's work load. If the driver work load ratio is greater than one (1.0), the driver does not have sufficient time to read the signs and drive his or her vehicle. The driver can function effectively for short periods of time with work load ratios of between 1.00 and 1.15. A greater ratio would create a severe problem for the motorist. Correspondingly, work load ratios less than one (1.00) are desirable and indicate that the motorist has more time available to drive than that required to read the freeway guide signs. The work load ratio is defined as:

$$W = T_r/T_a \quad (1)$$

where

W = work load ratio,
T_r = time required to read sign (sec), and
T_a = time available to read sign (sec).

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 the 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.

Standard Conditions

Standard conditions for the design and evaluation of freeway guide signing follows. Standard conditions may be considered 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. The standard conditions affect the overall navigational time available to the driver. As the time available decreases, the level of service becomes worse, and as the navigational time available increases, the level of service becomes better.

Navigational Time Availability

Motorists driving along an urban freeway perform three basic driving tasks: control, guidance, and navigation (6). The control and guidance tasks include operating the vehicle, maintaining lane tracking, maintaining a safe speed and headway, and avoiding hazardous traffic situations. 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 task 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 (6). As will be discussed later, motorists may require 25 to 50 percent of the total time available to perform the control and guidance tasks. Research also has indicated that at higher driving stress levels, the driver acts as a single channel processor and effectively performs only one task at a time (7).

Some research has been conducted to determine the percent of time required by drivers to maintain vehicle control while driving various horizontal alignment conditions. McDonald conducted an elaborate instrumented vehicle study (8) 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. On reaching the test section, subject drivers were not required to maintain the initial speed. McDonald found that drivers, traveling at 60 mph, are about 22 percent occupied when driving a tangent section and are 30 percent occupied when driving a 4.6-degree horizontal curve. It was also determined that drivers' work load and the percent of time drivers were occupied when driving a curve increased almost linearly with curvature for curves up to 15 degrees for a given speed.

Because the test data neither required speed control (to maintain a safe car-following headway) nor additional driver work load (to search for and possibly avoid vehicles in adjacent lanes), some additional increases in work load 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 percent (2 x 22 percent) and 60 percent (2 x 30 percent) occupied on a 4.6-degree horizontal curve.

Other research conducted along Ohio freeways, by Bhise and Rockwell (9), using the eye-marker camera system indicates the reasonableness of the adjusted time occupancy estimates for combining control and guidance tasks. In one case the Ohio researchers indicate that unfamiliar motorists driving in moderate to heavy freeway traffic began reading freeway guide signing as if they were occupied 45 to 50 percent of the time.

From the previous discussion, an estimate can be made of 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 work load study as a baseline, and the Ohio study 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:

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

$$P = 100 \text{ percent} - 2.0\,(22 \text{ percent} + 1.74\,D), \text{ percent}$$

$$P = 56 \text{ percent} - 3.5\,D, \text{ percent} \qquad (2)$$

where D is the degree of horizontal curvature.

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 in the last line of Table 2. The estimated times are based on the standard conditions, namely, legibility distance for various letter series, horizontal and vertical alignment, speed of the vehicle, and the amount of time the motorist has to read the signs.

TABLE 2 Estimated Time Available for Reading Overhead Freeway Guide Signing Under Standard Conditions as Related to Horizontal Curvature

	Degree of Horizontal Curvature								
Analysis Step	0	1	2	3	4	5	6	7	8
Basic legibility, ft[a] 16/12-in. letters	800	800	800	800	800	800	800	800	800
Maximum legibility, ft 10 horizontal angle	–	–	–	920	750	650	570	520	480
Effective legibility, ft[b] 7.5 vertical angle	650	650	650	650	600	500	420	370	330
Speed, mph[c]	60	59	58	57	57	56	55	54	53
Maximum time, seconds 100 percent available	7.4	7.5	7.6	7.7	7.2	6.1	5.3	4.7	4.3
Percent of motorist time available, P	56	53	49	46	42	39	35	32	28
Reading time, seconds	4.1	3.9	3.7	3.5	3.0	2.4	1.9	1.5	1.2

[a]The basic legibility distance 20/24 visual acuity is therefore calculated from the legibility rate of 50 ft/in. multiplied by the letter height of the initial uppercase letter of the destination name. Most destination names on urban freeway signs are composed of 16-in. uppercase letters and 12-in. lowercase letters, which is the assumed standard. The resulting basic legibility distance is 800 ft (16 x 50).

[b]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 cutoff angle of 7.5 degrees. Therefore, the effective legibility distance is 650 ft (800-150) for the 16/12 in. letter height standard.

[c]The standard operating speed for evaluating urban freeway signing systems 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.

REQUIRED READING TIME

The time drivers require to read overhead freeway signs has been estimated based on considerable laboratory study data at the Texas Transportation Institute for high-quality simulated freeway guide signs under moderate display rates. This research is fully documented in a companion research report (10). Required reading times were determined for overhead freeway guide signs with various levels of total information load on the sign and by the number of sign panels used to display the information.

The time required by the motorist to read overhead freeway guide sign information based on laboratory study data (10) is presented in Figure 1 as the family of four curves for two-, three-, four-, and five-panel overhead guide signs.

Level of Service Determination

The scale was subjectively specified based on the research available and the ramifications of W exceeding unity. It is known, for example, that motorists can perform at work load rates exceeding unity in a stressed condition for brief periods of time. However, driver errors would be expected to increase under these conditions. The example work load ratio of 1.0 would result in a work load level of service of D. A five-panel overhead freeway guide sign with a total of 20 units of information on the sign would require 4.1 seconds reading time. If it is assumed that the time available to read the sign is equal to 3.9 seconds, then the work load ratio (T_r/T_a) equals 1.05, which is a level of service of D. Any work load ratio greater than 1.0 is undesirable. Therefore, the following numerical scale was developed to determine the work load level of service.

Work Load 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 – 1.7	1.7 Or more

Work Load Ratio, W

RESPONSE DISTANCE PROVIDED TO THE DRIVER

A scale, similar to the ones in the two preceding sections, is used to estimate the response level of service. The scale is based on the calculation of the ratio of the estimated travel distance needed by the driver to perform the driving tasks (which includes decision times) divided by the travel distance provided on the freeway by the placement of the sign relative to the exiting location. The response ratio, R, is defined as:

$$R = \text{Travel distance elements required/Physical distance provided} \qquad (3)$$

Driver Actions Evaluated

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

1. Detect and read advance guide signs and exit direction signs,
2. Perform necessary lane changes,
3. Detect and read exit direction sign,
4. Perform exit preview, and
5. Exit.

The travel times and distances needed to perform each of these actions are presented in the following sections.

Detection and Reading of Advanced Guide Signs

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. Roadway design conditions do exist, however, whereby 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 ft from the sign structure. A 1.0- to 1.5-second detection time is considered to be satisfactory, based on existing literature sources (11,12). The following table presents the detection distance required for a 1.0-second and a 1.5-second detection time for various freeway speeds.

Speed of Vehicle (mph)	Detection Time (sec) 1.0	1.5
40	59	88
50	74	110
60	88	132

The time a motorist used while reading overhead freeway guide signs should account for the desired operating condition of providing a motorist sufficient space to maintain safe vehicle control and to avoid traffic hazards while routinely reading signs (6). The travel time (in seconds) a motorist would use while reading guide signs of a given information unit rate is estimated as:

$$T_s = T_r/(P/100) = T_r/0.56 - 0.0035\ D \quad (4)$$

where T_s is the travel time while reading signs. T_r was given in Figure 1 for various sign configurations and P was given in Table 2 for various horizontal curvatures. 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 in Figure 2. As an example, an overhead guide sign structure containing a total of 15 bits of information on 4 panels located on a 2-degree horizontal curve would result in an estimated sign reading travel time of

$$T_s = 3.7/0.56 - (0.035) \times 2 = 7.5 \text{ seconds} \quad (5)$$

and can be determined from the nomograph in Figure 3.

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

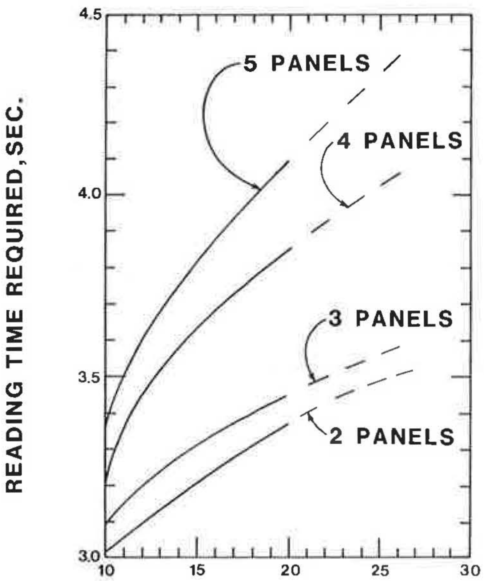

FIGURE 1 Reading time needed to acquire information as related to units of information on overhead guide sign.

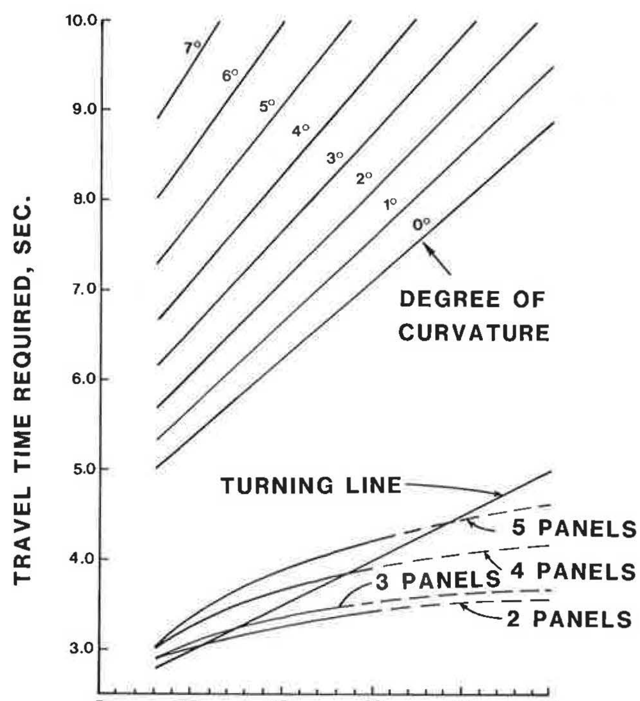

FIGURE 2 Nomograph for solving reading travel time.

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

$$D_r = 1.47 \cdot V \cdot T_s \quad (6)$$

A simplified procedure results in the satisfactory approximations for freeways not located on

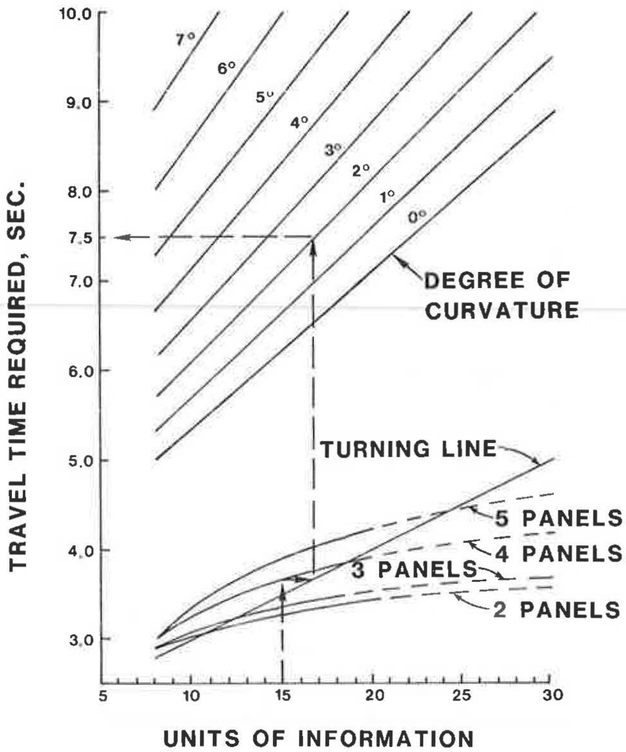

FIGURE 3 Example nomograph for solving reading travel time.

sharp horizontal curves (for example, less than 2 degrees) and typical freeway guide signs. The travel distance required for various speeds of the vehicle is given in Table 3. Under these conditions and assumptions, the average travel time ranges from about 6.5 to 7.5 seconds, with a midpoint of 7.0 seconds. The travel distances would result for a 7.0-second travel time (Table 3).

TABLE 3 Distance Traveled While Reading Signs at Different Operating Speeds

Speed (mph)	Approximate Travel Distance Dr (ft)
40	400
50	500
60	600

Lane Changing

Lane changing between freeway main lanes is frequently necessary to follow a route through an urban freeway system. One and probably more lane changes in succession may be required to follow the route as suggested by the overhead freeway guide signing. Although research has indicated that most motorists familiar with freeway guide signs probably do not follow the positioning of every overhead freeway guide sign (13), this same study demonstrated that a number of motorists (mostly motorists unfamiliar with freeway guide signs) were responding to the sign positioning over the freeway lanes.

The lane changing distance is the total distance traveled along the freeway while making lane changes of one or more lanes. 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 six-lane Gulf Freeway (14,15). McNees' lane changing study resulted in the development of a total lane change distance. Because it is desirable to provide some margin of safety, the 85th percentile data may be used as a guide for estimating the average lane changing distance per lane change. It is recommended that a lane changing distance of 700 ft 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 (ft)
4-lane	700
6-lane	1,400
8-lane	2,100
10-lane	2,800

Detect and Read Exit Direction Sign

The detection distance required for the exit direction sign is the same as that required for the advanced guide sign. Therefore the detection distances presented in Table 3 are applicable for the exit direction sign.

One-half of the time required to read the sign, obtained from Table 3, should be used because the motorist is not time-sharing between navigation and control. Approximate travel distances for typical signing conditions with little or no horizontal curvature (for example, less than 2 degrees) give travel distances for various freeway speeds. Sign reading distances for typical exit direction signs are as follows:

Speed, V (mph)	Travel Distance, Dr (ft)
40	200
50	250
60	300

Preview Exit

On 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, identify the appropriate departure path, and determine a safe exit speed. This exit preview time has been assumed to be 3.0 seconds by AASHO for the design of intersections and freeway deceleration lanes (16). In an FHWA publication (17) 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, whereas 3.0 seconds was considered to be required for more complex situations or where the geometric feature is particularly difficult to detect, or where driver expectancies are violated.

An exit preview time of 1.5 seconds is recommended for use when all of the following conditions exist:

1. The exit is a nominal single lane, single exit ramp;
2. The exit is located on the right side of the freeway;
3. The adjacent through lane continues;
4. The ramp nose is readily visible to oncoming traffic; and
5. The freeway has a horizontal curvature of no greater than 2 D.

In all other situations a previous time of 3.0 seconds should be used. The distances required for various freeway speeds are summarized in the table below. An additional 1.0 seconds has been used for a typical response time (16).

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

Exit Maneuver

An exit maneuver is any traffic maneuver that departs from the main freeway route. To determine the departure location, a natural direct departure path from the freeway should be assumed. This location is about 100 ft upstream of the physical gore locations.

Developing the Response Level of Service

To be able to determine the response level of service, two assumptions have to be made: (a) the driver will require 975 ft to exit the freeway, and (b) the design of the freeway provides only 800 ft from the location where the sign becomes visible and the actual exit ramp. The response ratio would be

$$R = 975/800 = 1.22 \quad (7)$$

A response ratio of 1.22 results in a level of service E as depicted in the following level of service scale:

Response Level of Service Grade

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

Response Ratio, R

OVERALL LEVEL OF SERVICE

After the level of service has been determined for navigation, work load, and response for a particular sign, an overall level of service characterizing the sign must also be developed to classify a particular sign while taking into account the three levels of service previously determined. The overall level of service will be the worst (highest) level of service associated with each of the three previously described levels of service. Figure 4 shows the method used to determine the overall level of service. The overall level of service is E because both the navigational and response level of service is E.

The overall level of service E means that the particular sign or signing system is poor with regard to presenting pertinent route directions to the motorists in a timely manner, given the physical constraints under which they are operating. With a freeway signing level of service E, much could be done to improve the level of service. The consistency rating could be improved by relating the destination names, exit number, and route priority areawide. This would improve the navigational level of service. The response level of service could be improved by spreading the information over a larger distance before the exit. Both of these changes to the signing system would improve the level of service from an E to a D. To improve the overall level of service to a C or better, the work load level of service must be improved.

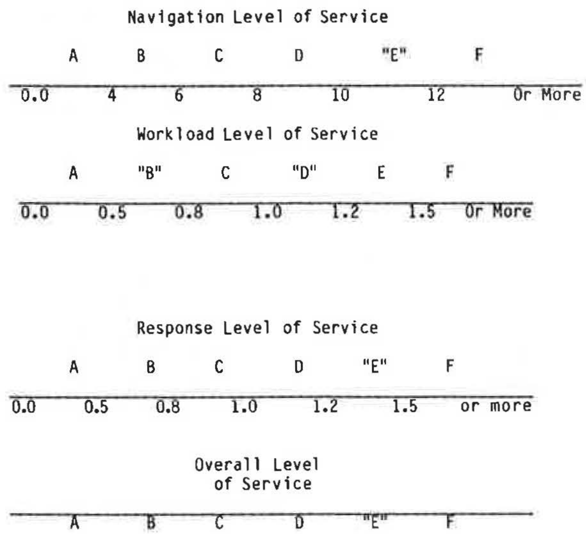

FIGURE 4 Determining the overall level of service.

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Abridgment

Evaluation of Vending Machine Operations in Rest Areas and Welcome Centers in Georgia

LAMAR CAYLOR

ABSTRACT

Section 153 of the Surface Transportation Assistance Act of 1978 authorized a demonstration program permitting the installation of vending machines in safety rest areas on the Interstate highway system. Georgia was one of the states selected by FHWA to participate in this demonstration program to evaluate the provision of vending machines in rest areas and welcome centers. Vending machines were installed in 13 rest areas and 5 welcome centers in Georgia for a 1-year evaluation period. About 92 percent of the 4,641 rest area and welcome center users interviewed indicated that providing vending machines in rest areas and welcome centers was a good idea. The provision of vending machines in the rest areas and welcome centers caused no serious security problems and only four incidents of vandalism occurred. All four of these break-ins occurred at welcome centers. The rest areas had no break-ins. Revenues from vending machines covered approximately 17 percent of the cost of operating a rest area. Revenues received during the 1-year evaluation period totaled $205,000 on gross sales of $639,000. Provision of vending machines in rest areas and welcome centers had no serious adverse effects on the operations of the rest areas and welcome centers during the evaluation period and it is recommended that they be made permanent.

Section 153 of the Surface Transportation Assistance Act of 1978 authorized a demonstration program permitting the installation of vending machines in safety rest areas on the Interstate highway system. According to the provisions of the Act the vending machines may dispense such food, drink, and other articles as the Secretary of the U.S. Department of Transportation determines necessary to ascertain the need for, and desirability of, this service to the traveling public. The Act also provided that the Secretary report to Congress by October 30, 1980, on the results of this demonstration project.

FHWA was empowered to select states to participate in this vending demonstration program. The states that were chosen to participate were required to evaluate the effects of vending machines on the operation of the rest areas. Georgia was one of the states selected to evaluate the provision of vending machines in rest areas and welcome centers.

The objective of this project was to evaluate the effects of vending machines on the operations of rest areas and welcome centers on Georgia Interstate highways by studying the effects on

- Maintenance of the rest area and welcome centers,
- Security,
- Vandalism,
- Litter on the highway downstream of the facility,
- Problems associated with increased stopping and length of stay, and
- Other problems or advantages of providing vending facilities.