STUDY OF DESIGN CONSIDERATIONS FOR REAL-TIME FREEWAY INFORMATION SYSTEMS

Conrad L. Dudek and Carroll J. Messer, Texas Transportation Institute; and
Hal B. Jones, Traffic Engineer, City of Austin, Texas

A comprehensive questionnaire study was conducted to obtain information from motorists in the cities of Houston and Dallas for the design of a real-time freeway information system. The following items were evaluated: need for real-time freeway information, driver preferences as to mode and location of information, type of information preferred by the freeway driver, and potential driver response to real-time freeway information. The participating motorists indicated a desire for additional traffic information that is not currently provided by passive signing. Changeable message signs and commercial radio were preferred over telephone and television services as modes for communicating with the driver in real-time. Motorists preferred to receive information about freeway traffic conditions before they entered the freeway. The types of information preferred were the location and length of the congested area and the degree of congestion. The quantitative descriptors of travel time and travel speed were the least preferred. The respondents indicated that they would respond to real-time information about freeway conditions by rerouting to an expedient alternate route when they know it is available. The motorists would be more inclined to divert to an alternate route before they enter the freeway than after they are on the freeway.

•EFFORTS have been made in recent years to increase the safety, efficiency, speed, and quality of travel on urban freeways by the use of several traffic engineering innovations. Freeway ramp-control systems have been developed and are capable of preventing congestion if no incidents occur on the freeway (1, 2, 3, 4, 5). This has been achieved primarily by keeping the demand less than the normal freeway capacity. However, the occurrence of an incident overtaxes a freeway ramp-control system to the extent that the system cannot effectively control the demand. If the traffic demand could be redistributed in time and in space, improvements in the level of service could be realized. This requires some type of real-time information system that allows the driver to intelligently choose a suitable route from the alternatives available to him.

To broaden the application of real-time freeway operations systems, the Texas Transportation Institute and the Texas Highway Department, in cooperation with the U.S. Department of Transportation, began a research project based on previous research on the Gulf Freeway in Houston. The earlier research culminated in an operational freeway ramp-control system.

Freeway lane control has been attempted through the use of overhead red X and green arrow signs to inform freeway motorists whether a particular lane ahead is

Sponsored by Committee on Freeway Operations and presented at the 50th Annual Meeting.

clear or closed (6). The effectiveness of these signs appears to be a function of the freeway demand (7) and is reduced when the freeway demand is greater than the capacity of the obstructed section. Variable speed messages have been used in some instances. The results of one study (7) indicate that motorists do not decrease their speeds to coincide with the posted speed unless there is an apparent reason to do so. In another study conducted in California (8) concerning the applicability of variable speed signs to traffic control during fog conditions, it was concluded that posted speeds of less than 35 to 40 mph have little effect in reducing speeds but that some reduction is possible at higher speeds. Experimentations have been conducted in Chicago (9) and Detroit (10) on the use of changeable message displays located on major streets near the freeway to inform the drivers of the freeway traffic conditions. Studies in Detroit have shown the displays to be cost effective. Evaluations of additional signs in the John C. Lodge Freeway corridor (11) currently are being made.

As evidenced by the previous discussion, motorists have not always responded to traffic information in the desired way. This failure to respond in the appropriate manner may have been due to one of the following: the signs were not observed; the motorists did not understand the message; the motorists thought they would not benefit from the information; or the information could not be beneficially utilized by the time it was received. Thus, for a real-time freeway system to effect appropriate driver response, it must be designed to provide the driver with information that is meaningful, accurate, timely, and useful. Because some of these points require driver comprehension and evaluation, it was reasoned that the motorists should play a major role in establishing any real-time freeway information system design. Therefore, this necessary information with regard to driver attitudes, preferences, and probable reaction to real-time freeway information was obtained by conducting a questionnaire survey. This paper contains some of the findings from the survey; all of the results obtained may be found in other publications (12, 13).

SURVEY DESIGN

The questionnaire survey was designed by a multidisciplinary research team of individuals having expertise in traffic and transportation engineering, psychology, human factors, and statistics. The questionnaire was directed to the population of motorists who drive in large metropolitan areas serviced by several freeways. Various business organizations in the cities of Houston and Dallas were asked to participate in the survey by permitting the questionnaire to be administered to groups of their employees selected at random. Instructions specified that each group be made up of individuals from both sexes, various age groups, and various levels of education. The only restrictions were that they must be licensed drivers and that no one who had experience in traffice engineering or had worked with highway signing could participate.

The questionnaire was administered to 17 different groups. From these, a total of 505 licensed drivers participated, 329 from the city of Houston and 176 from the city of Dallas. An analysis of the social, economic, and driving characteristics of the participants obtained from the survey indicated that a satisfactory representative sample of the desired driving population was obtained. Some of the social and driving characteristics are given in Table 1.

NEED FOR REAL-TIME FREEWAY INFORMATION

One of the most important items that must be determined during the development of any new system is the present and potential need for its services. There must be a personal need associated with a traffic information system if the driver is to respond in the desired manner in any voluntary operational environment.

TABLE 1
SOCIAL AND DRIVING CHARACTERISTICS OF RESPONDENTS

Characteristic	Respondents (percent)	Characteristic	Respondents (percent)
Sex		Years of driving experience	
Male	68	0 to 4	5
Female	32	5 to 14	36
Age		15 to 24	21
24 or under	24	25 to 34	22
25 to 44	45	35 to 44	13
45 to 64	31	45 or more	3
Educational level		Miles driven per year	
Grade school	4	8,000 or fewer	14
High school	29	8,000 to 12,000	28
Business college	12	12,000 to 18,000	37
Two years of college	21	18,000 to 30,000	18
Graduated from college	34	30,000 or more	3
Occupation		Number of trips per week	
Professional	30	0	3
Technician	26	1 to 5	15
Clerical	22	6 to 10	26
Salesworker	3	11 to 20	39
Craftsman	8	20 or more	17
Service worker	2	Normally use freeway	
Other blue collar	4	Yes	70
Student	5	No	30
Driving training		Travel facility preferred	
None	45	Freeway	90
Classroom	13	City streets	10
Behind the wheel	15		
Classroom and behind the wheel	27		

Two questions that indicate drivers' attitudes toward the need for real-time freeway traffic information were included in the questionnaire. One measurement of potential need was made by requesting the participants to indicate the freeway with which they would use accurate information about freeway traffic conditions to plan their trips. The following 4 choices were given: always, frequently, occasionally, and never. Responses are shown in Figure 1. The results show that 47 percent of the respondents indicated that they would always use freeway traffic information if it is accurate, and 38 percent responded that they would frequently use the information. Thus, at least 85 percent of the participants would make frequent use of the information to plan their trips.

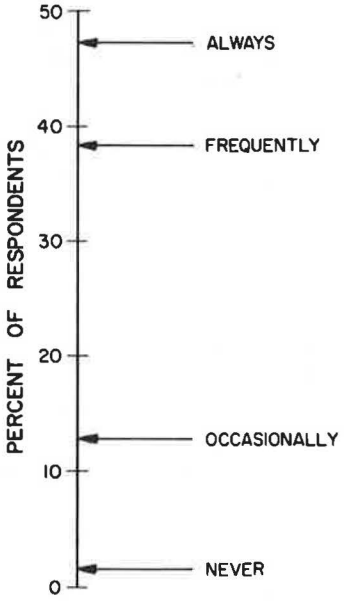

Figure 1. Drivers' use of real-time freeway information.

Driver attitudes toward the need for real-time freeway information were further evaluated by requesting the participants to allocate $100,000 for improvements to the existing freeway information being provided within a city. The improvements included the following: provide additional guide signs, provide freeway real-time information, and others (for write-in suggestions). The item regarding additional guide signs was included because it was felt that the participants should have some known basic freeway information for comparison. Table 2 gives the participants' allocations of money to the items.

These results indicate that drivers feel the need for additional freeway traffic information that is not provided by passive signing. Ninety-five percent of all the respondents allocated money to the provision of real-time freeway traffic information. In addition, 67 percent of all money allocated was spent on this item. This was more than twice the total amount spent on the other alternatives.

TABLE 2

ALLOCATION OF MONEY FOR IMPROVEMENTS IN FREEWAY COMMUNICATION

Improvement	Respondents (percent)	Money Allocated	
		Amount (thousands of dollars)	Percent
Additional guide signs	68	12,286	25
Real-time information	95	32,249	67
Others (written comments)	18	3,965	8

In summary, the responses to these 2 questions reveal that drivers desire additional freeway information beyond that provided by passive signing. These drivers indicated that they feel a definite need for real-time freeway traffic information, which is in agreement with the findings of Heathington (14). In addition, the results show that most drivers would frequently use this type of information.

PREFERENCES FOR MODE AND LOCATION OF INFORMATION

A real-time information system can be made more appealing and useful to motorists by providing the information when it is needed and in the desired form or mode. Although this may not always be possible to achieve, the utilization of an information system should be increased if the mode of communication is acceptable to the drivers and if the information is provided at locations most advantageous to them.

Mode of Communication

A portion of the questionnaire was devoted to the evaluation of drivers' preferences for modes of communication. This phase of the study is reported in detail by Dudek and Cummings (12). A summary of the results is provided here because of its relevancy to the problem. The results revealed that motorists definitely prefer to receive real-time freeway information by commercial radio and changeable message signs rather than by telephone or television. With respect to commercial radio or changeable message signs, 45 percent of the respondents chose commercial radio as the preferred alternative and 45 percent selected changeable message signs. Telephone and television modes of communication were not desired. The results indicate that a combination of commercial radio and changeable message signs could result in an effective real-time freeway information system for urban areas.

Locations for Receiving Information

In conjunction with selecting a mode of communication for a real-time freeway information system, it is also important to know where urban freeway drivers would like to receive this information. The participants were given the following list of locations and were asked to rank them in the order at which real-time freeway information would be most beneficial to them: on the freeway, on the major streets leading to the freeway, at the entrance ramps to the freeway, or at the beginning of the trip, such as at home or at the office. Table 3 gives the ranking distribution of each location.

The results of the analysis indicate that motorists prefer to receive information about the freeway traffic conditions before they enter the freeway and at locations where decisions can be made with respect to the selection of an alternate route. Forty-two percent of the participants selected the beginning of the trip as the most desirable loca-

TABLE 3

PREFERENCES FOR LOCATIONS FOR RECEIVING REAL-TIME FREEWAY INFORMATION

Location	First Choice (percent)	Second Choice (percent)	Third Choice (percent)	Fourth Choice (percent)	Average Ranking Points[a]	Standard Deviation
On the freeway	8	14	34	44	1.9	0.9
On the major street	34	39	18	9	3.0	0.9
At the entrance ramps	16	36	41	7	2.7	0.8
At the beginning of trip	42	11	7	40	2.6	1.3

Note: Kendall's coefficient of concordance = 0.1332; X^2 = 181.44, significant at 0.01 level; and degrees of freedom = 3.

[a]Based on assigning 4 points to each first choice, 3 points to each second choice, 2 points to each third choice, and 1 point to each fourth choice. Maximum possible mean = 4.0; minimum possible mean = 1.0.

tion in relation to the other alternatives, 34 percent chose to receive information on the major street, 16 percent at the entrance ramps, and 8 percent on the freeway. The lowest rankings were for information on the freeway and at the beginning of the trip.

The data were analyzed further by using Kendall's coefficient of concordance (15) to determine whether there was consistency in the rankings among the participants. The coefficient detects the consistency (or lack of consistency) in the ranking of ordinal data. The significance of the coefficient was then tested by using the chi-square statistic. This test is not designed to reveal the degree of preference but does yield an ordering effect of the respondents. The results of the computation revealed that Kendall's coefficient was equal to 0.1332. In addition, the computed chi-square value of 181.4 was highly significant at the 0.01 level, indicating that there was consistency in the rankings among respondents. The order of preference was as follows: on the major street, at the entrance ramp, at the beginning of the trip, and on the freeway.

The dichotomy of the results with respect to receiving information at the beginning of the trip is quite interesting in that 42 percent ranked this alternative as the most preferred, whereas 40 percent ranked it as the least preferred. In general, results indicate that the number of freeway drivers preferring to know the freeway traffic conditions in advance is approximately equal to those who do not feel it is necessary.

Dudek and Cummings (12) have shown that there is a relationship between the choices of communication mode and of location. They found that motorists who desire to receive freeway traffic information at the beginning of their trips prefer radio as the mode of communication. Motorists who consider information at the beginning of the trip to be of least value to them prefer changeable message signs. Drivers who prefer radio as the best real-time communication mode consider information at the beginning of the trip and on the major streets to be of greatest value. These individuals also are of the opinion that information on the freeway is of least importance in relation to the other alternatives. Motorists who prefer changeable message signs prefer information on the major streets and at the entrance ramps. Information at the beginning of the trip and information on the freeway are least preferred.

PREFERENCES FOR TYPE OF INFORMATION

A real-time freeway information system must be designated to allow the driver to make effective decisions regarding route selection, based on the information presented to him. Participants were asked to choose 2 of the following 5 alternatives that would be most helpful to them: degree of congestion, whether heavy, moderate, or light; location and length of congested areas; travel time to various reference points ahead; average travel speed obtainable between various reference points; reason for congested area, such as accident, maintenance, or stalled vehicle. The results of the driver preferences are summarized in Table 4. The results indicate that travel time and speed,

both quantitative forms of information, are not so valuable to the motorist as qualitative information in terms of location, length, and degree of congestion. This is not to say that all quantitative information is least preferred. The results must be interpreted in view of the alternatives that were available to the questionnaire participants and to their local driving environments.

TABLE 4

PREFERENCES FOR TYPES OF REAL-TIME FREEWAY INFORMATION

Type of Information	Respondents (percent)
Location and length of congested area	71
Degree of congestion	69
Reason for congested area	40
Average travel speed obtainable between various reference points	13
Travel time to various reference points ahead	7

An analysis was also made to determine whether there was any correlation between location priorities and the type of information preferred. The results revealed that the selection of the type of information preferred was not correlated with the selection of location alternatives.

POTENTIAL RESPONSE TO REAL-TIME FREEWAY INFORMATION

One of the possible reasons a driver-information system may not produce the desired operational results is that motorists are being asked to do something that, for some reason, they strongly object to doing. Hence, in the design of a real-time freeway information system, it is important to determine at certain points along their trips the drivers' potential responses to specific freeway traffic conditions. From these results, the feasibility of obtaining certain desired operational results for a given situation can be examined.

A study was made of potential driver responses by using a set of questions that placed the participants in hypothetical traffic situations. They were to assume that a major street was available as an alternate route that they could travel instead of the freeway. They were asked whether they would use the alternate route if informed that the freeway traffic was moving slower than usual for that time of day. Three situations were given: (a) if they were informed before they entered the freeway and the event occurred during the peak period, (b) if they were informed while traveling on the freeway and the event occurred during the peak period, and (c) if they were informed of the event while traveling on the freeway during the off-peak period. The results of the responses to these hypothetical situations are given in Table 5. The results indicate that the majority of the motorists sampled would be inclined to divert from the freeway if they had prior knowledge of an unusual condition ahead and if a suitable alternate route were available. They would be more inclined to divert to an alternate route before they reached the freeway than after they were on the facility.

The reactions of the motorists to real-time freeway information were further evaluated by the use of a slide presentation. The participants were placed in 3 different driving situations. In the first situation, each participant was requested to assume that he is driving along the major street that runs parallel to the freeway and that he is

TABLE 5

PROBABLE DIVERSION TO AN AVAILABLE MAJOR STREET WHEN INFORMATION IS GIVEN REGARDING AN UNUSUAL CONDITION ON THE FREEWAY

Alternative	Respondents (percent)	
	Would Divert	Would Not Divert
Information given before entering freeway, peak period	92	8
Information given after entering freeway, peak period	75	25
Information given after entering freeway, off-peak period	70	30

currently at location 1 shown in Figure 2. His intended route is to turn right at Smith Avenue, proceed to the freeway, and then turn north onto the freeway. For some reason, the northbound lanes of the freeway between Smith Avenue and Brown Avenue are heavily congested, as shown. This congestion will cause extra delay in his trip if he continues to use the freeway. Changeable message signs located in advance of the major street intersections informs drivers of the existing condition on the freeway. (It is recognized that signs are not the only mode that could be used to communicate with the driver. However, use of signs appeared to be the most effective way of showing to the participants by slide presentation that real-time information would be available to them.) The participant was then asked to choose one of the following to indicate his reactions if he was pressed for time and if he was not pressed for time: (a) proceed to the freeway and enter the main lanes at the Smith Avenue on-ramp; proceed to the freeway and use the service road to bypass the congested area; remain on the parallel major street until there is another sign indicating that the freeway is clear from that point north and then proceed to the freeway; or remain on the parallel major street until the destination is reached. The results of the analysis are given in Table 6. These results show that the majority of the participants, when pressed for time, would prefer to remain on the parallel major street until a cross street is reached where a sign would inform them that the freeway is clear upstream from that cross street. They would then proceed to the freeway. More than half of the participants not pressed for time preferred to divert around the congested area along the parallel street.

The second hypothetical situation was the same as in the first, except that each respondent, as a driver, has already committed himself to the freeway service road at location 2 shown in Figure 2. By means of signs located in advance of the freeway entrance ramps, he is informed of the traffic condition on the main lanes of the freeway and, as before, he was asked to give his reactions when pressed for time and when not pressed for time to the following alternatives: (a) enter the main lanes of the freeway at Smith Avenue; (b) continue on the service road to the entrance ramp where another sign will indicate that the freeway main lanes have no heavy congestion; or (c) detour to the parallel major street and continue to your destination. Table 7 gives the reactions to this situation. The results of the analysis show that, when pressed for time, the large majority of the respondents would prefer to remain on the service road until they reach an entrance ramp where there is a sign to indicate that the freeway main lanes are clear of any heavy congestion. When time is not a consideration, the participants indicated a greater willingness to divert to the major street.

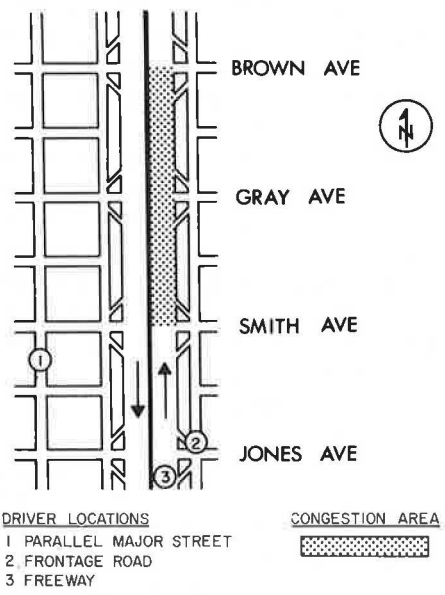

Figure 2. Three hypothetical situations used in studying expected driver response to freeway traffic information.

In the third situation, each participant was asked to assume that he is driving in the northbound direction on the freeway and is approaching the general area of Jones Avenue, as is shown by location 3 in Figure 2. As in previous cases, the northbound lanes between Smith Avenue and Brown Avenue are heavily congested because of

TABLE 6

RESPONSES TO REAL-TIME INFORMATION ON A PARALLEL MAJOR STREET

Alternative	Respondents (percent)	
	Pressed for Time	Not Pressed for Time
Proceed to freeway and enter main lanes at Smith Avenue on-ramp	1	3
Proceed to freeway and use service road to bypass congested area	14	16
Remain on parallel major street until there is another sign indicating that freeway is clear from that point north and then proceed to freeway	75	57
Remain on parallel major street to destination	10	24

TABLE 7

RESPONSES TO REAL-TIME INFORMATION AT THE FREEWAY ENTRANCE RAMPS

Alternative	Respondents (percent)	
	Pressed for Time	Not Pressed for Time
Enter main lanes of freeway at Smith Avenue	1	4
Continue on service road to entrance ramp where another sign will indicate that freeway main lanes have no heavy congestion	86	75
Detour to parallel major street and continue to destination	13	21

some incident. By means of signs located on the freeway, drivers are informed of the existing traffic conditions ahead. The participants were asked to give their reactions when pressed for time and when not pressed for time to the following alternatives: (a) continue driving at the same speed until you actually see that the traffic condition has changed; (b) immediately reduce your speed for the anticipated change in traffic condition ahead and remain on the main lanes of the freeway; (c) exit at the next off-ramp and use the service road to bypass the congested area; or (d) exit at the next off-ramp and continue to your destination by way of the parallel major street. The results of the participants' responses are tabulated in Table 8. A majority of the participants, when pressed for time, preferred to leave the freeway and take the service road to bypass the congested area. The results also reveal that the participants had a greater tendency to remain on the freeway when they were not pressed for time. A total of 61 percent expressed a desire to leave the freeway to bypass the congested area when not pressed for time, compared to 84 percent when time was important.

In summary, the responses to these hypothetical conditions indicate that the majority of the licensed drivers who participated in the survey would use real-time freeway information, and, based on the availability of this type of information, they would be inclined to reroute to avoid congested areas on the freeway. They would prefer to use either the freeway service roads or the major streets, depending on their location when they are informed of the condition. The majority of the drivers would use the alternate route only to bypass the congested area and would prefer to return to the main lanes of the freeway as soon as possible, regardless of the time of day. In addition, the motorists would be less inclined to divert once they are on the freeway.

The results of the study with respect to potential response to real-time freeway information should be interpreted in light of the manner in which the data were obtained. Individuals do not always respond in a real-world situation exactly as they do in some hypothetical situation. Therefore, the percentage distribution of the participants' reactions in the 3 hypothetical situations may not be identical to their reactions while actually driving. In addition, the responses were made on the premise that good alternate routes were available. However, the results do show definite patterns and desires of the motorists that are meaningful in the design of a real-time freeway information system. The responses to the hypothetical situations indicate the potential reactions by the motorists when certain sets of conditions exist.

TABLE 8

RESPONSES TO REAL-TIME INFORMATION ON THE FREEWAY

Alternative	Respondents (percent)	
	Pressed for Time	Not Pressed for Time
Continue driving at same speed until you actually see that traffic condition has changed	4	11
Immediately reduce speed for anticipated change in traffic condition ahead and remain on main lanes of freeway	12	28
Exit at next off-ramp and use service road to bypass congested area	69	42
Exit at next off-ramp and continue to destination by way of parallel major street	15	19

SUMMARY OF FINDINGS

This research was directed toward the study of design considerations for a real-time freeway information system for urban areas. The findings from an analysis of a questionnaire survey administered to 505 drivers in Dallas and Houston are as follows:

1. The participating motorists indicated a desire for additional traffic information that is not currently provided by passive signing and a need for real-time freeway traffic information that they would frequently utilize;
2. They preferred commercial radio and changeable message signs to telephone and television services;
3. They preferred to receive information about freeway traffic conditions before entering the freeway, and their ranked preferences for locations of communication were on the major street, at the entrance ramp, at the beginning of trip, and on the freeway;
4. The types of information preferred were the location and length of the congested area and the degree of congestion;
5. There was no correlation between the preferences for location alternatives and the preferences for type of freeway traffic information;
6. The respondents indicated that they would react to real-time information about freeway conditions by rerouting to a suitable alternate route when they know it is available, that they would use the alternate route only to bypass congested areas on the freeway, and that they would then return to the freeway; and
7. The motorists are more inclined to divert to an alternate route before they reach the freeway than after they are on the freeway.

ACKNOWLEDGMENT

The opinions, findings, and conclusions expressed or implied in this report are those of the authors and not necessarily those of the Texas Highway Department or of the Federal Highway Administration.

REFERENCES

1. May, A. D. Experimentation with Manual and Automatic Ramp Control. Highway Research Record 59, 1964, pp. 9-38.
2. DeRose, F., Jr. The Development and Evaluation of the John C. Lodge Freeway Traffic Surveillance and Control Research Project. Jan. 1963, pp. 53-66.
3. Drew, D. R., McCasland, W. R., Pinnell, C., and Wattleworth, J. A. The Development of an Automatic Freeway Merging Control System. Texas Transportation Institute, Res. Rept. 24-19.
4. Fonda, R. D. An Analysis of Short-Term Implementation of Ramp Control on the Dan Ryan Expressway. Chicago Area Expressway Project, 20, 1968.

5. Newman, L., Schaefer, W. E., and Moskowitz, K. Harbor Freeway Ramp Control Project. Paper presented at HRB Freeway Operations Committee Meeting, Jan. 1969.
6. Gervais, E. R. Report on Project Activities. National Proving Ground for Freeway Surveillance, Control and Electronic Traffic Aids, Aug. 1966.
7. Wattleworth, J. A., Courage, K. G., and Carvell, J. D. An Evaluation of Two Types of Freeway Control System. Texas Transportation Institute, Res. Rept. 488-6, April 1968.
8. Reduced Visibility (Fog) Study. California Division of Highways, March 1967.
9. Hoff, G. D. Development and Evaluation of Experimental Information Signs. Chicago Area Expressway Surveillance Project, Rept. 18, Dec. 1965, revised June 1968.
10. Courage, K. G., and Levin, M. A Freeway Corridor Surveillance, Information and Control System. Texas Transportation Institute, Res. Rept. 488-8, Dec. 1968.
11. Communication with University of Michigan staff, Jan. 1970.
12. Dudek, C. L., and Cummings, D. Application of Commercial Radio to Freeway Communications—A Study of Driver Attitudes. Texas Transportation Institute, Res. Rept. 139-3, July 1970.
13. Dudek, C. L., and Jones, H. B. Real-Time Information Needs for Urban Freeway Drivers. Texas Transportation Institute, Res. Rept. 139-4, Aug. 1970.
14. Heathington, K. W., Worrall, R. D., and Hoff, G. D. An Analysis of Driver Preferences for Alternate Visual Information Displays. Highway Research Record 303, 1970, pp. 1-11.
15. Siegel, S. Nonparametric Statistics. McGraw-Hill, New York, 1956.

DISCUSSION

R. L. Pretty, Highway Safety Research Institute, University of Michigan, Ann Arbor

It is not a new idea to give information on traffic conditions to motorists, particularly freeway motorists. Commercial radio has been doing this for years. The information may be generally reliable and up to date when the sources of information are airborne observers or monitored closed-circuit television systems. On the other hand, when the sources of information are mobile ground observers, the information will often be virtually useless, for the observers will be describing the very traffic jams in which they are stuck. A more recent concept, however, is to use changeable message signs that may be more reliable and up to date than commercial radio, but a wide area cannot easily be covered. It is, therefore, timely that the authors have reviewed information systems. Appropriately, they have used a carefully administered questionnaire as the basis for their report.

The authors noted that only a small response was found for sign displays erected in the Dan Ryan Expressway corridor in Chicago (12). The 24 percent of the motorists who use the Chicago signs may be compared with the 40 percent who use the Lodge Freeway signs (16). The reason suggested for the difference in these figures is that the sign designs differed considerably so that in Detroit motorists were shown in a positive way the location of the alternative route if its use was advised.

The low proportion of actual sign users contrasts with the very high proportion expected by the authors. In real traffic, other reasons for not using the information signs will have an effect. For example, some motorists may dislike the environment of a par-

ticular route or the usually greater driving strain on surface streets. The reason the authors gave for failure to respond is that the motorists may think that they would not benefit from utilizing the information. Thus, the possibility exists that the motorist may be looking for a less tangible benefit than travel time saving and one not available on the surface streets.

Commercial radio has also been shown to be far from ideal in the presenting of traffic information. Apart from doubts about the reliability of the observations to serve a radio station, any station has many other obligations to its sponsors, owners, and listeners. Most stations have commitments to broadcast news, music, sports, and advertisements, and all of these will take precedence over traffic information. Thus, in a real situation, a motorist may not be able to hear traffic information during the normally very short interval of time that the information would be useful.

While eliminating television and telephone traffic services, the authors have been unable to show a marked difference between changeable message signs and commercial radio. Although not specifically stated in the paper, it seems that many motorists would desire radio information at the start of their trips. Others or even the same motorists would like sign information on the major street when decisions on whether to enter the freeway must be made. The traffic information supplied by the 2 communication modes would presumably be of different types: general or area-wide information on the radio and particular information for a short freeway section on the signs. Any city considering the installation of a freeway information system should, therefore, consider a combination of radio and signs.

With regard to the type of information desired, the authors have compared their work with Heathington et al. (14). This paper was concerned with visual information displays on the freeway. However, the present paper has shown that this is probably the least desirable position of the sign displays. This is unfortunate as it is quite likely that Heathington et al. would have found a driver preference for different messages had they been designing a sign for use on major roads.

There is an important difference between the conclusions in this paper and those in the paper by Heathington et al. The paper suggests that travel speed is not an important descriptor, and yet the Heathington paper ranked travel speed second only to an accident message. In the latter study, participants were given a speed range and a specific length of freeway for which this applied. By contrast, the present paper did not allow for the possibility of presenting any 2 of the 5 alternatives together and gave a specific speed rather than a range of speeds. These differences and the method of presentation of displays probably account for the different results. Because the Heathington work appears to have a sound theoretical base, it would be folly to eliminate speed as a possibe descriptor at this stage. At least both papers have agreed that travel time is not desired despite the fact that this is the tool of the traffic engineer.

Another difference with the Heathington results is that the reason for congestion was not now the most preferred descriptor. This, however, is easily explained by the fact that, if a subject in the present study preferred the reason for congestion as a descriptor, he would usually receive no information at all. On the other hand, the Heathington paper confined the accident descriptor to the case of heavy congestion.

Finally, the authors have carefully presented 3 hypothetical situations for drivers approaching or traveling on a congested freeway and have reached the consistent conclusion that the majority of motorists would reroute to avoid the congestion. The writer would be interested to hear any comment from the authors on the likely change in responses if the congestion had been partly transferred by means of ramp metering from the freeway to the entrance ramp.

Reference

16. Pretty, R. L., and Cleveland, D. E. Evaluation of a Dynamic Freeway Ramp Entry Guidance System. Highway Safety Research Institute, Univ. of Michigan, Rept. TrS-3, in press.

Gerhart F. King, Transportation Research Department,
AIL, Division of Cutler-Hammer, Inc.

This excellent paper deals with a major aspect that has been ignored too often in the past: the role of the driver as a decision-maker in the operation of a highway system, and the influence that traffic engineering can have on these decisions.

Success, in the form of system optimization, in the relatively new field of network management will only be achieved if drivers' actions are predictable on a statistical basis. These actions will be predictable if they are rational; that is, if they have a cause-effect relationship with the set of premises underlying drivers' decisions. The statistical distribution of these premises is measurable on a population basis, and, therefore, the statistical distribution of the drivers' decisions is predictable, given a known information transmission to a defined driver population.

Successful network management is based on the ability of the managers to affect drivers' decisions so as to achieve an optimum redistribution of traffic in response to existing conditions. The information transmitted to the driver, and intended to cause a desired decision, must be in a form usable by the driver and must be received at a time and location appropriate to the decision.

The research reported on by Dudek, Messer, and Jones addressed itself to obtaining data on driver attitudes, preferences, and probable reactions to a real-time freeway information system. It, thus, begins to generate a part of the empirical data needed to construct and calibrate a model of the information-decision-action process that underlies drivers' diversionary behavior. Other research efforts in Chicago, Detroit, and elsewhere are furnishing additional inputs to this model.

However, involved in the construction of this model is a major point that may not be receiving sufficient attention. This is the fact that a freeway information system, as conceived by the authors and by the other researchers in the field, is only a subsystem of the entire drivers' information system and, as such, is constrained by certain elements of the larger system.

AIL's recent research (17) has identified and defined 3 major classes of motorists' information needs associated with 3 major levels of performance of the driving task. These are microperformance needs, situational needs, and macroperformance needs. Microperformance needs (control) are those concerned with the fine details of the driving task such as the mechanical operation of the vehicle, steering, and speed control. Situational needs (guidance) are those involved in responding to traffic and roadway situations and involve actions such as car following, overtaking, and passing and responding to alignment changes. The needs of the macroperformance (navigation) are those associated with trip preparation and direction finding.

The real-time freeway information system discussed here is designed primarily to transmit information that will serve the needs of the macroperformance, that is, trip preparation in the guise of route choice and alternate routing. The information will also serve to structure drivers' expectancies and yield information on the situational level, that is upcoming situations connected with traffic congestion, freeway incidents, or abnormal roadway or weather conditions.

Examination of individual needs shows that some needs are obviously more important than others and that, in situations where needs compete, there is an order defining the needs to be satisfied first. Further analysis showed that this order is applicable not only to individual needs but also to the 3 levels of performance. The term "primacy" has been given to this order.

The arrangement of levels of performance and their consequent information needs on this continuous primacy scale is made in accordance with 2 criteria. The first of these deals with the probable consequence of nonreceipt of the needed information; the second deals with the time frequency, or cycle, of the occurrence of these needs. It can thus be seen that the needs of the microperformance occur continuously and, if not attended to, lead to catastrophic failure. They are, therefore, highest on the primacy scale. Situational needs come next. Lowest on the primacy scale are macroperformance needs. The first reason is that a macroperformance failure is not so catastrophic as a microperformance or situational performance failure. Although getting lost or missing an exit represents a driver error, the resultant failure need not be catastrophic. The same, obviously, is applied to the choosing of a less than optimum route. Another reason for the low primacy of macroperformance information needs involves the infrequent occurrence relative to the continuous microperformance and frequent situational performance information needs. The third reason for the low primacy is that most of macroperformance information needs are, or should be, satisfied prior to driving and, therefore, should not exist as needs.

In summary, the concept of primacy derives directly from the levels of performance and provides the traffic engineer with the means for determining which information needs should be immediately satisfield for a given situation in which information needs are likely to compete.

It is important to note that there are two kinds of primacy. The first, objective primacy, determines the relative importance of computing events that require the driver's attention on the highway. The second, subjective primacy, is driver established. By placing the focus of his attention on one particular information source, the driver is tacitly indicating that particular source is providing the most important information at that moment. The degree to which objective and subjective primacy coincides is a measure of the success of an information system. The driver who established a primacy that is not in agreement with the objective primacy is placing himself in a potentially dangerous position. Diverting attention from a rapidly diminishing gap to a sign for route information is indicative of poor subjective primacy. A well-designed information system must attract the driver's attention to the primary need when competing needs exist and release his attention when the need is satisfied.

The data collected and discussed in the present paper, insofar as it concerns driver preferences as to type, mode, and location of the information, give an indication of subjective primacy as it applies to this particular class of information. This point must be kept in mind by the engineer designing or evaluating a real-time freeway information system.

Applying the principles of objective primacy to the design of a freeway or network real-time information system requires consideration of the relatively low ranking of this type of information. The basic conclusions of the AIL study, that macroperformance information should be available insofar as possible prior to the inception of a trip, should also enter into the design process. Whether a system can be optimized with this built-in time lag must be decided on an individual basis.

The second principle applying to the design of this type of information system involves the relative importance of the various classes of information and the fact that the information processing abilities of the driver are limited. The type of information discussed here should not be presented at locations where the driver can reasonably be expected to have to process more important microperformance and situational information. This

latter type of information need is most prevalent at those locations where control maneuvers are required under conditions of traffic congestion, adverse geometrics, or time pressure.

Data given in Table 2 show that 26 percent of the respondents picked the entrance ramp as either first or second choice while 36.5 percent picked the major street as the location where they would prefer to receive information. These 2 locations generally would rank highest among the 4 alternatives given insofar as the driver's need for competing, higher primacy information is concerned. More than 60 percent of the respondents thus indicated that their subjective primacy may not be in accordance with the objective primacy of the driving task.

In the design of a real-time freeway information system, driver education and available means of mass communication should be used to structure drivers' expectancies so that this type of information can be presented and can be used at those locations where, based on relative importance, usability, and likelihood of reception, it will assume its optimum position in the overall highway information system.

Reference

17. King, Gerhart F., et al. Development of Information Requirements and Transmission Techniques for Highway Users. NCHRP Rept. 123, 1971.

John J. Haynes, Civil Engineering Department, University of Texas at Arlington

The authors have carried out an interesting research study involving a timely question concerning freeway driver preferences for real-time information. Although the study was limited to a small number of participants and involved limited choices of modes and methods of information transfer, the results do seem to justify the conclusions the authors have listed.

The authors indicate that previous experimentations with changeable message displays have produced contrasting results because studies in Chicago have indicated that very little diversion was attributed to the information signs whereas in Detroit such studies have shown the displays to be cost effective. It should be pointed out that, although there was little diversion in the Chicago studies, such diversion could have been cost effective, as was found in the Detroit study. The relative amount of diversion and the cost effectiveness of such diversion have not been well established; thus, there may not be such contrasting results after all.

An extension of this or any study of a real-time freeway information system should be that of evaluating the conditions on diversion routes, if it is assumed that large volumes of traffic could be diverted. It would seem that such study must ultimately consider the interrelationship between the willingness of freeway drivers to divert and the effect of large quantities of diverted traffic on alternate route systems. The questions asked and the impressions formed in the minds of the respondents in this study probably involved an image of practically free-flow conditions on alternate routes or parallel major streets along with congestion due to some incident on the freeway. Such conceptions will logically bias the answers supplied by participants in a questionnaire survey.

The authors have enumerated several reasons why motorists have not always responded to traffic information in the desired way. Among the reasons listed are "the signs were not observed" and "the motorists did not understand the message." Although

the authors have not pursued these problems, an extension of this research should consider these important reasons for improper driver response to traffic information.

There is some doubt concerning the nature and size of the sample. If some of those responding did not usually drive on the freeways, it is not clear how they could have answered some of the questions properly. The number of participants sampled obviously constituted less than 1 percent of the drivers who use the freeways in these 2 cities during a peak hour. Such a small sample of the freeway driver population could lead to exaggerated biases if the small sample is not truly representative.

The authors point out that 2 of their questions were devised to determine the driver's attitude toward the need for real-time freeway information. One question asked each participant to allocate a fixed sum ($100,000) for improvements in the existing freeway information being provided within a city. Because the participants were required to spend the fictitious money in some way, it is doubtful that this question can properly indicate the driver's attitude toward the need for such a real-time freeway information system. The choices that the participants had for spending their money were to provide additional guide signs, to provide freeway real-time information, or other (write-in suggestions). One should not really expect write-in suggestions to constitute a significant choice in such a questionnaire. The type of question that directs one to "spend" a fixed sum by allocating various amounts to several competing choices usually appeals to a basic trait of most civilized people, and that is to "share and share alike." For example, if a group were required to allocate money between heaven and hell, there would be the expected large percentage allocated for heaven, yet there could be 10 percent for hell.

In this study of design considerations, the modes presented to the participants were limited. They were commercial radio and changeable message signs, the applications of which are generally easy to grasp, and 2 others that were more difficult to properly understand unless elaborated on by those conducting the survey. These two were telephone and television. Thus, the understandably applicable choices were commercial radio and changeable message signs. Forty-five percent chose commercial radio as the most preferred alternative, and 45 percent selected changeable message signs; this left 10 percent who apparently felt that some application of television or telephone might be preferable. The authors indicate that this study revealed that a combination of the 2 popular modes, commercial radio and changeable message signs, could result in an effective real-time freeway information system for urban areas. The result of the study perhaps implied that such could possibly be true, but the respondents for this questionnaire were not specifically asked whether such a combination would be preferred.

In the part of the study devoted to preferred locations for receiving information, 4 choices were investigated: on the freeway, on the major streets leading to the freeways, at the entrance ramps to the freeways, and at the beginning of the trips, such as at home or the office. At this point in the questionnaire, about an equal number of participants had in mind either commercial radio or changeable message signs as the desired mode of information transfer. It is difficult to imagine a changeable message sign being located "at the beginning of a trip" such as at one's home. It is equally unlikely that television or telephone would be appropriately located "on the freeway or on the major streets leading to the freeways." The mode the participant had in mind obviously dictated the location chosen for receiving such information. The fact that 42 percent ranked receiving information at the beginning of the trip "most preferred" whereas 40 percent ranked it as "least preferred" is an understandable relationship between the preferred mode of information transfer and the logical location associated with receiving this information.

With regard to the type of information preferred by the freeway driver, the respondents to the questionnaire were offered 5 types: degree of congestion (such as heavy,

moderate, or light), location and length of a congested area, reason for the congested area (such as accident, maintenance, or stalled vehicles), travel time to various reference points ahead, and average travel speed obtainable between various reference points. The last 2 types of information mentioned, dealing with travel time and average speed, were obviously difficult to relate to one's individual trip. The results seem to indicate that few people think they know what their accurate travel time might be to various reference points ahead, even when freeway conditions are good. In addition, most drivers seem to feel they have only a poor idea of their average travel speed. If the drivers cannot relate information regarding the average speed attainable between various reference points to both good and bad traffic conditions, this information would also be less desirable. The questionnaire results seemed to indicate that such may be the case.

Among the conclusions, the authors find that "motorists are more inclined to divert to an alternate route before they reach the freeway than after they are on the freeway." It should be pointed out that before a motorist reaches the freeway he, in fact, does not divert; he is already on the alternative route and, thus, simply continues on that route. The use of the term diversion in this context should be avoided.

In conclusion, the authors are commended for their very interesting study. This research was necessary and did lead to some rather conclusive results and raised additional questions that, it is hoped, the authors will pursue and thus extend the knowledge concerning design consideration for real-time freeway information systems.

AUTHORS' CLOSURE

The authors would like to thank the discussants for their stimulating reviews of the paper. The reviews, in themselves, make an invaluable contribution to the field of real-time freeway information systems. Discussion was presented that correlates this study to previous work in Chicago and Detroit, and several areas for meaningful future research as an extension of this paper were suggested.

Haynes has noted the need for evaluating existing traffic conditions both on the freeway and on those routes that would be used for diversion by freeway motorists. Having this information, together with established relationships that show the willingness of freeway drivers to divert for a given set of traffic conditions, would make it possible to determine the volume of diverted traffic. Certainly this is a noteworthy objective but was beyond the scope of this initial research effort. A basic objective of this effort was to determine whether traffic diversion appeared feasible under favorable circumstances before actual field implementation was begun.

Pretty has explicitly explained the differences between some of the results reported in this paper and those reported by Heathington et al. The points that were raised should be helpful to the reader in interpreting both papers. The differences cited suggest that similar studies should be made in other geographical areas to furnish additional empirical inputs to this important subject.

As was stated in the paper, the responses to the 3 hypothetical situations were made on the premise that good alternate routes were available. Based on this premise, the authors do not believe that the response to the questionnaire would be materially different if the congestion had been partly transferred, by means of ramp metering, from the freeway to the entrance ramp; however, unless certain basic conditions are met, the participants may not respond identically in a real-world situation as they had indicated in the questionnaire. Therefore, the percentage distribution of the participants' reactions may be different. It is essential that the motorists gain confidence in the system as it is implemented. Otherwise, the effectiveness and the potential of the

system will deteriorate rapidly. It is important, therefore, that surveillance and control of alternate routes be integrated with those of the freeway system before alternate routes are suggested to the driver in real-time. Otherwise, the driver may be directed to routes that are less attractive than the congested freeway.

King has presented an excellent summary of the work at AIL relating to driver primacy of information needs and has presented a discussion pertaining to the relationship of a real-time freeway information system to the overall highway information system. This work by him and his associates was considered in the development of plans for staged implementation of real-time information devices on the Gulf Freeway. Based on the primacy of information needs, a prototype safety warning device has been designed and will be installed on the operating lanes of the freeway for test and evaluation as the first stage of a multistage implementation program. The restricted sight distances created by overpasses on the freeway in many instances do not allow ample warning time when an incident occurs downstream and thus creates unexpected situations for the approaching motorists. In many cases, the unexpectancy of the situation does not allow sufficient opportunity to adjust to the conditions, and rear-end collisions or near misses are prevalent. The safety warning device will be located upstream of the overpass crest and will automatically be activated by a central digital computer in accordance with preestablished traffic characteristic criteria. Additional traffic information signs will be installed later to form an integrated system.