the 95th percentile design level. The corresponding lowest bulb-loss percentages were 10 and 6 percent by nine and eight-character words respectively for the unfamiliar state and 16 and 6 percent also by nine and eight-character words respectively for the average state. These performances should be considered in bulb replacement for multiword messages.

Route numerals pose special problems of concern with degradation and legibility. For an average state, unsatisfactory performance is exhibited for the 85th percentile correct-response level beyond a bulb loss of approximately 20 percent and for the 95th percentile level beyond a bulb loss of approximately 10 percent. This indicates that the tolerable bulb-loss criteria for both legibility and appearance of route numerals are closely related. Special bulb specifications should be considered when using messages with route numerals. Numbers are harder to recognize than words because there is no sequential redundancy, i.e., knowing one number does not help a driver to anticipate the next, but the verbal language does permit filling in missing or distorted letters.

CONCLUSIONS AND RECOMMENDATIONS

Several conclusions and recommendations concerning the effects of bulb loss on the legibility of words, route numerals, and the messages displayed on electronic variable-matrix signs are suggested by the results of this study. Some are as follows:

1. For 85 or 95 percent of traffic-related words to be correctly read, the percentage of bulb failures must not be greater than that shown below.

Motorist State	Correct-Response Criteria	
	95	85
Unfamiliar	8	18
Average	14	28
Familiar	28	44

2. Bulb-replacement criteria for a specified level of legibility performance vary with the motorist state.
3. At the 85th percentile performance criterion, for both familiar and unfamiliar-motorist states, bulb replacement will probably be controlled by appearance (e.g., 10 percent bulb loss) rather than by legibility. The matrix sign may be legible at a level of bulb loss at which the overall appearance is unacceptable.
4. Only in the unfamiliar state and at the 95th percentile does the bulb-replacement criterion approach that designated by sign manufacturers (approximately 10 percent).
5. Messages with route numbers are read with difficulty at bulb failures beyond approximately 15 percent. Special considerations are advised for route numeral bulb replacement specifications.

In summary, it is emphasized that the manufacturer's specifications for bulb replacement should be adhered to beyond a 10 percent failure rate. There is also a need to further evaluate the results of this study and how they relate to real-world situations. On-site testing and a study of the legibility performance of three-character words and multiword combinations are justified.

ACKNOWLEDGMENT

This paper is part of a study conducted by the Texas Transportation Institute and sponsored by the Federal Highway Administration and entitled Human Factors Requirements for Real-Time Motorist-Information Displays. The contents of this report reflect the views of the authors who are responsible for the facts and the 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.

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Publication of this paper sponsored by Committee on Motorist Information Systems.

Abridgment

Survey of Motorist Route-Selection Criteria

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Other research and surveys have focused on the types of traffic descriptors motorists prefer (1, 2, 3) and the specific techniques for displaying such information in real-time.

It is also necessary to ask the motorist directly certain questions about his or her typical driving habits—the routes taken and the reasons for selecting these routes when he or she is familiar with other routes. The daily commuter makes a route-choice decision in traveling to and from work, and the intercity traveler makes

a route-choice decision in passing through major cities or in traveling to destinations within the city. It was hypothesized that the reasons for selecting typical routes would be similar to the reasons for selecting alternative routes in incident-type situations. The driver's hierarchy of route-choice criteria would be used in either situation.

If the information drivers need most in making a route-choice decision were available, it would then be feasible to determine whether such information was measurable and how it might be best displayed to the motorist.

METHOD

Motorist Samples

A sample of 202 drivers from the central business district of Dallas was selected to respond to the work-trip questionnaire. This sample consisted of daily commuters; they were 56 percent male and 44 percent female and had a median education of 14 years, a median age of 25 to 44 years, and a median driving experience of 11 to 20 years.

Another sample of 215 drivers was interviewed at rest stops on an Interstate leading into Houston. They were not asked personal information, nor was this a criterion in their selection. Of them, 123 reported a destination within the city and 92 a destination beyond the city. Thirty-five percent of those having a destination within the city and 76 percent of the through motorists were unfamiliar with the city.

Questionnaire Description

The format of the two questionnaires was similar, but the individual questions were necessarily different.

The rest-stop subjects were asked to describe the route they planned to take, whether they knew of other routes, and specifically why they had chosen the route they had previously described. They were also asked why they had not taken a familiar alternative route. A second series of questions related to what they would do in a situation in which they learned over the radio that traffic was stop-and-go ahead, because of an incident, and the reasons for their actions. They were also asked what information they would like to know in advance about the route they had chosen. These drivers were given a mail-in portion of the questionnaire that asked for recall of a time when a traffic jam had inconvenienced them. The questions were similar to those on the first questionnaire, except that the answers were based on actual experiences.

The work-trip questionnaire was given to the commuters through the personnel departments of their employers. The employers were two life insurance companies, a gas company, an electric company, a telephone company, an oil company, and the county offices.

The commuters were asked to describe the routes they regularly took to work and home, the alternative routes, and the reasons for their choice of route. The second portion of the questionnaire was analogous to the mail-in questionnaire for the rest-stop drivers. The questions related to their reasons for selecting a particular alternative route, if they did so, or why they decided to wait out a traffic jam. To determine the importance of the information they had just given about the alternative route, they were asked how the existence of advance information would have influenced their route-choice decision.

RESULTS AND DISCUSSION

Rest-Stop Survey

The reasons for their route choice given by drivers with destinations within and beyond the city are given below.

Reason	Percentage of Drivers	
	Within City	Beyond City
For choosing present route		
Convenience	45	50
Direct, short	23	13
Faster	20	21
Less congested	5	5
Other	7	11
For rejecting alternative route		
Takes longer	46	44
Less direct	42	44
More congested	3	4
Other	9	8

There were few differences in the reasons given for taking their present route or for not taking a known alternative route. The usual ones were that the present route was more convenient, direct, or faster, while the alternative route took longer and was less direct.

The major information about the route ahead sought was route guidance (33 percent), the level of congestion (17 percent), and the locations of congestion, accidents, and maintenance (13 percent).

The two destination groups were fairly consistent in their reactions to a radio advisory of an incident ahead, as shown below.

Action	Percentage of Drivers		
	Within City	Beyond City	Total
Divert around incident	77	65	72
Continue	13	21	16
Wait and continue	7	13	9
Depends on delay	3	1	2

Collectively, 72 percent said they would divert around the incident. Only 16 percent would continue, and 9 percent would wait it out. The major reasons given for either continuing or diverting are summarized below.

Reason	Percentage of Drivers
To continue	
Unfamiliar with area	66
Type of alternative facility disliked	9
Time not a factor	7
Other	18
To divert	
Avoid congestion	48
Save time	27
Avoid delay	20
Other	5

The major reason for continuing was a lack of familiarity with the area. The major reasons for diverting were to avoid congestion and delay and to save time.

Both those diverting and those continuing were asked what information about the alternative route they would like before they got on it. Of those continuing, 30 percent were mainly concerned about where to exit and reenter the Interstate, and 44 percent of those diverting were concerned about adequate route guidance.

Mail-in Survey

Thirty-three percent of those asked to complete an additional questionnaire returned their forms. The survey focused on a freeway or Interstate incident they could recall in which a traffic jam had inconvenienced them.

The actions taken in these incidents are summarized below.

Action	Percentage of Drivers
Diverted (took another route)	9
Continued	49
Waited and continued	42
Other	0

These values can be compared to the 72 percent who had previously stated that they would divert. The major reasons given for continuing were that the alternative route would not save time (23 percent) and that they were unfamiliar with the alternative routes available (20 percent). The types of information desired by these drivers before deciding to continue were the locations of the diversion routes (27 percent) and the level of congestion ahead (16 percent).

Commuter Survey

The 202 commuters from the central business district were asked to describe the route they regularly took to work. This requirement was mainly to make them focus on a particular route. The reasons these commuters gave for taking their present routes to work and homeward are given below and compared with the reasons given by rest-stop drivers for their route choice.

Reason	Percentage of Drivers		
	Commuters		Rest-Stop Drivers
	To Work	To Home	
Fastest route	23	24	20
Fewest stops	14	8	3
Convenience and accessibility	12	6	46
Shortest, most direct	22	14	20
Less traffic	8	19	5
Good traffic flow	5	10	0
Other	16	19	7

The major factors of speed, directness, and convenience are comparable, but the commuters had more different reasons, and convenience and accessibility were mentioned much less often. Sixty percent of the commuters had taken one or more alternative routes to work, and 74 percent of these had done so during the previous month. These drivers were asked to detail two alternative routes and the reasons for their route choice. The principal reasons were lighter traffic (29 percent), change of scenery (15 percent), and the need to make specific stops (13 percent).

The second series of questions related to the route taken homeward. Thirty-seven percent always or often took a homeward route different from the route to work, and 60 percent sometimes took a different route home. The major reasons and percentages of drivers taking these alternative routes were very similar to those taking an alternative route to work.

Like the rest-stop drivers, the commuters were asked to recall an incident situation that had inconvenienced them. The percentages taking various courses of action are given below and compared with the actions taken by the rest-stop drivers.

Action	Percentage of Drivers	
	Commuters	Rest-Stop Drivers
Divert	27	9
Continue	45	49
Wait and continue	24	42
Other	4	0

About the same percentages elected to continue on the route, but three times as many commuters diverted, and about half as many waited it out. The options for diverting may be more numerous for commuters driving in a metropolitan area than they are for drivers on an Interstate or freeway. Slightly fewer of the commuters (40 percent as opposed to 52 percent of the rest-stop drivers) said they would still have stayed on the original route even if they had known in advance of the traffic jam. Again, this may be due to the larger number of route options available to the commuter.

The reasons given by those who elected to divert and by those who elected to continue are given below.

Reason	Percentage of Drivers
For diverting	
Better traffic flow	35
Less traffic	25
Convenient to get on	18
Directness, shorter	8
Followed others	4
Other	10
For continuing	
Faster even with incident	50
No way to get off	28
No alternative route	12
Alternative more congested	3
Other	7

Those diverting thought that the diversion route would be less congested and traffic would be faster, while those not diverting believed, as did the rest-stop drivers, that the freeway was still the fastest route. Drivers needed assurance that they would be saving time by diverting.

Of those remaining on the primary route, 77 percent were satisfied, but 49 percent would have liked additional information on the length of the delay and traffic conditions. Fifty-five percent of those staying believed they would have diverted if they had had that information.

SUMMARY AND CONCLUSIONS

1. The criteria for taking alternative routes are fairly consistent both among motorists and by the same motorist at different times. The commonalities in the reasons given for selecting routes suggest that a message system could satisfy the needs of a great majority by presenting traffic information and positive route guidance.
2. The unfamiliar motorist was more concerned than the familiar motorist with route guidance and distrusted being diverted into unfamiliar territory.
3. At least 50 percent of those electing to continue through incident-related congestion would have diverted if they had had additional information.
4. While 72 percent of drivers said they would divert on hearing an incident advisory, few could recall instances of actually doing so. One reason for this may be lack of adequate information on where diversion routes are and how to get to them.
5. Drivers are not committed to a single route. Typical route-choice decisions, as well as incident-related decisions, are dictated by driver expectations regarding comparative traffic conditions on the routes.

Real-time signing and the radio are among the means of presenting to drivers the kinds of information they require. The public must be taught that the system is credible, so as to develop confidence in the information displayed. Present driving habits in both typical and route-diversion situations are based largely on previous driving experiences and not on current information.

The driver can be induced to divert if given timely information needed to make the correct decision.

ACKNOWLEDGMENTS

This paper discusses one phase of a research project entitled A Survey of Motorist Route-Selection Criteria, which was conducted by the Texas Transportation Institute and sponsored by the Federal Highway Administration. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented. The contents do not reflect the official views or policies of the Federal Highway Administration. The paper does not constitute a standard, specification, or regulation.

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Publication of this paper sponsored by Committee on Motorist Information Systems.

Motorist-Aid System on a Rural Freeway: The Illinois Experience

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The state of Illinois has installed an experimental motorist-aid telephone system along 221 km (138 miles) of I-80 between Rock Island and Joliet. The system consists of 302 roadside terminals in pairs, one telephone in each direction of travel, at approximately 1.6-km (1-mile) intervals. Before and after studies were conducted to evaluate the effectiveness of the system in terms of system use, response time, convenience, reliability, and costs. The sources for these data were stopped-vehicle surveys, state police assistance-rendered reports, service-unit assistance-rendered reports, a public-opinion survey, and a motorist-aid system-use survey. The major findings were that (a) approximately 24 percent of all I-80 aid candidates are using the motorist-aid system, (b) the average time between incident occurrence and police notification is reduced from 15.5 min in the before period to 12.8 min in the after period and to 9.6 min when the aid telephones were used, and (c) the cost-effectiveness of the system, considering accident reduction and time saved only, is in the 0.6 to 0.7 range for the total investment.

The state of Illinois has installed an experimental motorist-aid telephone system along 221 km (138 miles) of I-80 between I-74 (Rock Island) and Ill-43 (Joliet). The system consists of 302 roadside terminals in pairs, one telephone in each direction of travel, at approximately 1.6-km (1-mile) intervals. The Illinois Department of Transportation (IDOT) owned system is a two-way voice carrier, hard-wire (25 pairs) installation, operated through the state police headquarters near Joliet (police district 5) and Rock Island (police District 7). Toll-free calls from motorists requiring assistance are answered by a police desk sergeant, who either dispatches the necessary services or provides the required information.

The primary goals of the system, as defined in a 1968 feasibility study (1), were

1. To provide aid in an efficient manner to the motorist in need,
2. To minimize the hazard caused by the motorist in distress, and
3. To keep traffic flowing.

The secondary goals, which have varying degrees of importance, were

1. To maximize the service quality,
2. To maximize the extent and quality of upstream warnings of hazards,
3. To maximize the use of existing and planned resources,
4. To minimize the system obsolescence, and
5. To provide for the collection of adequate statistical operative data to analyze and evaluate the performance of the system and ensure legal backup for each incident in case of motorist suit.

SYSTEM EVALUATION

In the evaluation program, the pertinent measures of effectiveness were defined and placed in three categories—system use, response time, and convenience. The evaluation consisted of before and after studies related to the costs of the system and the measures of effectiveness (2, 3).

The measures of effectiveness related to system use were

1. The system-utilization ratio, i.e., the ratio of the number of system activations by aid candidates to the total number of aid candidates;
2. The system-efficiency ratio, i.e., the ratio of the number of successful motorist aids to the total number of aid candidates; and
3. The system-success ratio, i.e., the ratio of the number of successful motorist aids to the number of system-aid activations.

In the before study, an activation was defined as a