appraisal of the location of other vehicles around them in short-term memory.

Finally, one might legitimately ask what the relevance of obtaining frequency and duration of glance behavior in mirrors is in relationship to accidents in which rear-vision information may have been inadequate? The overall duration of mirror glances would be important in those situations where little time is available to make a decision in an evasive maneuver. On the other hand, the quality of the information that is obtained is also critical. Thus, one might ask whether drivers obtain more accurate information concerning the location, distance, and relative velocity of other vehicles with a right-side convex mirror than with no mirror on the right side and how safe the resulting lane-change maneuvers are. The latter question was not addressed in this study. This raises the issue of the relevance of performance criteria in rear-visibility studies. Perhaps such criteria cannot be structured properly until more information becomes available as to the underlying causes of crashes that involve inadequacies in visibility to the rear.

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Authors' Closure

Both Mortimer and Rockwell had positive comments on the use of left lane-change data for experimental control purposes. These left lane-change data indicated that the effects of traffic, weather, and driver motivation were averaged out when computed over 60 left lane-change maneuvers. These data may also serve as a standard reference when considering driver search behavior with reference to left lane changes. In this regard, the data show that drivers made only six direct looks to the rear while executing 127 left lane-change maneuvers. However, drivers did rely heavily on their left outside mirrors; they looked at them more than twice per maneuver.

Concerns were voiced about the small number of subjects in the study of age effects. We agree that more data should be collected on this very important variable. The data could be used to develop aids and countermeasures for the older driver. Perhaps older drivers will find convex mirrors useful, in that they will partially eliminate the need for head turns to the right rear.

It should be noted that all data were collected while driving on freeways in the city of Detroit in moderate to heavy traffic. We considered this to be a very demanding task for most drivers. Thus, instructions to the subjects probably had very little effect on driver performance. Many times, when the experimenter gave the command to execute a lane change, other traffic in adjacent lanes prevented the subject from immediately executing the maneuver. Thus drivers had to search by using their mirrors or by making direct looks to determine when to proceed with the lane change. Because the traffic flow on the freeways was always moderate to heavy, it had little effect on comparisons between door- and fender-mounted mirrors.

Since the data in this study have shown that the use of a door-mounted convex mirror has reduced the frequency of direct looks per 100 maneuvers from 40 (with no right-side mirror) to 4, we believe that automobile drivers will have no problem in using a right-side convex mirror.

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Human Factors Considerations for In-Vehicle Route Guidance

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This paper considers the development and maintenance of credibility in the design, implementation, and operation of a route guidance system. Because drivers will have positive attitudes about a system that provides them with relevant, reliable, and accurate information, all precautions must be taken to ensure that these driver expectations are met. Messages must be presented clearly and must allow ample time for the driver to respond to a given situation. Factors that affect reading time of displays include driver work load, message load, message length, message familiarity, and display format. In order to maintain driver credibility, surveillance must be an integral part of a route guidance system. Such surveillance must be able to detect adverse conditions, validate the adverse conditions, and determine the nature and scope of the problem. Electronic sensor surveillance, however, has some limitations. Because it is a blind system, (a) some form of visual validation and assessment of incidents to ensure the accuracy of displayed messages and (b) some guarantee of adequate system maintenance are necessary. A "forgiving" system—one that alerts the driver and provides instructions about how to return to a scheduled route after a diversion—must also be considered.

An important consideration in a successful route guidance system for the United States (where success is measured by achieving desirable driver response) is to develop and maintain credibility, that is, driver faith in the system. The quickest way to fail is to lose driver confidence. The most elaborate and costliest system can deteriorate into an operational headache if the confidence of the motoring public is lost (1).

My remarks, therefore, center on credibility. In particular, this paper highlights software and hardware issues that I view as important human factors considerations during the development, design, implementation, and operation of a route guidance system in order to achieve and to maintain driver credibility.

My understanding of the system proposed for the United States is that it is a two-level system (2). The first level, referred to as a static routing system, provides instructions to drivers based on the best route information derived from historical data. The second level, referred to as a dynamic routing system, gives instructions to drivers based on current traffic conditions obtained from surveillance of the highway system. This paper essentially considers the dynamic system, although many of the same principles may be applied to the static-type system. A constraint in preparing this presentation was that the exact configuration of the U.S. in-vehicle display (i.e., whether it will give only routing information or traffic information in addition to routing information, or use both visual and audio displays) was not known.

DISPLAYS

First, it is necessary to consider the in-vehicle displays themselves and a system in which only routing information is visually displayed. Will this type of information suffice? Recent research has indicated that under certain applications it will suffice, provided drivers are convinced that the system is indeed directing them to the best route. One application is during the routing of traffic for a special event (e.g., football game, baseball game, or state fair). Recent experience with changeable message signing indicated that drivers will be responsive (3, 4). Since most drivers will be expecting some form of congestion on the primary highway near the major generator and many drivers will be unfamiliar with alternate routes, they will respond to BEST-ROUTE information. Another application is the routing of unfamiliar through-drivers along alternate freeways through and between metropolitan areas (5).

When dealing with local drivers, particularly commuters, there is a strong indication that drivers wish to know the location of a problem ahead; they desire diversion information and at least one good reason for being diverted (1)—for example, a major delay. They may have to be convinced that diversion is in their best interests. Therefore, it may be necessary to use word messages that describe the incident, location, and degree of the problem in addition to the routing instructions.

The question as to whether traffic information should be presented on a visual display or an auditory display requires further research.

CREDIBILITY

Drivers will have positive attitudes about a system that provides them with relevant, reliable, accurate, up-to-date, and timely information displayed in a manner that is clear and can be read in ample time to make a decision (1). All precautions must be taken to ensure that these driver expectations are met. Drivers will have negative attitudes about a system that does not meet these expectations. Each of these factors is examined briefly.

Clarity and Reading Time

As I understand the guidance system, information will not be continuously displayed but will be presented only at key intersection areas or other important locations. In reality, then, there will be constraints on message presentation time similar to those of on-road changeable message signs. At a given driving speed, factors that affect the reading time of displays include driver work load, message load, message length, message familiarity, and display format (1).

Messages must be viewed within a distance that allows sufficient exposure time for drivers to attend to the complex driving situation and glance at the display a sufficient number of times to read and comprehend the message. The higher the driver work load, the longer time the message must be legible.

With the enormous capability and flexibility of the types of visual displays that I envision for use with a route guidance system, there may be a temptation to display more information than drivers can read and comprehend during the available reading time. This has been a problem in some cases with the use of on-road changeable message signs (5). Hopefully, the lessons learned from this experience will help establish optimum message lengths for in-vehicle displays.

When too much information is displayed, drivers can become overwhelmed to the extent that they have difficulty in scanning and reading the message. There is evidence, for example, that for on-road changeable message signs, no more than four units of information should be displayed when all four units must be recalled by drivers (1). The informational unit refers to each separate data item given in a message that a motorist could recall and that would form the basis for making a decision. On proposed in-vehicle displays, definitive turning movements designated by arrows in contrast to word messages should enhance information transfer.

There is also evidence that an eight-word message (excluding prepositions) is approaching the processing limits of drivers traveling at high speeds. A recent Human Factors Design Guide (1) recommends minimum message exposure time of 1 s/short word (up to eight words) or 2 s/unit of information, whichever is larger. Research in the form of in-situ and field operational studies is necessary to better assess optimum message lengths for route guidance systems.

Another factor that influences message reading time is driver expectancy and familiarity with what will be displayed. Commuters, for example, who have seen several messages on the in-vehicle display, will develop expectations of message classes and types. Based on previous experience, they will more than likely tend to gloss over familiar elements of the message and concentrate on those elements that change from one situation to another. (This assumes that standard message formats are used consistently.) Unfamiliar drivers, on the other hand, who see the message for the first time, must read the entire message. Their reading times will thus be longer than those required for familiar drivers (1).

With respect to display formating, there are several human factors concepts that can be used (1). I will discuss two. First, when word messages are used, it is best to arrange the message somewhat proportionally within the horizontal and vertical dimensions. Messages that extend considerably on either the horizontal or the vertical scale are more difficult to read.

Second, redundancy can be used either in the form of repetition or coding. Color coding of critical messages, for example, would enhance recognition and reading times. With the advent of solid-state digital television image generation and anticipated technology advances in the future, this is not outside the realm of reality.

There are various messages that can be used to describe traffic conditions or so-called traffic states. Recent studies have indicated that drivers can only distinguish about three, or at most four, levels of traffic conditions (6). The studies have also shown that drivers from small cities perceive congestion at a much lower traffic density than drivers from large cities. Words used to describe traffic conditions must be carefully selected. For example, the descriptors STOP AND GO TRAFFIC and NORMAL TRAFFIC are very vague and should not be used. The traffic state descriptor, CONGESTION, is vague and should not be used (1).

Drivers who are given delay durations (or time saved) will base their decisions to divert or to continue on the delay information more than information about the particular type of incident. If a quantitative indication of delay (in minutes) is displayed, it must be reasonably accurate because its validity can be easily checked by the drivers. Studies conducted in four U.S. cities revealed that more than 50 percent of the surveyed drivers indicated that they would divert to avoid a delay of 20 min or more. Only 8 percent stated that they would divert to a delay duration of less than 5 min (7). MAJOR ACCIDENT implies to the average driver a delay of at least 20-25 min and MINOR ACCIDENT, a delay of not more than 15 min (7).

In areas where most drivers are primarily commuters, cross-street names should be used to identify the location of the incident. The incident location may also be referenced to a well-known landmark if available. For unfamiliar drivers, the incident location should be expressed in terms of distance (1). When names of cities are used on the display, they should be identical to those used on existing static signs (1).

Even with the flexibility of the in-vehicle displays, it will be necessary in many cases to use abbreviations because of the physical size limitations. Driver interpretations of several types of abbreviations more commonly used with traffic condition and routing information are not fully known at this time (5). More research is needed in order to ensure that proper, well-understood abbreviations are used.

Timely Information

Routing and lane assignment information must be given in ample time for drivers to respond to instructions. Lane assignments must be made far in advance of the turning point and far enough upstream of any possible traffic queues so that drivers can maneuver into the appropriate lane. Therefore, a route guidance system must have the capability for measuring traffic queues and adjusting itself accordingly so that drivers are not trapped. For example, under light flow conditions, the lane assignment information can be made rather close to the turning point; but, under heavy traffic conditions, it must be made much sooner.

We also need to consider those cases where the driver has two choice points in close proximity. The situation at a freeway-to-freeway interchange is an example. Information may have to be given far in advance of the interchange. If so, it must be presented clearly so that the driver does not incorrectly exit at a ramp upstream of the major interchange. It may be necessary, therefore, to display route shields (1).

Without question, the information displayed must be compatible with existing static guide signs. Therefore, the relative time frame or spatial frame with respect to the static signs is important. It is yet to be determined if routing instructions should be displayed in advance of interchange signs, in conjunction with advance interchange signs, or beyond advance interchange signs.

Relevant Information

Telling drivers that they are in congested traffic or repeatedly telling commuters of recurrent congestion when such information is obvious decreases confidence in the capability of the system to provide useful information. What is obvious should never be displayed (1).

The route guidance system should not be used to balance demands with available capacity during recurrent congestion conditions. There have been attempts to balance on-ramp demands during daily peak periods by suggesting that drivers use other ramps on the freeway. This approach was found to be ineffective and is a good way to lose credibility. Drivers are concerned with their individual travel times and are unconcerned with optimizing flow in a corridor. It is important that they realize a significant reduction in their personal travel time if they are to continuously abide by the information presented (1).

Reliable and Accurate Information

The specific messages that can be displayed with confidence to maintain driver credibility are influenced by the operating agency's ability to detect a traffic problem and to determine the nature and scope of the problem. Therefore, surveillance will be an integral part of a route guidance system and must serve the following functions (5):

1. Detection of adverse conditions,
2. Validation of the adverse conditions, and
3. Determination of the nature and scope of the problem.

Knowing what is occurring on the affected freeways and streets has an impact on the messages one can display. Driver credibility is at stake. Repeated display of erroneous information or route recommendations that are not the best in the driver's viewpoint are ways of losing driver confidence.

Electronic surveillance with in-place detectors does not always ensure that the information received is accurate. Detection systems seem to be a problem in several existing changeable message sign installations.

Electronic sensor surveillance has other inherent limitations. First, there could be considerable delay in recognizing that an incident has occurred (8). This is due to several reasons:

1. Because of cost, sensors are normally placed at long intervals—0.8 km (0.5 mile) or longer on freeways.
2. Sensors are a point source of information.
3. Current incident detection algorithms are not 100 percent accurate. (Changing the algorithm parameters to increase the percentage of incidents detected also increases the chance of false alarms. Thus, there is a need for additional work in this area.)

Another limitation of electronic sensor surveillance is that it is a blind system. The agency must rely on other means to assess the nature of the incident in order to display appropriate messages.

Because electronic surveillance is a blind system, some form of visual validation and assessment of incidents is necessary to ensure that accurate messages are displayed. Highway agencies are now emphasizing the need for closed-circuit television as an integral part of urban traffic advisory and incident management changeable message sign systems—not as a primary surveillance technique but as a means for rapidly validating incidents and determining the nature and scope of the problem (5).

One facet that is often overlooked during the design, development, and implementation of a traffic control system is hardware maintenance. Relative to the route guidance system, it is quite apparent that hardware will be installed in various local and state jurisdictions. The question that arises concerns the guarantee of adequate system maintenance. Assuming that each city will have the responsibility for maintaining the system within its own local jurisdiction, some cities may perform better than others because of attitude, availability of money, and better-qualified personnel. A motorist traveling crosscountry and following a given route would expect to have continuous information. What safeguards can be provided so that the motorist does indeed have continuous information, or what can be built into the system to at least make the driver aware that the system may be inoperative within a given stretch of highway?

Even with our on-road changeable message sign systems, highway agencies are concerned with the lack of funds to purchase replacement parts. Another concern is the long delay in having components repaired by the manufacturer. Still another concern is the unavailability of replacement parts. Incorporating more off-the-shelf components into the route guidance system may help somewhat, but this is not the total solution to the potential maintenance problem.

What safeguards and provisions will be made during partial system failures, either at an intersection point area or along a segmented link of the primary or alternate route? How will the driver be routed back to the primary facility if there is a system failure while the motorist is on the alternate route? The system design will have to address these questions.

THE "FORGIVING" SYSTEM

A "forgiving" system must also be considered. For example, assume that a driver who is being directed along an unfamiliar alternate route did not make the turn according to the display. It would appear that there would be a need to alert the driver and provide instructions about how to return to the scheduled route.

Before a driver diverts, he or she needs the assurance that the route will lead to the final destination or return the driver to a primary facility (1). One approach to provide this assurance is to continuously display the final destination while the driver is traversing the primary or alternate route. Thus, the driver will be assured that this route will lead to his or her destination. When the destination name disappears from the display, it could be an indication that the driver has failed to follow the instructions given.

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Feasibility Study of Route Guidance System

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The Comprehensive Automobile Traffic Control (CAC) Project was started in 1973 as a six-year project sponsored by the Agency of Industrial Science and Technology, Ministry of International Trade and Industry. The aim of this major project is to develop a comprehensive system for controlling the flow of vehicular traffic through the use of the most up-to-date computer and other technology for monitoring and controlling traffic in order to improve overall traffic conditions by reducing accidents, congestion, and air pollution and to relieve drivers of unnecessary mental stress. This paper presents some results of the feasibility study of this CAC system. Since route guidance plays the most important role in the CAC