SOME PRINCIPLES FOR COMMUNICATING WITH DRIVERS THROUGH THE USE OF VARIABLE-MESSAGE DISPLAYS

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A sizable number of potential applications of variable- or changeable-message, traffic-control signs have emerged in the past few years. Such signs are envisioned as being a more efficient method for communicating current or imminent roadway or traffic conditions to motorists so that level of service and traffic flow relations will be optimized. Because of the growing number of applications of this kind of communication system, those of us who are concerned specifically with effective communication of highway and traffic conditions must establish bases for rules, tenets, or principles to be applied to the use of changeable-message signs.

MEETING EXPECTATIONS OF MOTORISTS

A statement frequently made by traffic engineers is that motirists generally will be responsive to signs, signals, and other communication devices when the message presented is one that is accurate and timely. For example, a red signal at an intersection is taken seriously, but a fixed sign near a bridge with the message SLIPPERY WHEN WET is given little notice on a bright summer day. A general term for such behavior is is "driver expectancy."

King (1) formulated 5 "basic tenets for the systematic presentation of information needed by the driver." Among those rules is expectancy, which King interprets to mean that traffic and highway designers should avoid surprising motorists. There is a substantial amount of evidence from the literature on human behavior that indicates that King's statement must be qualified and that, in general, the surprise value of a message contributes substantially to its comprehension. A program of studies undertaken by Berlyne indicates that attentiveness to various displays depends to a large extent on their complexity (2). Various simple displays with high predictability generally do not maintain one's attention for very long, whereas a somewhat more complex or novel display generally sustains attention. Studies conducted by Pribram (3) also convey that only so long as inputs provide some elements that are relatively novel does the individual continue to sample or attend to the display.

The other important aspect of the statement by traffic engineers, i.e., the message must be accurate and timely, is related to learning. Motorists must learn relations between the message content and the performance expected of them. For example, the color red has little ambiguity for motorists, at least for American motorists. Although it is assumed that there is a variety of possible interpretations made by different mo-

torists of the same content, there appears to be little evidence for that assumption in the literature. We do find that where there is redundancy of various cues on signs the cues are used selectively. For example, a 1962 study conducted by Gray and Russell (4) revealed that approximately one-third of unfamiliar motorists queried indicated that they used destination names on guide signs, one-third used route numbers, and one-third used both. Such differences reflect different strategies of different motorists in carrying out trips but provide no information on possible ambiguities as associated with low-redundancy signs.

It is difficult to know whether a specific road sign was seen and understood or needed by the motorist. There is some evidence that road signs with messages that are important to drivers simply do not communicate that message. A series of studies reported by Johansson and others (5, 6) indicate that 5 warning signs experimentally placed on Swedish roadways had a likelihood of being noticed 26 to 66 percent of the time, depending on the specific sign. In a recently published study, Johansson and Backlund (6) separated samples of subjects into 2 groups: (a) those who were aware of the experiment and were looking for experimentally positioned warning and speed-limit signs and (b) those who were naive with regard to the experiment. Although under none of the signing conditions did all of the subjects interviewed correctly report the types of signs they had just passed, the enhanced expectancy of prepared motorists contributed to substantial increase in the likelihood of correct responses. Correct reports were given 1.5 to 2.8 times more often by those looking for the signs than by the naive motorists. For a substantial number of the motorists in these experiments, the signed information appears to have merely blended into the background; it is not possible to determine whether the signed information was not conspicuous enough or whether many motorists simply could not believe that an external fixed sign provides timely information.

PROVIDING DIRECTIONS THAT CONFORM WITH BEST INTERESTS OF INDIVIDUAL MOTORISTS

Although the "nut-behind-the-wheel" notion is still a part of our accident causation folklore, many traffic engineers think of the driver as a capable and rational being bent on optimizing his best interests and frequently making even poorly design geometrics and traffic control devices operate reasonably well a great deal of the time. If traffic engineers attempt to optimize traffic flow to the detriment of individual motorists, it is probable that motorists will catch on. Most signal-timing schemes seem to be partially based on such an assumption. Nearly nothing has been published relevant to this point.

Among the traffic control strategies utilized at the National Proving Ground in Detroit was the use of overhead lane-control signs and variable-message speed limit signs. Wattleworth et al. (7) reported that some drivers (we do not know how many, but it is implied that the number is considerable) used the closed lanes "to their advantage because they were nearly vacant of other vehicles and high speeds were possible." Wattleworth reports that variable speed-limit signs appeared to be somewhat effective until motorists detected a staged incident (which presumably they inferred was the reason for a reduced speed limit). After the incident was detected, motorists resumed "a more natural speed" and appeared to ignore the speed-limit signs.

Current research underway at FHWA also seems to indicate that, where regulatory signing prohibiting certain traffic movements is in conflict with perceived time savings by motorists, a substantial number of drivers will disobey the regulatory sign. The number of violations in this situation appears to be directly related to the time savings to be gained by motorists.

MAINTAINING CONTINUITY, RELIABILITY, AND ADVANCE NOTICE IN SIGNING

More than a decade ago, a study on freeway directional signing was reported by Schoppert et al. (8). Based on an analysis of reports of motorists' experiences on freeways, a set of principles for improved directional freeway signing was developed.

Those principles include interpretation, relatability, continuity, advance notice, and prominence. Interpretation and prominence seem bound up with the factors that we considered earlier. All of the principles can be generalized to directional signs as well as to other forms of road signs.

The principal reason that those results are recalled in the context of this discussion on changeable-message signs is simply that they may be easily forgotten or otherwise ignored. Let us consider the importance of continuity in the use of variable-message signs. Continuity, of course, refers to the consistent use of information content within a circumscribed geographical area. For example, if WEST BEACH is used in a guide sign in advance of the interchange, it should also be used in signs at the exit and at subsequent splits within the interchange area and on the road beyond.

Conditional guide signs that attempt to convey alternate courses depending on traffic load must be so constructed that continuity with existing fixed signing is maintained. Converting a fixed sign to a changeable-message guide sign at a single location could lead to greater rather than lesser confusion.

Relatability refers to a signed reference to the actual geometric and traffic conditions as well as to a map representation of such conditions. Corridor and ramp control systems, such as the one on the Gulf Freeway in Houston, are incorporating dynamic displays of the system for motorists. Those dynamic displays obviously must be related to prevailing traffic conditions. The prominence of such signals, of course, could easily overshadow important displays of geometric conditions such as lane drops. In such cases, the lane-positioning directions could easily be brought into conflict, unless optimal spacing schemes or integration of such displays are developed.

Advance notice refers to the positioning of road displays in relation to the location of the condition that is the subject of the display. Some evidence from the National Proving Ground tests conducted by the Texas Transportation Institute suggests that in cases where sight distance is restricted variable-message, speed-control signs were effective in alerting drivers. The data also indicate that those signs were capable of inducing progressive decreases in the standard deviation of vehicle speeds under conditions where a specific incident (presumably associated with the speed sign) was not viewed directly.

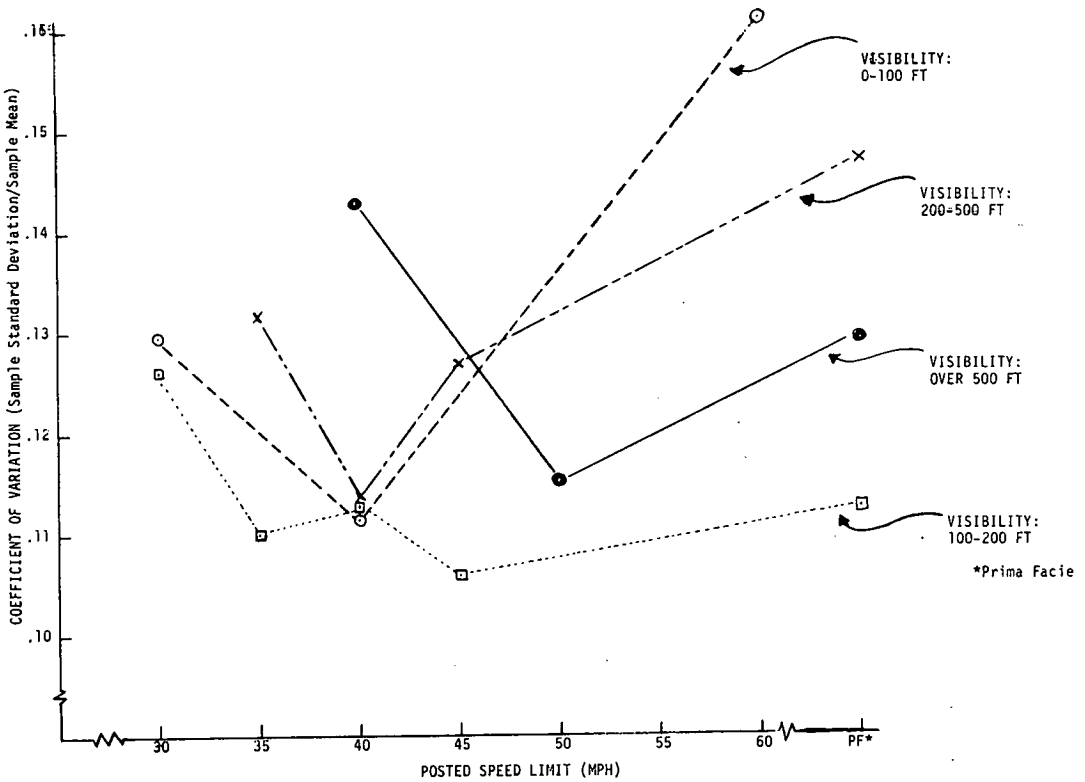
Closely associated with the concept of advance notice is the notion of providing information that helps the motorist overcome sight distance limitations. Nature provides a changeable sight distance problem that appears to be capable of being compensated for by the judicious use of variable-message signs. Recently we had occasion to extend analysis of a 1966 fog study conducted by the California Division of Highways (9). In this study a number of techniques were employed in an attempt to improve traffic movement and reduce accidents on fog-laden roads. The California investigators concluded that "of all the devices and techniques tried on the highway only the posting of speed limits (using changeable message speed signs) had any measurable effect on traffic." As a part of this study, spot speed measurements were taken under various conditions of fog density. Speed limits were systematically varied for various traffic volume conditions.

Our analysis involved making calculations of the coefficient of variation of speeds (an inverse measure of traffic speed stability). Those measures were then related to the posted speed limits as a function of fog-related sight distance. Speed data were used from a 4-lane divided expressway with partial control of access (San Francisco) and Interstate 80 and Calif-160 (Sacramento) for night and day conditions under high and low traffic volumes. Where sufficient data exist, the results are practically unequivocal. There is an advisory speed at which maximum stability exists, and that value differs depending on the visibility conditions. As visibility decreases, the posted speed at which the relative dispersion is minimal is lowered (Fig. 1). In other words, lowering the posted speed a little below the nonsigned "natural speeds" can improve traffic stability; lowering the posted speed too much will reduce stability. Each visibility distance condition has its own optimal value.

OTHER PRINCIPLES

A great deal of effort has been expended to ensure that specific highway and street signs can be detected and the content recognized. Much of the production and painstak-

Figure 1. Speed turbulence as a function of posted speed limit for 4 visibility conditions.



ing efforts have been carried out by Forbes and others at Michigan State University. A great deal of the work completed in applicable both to changeable-message signs and to fixed signs. However, some of the problems of variable-message signs are different and may require further work on visibility, legibility, and attentional demands. Some of these areas are suggested in the following list:

1. Most contemplated changeable-message signs involve luminous sources rather than reflected light, posing specific visibility problems. Contrast between background areas will be much different; compensatory circuits will probably be required for day-night differences and possibly for different gradients of sky brightness.
2. An evaluation of confusion between traffic control devices and commercial displays may be necessary. A proliferation of variable-message signs using matrices and an increased range of spectral characteristics in urban areas would be expected to have detrimental effects on operator detection and discrimination performances.
3. Confusion between similar letters and numbers (such as 5 and S) can be increased with bulb matrix designs or neon or similar light sources. It is not unlikely that other standard numerical-alphabetical series will have to be adopted.
4. Working with the new medium may facilitate the tendency of designers to put too much information on the sign partly because of basic costs for such signs. Masking of "off" portions of the sign must be accomplished cleanly.
5. Initial implementation should employ simple sign arrays. In a 1970 study by Dudek and Jones (10), motorists indicated a preference for "real-time information displays that were simple...over designs containing diagrams that orient them to the freeway and arterial streets."

APPLICATIONS

The direct evidence for establishing the benefits of variable-message signs is meager. Many of the data collected thus far have involved the use of questionnaires and attitude measurement of an abstract nature or laboratory experimentation [for example, Heathington et al. (11) and Dudek and Jones (10)]. Some of the traffic data were discussed earlier.

It seems reasonable to advise motorists of desirable speeds under reduced visibility or restricted sight distance, but optimal speeds to be displayed are dependent on the "natural" speeds of traffic without variable-message signs.

Ramp controls or conditional directional guide signs must be kept simple, and there is some empirical support for their use.

The direct evidence against the use of simple warning displays was not presented in this discussion. It derives primarily from preliminary results of work now being conducted by the Oregon Department of Transportation (12). Specific instructions, such as REDUCE SPEED or CHANGE LANES, that are based on a real system demand may prove effective to improve traffic operations in hazardous areas.

Changeable-message signs have a potential application to traffic operations, but this is an area to which neither operational experience nor research has offered very much. A great deal of both is required before effective principles and standards can be generated.

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