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Contents

Signing Treatments for Interchange Lane Drops

Harold Lunenfeld and Gerson J. Alexander, Federal Highway Administration

Drivers often experience difficulty when freeway lanes are not continued beyond an interchange. Interchange lane drops represent situations that drivers do not expect and for which they are unprepared. The problem was studied to aid the driver's task by developing effective signing treatments. Devices in the Manual on Uniform Traffic Control Devices (MUTCD) were found to be not entirely satisfactory because of questions about their applicability, latitude in their application, and suitability for their intended purpose. Data from surveys, a state-of-the-art review, observations of as-built installations, and laboratory evaluations were used within the framework of a human factors analysis to assess MUTCD standards and recommend changes. Driver expectancy provided the basis for problem identification and solution development. Configurations were categorized by geometric and route attributes into eight types of exits and splits. Their concomitant expectancy violations were identified, and their effect on unfamiliar drivers was assessed. Each type violated the expectancy that all lanes will continue. Additional differing geometric and route expectancy violations precluded the use of a single signing treatment for all types. The black-on-yellow EXIT ONLY treatment was recommended for exit lane drops with route continuity. Diagrammatic treatments were recommended when the off-route was to the left of the through-route. Empirical evaluations demonstrated the effectiveness of the recommendations.

There are locations on freeways and expressways where traffic volumes do not warrant the continuation of a lane or lanes. One of the ways to discontinue a lane is in conjunction with an interchange. Interchange lane drops can lead to considerable driver difficulty. They occur on high-speed highways where drivers are often required to make simultaneous decisions under extreme time pressures. They present drivers with a set of unusual maneuvers that they do not expect and for which they are usually unprepared. They may be further complicated when routes as well as lanes are not carried beyond the interchange. Even without the discontinuation of a route, interchange lane drops represent serious problems in terms of safety and efficiency. Unlike the main-line lane drop, which forces the driver in a lane about to be terminated to merge with traffic in an adjacent lane, the terminated lane may cause the driver to take an undesired path or route. The consequences of interchange lane drops include accidents, turbulence caused by last-minute merges, erratic maneuvers at gores and on-ramps, and drivers getting lost or delayed.

Although there was agreement among highway engineers that interchange lane drops created problems, there was little consensus on how to characterize them and how the problems could be solved. Early evidence pointed to the usefulness of a black-on-yellow EXIT ONLY treatment (1). With its inclusion in the Manual on Uniform Traffic Control Devices (MUTCD) (2), the Office of Traffic Operations (OTO) of the Federal Highway Administration (FHWA) initiated a program to study its applicability and effectiveness. The primary objective was to evaluate all interchange lane drop signing standards and recommend MUTCD changes where applicable.

CATEGORIZATION

An initial problem analysis showed that a variety of geometric and route configurations were associated with interchange lane drops. The simplest case is that in which three lanes approach an interchange, two lanes go through, and one, usually the right lane, becomes the exit ramp. Exit lane drops are more complex when the left lane becomes the exit ramp. The situation is essentially similar to a major split. With splits, at least one (usually two or more) of the lanes is not continued through the interchange. Splits may be further complicated by an optional lane. Analysis showed that most interchange lane drops could be defined in terms of the following minimum characteristics:

1. Reduction in lanes;
2. Association with an interchange;
3. Right or left lane or lanes not continuing through the interchange; and
4. In some cases, through route not continuing through the interchange.

Eight basic types, shown in Figures 1 and 2, were categorized by using the scheme of Table 1. Although some

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interchange lane drops might not fit into the scheme, these four exit lane drops and four splits are representative of the majority of cases.

APPLICABILITY OF EXIT ONLY TREATMENT

OTO had promoted the EXIT ONLY panel for right exit lane drops before its inclusion in the MUTCD. Its adoption, however, still left several unresolved questions related to its applicability with variations in geometrics and route continuity. A preliminary survey of OTO personnel (37 in sample) was conducted to assess its applicability as judged by professionals and nonprofessionals. Those sampled were asked to indicate whether EXIT ONLY should be applied to each of six types of exits or splits. A χ^2 goodness-of-fit test was used to test, at the 0.05 and 0.01 significance levels, whether the respondent's judgment of the applicability of the EXIT ONLY panel is dependent on the interaction between route and geometrics. The results are given in Table 2. Significant results were obtained in favor of EXIT ONLY at exit lane drops with route continuity (exit type 1) and in opposition when the through route is carried on the ramp (exit type 3). Split type 2 was the only split to yield significant results, with respondents opposing the use of the EXIT ONLY panel. The preliminary survey, a follow-up survey of redesigned treatments that yielded no significant results, and interviews with traffic highway engineers showed considerable disagreement concerning the use of the EXIT ONLY treatment and acceptable alternatives when it was not applicable. This resulted in a program expansion to consider other aspects of the program.

STATE-OF-THE-ART REVIEW

A literature review showed that relatively little research existed on interchange lane drops. One study looked at accident rates (3). It found that rates increased as a function of interchange versus main-line lane drop whether the drop was on the left or right and whether the geometrics could be seen. No conclusions were drawn regarding signing or marking treatments. A recent study in Kentucky studied traffic conflicts at sites with differing designs and information treatments (4). Whenever horizontal curves were minimized and vertical curves were either nonexistent or were sags, conflict rates were lowest. No single signing or marking treatment was significantly effective for all configurations. The conclusions of the Kentucky study were similar to those derived analytically elsewhere (5). Research on other traffic control devices is sparse. Some pavement treatments, including color coding (6) and raised pavement markings (7), were found to be effective. Although Michigan obtained a significant reduction of greater than 75 percent in erratic manuevers with the black-on-yellow EXIT ONLY panel (1), questions were raised about the suitability of the message. One jurisdiction in California conducted a questionnaire evaluation that showed ambiguity with EXIT ONLY and concluded that MUST EXIT was superior. This study was replicated by the FHWA (8) by using a variety of verbal messages. The FHWA study found all messages to be ambiguous and concluded that replacing EXIT ONLY with MUST EXIT was not warranted. Although literature is conflicting on verbal treatments, one study on diagrammatics (9) does provide definitive conclusions for several types of interchange lane drops. Although the study did not evaluate exit lane drops per se, its conclusions that diagrammatics are effective in situations where the off-route movement is to the left of the through-route movement are applicable to left lane drops and splits where the off-route movement is on the left leg.

State Survey

A survey of states (all states plus the District of Columbia and Puerto Rico) found that all types of interchange lane drops occur throughout the country and are distributed as follows:

Category	Number	Percent	Category	Number	Percent
Exit			Split		
1	48	93	1	25	48
2	26	50	2	21	40
3	33	64	3	34	66
4	17	33	4	30	58

Each state reported at least one of the types on its highway system. Exit type 1 was the most common, occurring in 92 percent of all jurisdictions, and split type 2 was least common, occurring in 40 percent of the jurisdictions. Seven urban states reported all types, and six rural states reported only one type.

Observation of Installations

Observations of interchange lane drops throughout the country found that drivers encounter differing signing treatments from state to state, from location to location within states, and from interchange to interchange at a specific location. This variability in treatment represents a source of driver confusion. Interchange lane drop signing that is nonstandard, inconsistently applied, or unique to a particular jurisdiction is potentially confusing. Consistent and standardized treatments are needed to aid the driver. Uniform traffic control devices consistently applied lead to self-learning, which enables drivers to link situations with information presentation, comprehend its meaning, and predict situations that will occur. Several examples of differing treatments are shown to illustrate the variability that a driver may encounter. The most typical treatment is to apply the black-on-yellow EXIT ONLY panel to the lowest line of the guide sign with the message bracketing a white or black down arrow as shown in Figure 3. Variations in arrow treatment, word message, and panel position are shown in Figures 4, 5, and 6. These represent only a small fraction of the kinds of signing found throughout the country. Reasons for this variability determined in discussions with operations personnel include local practice and MUTCD latitude.

MUTCD Analysis

The EXIT ONLY panel is the only treatment in the MUTCD specifically designed for interchange lane drops, although a conventional down arrow treatment applicable to one type of split is covered elsewhere. The EXIT ONLY treatment is not given emphasis or prominence and is included in a section on miscellaneous guide signs. Guidelines on applicability of the treatment are lacking, and there is latitude allowed in its use. EXIT ONLY is not a mandatory treatment. There is latitude in its application because it is not required on all guide signs in a given sequence. The only requirement on the subject governs the use of a down arrow with the panel when it is used at the advance guide sign location.

PROBLEM ANALYSIS

The surveys and state-of-art review activities served as the data base for an assessment of existing signing standards and as input to the problem analysis and solution development. Standards were not satisfactory because of latitude and questions of applicability and effectiveness. A driver-centered human factors analysis was performed to develop standards for each configuration because a single treatment was not possible. The analysis was based to a large extent on driver expec-

Figure 1. Types of exit lane drops.

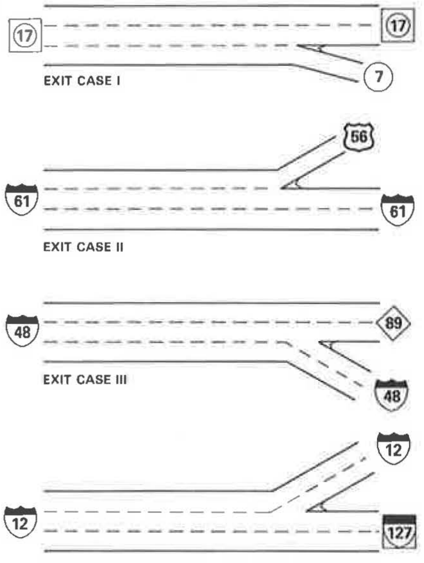


Figure 2. Types of splits.

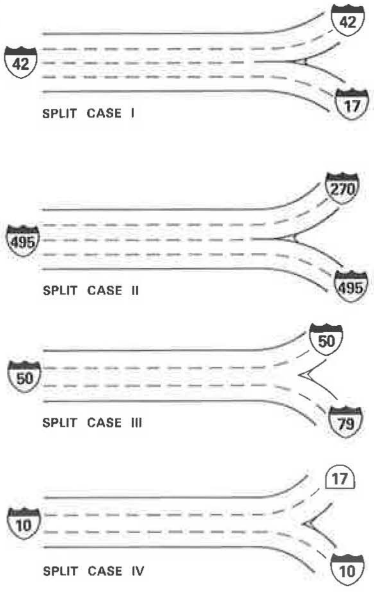


Table 1. Interchange lane drop categorization.

Type of Through Route	Geometric Design	Type of Exit	Type of Split
On main line	Right exit lane dropped	1	
	Left exit lane dropped	2	
On ramp	Right exit lane dropped	3	
	Left exit lane dropped	4	
On left leg	Split without optional lane		1
	Split with optional lane		3
On right leg	Split without optional lane		2
	Split with optional lane		4

Table 2. Mean responses of OTO personnel on applicability of EXIT ONLY treatment.

EXIT ONLY Panel	Exit Lane Drops		Splits			
	Type 1	Type 3	Type 1	Type 2	Type 3	Type 4
Should be applied	32.0[a]	11.3[b]	15.1	12.2[b]	14.5	14.7
Should not be applied	5.0[a]	25.7[b]	21.9	24.8[b]	22.5	22.3

Note: Number in sample was 37.
[a]Significant at 0.01 level. [b]Significant at 0.05 level.

Figure 3. Typical EXIT ONLY treatment.

Figure 4. Variation in arrow treatment.

Figure 5. Variation in message.

tancies and the effects of their violations. Recommendations for MUTCD standards have been made for all types and submitted for approval. It is beyond the scope of this paper to discuss all eight types. Exit types 1 and 2 are presented to illustrate methodology and treatments.

Figure 6. Variation in location.

Table 3. Interchange expectancies and concomitant violations upstream of interchange.

Characteristic	Expectancy	Typical Concomitant Violation
Design	Exit configuration	Split, directional
	Off-ramp on right	Left exit
	Movement to deceleration lane	Exit lane drop
	Single egress	Multilane, split
	All lanes continue	Exit lane drop, split
	Selected lane leads to choice	Optional lane
Route	Route and facility coincide	Through-route on ramp, off-route on main line
	Off-route to right of through-route	Left exit, split with off-route on left leg
	Choices identified	Route not signed, destinations not signed

Table 4. Interchange expectancies and concomitant violations at interchange.

Characteristic	Expectancy	Typical Concomitant Violation
Design	All movements on clearly defined path	Off-facility path unclear, through-facility path unclear
	All movements free from conflicts	Weaving sections
Route	Route and facility coincide	Through-route on ramp, off-route on main line
	Choices identified	Route not signed, destinations not signed
	Agreement between advance and exit direction signs	Disagreement

Expectancies

Expectancy relates to a driver's readiness to respond to common situations in predictable and successful ways. It affects the speed and accuracy of a driver's information handling, decision making, and response. Ordinary situations reinforce expectancies and help drivers respond rapidly and correctly. Unusual, unique, and uncommon situations violate driver expectancies. They may cause drivers to take longer to respond properly or cause them to respond poorly or commit errors (10).

Most freeway interchanges are sufficiently similar to cause drivers to develop a set of expectancies related to common geometric design and route characteristics. They are part of the deductive knowledge that drivers bring into the driving task. Common interchange expectancies and typical concomitant violations are given in Table 3 at locations upstream of the interchange where the interchange is not visible and where advance signing is either not present or not visible or, if visible, is ground mounted. Table 4 gives a summary of expectancies and typical concomitant violations in the vicinity of the interchange when its geometric design is visible.

Expectancy Violations

The driving task when one approaches and negotiates an interchange is usually complex and demanding even when expectancies are reinforced by usual geometric and route

Figure 7. Signing for exit type 1.

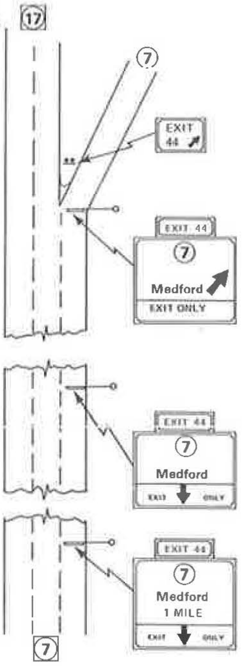


Table 5. Deductive expectancy violations.

Type of Exit	Description	Characteristic	Expectancy	Violation
1	Right exit lane drop, off-route on ramp	Design	Movement to deceleration lane to leave facility	Right lane becomes ramp
			All lanes continue beyond interchange	Right lane terminates at ramp
2	Left exit lane drop, off-route on ramp	Design	Off-ramp on right	Left off-ramp
			Movement to deceleration lane to leave facility	Left lane becomes ramp
			All lanes continue beyond interchange	Left lane terminates at ramp
		Route	Off-route to right of through-route	Off-route on left ramp

characteristics. The potential for overload, confusion, and driver error is greatly increased by configurations that violate expectancies. Effective signing aids the driver's task by warning him of unexpected situations and restructuring expectancies.

Expectancies that a driver holds before seeing interchange geometry or signing may be modified or restructured by their appearance. Design features provide information that the driver continually uses. Drivers generally believe what the roadway and its environment seem to be telling them when geometric design is consistent with their expectancies and have difficulty when their expectancies are violated. Signing should always match and augment design to be credible and effective. Exit lane drops with route discontinuity (exit types 3 and 4) and optional lane splits (split types 3 and 4) present credibility problems because signing can never fully match design. Exit types 1 and 2 also violate expectancies. However, properly designed signing treatments are both credible and effective for these cases because, after expectancies are restructured, they match the interchange geometrics.

Table 5 gives the expectancies violated by the geometric and route characteristics in exit types 1 and 2. These are the expectancy violations that the driver must be warned of at advance guide sign locations upstream of the interchange.

At these locations, when geometric and route characteristics are likely to be neither visible nor apparent, it is important to gain driver's attention, warn them of an unexpected situation, and restructure violated expectancies.

Affected Drivers

Interchange lane drops cause some drivers to perform unexpected and unusual maneuvers. Interchange lane drop signing treatments are intended for those drivers whose expectancies are violated. Drivers can be grouped into two broad categories: those who are familiar with the facility and routes and those who are unfamiliar with the facility and routes. The familiar group generally constitutes the majority of the traffic stream, particularly during peak periods. Unusual features of an interchange lane drop do not violate their expectancies. The unfamiliar group is the primary target group for interchange lane drop signing. The unfamiliar group includes local strangers who are somewhat familiar with the area and complete strangers who are driving the route for the first time. A recent study (11) shows that nearly all strangers have a trip plan prepared from available road maps. Drivers sampled by the study judged route choices as the most important information need. When approaching an interchange, strangers would not know geometric design but would have a trip plan and would want to (a) change routes to the off-route or (b) stay on the through-route.

Synthesis

All elements of the problem analysis were combined to identify expectancy violations that required restructuring and information needs that had to be satisfied for unfamiliar drivers. A synthesis was accomplished for each type of interchange lane drop as a function of lane position and trip plan. It was performed for advance locations and for the proximity of the interchange.

The synthesis for exit type 1 showed that, upstream of the interchange, the driver changing lanes is largely unaffected by the lane drop feature. He or she primarily needs route choice (destination, exit number) information. Because the driver expects the exit to be on the right, he or she will tend to be in the right lane and does not need to be told that the exit is on the right. The driver should be told, however, that the interchange geometrics will not require a change to a deceleration lane. This should be followed up at the interchange by information telling where the egress is from the facility. Through-route drivers are most affected by the terminated lane. If they are in the right lane, which they expect to continue, they must be warned that it will not continue. This should be accomplished upstream of the gore area to minimize chances of their being pulled off the route and the facility and to minimize turbulence brought about by last-minute lane changing. Similarly, through-route drivers in other lanes should be told to stay out of the right lane. This information should be repeated at the exit direction location to confirm information presented upstream.

The synthesis for exit type 2 showed that its associated geometric and route expectancy violations affect all unfamiliar drivers in all lanes. Drivers who want to change lanes need route choice information. They also need to know that the off-route is to the left of the through-route because they expect a right-hand exit. Drivers cutting across several lanes of traffic from right to left to take the exit are a consequence of not restructuring these expectancies. At both the advance guide sign and exit direction sign locations, drivers must be told that the left lane is the proper lane for changing routes. They also need to know that the interchange geometrics will not require a change to a deceleration lane. Through-route drivers must be warned that the left lane, the traditional through lane, is the exit lane so that they can leave it if they are in it and stay out of it if they are in the adjacent lane.

RECOMMENDED SIGNING TREATMENTS

Data developed by the program were used to develop a set of recommended treatments. These treatments were empirically evaluated by the FHWA and were found to be effective in restructuring driver expectancies. Recommended changes to the MUTCD are summarized for exit types 1 and 2.

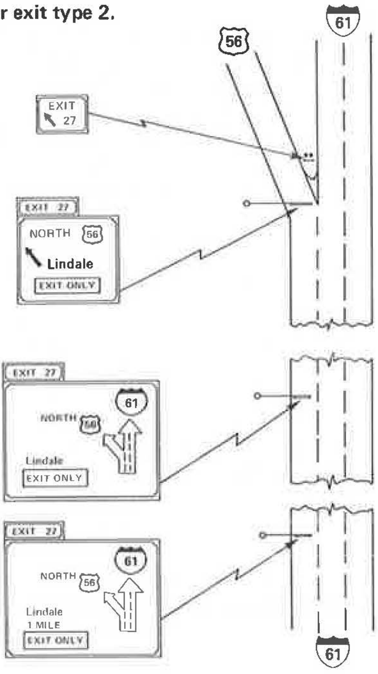
Exit Type 1

Because of the importance of proper signing, it was recommended that advance and exit direction signs be overhead mounted for all interchange lane drops. Analytical and empirical evidence shows the EXIT ONLY treatment to be effective for exit type 1 lane drops when applied consistently and uniformly. It was recommended that its use be made mandatory for all guide signs in the exit type 1 sequence.

Analysis of arrow style requirements shows that down arrows should be required for advance guide signs and upward sloping arrows should be required for overhead exit direction signs. The down arrow on advance guide signs serves to provide lane assignment, a primary information need for all drivers upstream of the gore. On overhead exit direction signs, an upward sloping arrow providing exiting drivers with "here it is" information is most important because lane assignment information has already been provided on the advance guide signs.

Analysis of distance information needs shows that, for the two advance guide signs case, the first advance guide sign is analogous to the first advance for a conventional exit; both off-route and through-route drivers need "where it is" information (displayed by distance information), and "what it is" information (displayed by EXIT ONLY). The second advance guide sign, which is the only advance guide sign in the single advance sign

Figure 8. Signing for exit type 2.



case, is usually located 0.8 km (0.5 mile) or less from the interchange. Safe and efficient operations require that all lane changes occur upstream of the gore. Because the EXIT ONLY panel, in the absence of distance information, implies immediacy, it will lead to desirable lane changing at an advance location for through-route drivers in the right lane and exiting drivers in the adjacent lanes. Distance information therefore should not be provided at this location because it may give drivers the impression that they can delay their decision. This could lead to undesirable lane changing in the vicinity of the gore. Recommended signing treatments for exit type 1 are shown in Figure 7.

Exit Type 2

The evidence showing the effectiveness of diagrammatics for configurations where the off-route is to the left of the through-route led to the recommendation that a diagrammatic treatment should be used as the standard for exit type 2 (9). Recommendations were in accordance with criteria for diagrammatics at left-hand exits: Diagrammatic treatment is used at the advance guide sign locations and conventional exit lane drop signing (as used in exit type 1) is used over the left lane on the overhead exit direction sign. Because the EXIT ONLY treatment was shown to have the attention-gaining characteristics required by the lane drop situation, its use without a down arrow was recommended along with the diagrammatics. Figure 8 shows the recommended signing.

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King M. Roberts and Alfred G. Klipple of the Traffic Systems Division of the Federal Highway Administration provided empirical support for the interchange lane drop project. Their contribution is appreciated.

The contents of this paper reflect our views. The contents do not necessarily reflect the official views or policy of the U.S. Department of Transportation.

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Diagrammatic Highway Signs: The Laboratory Revisited

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The experiment summarized in this report was designed to establish a low-cost reliable laboratory technique for the evaluation of highway guide signs and to resolve differences in previous laboratory studies with regard to diagrammatic guide signs. It was found that the differences in two previous studies on diagrammatic signs could be resolved if one simply applied the same criteria for the scoring of the data to each of the studies. Therefore, the methodology established in the current investigation, which controlled for methodological differences in earlier studies, was concluded to be a reliable means for assessing the impact of guide sign changes. The validity of the methodology is yet to be established. Response times were consistently longer for diagrammatic signs than for conventional signs. This difference was probably due to an increase in information on diagrammatic signs. Subjects reported being more confident of and having a preference for conventional signs. The correctness of lane choices was slightly higher for conventional signs than for diagrammatic signs.

One purpose of the research described in this report was to establish a laboratory method for the evaluation of highway signing practices that could be generalized. An additional benefit of the current investigation is an assessment of the reliability of previous research findings concerning the use of graphic guide signs.

Several independent research needs dictated the specific research design used in the study. Historically, signing plans have frequently been made and approved and signs erected without adequate opportunity to conduct research studies on the probable impact of such changes. The use of engineering judgment and field performance data is probably ultimately effective but usually quite costly. Inevitably, the high cost of such field research restricts the frequency with which it is employed, which in turn results in an increasing reliance on judgment. As a consequence, significant savings in time, money, and personnel would be possible if traffic response data could be obtained reliably and economically in the laboratory. Therefore, one of the major purposes of the investigation was to assess the reliability and validity of laboratory methods of evaluating guide sign information.

As its primary purpose, the research attempts to focus on the problem of evaluation of innovations in guide signing, specifically the use of graphics. Recently, a great deal has been said and written about the use of graphics in highway signing. Symbology for warning and regulatory signs has been used in Europe for many years, and has now been included in the 1971 edition of the Manual on Uniform Traffic Control Devices (7). However, few of the recommended uses are based on sound empirical evidence. Several laboratory studies have been conducted to assess the effectiveness of diagrammatic guide signs (1, 2) but have produced contradictory conclusions and recommendations. On the other hand, field tests of diagrammatic signs (4, 6) have been well received but of somewhat limited use because of a lack of generalizability. However, limited recommendations have been made for the use of diagrammatics by Mast and Kolsrud (5) based on their synthesis of research findings. In this investigation, an explicit attempt has been made to assess the differences in methodology and results obtained in the Gordon (2) and Berger (1) studies.

The two major laboratory investigations that preceded the present investigation (1, 2) were characterized by significant differences in methodology as well as in results. Differences in methodology occurred along a number of dimensions, including group versus individual testing, practice versus no practice, short stimulus presentation time versus indefinite stimulus presentation time, and questionnaire versus automated means of gathering response data. Similarly, the studies were not identical in terms of the response measures that were employed. The Gordon study (2) employed lane choices, overall preferences, and latency data. The Berger study (1) employed lane choices and confidence of lane choices in the complete interchange signing study. It was also determined that there were significant differences in the criteria employed for assigning correctness of lane choice. It is obvious that such differences were sufficient to produce conflicting findings that result in a recommendation for conventional signs in one case and a recommendation for diagrammatic signs in the other.

Therefore, this study was designed to assess the importance of both the methodological and criterial differences inherent in those studies. Initial efforts dealt with methodological and procedural problems. First, it

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was decided that a system with the capability for both telegraph key responses and voice key responses would simulate the essential differences between an automated data system and a questionnaire technique. This procedure permits the collection of latency data and lane choice data to thus allow a comparative analysis of methods not possible in earlier investigations. Second, it was decided that either an unlimited or an extremely brief stimulus presentation time was not a realistic representation of the amount of time that guide sign information is available to drivers. Therefore, an empirically determined estimate of this time interval was substituted for the external values used in the previous investigations. Third, rather than employ an overall preference for each interchange, a paired comparison technique was employed for each sign within an interchange. Fourth, several levels of practice were employed to simulate learning effects. Finally, stimuli identical to those employed by Gordon (2) were used to ensure the generalizability of our findings to the earlier studies.

Criterion differences between the two studies were examined in a direct fashion. To accomplish this analysis, the criteria employed by previous investigators were requested and obtained. The correctness of lane choice data was then analyzed twice, once by using the Berger criteria and once by using the Gordon criteria. Subsequently, three tests of significance were performed. In the first two of these tests, the current data were compared against both the Berger (1) and Gordon (2) data by using their own criteria of correctness. In the third comparison, the current data were compared against themselves by employing those same criteria. Similar comparisons were made on the confidence and latency data. Each of these analyses is discussed in greater detail in the following sections of the report.

METHOD

Experimental Design

The experiment followed a 2 (response method) × 2 (practice) × 2 (type of sign) × 6 (intersection) factorial design with repeated measures on type of sign and intersections. Dependent measures included correctness of lane choice, confidence of lane choice, preference of types of signs, and latency of response to signs.

Stimulus Materials

The basic stimuli used in this experiment were eight sets of color slides. Each set consisted of 29 roadway scenes and six destination names. The slides, provided by FHWA, were identical to those used in the Gordon report (2). In brief, they depicted highway scenes along the Washington, D.C., beltway (I-495) approximately 60 m (200 ft) upstream from an appropriate guide sign and included number designations on each driving lane shown. These slides contained stimuli from six different types of freeway interchange:

1. Lane drop (six slides on interchange 1),
2. Multiple-split ramp (four slides on interchange 4N),
3. Left ramp downstream from right ramp (four slides on interchange 4E),
4. Two right ramps in quick succession (six slides on interchange 16),
5. Major fork (three slides on interchange 17), and
6. Cloverleaf (six slides on interchange 29).

In addition, each interchange grouping was preceded by a destination name that served as the choice cue for the subjects. A more complete description of these intersections can be obtained in the Gordon report (2).

The roadway scenes depicted in each set of slides were identical except for the types of signs used. Signs in four of the sets were of the conventional style [in conformity with the U.S. Manual on Uniform Traffic Control Devices (7)]; signs in the remaining four sets were of the diagrammatic type, duplicating the designs used in the Berger study (1).

Because all of the interchange signs indicated a right, left, or through destination, several destinations were possible for each interchange. The availability of four sets each of the 29 conventional and the 29 diagrammatic type of slides therefore made it possible to construct four different sequence combinations of destinations, which, in effect, created a counterbalancing of turn directions for the stimuli, which would control for any preference bias. Keeping the order of the six types of interchanges constant in conformity with the Berger and Gordon studies (1, 2) (1, 4N, 4E, 16, 17, 29), one set of slides depicting conventional and diagrammatic signs included only all right-turn destinations, a second set included only all left-turn or through destinations, a third set alternated with right-turn then left-turn or through destinations, and a fourth set alternated with left-turn or through then right-turn destinations.

A second set of stimuli was then prepared in which a basic set of 29 conventional and 29 diagrammatic slides was converted into color prints. Two scenes were subsequently eliminated from each set of prints (the first interchange picture for interchanges 4N and 17) because the conventional and diagrammatic signs used in the comparable scenes were identical for both. This left a total of 54 prints. These 54 prints depicted 27 pairs of highway scenes; one print from each pair showed a conventional style of sign, and the comparable print showed a diagrammatic type of sign. The two prints in each pair were then mounted side by side [positioning on the right or left was random on separate pieces of 11.4 by 31.75-cm (4.5 by 12.5-in) poster board]. Above each scene with a conventional sign was printed a number one, and above each scene with a diagrammatic sign was printed a number two. This second set of stimuli, thus prepared, provided individual pair-wise comparisons of the two types of signs within the 27 roadway scenes.

Subjects

One hundred and twenty subjects were used for this experiment, constituting a random sample of licensed drivers with varied driving experience from among the Wayne State University student body. Each subject was paid $2.00 for participating.

Experimental Procedure

The experimental procedure was basically the same for all subjects. After arriving at the laboratory, they were randomly assigned to one of four experimental conditions: (a) voice response with no practice session before the testing session—30 subjects; (b) voice response with a practice session before the testing session—30 subjects; (c) key response with no practice session before the testing session—30 subjects; and (d) key response with a practice session before the testing session—30 subjects. Subjects then sat at a table 2.4 m (8 ft) away from and facing a rear projection screen and viewed slide sets of highway scenes from six freeway interchanges, half of which depicted conventional highway signs and half of which depicted diagrammatic signs (as previously described in the section on stimulus materials). The presentation order of conventional or diagrammatic signs was counterbalanced so that half of the subjects (60) viewed conventional signs before viewing diagrammatic signs, and the other half (60 subjects) viewed graphic signs before the conventional ones. Furthermore, subjects within each of these two groups were presented one of four turn-direction orders (as described in the section on stimulus materials). Forty subjects received all left-turn or through destinations; another 40 subjects received right-turn destinations. In the last group, 20 subjects received left-turn or through then right-turn destinations; the remaining 20 subjects received right-turn then left-turn or through destinations.

Before viewing the scenes from each interchange, a destination name was presented on the screen for the subject, which he or she announced aloud. Following this, the subject was presented the highway scenes for that particular interchange one at a time for a maximum period of 5 s, approximating the amount of time sign information is paid attention to by freeway drivers. Subjects were instructed to respond as quickly as possible (following the initial presentation of the slide) with the number corresponding to the lane in which they felt they should be in if traveling to the already designated destination. After responding with their lane choice, subjects then indicated their degree of confidence in the correctness of their lane choice. During the intertrial (slide) interval of 10 s, the experimenter recorded the subject's lane choice, the latency of that response, and the confidence level. The equipment was then reset, and the next scene was displayed.

There were four variations on this basic procedure, corresponding to the four major experimental conditions. Subjects who received no practice session before testing viewed and responded to one set each of the diagrammatic and conventional signs. Practice condition subjects, on the other hand, received two presentations each of the conventional and diagrammatic signs and made the appropriate responses. Although the order of the types of signs that these latter subjects received was maintained in the second session, the turn-direction order was reversed; for example, subjects who viewed all right-turn destinations in practice viewed all left-turn or through destinations in the test session. Thus, as in the Gordon study (2), although subjects became familiar with the various sign designs, they did not become familiar with the actual problems asked in the test sessions.

Another variation in the basic procedure corresponded to the type of response condition. Half of the subjects within each of the practice and no practice conditions made their lane choices into a voice microphone, and the second half used a response key. In each case the subject's response served to stop a latency timer. The response key condition corresponded to that used by Gordon; the voice response condition was included to approximate the questionnaire method used by Berger. A comparison of the latency obtained under these two conditions thus would permit an analysis of performance as a function of method.

A second phase of the experiment followed the slide presentations and was identical for all subjects regardless of which experimental group they were in. In this session, subjects were presented 27 pairs of color prints (as described in the section on stimulus materials) depicting the highway scenes that had just been viewed in slide form. Subjects viewed each of these pairs one at a time and indicated which picture of the two presented sign information that they felt was easier to use and therefore which they would prefer to see used in highway signing.

After indicating their 27 preferences, subjects were then asked to make any comment they wished concerning the two types of highway signs, indicating in particular what they may have liked or disliked about each. The experimenter recorded these comments, at the end of which the entire experimental session was completed.

Equipment

The equipment used in the investigation consisted of a reaction time control and a voice-activated relay. The reaction time unit consists of three major components: a standard automatic projection tachistoscope; a response panel containing five response keys, a five-way connection block for additional response devices, and a 2800-Hz Sonalert ready signal; and a control panel containing a four-bank timer, six response indicators, a $\frac{1}{100}$-s digital stop clock, a manual override control for advancing slides and triggering the shutter, and a mode selection switch that determines whether a slide aborts after a response. The unit is designed to automatically time an intertrial interval (ITI), a ready signal period, a delay period, and the presentation time of the slide. The stop clock is automatically initiated on slide presentation. Any response is recorded on the central control panel, automatically stops the clock, and terminates the slide presentation. During the ITI period, the experimenter must record the reaction time, reset the response indicators, and make any desired timing changes. Otherwise, the unit is fully automatic and will continue to recycle until manually stopped. The voice-activated relay is fully compatible with this unit and provides for the alternative of a vocal input. The advantages of a unit such as this are its standard manufacture, its relatively low cost, and its mobility. With a minimum of experience and modest instruction in the overall methodology, various types of agencies can acquire the capability to conduct their own exploratory investigations.

RESULTS

We shall first examine those data for which direct comparisons can be made of the results of the Gordon (1), Berger (2), and current studies. The only data on which the three studies could be directly compared was the correctness of lane choices. The data are summarized by type of interchange in Table 1. Three tests of significance were run on each interchange. First, the original Berger (1) data were compared with the current data by employing the Berger criteria. Two such tests were possible for each interchange allowing for type of sign (conventional or diagrammatic) and practice (practice or no practice). Only four of the 12 possible tests reached significance. This suggests that the data obtained in the current study are essentially of the same nature as those obtained in the Berger study. This finding clearly suggests that the data obtained in the Berger study are reliable. Our second set of significance tests compared the original Gordon data with the current data by employing the Gordon criteria. Only 2 of 24 such comparisons were found to be significant. This finding suggests that the data obtained in the Gordon study are also reliable. However, the final set of significance tests provides the data for a rather important conclusion. In this final set of analyses, the current data scored by the Berger criteria were compared with the same data scored by the Gordon criteria. Fifteen of 24 comparisons were found to be significant (the means were significantly different from each other). Because no essential significant differences were found when the earlier data were compared with current data by the same criteria, only one conclusion is possible. We suggest that data obtained in earlier laboratory studies are reliable but that the criteria employed in those studies were not. A summary of correctness by Gordon criteria at exit point broken down by interchange, sign, and practice is given in Table 2. The mean proportion correct was 0.96 for conventional signs and 0.91 for diagrammatic signs. An analysis of variance of correctness of lane choice across all interchanges revealed no significant differences in correctness due to type of sign (conventional versus diagrammatic) $[F_{(1,112)} = 2.8188]$ or experience (practice versus no practice) $[F_{(1,112)} = 1.0757]$ when analyzed by Gordon criteria. Similar results were obtained in an analysis of variance by using the Berger criteria. Generally, the results tend to support Gordon's findings that the proportion of correct lane choice is higher for conventional signs than for diagrammatic signs although, in this investigation, this difference was not statistically significant. A result such as this is not unanticipated because most drivers are familiar with conventional signs, and consequently diagrammatic signs produce a novelty effect that initially may cause some slight deteriorations in performance. However, as data obtained in other studies will show, diagrammatic signs can have some utility when employed in unusual driving situations and when designed properly for the circumstances in which they are employed.

Table 3 summarizes the comparative analyses on confidence of lane choices. Only comparisons with the Berger data were possible because Gordon did not collect confidence data. In the six possible comparisons (across interchanges) of the Berger data and the current data on conventional signs, the means were statistically different from one another only in a single instance. In the case of diagrammatic signs, none of the six mean differences was statistically different from one another. As in the case of correctness of lane choices, this finding is interpreted to mean that the data obtained in the earlier investigation are reliable. When the mean of the conventional confidences (3.43 on a scale ranging from 1 to 4) was compared with the mean of the diagrammatic confidences (3.13) for the current data, the difference between means was found to be significant both for practice $[t_{(5\,df)} = 4.098$, $p < 0.005]$ and for no practice conditions $[t_{(5\,df)} = 3.88$, $p < 0.01]$. Berger obtained results that were not in agreement with the above findings (the mean confidence was 3.09 for conventional signs and 3.02 for diagrammatic signs). The findings of the present investigation are believed to be intuitively more interpretable in that individuals should be more confident of stimuli that are familiar to them and less confident of stimuli that are novel or unique. Of course, diagrammatic signs fall into this latter category. The χ^2 tests in part A of Table 4 also indicate that there is a significant relationship between confidence of lane choice and correctness of lane choice. That is, the more confident an individual is of his or her lane choices, the more apt he or she is to be correct. Moreover, as part C of Table 4 shows, if an individual prefers diagrammatic signs, he or she is also confident of his or her responses to them and this is independent of practice condition. However, this relationship does not appear to hold for conventional signs.

The subjects also clearly preferred conventional signs over diagrammatic signs $[t_{(26\,df),} = 47.91$, $p < 0.0005]$. The mean percentage of preferences for each interchange is given in Table 5. Reference to Table 4, part B, indicates that the subjects were more often correct for signs that they preferred. These results tend to corroborate the preference findings of Gordon (2).

Comparisons of latency data were possible only for the Gordon (2) and current data. The comparisons are summarized for overall interchanges in Table 6 and for the exit point within each interchange in Table 7. It can be observed from Table 6 that, in two out of four comparisons with the Gordon (2) data, the mean latencies obtained in the two studies were significantly different from one another. The effects were restricted to the practice condition and, in general, mean latencies were higher in the current investigation than in the Gordon study.

Although the studies differed significantly in magnitude of mean latencies, the pattern of means is quite similar. That is, response latencies to conventional signs are lower than those to diagrammatic signs. Thus, latency data of the current investigation tend to support the earlier findings of Gordon. This sort of interpretation is supported by an examination of Table 7 where a similar pattern of results was obtained for latency at the exit point. We conclude from these comparisons that the results obtained in the current study are essentially of the same nature as those obtained in the Gordon (2) study.

In an overall analysis of variance of latency data, the main effects of type of sign $[F_{(1,116)} = 80.41$, $p < 0.001]$ and type of interchange $[F_{(5,580)} = 8.89$, $p < 0.001]$ were found to be significant. The former effect is based on the fact that the mean latency of response to conventional signs (2.8125) was significantly faster than the mean latency to diagrammatic signs (3.2075). The latter effect is due of course to the fact that latencies differed significantly as a function of the type of interchange employed. Surprisingly, the interchange that produced the longest overall mean latency (3.115) was the major fork. Although this finding seems to be consistent with other studies, it is nevertheless puzzling because this type of interchange is neither the most geometrically complex nor the one that requires an extreme amount of explanatory information on guide signs. Intuitively, it would also appear to be the most easily understood of the diagrammatic signs. This point would seem to be verified by the fact that the overall mean percentage of correct lane choices for this interchange was the highest (94.37 by Gordon criteria) of all those obtained in this study. One significant difference between this interchange and all others employed in the study was that the major fork requires a driver to make a judgment or a direction change at highway speeds and all the others require an exit judgment that would involve slowing the vehicle.

Several other significant latency effects were found in this overall analysis. Verbal responses were found to be significantly faster than key-pressing responses $[F_{(1,116)} = 14.63$, $p < 0.001]$. The magnitude of this difference was approximately 0.50 s. Practice $[F_{(5,580)} = 8.55$, $p < 0.001]$, type of response $[F_{(5,580)} = 4.52$, $p < 0.001]$, and type of sign $[F_{(5,58)} = 13.71$, $p < 0.001]$ also were found to interact significantly with type of interchange. The basis for the interaction with practice was that, in several instances, mean latencies increased when practice was given and in others it decreased. We suggest that this effect is both uninterpretable and of little practical significance. A similar analysis can be made for the interaction of type of response with type of interchange. The type of sign by interchange interaction is due primarily to two interchanges: one in which the mean latencies for conventional and diagrammatic signs tend to converge toward one another and a second in which they tend to diverge. A similar analysis of variance was done on the latencies at the exit point only. The results of this analysis were essentially the same as the analysis on overall latencies.

Analyses of variance were also performed on the latencies to individual intersections. The major portion of the analyses duplicate the findings of the overall analyses with respect to practice, type of sign, and type

Table 1. Comparative analyses of lane choice data.

	No Practice Group						Practice Group					
	Conventional Sign			Diagrammatic Sign			Conventional Sign			Diagrammatic Sign		
Type of Interchange	A	B	C	A	B	C	A	B	C	A	B	C
Lane drop	<0.01	NS	NS	NS	NS	NS	—	NS	NS	—	NS	NS
Multiple-split ramp	NS	NS	<0.001	<0.05	<0.05	NS	—	NS	<0.001	—	NS	NS
Left ramp downstream from right ramp	NS	NS	NS	NS	NS	<0.001	—	NS	<0.001	—	NS	<0.05
Two right ramps in quick succession	NS	NS	<0.001	NS	NS	<0.001	—	<0.05	<0.001	—	NS	<0.001
Major fork	<0.05	NS	<0.001	NS	NS	<0.001	—	NS	<0.01	—	NS	NS
Cloverleaf	NS	NS	<0.001	<0.01	NS	<0.001	—	NS	<0.05	—	NS	<0.01

Note: A = Berger study versus current study by Berger criteria; B = Gordon study versus current study by Gordon criteria; C = current study by Berger criteria versus Gordon criteria; and NS = not significant.

Table 2. Correctness of lane choice at exit point.

		Conventional Sign			Diagrammatic Sign			
Interchange	Group	Number Correct	Number Incorrect	Proportion Correct[a]	Number Correct	Number Incorrect	Proportion Correct[b]	Significant Difference
1	No practice	118	2	0.983	115	5	0.958	NS
	Practice	60	0	1.000	60	0	1.000	NS
4N	No practice	113	7	0.942	113	7	0.942	NS
	Practice	60	0	1.000	60	0	1.000	NS
4E	No practice	114	6	0.950	96	24	0.800	—[c]
	Practice	56	4	0.933	54	6	0.900	NS
16	No practice	113	7	0.942	109	11	0.908	NS
	Practice	60	0	1.000	56	4	0.933	—[c]
17	No practice	113	7	0.942	109	11	0.908	NS
	Practice	58	2	0.967	55	5	0.917	NS
29	No practice	115	5	0.958	107	13	0.892	NS
	Practice	60	0	1.000	51	9	0.850	—[c]
Total	No practice	686	34	0.953	649	71	0.901	
	Practice	354	6	0.983	336	24	0.933	

[a] Mean proportion correct = 0.96. [b] Mean proportion correct = 0.91. [c] 0.05 significance level.

Table 3. Comparisons of confidence of responses.

	No Practice Group			Practice Group		
Type of Interchange	A	B	C	A	B	C
Lane drop	NS	NS	<0.025	—	—	<0.05
Multiple-split ramp	NS	NS	<0.05	—	—	<0.05
Left ramp downstream from right ramp	NS	NS	NS	NS	NS	<0.005
Two right ramps in quick succession	NS	NS	<0.05	—	—	<0.05
Major fork	NS	NS	<0.005	—	—	<0.01
Cloverleaf	<0.05	NS	NS	—	—	<0.05

Note: A = Berger conventional versus current study conventional; B = Berger diagrammatic versus current study diagrammatic; C = current study conventional versus current study diagrammatic; and NS = not significant.

Table 4. χ^2 tests of variable interrelationships.

Part	Group	Sign	χ^2	df	p	C	N
A	No practice	Conventional	67.68	3	0.001	0.6004	120
		Diagrammatic	127.10	3	0.001	0.7130	120
	Practice	Conventional	38.807	3	0.001	0.6266	60
		Diagrammatic	75.97	2	0.001	0.7434	60
B[a]	No practice	Conventional	11.024	1	0.001	0.2685	120
		Diagrammatic	159.86	1	0.001	0.7557	120
	Practice	Conventional	2.002	1	0.250[b]	0.1794	60
		Diagrammatic	11.777	1	0.001	0.4049	60
C[a]	No practice	Conventional	4.86	3	0.250[b]	0.1972	120
		Diagrammatic	53.10	3	0.001	0.5538	120
	Practice	Conventional	0.739	3	0.500[b]	0.1100	60
		Diagrammatic	36.897	3	0.001	0.6170	60

Note: Part A contains tests for correctness of lane choice to conventional and diagrammatic sign by degree of confidence in lane choice; part B contains tests for correctness of lane choice to conventional and diagrammatic signs by preference for conventional or diagrammatic signs; and part C contains tests for preference for conventional or diagrammatic signs by degree of confidence in lane choice.

[a] Preference for slide 1 for interchanges 4N and 17 not included. [b] Not significant.

Table 5. Mean percentage of preferences for conventional and diagrammatic signs.

Interchange	Conventional Sign	Diagrammatic Sign
1	69.17	30.83
4E	67.07	32.93
4N	76.40	23.60
16	78.48	21.51
17	62.90	37.10
29	84.05	15.95
Exit point only	75.15	24.85

of response. However, latencies also were found to differ significantly as a function of their position in the entire sequence of signs. In general, the initial latency is relatively low. Latencies in the middle of the sequence have a tendency to be greater than the initial sign latency and are followed by a general decline in latencies near the end of the sequence. This pattern seems to reflect the information-processing behavior of the driver who is extracting information from highway guide signs. It would seem logical to assume that the initial sign in sequence is simply an announcement of subsequent information tasks that will be demanded; consequently, it required little processing. This would be reflected in relatively low latencies. The signs in the middle of a sequence are those that communicate information relevant to the driving task and thus require somewhat longer responses because of the information processing required. The final sign in the sequence is a simple announcement that emphasizes more the detection of a point of action for which a decision has previously been made than any additional information processing.

The final set of analyses dealing with latencies demonstrates the relationship between latency and the two dependent measures of correctness of lane choice and confidence of lane choice. The average correlation between confidence and latency was -0.79, $p < 0.001$, which suggests that the more confident the individual is of his or her judgment, the more quickly he or she will re-

Table 6. Comparative data on mean latency of response in seconds.

Group	Type of Sign	Study	N	Interchange						Average	Significance Test
				1	4E	4N	16	17	29		
No practice	Conventional	Gordon	60	3.18	3.19	3.04	3.22	3.15	2.91	3.12	NS
		Current	60	3.14	2.89	3.01	3.14	3.39	2.74	3.05	NS
	Diagrammatic	Gordon	60	3.80	3.33	3.46	3.59	3.32	3.51	3.50	NS
		Current	60	3.54	3.21	3.18	3.55	3.64	3.50	3.44	NS
Practice	Conventional	Gordon	60	2.60	2.68	2.56	2.70	2.66	2.48	2.61	<0.005
		Current	60	2.78	2.98	3.10	3.24	3.25	2.89	3.04	<0.005
	Diagrammatic	Gordon	60	2.92	2.81	2.83	2.90	2.83	3.16	2.91	<0.005
		Current	60	3.20	3.50	3.36	3.61	3.59	3.78	3.51	<0.005

Note: NS = not significant.

Table 7. Comparative data on mean latency at exit point in seconds.

Group	Type of Sign	Study	Interchange						$\bar{x}$	Significance Test Between Means
			1	4E	4N	16	17	29		
No practice	Conventional	Gordon	1.94	2.57	2.47	1.86	3.20	1.81	2.31	NS
		Current (key)	2.14	2.27	2.65	1.95	3.32	2.07	2.40	NS
	Diagrammatic	Gordon	2.37	2.96	3.05	2.12	2.24	2.57	2.55	<0.05
		Current (key)	2.18	2.62	2.98	2.28	3.63	2.99	2.78	<0.05
Practice	Conventional	Gordon	1.64	2.32	2.19	1.67	2.78	1.57	2.03	<0.005
		Current (key)	1.92	2.69	2.67	1.88	3.64	2.03	2.47	<0.005
	Diagrammatic	Gordon	1.87	2.69	2.43	1.88	2.83	2.29	2.33	<0.0005
		Current (key)	1.95	3.35	3.30	2.48	3.78	3.54	3.07	<0.0005

Note: NS = not significant.

Table 8. Postexperimental interview comments.

Frequency of Comment	Comment
61	Diagrammatic sign too confusing, too long, or difficult to understand
30	Too much information or too many directions on diagrammatic signs
28	Prefer conventional signs with small arrow pointing to exit lane
9	Diagrammatic signs as clear as conventional signs with practice
5	Prefer long curved arrows at exit point if they are not too complicated
3	Sign preceding exit should include only distance to exit and sign at exit should indicate where to go
2	Sign preceding exit should be diagrammatic and sign near exit should be conventional
1	With multiple arrows on signs information is needed to indicate which lane goes with each arrow

spond. The average correlation between correctness of lane choices and latencies of response was -0.43, $p < 0.02$, which suggests that individuals respond more quickly to stimuli on which they have made a correct judgment. Clearly, these findings demonstrate the sensitivity of measures of latency to other variables that play an important role in the analysis of sign reading behavior.

In an analysis of the absolute number of lane changes (position change between lanes) across interchanges, no significant difference [$t_{(5\,df)}$ - 0.77] was found between conventional ($\bar{x}$ = 195.17) and diagrammatic ($\bar{x}$ = 189.17) signs, but such changes decreased as a function of practice. Generally, the total number of lane changes was lower for practice conditions (124.83) than for no practice conditions (259.50).

Finally, at the end of the experimental session, each subject was invited to make whatever evaluative statement he or she desired with respect to the advantages or disadvantages of conventional or diagrammatic signs. These comments are summarized in Table 8. The categories are nonindependent; that is, one person may be included in a number of categories. The experimenter collapsed comments into categories with essentially synonymous meaning. This classification is arbitrary, but an examination of the comments should give the researcher some insight into the user's view of guide sign problems. This view, freely translated, is that users require a logical sequence of information that is presented with a minimum of complexity and that is specifically relevant to the particular type of decision required for that choice point.

DISCUSSION OF RESULTS

As previously stated, the purpose of this experiment was to assess the differences in methodology and results obtained in the Berger (1) and Gordon (2) studies of diagrammatic signs. The specific goal was the development of a reliable laboratory method for the evaluation of highway guide signs. We believe that this experiment has accomplished these goals. The analysis of correctness of lane choices demonstrated that the results of the current investigation could be made to match the results of the other two studies depending on the criteria employed. When the effects of employing the different criteria are analyzed, the conflicting results of the earlier studies are also obtained. Obviously, the conclusion to be reached from this observation is that either of the two laboratory methods can produce reliable data but that validity requires an independent field check because the data analyses did differ significantly.

It should be pointed out that we prefer the methodology employed by Gordon, with our equipment modification, because of its relative simplicity and ease of obtaining data and because of its mobility. With a minimum of equipment expense and a small amount of training in the procedural aspects of the research, any agency can carry out an evaluative guide signing project before significant economic commitments are made. This would seem to be a reasonable alternative to current practices in guide sign decision making.

Again no overall differences were found in correctness of lane choices to conventional or diagrammatic guide signs. Conventional guide signs were preferred over diagrammatic guide signs. Subjects also seemed to be more confident of their responses to conventional guide signs and on the whole responded more quickly to them. Thus it would appear that, for the particular interchanges employed in this investigation, diagrammatic guides would produce no significant benefits over conventional guide signs. However, in our opinion, the stimuli employed in this study, which were identical to those employed in earlier investigations, were not of a particularly high quality. This is to be expected in pioneering research because of a lack of guidelines. It is anticipated that with more tested and trustworthy methodology, and with a selection of sites that have unexpected visual or geometric components, diagrammatic signs may prove to be beneficial.

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Diversionary Signing Content and Driver Behavior

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The purpose of this study was to investigate the influence of certain diversionary highway guide sign variables on the driver's ability to process and interpret directional information. The work was conducted under controlled field conditions by using an instrumented vehicle with an in-vehicle sign simulation device. The primary independent variables consisted of message content, message severity, and message redundancy. Driver route choice behavior, information interpretation time, message preference, and interrogative responses concerning route choice decisions were the measured dependent variables in the study. Results indicated that the frequency of bypass choice was related to the severity of the message on the advisory sign and the type of information. Higher severity messages and time delay information were associated with decisions to bypass the main route. The advisory signs used in the study were interpreted as being directive, especially when congestion information was presented. Congestion information was also more familiar to the subjects and was associated with quicker information interpretation time, indicating that decisions were quicker and easier with congestion information.

Advanced forms of electronic surveillance and control systems are currently being developed to optimize traffic flow in and between cities. Variable-message signs constitute an important element in these control systems. The variable-message sign can be used to provide motorists with updated information about prevailing traffic conditions and advise them of an appropriate course of action. In other words, real-time highway information can be communicated to drivers so that they can plan ahead for safer and more efficient travel.

An effective real-time highway information system must be human engineered to ensure that motorists can understand the advisory messages within the time the signs are in view. The success of the system requires that display features such as information content and redundancy be designed as effectively as possible. To achieve this goal, human factors research is now in progress under the Federal Highway Administration's Federally Coordinated Program Project 2-C, Requirements for Alternate Routing to Distribute Traffic Between and Around Cities. The work reported here was conducted as a part of this research.

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METHOD

Subjects

The subjects tested in the study consisted of 60 paid volunteers. They were assigned randomly to three test groups; there was some matching between groups on the basis of age and sex. The mean age of the 31 males and 29 females in the sample was 22.3 years. Each subject possessed a valid driver's license and demonstrated driving competence with the instrumented vehicle before actual roadway tests.

Instrumented Vehicle

An instrumented 1970 Chrysler was used to provide an in-vehicle simulation of highway signs and to record the response and driving performance of drivers under the influence of the experimental signs.

Experimental sign displays in the form of 35-mm color transparencies were projected on a 27 by 9-cm (10.75 by 3.5-in) screen mounted on the inside of the upper right portion of the driver's windshield (Figure 1). The slide projector was mounted on a platform in the back seat behind the driver's right shoulder.

The vehicle's horn button located in the rim of the steering wheel was wired as a special response button. It was used by the subject to terminate sign presentations.

The experimenter's control panel was located in the

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back seat of the vehicle. A control button was used by the experimenter to present the test signs to the subject. A meter readout of accumulated distance values, zeroed at the beginning of the test route, was used to control the location of the sign presentation points along the road.

An on-board audio recorder was used to record verbal responses made by the subject during the test drive and during the debriefing interview.

Test Route

The test route was located on a 15-km (9-mile), four-lane divided section of the Baltimore-Washington Parkway between the Beltsville and Md-175 interchanges. A total of six interchanges were used as experimental diversion decision points on the test route.

All test drives were conducted in the fall and winter of 1974 during daylight off-peak traffic periods under dry pavement conditions. The visual environment along most of the test route was homogeneous in that the highway was continuously bordered by a heavy tree line. Furthermore, the geometrics of the test interchanges were similar, and horizontal curvature was minimal. The first three interchanges were negotiated in the northbound direction, and the last three interchanges were approached from the southbound direction.

Independent Variables

The independent variables were message content, message severity, and message redundancy. The message content variable was represented by three independent groups each of which contained 20 subjects. Message severity and message redundancy were represented by three and two levels respectively.

Dependent Variables and Measures

The dependent variables and measures considered were

1. Route choice behavior. The test subject's route choice at each of the six test interchanges was recorded. Drivers indicated their route choice by actually performing an exiting maneuver or by continuing to drive on the parkway.
2. Information interpretation time (IIT). Subjects were instructed to press the button on the steering wheel rim as soon as they understood the information on the sign. The latency between the onset of the stimulus presentation and the subject's response was recorded to the nearest 0.01 s and was called information interpretation time (IIT).
3. Interrogative responses. As soon as a driver executed his or her decision at a given interchange, he or she was orally interrogated about the reasons for his or her decision. The questions were open ended and attempted to probe into the driver's decision process associated with the route choice.
4. Sign preference. In the debriefing at the conclusion of the test drive, the subjects were shown pictures of signs differing in message content and severity and were asked to rank them according to their preference.

Experimental Signs

Drivers in the study experienced simulated real-time variable-message signs interspersed with simulated standard directional guide signs at six interchanges along the test route. Three types of variable-message content were tested: (a) time delay information, (b) level of congestion information, and (c) incident description information. Table 1 gives a description of the information content displayed on the advisory signs at the six choice points in the experiment.

The physical characteristics of the signs other than those manipulated as independent variables were held constant. Letter style and capitalization conformed to existing freeway and expressway standards as described in the Manual on Uniform Traffic Control Devices (5). Color also conformed to these standards. The place names on the guide signs all had seven letters and referred to locally fictitious places. The advisory sign displays simulated rotating drum signs with four changeable message panels (Figure 2). The messages on the first, second, and fourth panels from the top of the sign were held constant throughout the study. The message on the third panel represented the content variable. The background color was always green for the first and second panels and red for the third and fourth panels. All of the information displays simulated freeway overhead signs. The experimental signing presented at test interchange 2 is also shown in Figure 2. The signs in Figure 2 were tested with the delay time group. Those shown in the offset of Figure 2 were tested with the level of congestion group and incident description group respectively. The variable-message advisory sign was presented to the test driver 2.4 km (1.5 miles) before the interchange. The advance guide sign and exit direction sign were shown 1.6 km and 0.8 km (1 mile and 0.5 mile) respectively before the interchange. The exit sign was presented approximately 150 m (500 ft) before the exit ramp.

At the test interchanges where the advisory sign was presented twice (interchanges 1, 3, and 5), the second advisory sign presentation was positioned between the advance and exit direction guide signs. Otherwise, the rest of the signing in the sequence remained the same.

Procedure

Volunteer subjects reported to a mobile base laboratory located near the beginning of the test route. After the subjects completed a brief biographical questionnaire and were examined for vision defects, they were seated behind the wheel of the instrumented vehicle and read a set of instructions.

After reading the instructions, the experimenter guided the subjects on a practice route to familiarize them with the driving characteristics of the vehicle. The subjects were also given practice with the in-vehicle sign display and the response button on the steering wheel rim. On the practice and test routes, all sign presentations were initiated by the experimenter and were cued by a distance readout meter. Subjects were instructed to press the response button as soon as they understood the information on the sign. As soon as the subjects indicated that they felt confident driving the vehicle and understood the test procedures, their trip on the test route began.

Before entering the ramp to the test route, the subjects were given a fictitious route number for the roadway that they would travel and a fictitious place name for their destination. The advisory and guide sign displays previously described were then presented to the subjects as they traveled the test route. The subjects were instructed to ignore the real guide signs along the test route and to respond to only the signs simulated inside the car. However, they were told to obey all on-road regulatory traffic signs such as speed limit and yield signs. The test route was open to normal traffic operations and the subjects had to cope with driving in real traffic as they carried out their information processing and decision making.

On approaching each of the six test interchanges along the test route, the subjects processed the information on each of the signs and made a decision either to continue on the road on which they were traveling or to exit. Immediately after they either performed the exit maneuver or continued driving through the interchange, the experimenter asked the subjects to state the reasons for their decision and recorded their response on audio tape. A new fictitious destination and a new route number were given to the subjects before each of the six test interchanges. At interchanges where the subjects exited, the experimenter verbally directed them back onto the main route.

After completing the test drive, the subjects were directed back to the base laboratory for a debriefing that assessed their subjective reaction to the experiment, their previous driving experience on the test route, and their preference ranking of the three types of message content studied in the experiment.

RESULTS

Route Choice

Overall, the subjects took the exit to bypass the main route approximately two-thirds of the time. Table 2 gives the frequency of exiting at each of the six interchanges. There was a statistically significant relationship between the level of message severity and the frequency of exiting. Higher levels of severity were associated with higher exit frequencies ($\chi^2 = 102.0$, $p < 0.001$):

Route Choice	Low	Moderate	High	Total
Exit	39	80	114	233
Continue	81	40	6	127
Total	120	120	120	360

Approximately one-third of the route choices under the low message severity condition, two-thirds of the choices

Figure 1. Driver's view of in-vehicle display.

Figure 2. Typical signing presented before an exit.

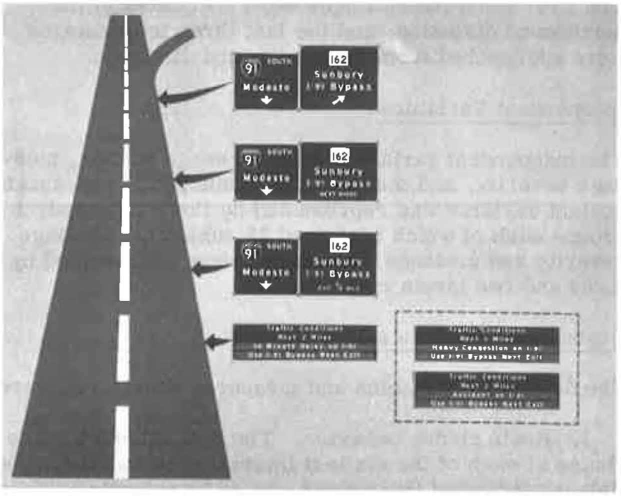


Table 1. Information content on variable-message signs.

	Time Descriptor		Congestion Descriptor		Incident Descriptor	
Interchange	Time Delay (min)	Redundancy[a]	Congestion Level	Redundancy[a]	Type of Incident	Redundancy[a]
1	20	2	Moderate	2	Disabled vehicle	2
2	30	1	Heavy	1	Truck overturned	1
3	10	2	Light	2	Grass cutting operations	2
4	10	1	Light	1	Slow vehicles	1
5	30	2	Heavy	2	Accident	2
6	20	1	Moderate	1	Men working	1

[a] 1 = one variable message advisory sign. 2 = two variable message advisory signs.

Table 2. Frequency of exiting by interchange and advisory sign content.

	Interchange Variables			Number of Exits by Advisory Sign Content			
Interchange	Message Severity	Redundancy Present	Direction of Travel	Time	Incident	Congestion	Total
1	Moderate	Yes	North	17	14	12	43
2	High	No	North	19	17	19	55
3	Low	Yes	North	9	5	3	17
4	Low	No	South	9	8	5	22
5	High	Yes	South	20	19	20	59
6	Moderate	No	South	17	10	10	37

Note: Highest possible number of exits per cell is 20.

under moderate severity, and almost all of the choices under high severity were decisions to exit.

Exit frequency was also significantly affected by type of information contained. More exits were made by those subjects in the time delay group than by those in either the incident or congestion group ($\chi^2 = 10.02$, $p < 0.01$):

Route Choice	Congestion	Incident	Time	Total
Exit	69	73	91	233
Continue	51	47	29	127
Total	120	120	120	360

Although both type of message content and level of severity had a significant effect on the subject's exiting behavior, a statistical test of the interaction between these two variables failed to show significance ($p \cong 0.4$, χ^2).

No apparent differences were found between the frequency of exits made on the first half of the test route and the frequency of exits made on the second half (north and south directions respectively) or the frequency of exits at those interchanges where the advisory sign was repeated (redundancy present) and the frequency of exits at those interchanges where the advisory sign was only presented once.

In general, the results suggest that motorists will exhibit a differential exiting response as a function of diversionary signing message content. The absolute exiting values for the different signing conditions should be considered tenuous because the subject sample was small and made up of college students. However, the relative difference between the conditions may be consistent with the motoring public at large.

Reasons for Decisions

Responses to the open-ended question, What was the reason for your choice? were classified into one of four categories:

1. Estimative. This type of reason involved some sort of expressed quantification or estimate of the amount of delay suggested by the advisory sign.
2. Directive. A directive kind of reason suggested that the information on the sign implied a command to act. No other reason was given.
3. Hypothetical. This category pertained to reasons that derived from subjects' imagining what the situation ahead might be as suggested by the sign. Elements of past experiences were brought to bear.
4. Nonspecific. None of the previous reasons applied.

As might be expected, a significant association was found between the type of reason and the type of route choice (exit from or continue on main route). The following tabulation shows this association ($\chi^2 = 60.5$, $p = 0.001$):

Route Choice	Hypothetical	Estimative	Directive	Nonspecific	Total
Exit	57	52	119	5	233
Continue	67	35	15	10	127
Total	124	87	134	15	360

Directive reasons were strongly associated with exit choices. Hypothetical reasons, on the other hand, were more associated with choices to continue than with choices to exit. The distribution of choices associated with estimative reasons was similar to the overall distribution of route choices.

A significant relationship was also found between type of reason and type of information. In the following tabulation, one can see that subjects in the incident descriptor group tended to give hypothetical reasons ($\chi^2 = 76.6$, $p = 0.001$):

Type of Information	Hypothetical	Estimative	Directive	Nonspecific	Total
Congestion	30	21	58	11	120
Incident	71	15	32	2	120
Time	23	51	44	2	120
Total	124	87	134	15	360

Subjects in the congestion level group tended to give directive reasons, and subjects in the time delay group tended to give estimative reasons.

The relatively high proportion of drivers using directive decision reasoning is a particularly interesting finding. Clearly, drivers who gave directive reasons keyed on the bottom line of the advisory sign that said USE I-XX BYPASS NEXT EXIT and interpreted it as a command. This probably accounts for the higher than expected number of exits (39 out of a possible 120) recorded under the low message severity conditions given in the tabulation on levels of severity.

Information Interpretation Time

IIT is the length of time required by the driver to read and interpret the sign information presented on the screen (1). IIT was recorded automatically for each of the 27 signs the subject viewed at the six interchanges on the test route.

Analysis of variance (ANOVA) was used to determine the effects of the independent variables on IIT. A nested, 5-variable factorial analysis was chosen. The independent variables were message content C, subjects nested within content, level of message severity S, direction of travel D, and type of sign T. The levels of each of these variables were 3, 20, 3, 2, and 4 respectively. The variable of direction was interpreted as an indicator of practice effects because the first half of the test occurred on the northbound section of the route and the second half occurred on the southbound section.

Because IIT is a type of response latency measure, the distribution of the scores was positively skewed. A logarithmic transformation of the form $X = \log (x + 1)$ produced approximately normal distributions and was used for the ANOVA. The ANOVA source table is given in Table 3. All the main effects were significant at the 5 percent level of confidence or better. Two-variable interactions that were significant were ST and DT. A significant three-variable interaction was found among S, D, and T. This three-way interaction indicates that one or several individual slides were associated with a substantially higher or lower IIT score across content and subjects.

The untransformed cell means for each level of the main effects are shown in Figure 3. Individual comparisons between the cell means were made by using the Tukey A test, which provided a simultaneous test of all possible differences between the cell means (2, p. 87). For the Tukey test, the means and variances from the transformed IIT values were used. The results of these comparisons are also shown in Figure 3.

Based on the significant comparisons, the following main effect results were found to be significant. Among the three content conditions, the shortest IIT was found with congestion information. Of the three levels of message severity, the shortest IIT was found for high severity. With the main effect of direction, the south portion of the route, which was the last half of the test, was associated with shorter IITs.

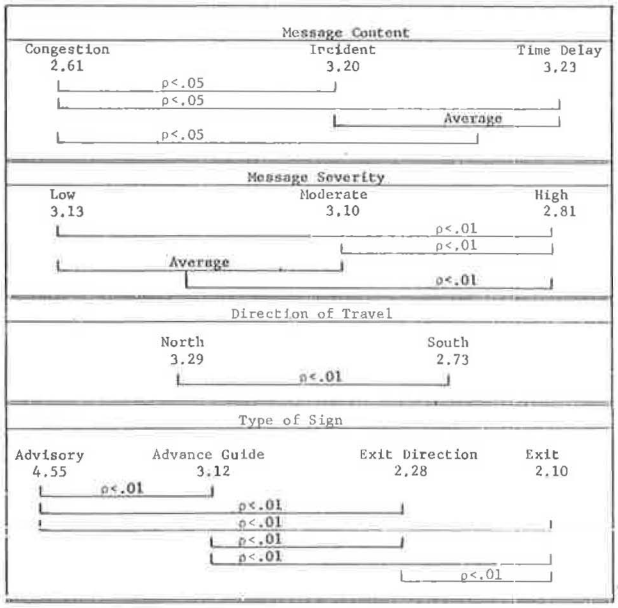
Finally, the type of sign had a substantial effect on IIT. Generally, there was a significant decrease in IIT from the advisory sign, the first sign for a particular interchange, to the exit sign, the last sign before the route decision was made. The largest difference between any two adjacent signs was that between the advisory sign and the advance guide sign; the latter always followed the advisory sign and was the first in a series of three guide signs.

Table 3. ANOVA source table for IIT.

Source	df	F	Source	df	F
C	2	3.9398^a	ST	6	14.1609^b
S	2	10.8401^b	DT	3	5.7643^b
D	1	78.0509^b	CSD	4	0.7042
T	3	345.6453^b	CST	12	1.0259
CS	4	0.8696	CDT	6	1.3126
CD	2	0.2567	SDT	6	14.5968^b
SD	2	2.1503	CSDT	12	1.0986
CT	6	1.3506			

$^a p < 0.05$. $^b p < 0.01$.

Figure 3. Significant comparisons of IIT means in seconds for ANOVA main effects.



The decrease in IIT from the first to the last sign within each interchange could be interpreted as a practice effect. This is probably the case with the three guide signs, which are similar in format and content. However, the large difference between the advisory and the advance guide signs is due to the type of sign rather than to practice. The untransformed mean for the advisory signs was 4.55 s, 1.43 s longer than the mean for the advance guide signs. This is a long IIT for a freeway sign, too long when one considers that, at 88 km/h (55 mph), a motorist will travel 110 m (370 ft) in 4.5 s. Research is currently under way into methods of more quickly conveying the information on the advisory sign to motorists. One method being tested is putting the description of the traffic situation (HEAVY CONGESTION ON I-XX) and the advice on a course of action (USE I-XX BYPASS NEXT EXIT) on separate signs. Another method being tested is conveying the descriptive information with a simulated overhead sign and the advisory information with a radio message.

The influence of content on IIT turned out to be more pervasive than expected. It should be kept in mind that the guide signs remained constant across the main effect of the content. And yet, as shown in Figure 4, the shorter IIT values associated with congestion information were found not only with the advisory but also with the three successive guide signs. This may be an illustration of how an upstream sign can affect the IIT of subsequent signs downstream, a result previously reported by Mast, Chernisky, and Hooper (1). The low IIT mean for the congestion message content group on the advisory sign is consistent with the finding that there was a disproportionately large amount of directive reasoning elicited by congestion level information as shown by the tabulation on type of information. It is reasonable that directive reasoning is associated with faster IIT in comparison with estimative and hypothetical reasoning because more cognitive processing time is involved with the latter two types.

As shown by the data given in Table 3, there were three statistically significant interactions on the IIT measure: (a) level of message severity by type of sign, (b) travel direction by type of sign, and (c) level of message severity by direction of travel by type of sign. These interactions were primarily if not solely due to a longer IIT for a three-panel exit sign located at the third interchange (see Figure 5). The mean IIT for this sign across content and subjects (nested in content) was 3.41 s. The

Figure 4. Information interpretation times for each type of sign within each information content group.

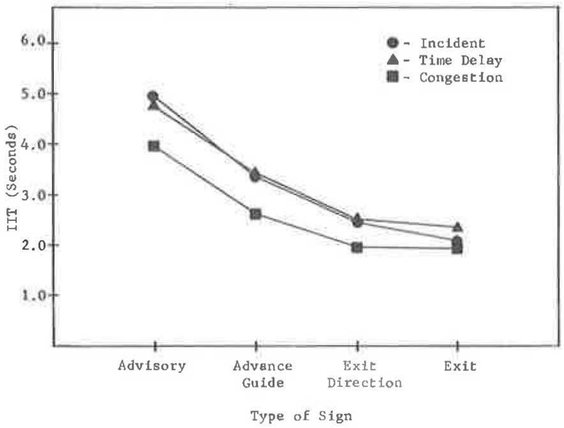
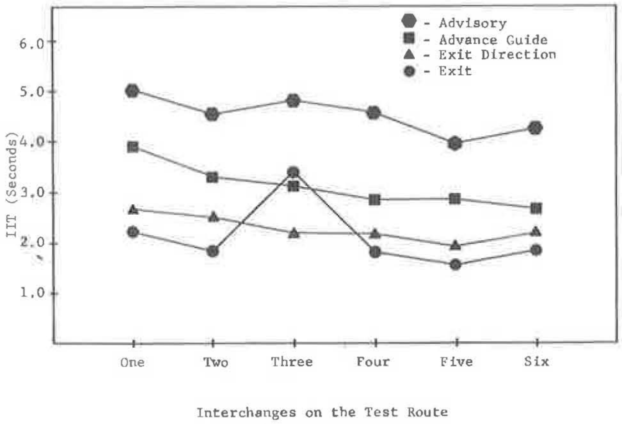


Figure 5. Information interpretation times for each type of sign presented before each interchange.



overall mean for the two-panel exit signs was 1.84 s, which indicates that the additional panel added more than 1 s to the information processing time.

Message Preference

In the debriefing questionnaire, amount of time delay was preferred over congestion or incident information (all values are average preference ranking of message content within a severity level along a scale of 1 to 3 where 1 represents the most preferred type of message):

Type of Information	Message Severity		
	Low	Moderate	High
Time delay	1.3	1.4	1.5
Incident	2.6	2.5	2.2
Congestion	2.0	2.2	2.3

The finding that time delay information is preferred by drivers over incident information is consistent with results reported by Case, Hulbert, and Beers (3) and Beers (4). However, in this study, subjects often qualified their preference for time delay information by indicating that it must be accurate. Level of congestion was the most familiar type of information, which may be another reason why it was associated with shorter IITs. The main disadvantage to congestion information that was reported was that it was subjective. With regard to incident information, the consensus of opinion was that it satisfied the curiosity of the driver but relayed no information about how the particular incident was affecting the flow of traffic.

CONCLUSIONS

This study examined several traffic advisory sign variables that influence the decision whether to take an alternate route around a traffic delay. Three aspects of this type of decision were of primary interest: (a) what the decision was with different types of messages; (b) the reasons for the decisions; and (c) how long it takes to process the information on the signs that, in a sense, set up the decision. The study showed that a bypass route is more often chosen when the advisory signs indicate more serious situations on the primary route, a not surprising finding. The relationship between advisory sign messages and exiting behavior should be checked in an operational setting. If stable results can be validated in the field, they will be an effective guide for the real-time operation of traffic advisory signs.

The reasons that subjects gave for choosing or not choosing the bypass provided valuable insights into this decision process. The last panel on the advisory sign, which said USE I-XX BYPASS NEXT EXIT, was interpreted as a directive message and probably influenced many decisions to exit when the description of the situation hardly warranted bypassing.

Congestion information promoted directive reasoning perhaps because congestion level descriptors offered little objective information about the traffic situation and subjects had to rely on the advice to take the bypass. Time delay information was associated with estimative reasons probably because it provided an objective reference against which the likely delay on a bypass route could be evaluated. The decisions for incident information were often based on hypothetical reasons, which means that the subject made his or her decision based on prior experience. One would expect that there would be more random variation in decisions made on the basis of incident information simply because individual experiences with incidents vary greatly.

The third aspect of the decision process that was evaluated was the time required to process the information setting up the choice. The measure used, IIT, has elements of information processing and decision making and is not simply a function of reading time. The evidence for the decision-making component of IIT derives from the fact that some signs took significantly longer to process than others that, except for a word or two, were identical. Further evidence is indicated from the finding that congestion information, which was most familiar to the subjects and which promoted directive reasons, was associated with a shorter IIT not only with the advisory sign but also with the following guide signs. The guide signs were not changed from one content condition to the next; each presented the choice situation. The conclusion to be drawn is that congestion information promoted quicker and perhaps easier decisions.

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Evaluation of Signing to Warn of Wet Weather Skidding Hazard

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This field study examined driver responses to the potential skidding hazard of wet pavements subjected to high frictional driving demands. Study objectives were to examine motorists' general awareness of the hazard and to assess the relative effectiveness of various signing treatments that warn of the hazard. Measures of signing effectiveness were motorists' speeds at critical curve locations and questionnaire responses regarding motorists' observations and interpretations of the signs. Three curved highway sections were treated with five experimental signing conditions. Variations on the slippery when wet symbolic sign ranged from its use by itself to increasing levels of specificity and conspicuity to its use with flashing lights and an advisory speed limit. Experimental signing conditions incorporating flashing lights were effective at reducing highest quartile mean speeds below the critical safe wet pavement speed based on roadway geometry and surface conditions. Signing without flashing lights was not shown to be effective. Those questioned saw and properly interpreted the more conspicuous warning signs. Motorists' cues of potential hazard were observed to be roadway curvature and superelevation, behavior of other motorists, appearance of pavement surface, ambient conditions, known accident history of site, and presence of the warning sign. About 1 percent of the interviewed motorists cited the warning sign as their cue of potential skidding hazard.

The development of human factors techniques aimed at the reduction of skidding accidents is long overdue. For more than 2 decades, highway researchers have directed their efforts almost exclusively to studying tire-pavement interactive phenomena. Concurrently, developments of the automotive industry have been primarily limited to radial tires and antiskid braking devices. No systematic effort to examine broadly based causes of skidding accidents has ever been documented. Most sorely neglected is the cause of all skidding accidents—the driver.

Investigation of driver reaction to environmental elements that affect the operation of the vehicle is a necessary approach toward the prevention of skidding accidents. This follows from the fact that skidding accidents generally occur because the motorist is unaware of an existing threat. Therefore, this research was undertaken to seek an effective means of warning drivers of the potential hazard.

The objective of this study was to assess the effectiveness of signing to warn of the wet pavement skidding hazard. Various levels of signing were achieved through the use of flashing lights and messages of varying specificity. Measures of signing effectiveness were vehicle speeds at critical curve locations and driver questionnaire responses. In addition, driver cues of the hazard were determined from the questionnaire.

BACKGROUND

Driver awareness of skidding accident potential remains virtually undocumented. However, one study undertaken in the Netherlands did examine steering and driver detection of skidding (1). A systems approach to identify factors affecting the skidding accident noted that the role of drivers is difficult to determine because of inherent differences in psychological and physiological conditions (2). Yet these conditions do affect accident occurrence (3), and their effects are transitory (4).

Hankins and others identified components of the driver's communication system relevant to skidding accidents (2). In addition to traffic signs, signals, and markings, certain geometric features (curvature, guardrails, and delineation devices) were noted to have the potential of communicating a skid hazard, yet the relative effect on the motorist of these communicative devices is unknown. Sparse documentation exists regarding the effects of curvature; conflicting safety implications result from signing studies; and no prior documentation exists regarding driver reliance on any of the devices as a hazard cue. There is evidence that drivers rely on their perception of curve geometry to select curve entry speeds regardless of advisory speed signing (5). Furthermore, speed studies of advisory speed signs have shown them to be ineffective (6). This finding seems to confirm other field studies that indicate that motorists ignore general speed limit signing (7, 8). However, there is strong conflicting evidence that signing that is sensitive to specific conditions can provide an effective remedy. A before-and-after study of advisory speed limit signing in combination with standard curve warning signs demonstrated a significant reduction in single vehicle

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accidents (9). A variety of curve warning signs were studied in Finland by using speed data in combination with 2768 driver surveys (10). Results showed that driver recognition and deceleration in response to specific speed limit signing were better than the response to more general warning signs.

It is well known that, for signing to be effective as a hazard cue, it must be credible to the driver (11, 12, 13). Activated warning signs have been shown to be effective in the presence of a hazard that is perceivable to the driver (7, 14, 15).

PROCEDURE

Study Design

The structure of this field study is a two-dimensional examination of signing treatment effects across roadway surface conditions. Data were derived from a population of motorists negotiating curved sections of roadway. Independent variables and their parameters are signing (varying levels of conspicuity and specificity) and pavement condition (varying levels of slipperiness due to wetness). Dependent variables to describe signing effects were vehicle performance measures (speed, intervehicle gap, position on roadway, mean acceleration and deceleration) and driver response measures (sign observation, recognition of message and appearance, rating sign as helpful).

A secondary experimental objective, but a primary task undertaken through the questionnaire procedure, was to derive knowledge of motorists' perceptions of potential skid hazard. For this reason, the interrelationships among numerous variables are examined in the questionnaire analysis. They include driver characteristics (age, sex, driving practice, site familiarity) and their observations relating to hazard (assessment of safe wet pavement speed, cue of potential skid hazard).

Parameters of roadway wetness were dry condition and wet condition. The dry condition was defined as a pavement that was dry in appearance when no rainfall had been evident for a considerable period. The wet condition was in effect when there was measurable rainfall or water film depth on the pavement. An attempt to quantify pavement skid resistance by using a decelerometer was not successful because obtained readings were not sensitive to rainfall onset and termination. Variables to describe signing condition were specificity (the extent to which specific instructions advising of hazard-responsive action were provided to the driver) and conspicuity (the use of flashing hazard beacons). Low specificity signing consisted of the symbolic SLIPPERY WHEN WET panel with no supplementary wording. Moderate specificity signing that required some assessment on the part of the motorist was the display of a SLOW WHEN WET panel on a nonactivated sign or the display of a SLOW WHEN FLASHING panel on a sign with flashing beacons. High specificity signing provided explicit instructions through the provision of an advisory speed limit. Two levels of conspicuity were high and low; the high level was achieved by the addition of two standard yellow flashing beacons to the standard or low level sign. Figure 1 shows sign conditions that were tested. Six signing conditions ranged from condition 1, the no-sign condition, to condition 6, which was made up of high levels of both conspicuity and specificity.

Field Sites

To permit the evaluation of signing treatments under diverse, potentially skid-hazardous driving conditions, three field study sites were selected on the basis of differing cornering characteristics. Each site represented a potential skidding hazard as determined by accident history and site geometry. All sites permitted examination of driver acceleration and deceleration behavior. Site 1 was the target of primary interest because its curvature of 20 deg was characterized by high driver cornering forces (16). In addition, the availability of pavement skid resistance data at site 1 permitted computation of the critical wet weather speed. Sites 2 and 3 were used to confirm or refute site 1 observations.

Data Collection Methodologies

Two primary data collection techniques were employed. Vehicle performance data were gathered by using the traffic evaluator system (TES), and driver characteristic data were obtained by questionnaire.

Traffic Evaluator System

TES consists of unobtrusive pavement sensors, a recorder and electronics unit, power supplies, manual code boxes, associated cabling, and a set of computer programs for reconstruction of the original vehicle characteristics. Pavement sensors convey vehicle presence data to the recorder where they are stored in digital format for computer processing. Computer programs are used to prepare data obtained in the field with TES. These programs translate time and switch codes into vehicle and traffic flow histories, reproducing the conditions actually experienced on the roadway. A complete description of the TES is available elsewhere (19, Part 2, Appendixes A and B).

Driver Questionnaire

Interviewing of motorists was conducted during the testing of all experimental signing conditions and under all ambient conditions studied. Drivers' questionnaire responses were matched with their vehicle speed data. Interview sites were located beyond driver sight distances from the curve to permit the acquisition of unbiased speed data. Vehicles selected for driver interviewing were those exhibiting such sufficient headways that their speeds were not influenced by others in the traffic stream.

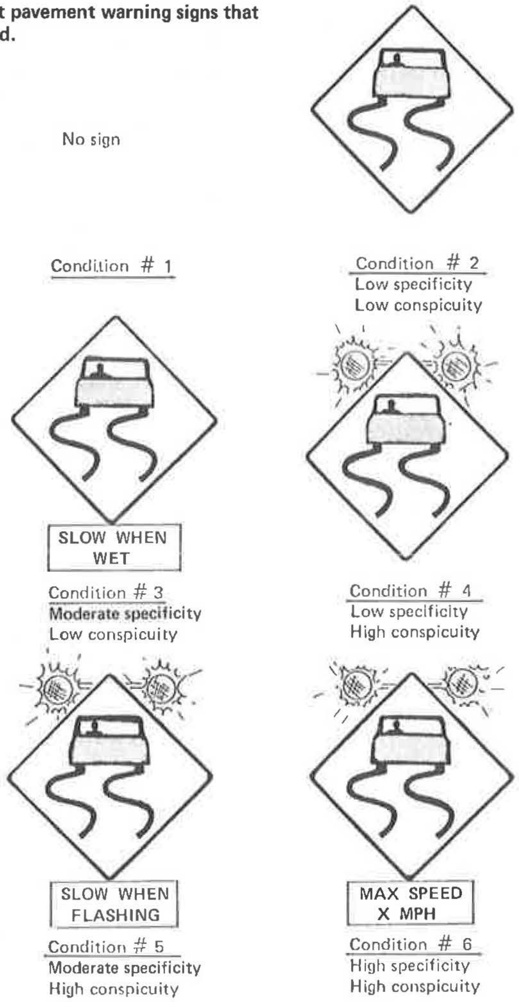
An interviewing strategy was adopted to permit certain driver characteristic data to be obtained before the driver knew that the study related to potential skid hazard. After a brief introduction that advised the motorist that a safety study was being conducted, the driver was asked about his or her skidding experience both at the site and within overall driving experience. Drivers were asked for an assessment of the potential skidding hazard and what their cues of the hazard were. In cases where the experimental sign was not cited as the cue, drivers were asked if they had seen the sign.

ANALYSIS AND RESULTS

Vehicle Performance Data

Specific measures derived from the TES were vehicle speeds, accelerations, lateral placements, and intervehicle gaps. Data collection points on each roadway curve consisted of an advance location [60 m (200 ft) in advance of the curve], the curve entry point, the point of sharpest curvature, and the curve exit point. The literature has overwhelmingly demonstrated the importance of speed as an indicator of skidding hazard. Therefore, speeds of individual vehicles became the primary TES measure of effectiveness used to examine

Figure 1. Wet pavement warning signs that were evaluated.



motorists' responses to varying hazard situations and experimental warning sign conditions. Intervehicle gaps were used for selecting free-flowing vehicles for speed analyses.

As noted earlier, site 1 is representative of a potentially severe wet pavement skidding hazard. Therefore, a thorough examination of all signing conditions was conducted at site 1, followed by an attempt to confirm observed effects at sites 2 and 3. Three types of sign evaluative data were collected:

1. Normative (unobtrusive or no signing and dry pavement throughout all times of day to determine normal driving patterns);
2. Dry pavement both with and without signing to determine dry pavement effect; and
3. Wet pavement both with and without signing to determine wet pavement effect.

Site 1

Wet pavement data were collected in two attempts for all experimental signing conditions. In each case, light rainfall began before the data collection period and ended during the procedure. Pavement slipperiness was monitored by using the decelerometer technique to monitor the effects of rain stoppage. Data collection was terminated before any detectable effect of rain stoppage.

The critical wet weather driving speed, based on site roadway geometry and pavement skid resistance qualities, was calculated by using a method reported by Weaver, Hankins, and Ivey (17). The calculated speed of 61.1 km/h (38 mph) was exceeded by the highest quartile speed driver group at the tight curvature, which showed that this driver group is the appropriate target sample to be studied.

Using this sample, Figure 2 shows mean speed effects of sign conditions tested on 1 data collection day.

Figure 2. Mean speeds of highest quartile motorists depicting experimental signing effects during wet pavement conditions at site 1 on day 1.

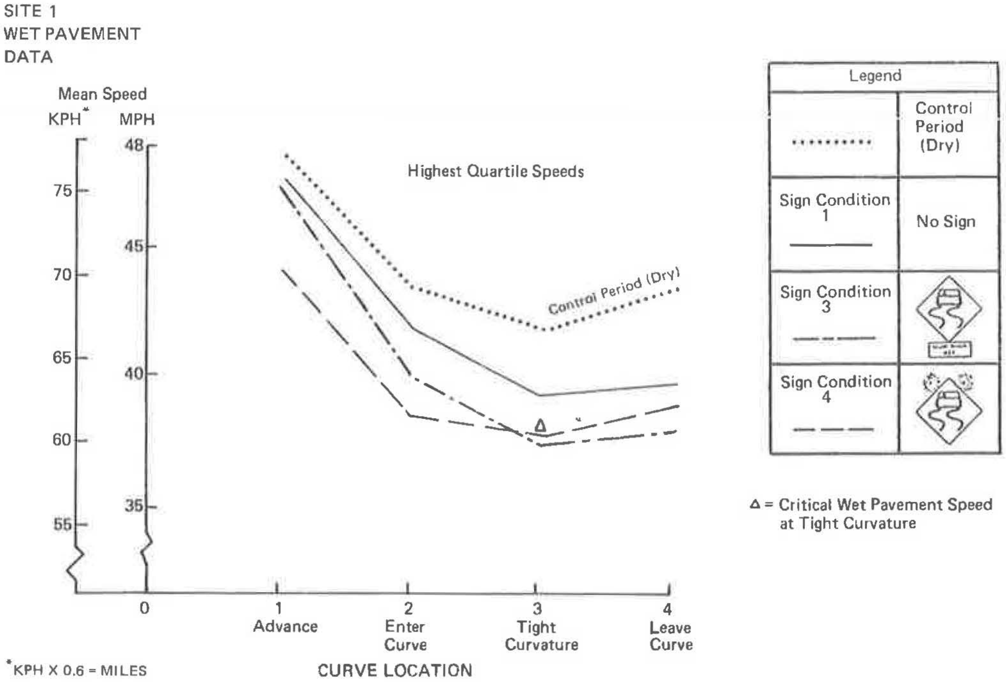
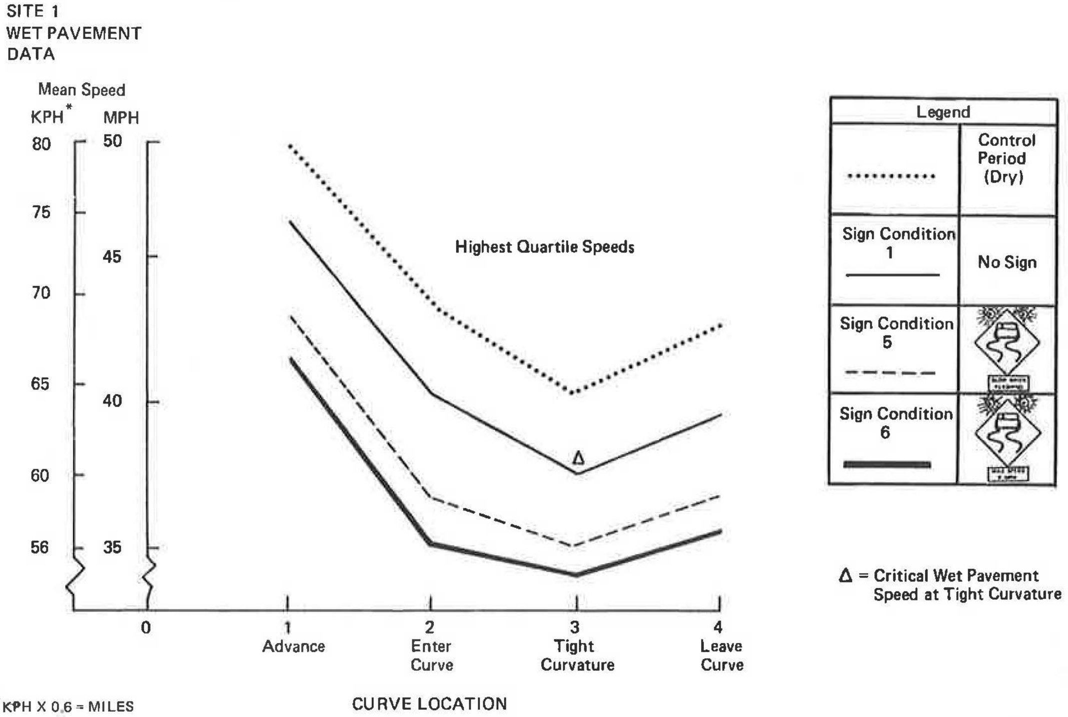


Figure 3. Mean speeds of highest quartile motorists depicting experimental signing effects during wet pavement conditions at site 1 on day 2.



To provide a frame of reference, average dry pavement speeds for the corresponding times of day are also shown. Significant reductions from the no-sign, wet pavement condition are noted for two experimental sign conditions (condition 3, SLOW WHEN WET, and condition 4, flashing beacons). Speeds observed during the display of sign condition 2, SLIPPERY WHEN WET used by itself, were virtually identical to those observed during the no-sign condition; therefore, no plot would be distinguishable. The figure shows that the flashing beacons did elicit a somewhat improved overall response to that of the SLOW WHEN WET panel.

A similar highest quartile speed plot shows data collected on another data collection day (Figure 3). Again, signs displaying flashing beacons were seen to elicit significant speed reductions from the no-sign conditions. The moderate and high specificity signing was observed to reduce speeds to a greater extent than the low specificity signing had previously done. Some benefit appears to be derived from high specificity wording (MAX SPEED—35 MPH) over moderate specificity wording (SLOW WHEN FLASHING). Speeds observed for the no-sign condition were below the critical wet pavement speed. This difference from the data of the previous day was due to a higher proportion of familiar motorists in the traffic stream because data were collected in the late afternoon as commuters were returning home from work.

To correct for time-of-day speed variation during each signing condition, normal driving data were matched to experimental signing data on an hour-for-hour basis. Comparisons were made of mean highest quartile speeds obtained under normal driving and experimental signing conditions. A general degradation of motorists' speed responses was noted everywhere except at the tight curvature during the period when sign condition 2 was displayed. Other signing conditions elicited improved responses with increasing levels of signing. These data were seen to bear out the evidence that familiar motorists on the second day were more sensitive to the wet pavement condition without signing than they were on the first day.

A number of observations can be made regarding the effects of experimental signing during wet pavement conditions. Significant reductions in the mean speeds for both the total driving sample and the highest quartile sample were observed when experimental signing with flashing beacons was displayed. The signing was seen to affect the speeds of motorists in all quartile groups about equally. During periods with a lower proportion of familiar motorists, the mean speed of the highest quartile was seen to exceed the critical wet driving speed when no warning signs were displayed. Warning signs that displayed flashing beacons or a SLOW WHEN WET panel were effective in reducing highest quartile mean speeds below the critical level. When time-of-day speed variation corrections were applied to the data, a diminished effect of the SLOW WHEN WET sign was realized. However, it was seen to elicit an effect superior to that of the symbol sign used by itself.

Acceleration and deceleration behaviors were observed to vary as a function of approach speed. Motorists who approached the curve at higher speeds exhibited greater decelerations into the curve and greater accelerations leaving the curve. This finding merely confirms speed change behavior cited in the literature (6). No significant effect on deceleration was observed as a function of the signing because greater slowing was initiated further in advance of the curve in the case of activated signing. Somewhat reduced deceleration rates were observed as motorists entered the curve during periods of activated signing; however, they were not shown to be statistically significant. No reduction in acceleration rate for motorists leaving the curves was observed to be related to signing.

Sites 2 and 3

In an attempt to determine the generalizability of driver responses, similar data were gathered at sites 2 and 3. Analyses identical to that described for site 1 were applied to the data. However, in the interest of brevity, only the results of these analyses are presented.

Site 2 wet pavement data generally confirmed site 1 observations in that the use of signs with flashing beacons resulted in significant decreases of both the total sample and highest quartile mean speeds both in advance of the curve and in the tight curvature. Dry pavement data results were the same as those for site 1 in that significant speed reductions were generally realized with activated signs.

At site 3, a lower speed site, all higher level signing produced significant speed reductions in advance of the curve. Fewer significant speed reductions were observed in the tight curvature because of low normal operating speeds [about 32 km/h (20 mph) average]. Dry pavement results were similar.

Overview of Sign Effects

Generally consistent effects of experimental signing to warn of potential skidding hazards were observed at all three sites. With one exception, no evidence supported the use of low conspicuity signing. At site 1, the use of low conspicuity, moderate specificity signing (SLOW WHEN WET) elicited significantly reduced motorist speeds at the curve entry point and in the tight curvature during wet pavement conditions. However, this observation was not replicated at either site 2 or site 3.

Sufficient site characterization data at site 1 permitted a comparison of observed motorists' speeds; the critical wet pavement speed was based on the site geometry and pavement characteristics. All high conspicuity experimental signing caused almost all motorists to drive below that speed during wet pavement conditions. Substantial speed reductions obtained at the remaining sites with high conspicuity signing displayed during wet pavement conditions corroborated that the flashing beacons were more effective in warning motorists of the potential hazard.

The foregoing is based on mean speeds for both the total driving sample and the highest quartile speed group. No significant changes in deceleration behavior could be attributed to the signing because speed reductions due to flashing signs were initiated sufficiently in advance of the test curves.

Driver Survey Data

This analysis is based on 305 driver interviews gathered during wet and dry pavement conditions with and without the presence of experimental signing. Vehicle speeds for each interviewed motorist were matched to his or her questionnaire responses. Questionnaire responses were categorized into 26 variables, and variable-paired comparisons were obtained through regression analysis. Variables were assigned to the following categories: signing, pavement condition, driver responses to signing, general driver characteristics, vehicle characteristics, and observed vehicle speeds.

Sign Condition

Drivers at all sites were more prone to observe and properly identify the appearance of the higher level signing. However, the proper identification of sign wording did not increase with higher level signing. The more conspicuous signing called attention to itself but did not arouse motorists' attention to the point of increased retention of sign wording. However, drivers were more likely to identify the higher specificity wording. This is the result of the motorists' apparently increased tendency to recall specific advisory speed limits as they were used for high specificity signing. Similar observations have been cited in the literature (10). To be credited with a proper response to sign message, the interviewed motorists had to identify the most specific meaning conveyed by the sign. For example, "slow" would not suffice as a correct response if the displayed sign was SLOW WHEN WET. At one site, more specific signing was viewed by motorists as being more helpful.

When highly conspicuous signing conditions were used, significantly more motorists saw and correctly identified the sign. Motorists gave lower estimates of safe wet speeds when highly conspicuous signs were displayed.

The relative effects of sign specificity and conspicuity were reflected by their respective correlations with speeds of interviewed motorists. The impact on speed reduction of increased conspicuity was greater than that of increased specificity for all curve locations. The fact that increased conspicuity did not correlate with increased motorist recognition of sign wording implies a reduction of speed due merely to the presence of the flashing beacons.

Pavement Condition

The effect of wet pavement was seen at one site in a motorist scalar rating of skidding danger associated with prevailing conditions. Motorists rated the site as more hazardous during conditions of wet pavement.

Driver Responses to Signing

Motorists' responses to signing consisted of (a) observation of skid hazard warning sign, (b) identification of appearance and message of sign, and (c) assessment of helpfulness of sign. Expansion and clarification were obtained on point c by asking how the sign was helpful.

Observation

The use of higher level and high conspicuity signing conditions resulted in more motorists observing the signing at all sites. No significant differences were noted in motorists' observation rates between the highly conspicuous signing conditions. The signs were more often seen by familiar motorists at one site. Forty-four percent of first-time motorists saw the signs. Motorists at one site who saw the sign gave a lower estimate of safe wet weather driving speed. Sign observation also affected motorists' speeds. Those drivers who saw the experimental signs negotiated the entire curve at lower average speeds at one site and slowed for the tight curvature at another site.

Recognition of Appearance

Higher level and more conspicuous signs prompted more motorists to correctly identify sign appearance. Of those motorists seeing the test signs, the more familiar were more prone to properly identify sign appearance. This finding is consistent with that for the familiar motorists who were more likely to observe the signing.

Recognition of Wording

The use of higher specificity signing resulted in more motorists properly recalling sign wording at all sites.

Motorists who reported prior skidding experience were less likely to recognize wording on the test signs. Drivers at one site who drove fewer kilometers per year were more likely to recognize sign wording. There were no correlations between motorists' speeds and their having properly read the test signing.

Assessment as Helpful

Higher level signs and more specific sign wording were rated as being more helpful by motorists at one site. Those drivers who thought the posted speed limit should be higher were less prone to regard the test sign as helpful. It is noteworthy that motorists who designated the signing as being helpful did not drive through the sites at significantly lower speeds. A number of motorists when asked how the sign was helpful said that they had slowed down as a result of it. A spot check of the data revealed that most of those drivers actually did reduce their speed. Numerous other drivers who said that the sign was a helpful reminder of the curve did not exhibit significant slowing compared with the total population.

Driver Characteristics

An examination of the driver in terms of selected demographic characteristics, driving experience items, and site hazard observations was used in the analysis of motorists' responses to experimental signing and the prevailing skid hazard.

Familiarity With Site

Familiar motorists were more likely to see test signing at one site. Those familiar drivers who saw the signing exhibited a greater tendency than unfamiliar drivers to properly recall sign appearance. At another site, the more familiar motorists rated the sign as being helpful.

The drivers' reactions to potential skid hazard, taken on the basis of their familiarity with the site, were mixed. A trend was evident in that the more familiar d drivers at one site were less likely to assess the site as a hazard, and the more familiar drivers elsewhere thought that posted speed limits were too low. However, that the more familiar motorists consistently exhibited lower speeds indicated their increased awareness of the potential hazard. As expected, the more familiar drivers were more likely to report prior skidding experience at the site.

Assessment of Posted Speed Limit

At one site, those motorists who said that the posted speed limit should be higher exhibited higher speeds as they drove through the site. Motorists interviewed while the pavement was wet were more likely to say the posted limit was too low because it pertained to the dry pavement condition. At another site, drivers who asserted that the speed limit should be higher were the ones with the most skidding experience at the site.

At both sites, motorists who wanted the higher speed limits were the more familiar ones and the ones less likely to perceive the site as a skid hazard. Motorists who thought the posted speed limit was too low also gave higher estimates of safe wet driving speeds.

Estimate of Safe Wet Driving Speed

During periods when more conspicuous signing was displayed, motorists gave lower estimates of safe wet weather driving speeds. This effect of experimental signing is compatible with the fact that motorists at one site who did not see the signing gave higher estimates.

Positive correlations between motorists' driving speeds and estimated safe wet speeds were observed. Those drivers who gave higher wet pavement speed estimates also thought the posted speed limit was too low. Higher estimates were given by male drivers and by those motorists who currently drive the most kilometers per year.

Driving Practice

Annual kilometers per year driven was taken to be an indicator of the level of current driving practice. Drivers with more practice gave higher estimates of safe wet driving speed, indicated that they would react more calmly in the event of an unexpected skid, and drove through the curve faster than those with less practice. Male drivers indicated more practice than female drivers at both sites.

Driver Age

Of those motorists who saw the experimental signing, the older ones were more likely to describe the sign as being helpful. Older drivers were less likely to assess the site as a skid hazard. Certain differences in vehicle speeds were observed as a function of driver age. Younger drivers exhibited higher speeds both before and beyond the curves. Mean driver age in the sample was 39 years.

Sex of Driver

Male drivers who observed test signs were more prone to rate them as being helpful. Males gave higher estimates of safe wet weather driving speeds; females reported less prior weather-related skidding. Female drivers expressed a greater tendency to panic in the event of an unexpected skid. It follows that lower vehicle speeds were observed for female motorists both at advance locations and in the curves.

Assessment of Skid Hazard

Interviewed motorists were asked whether they believed that the curve that they had just driven through might be a skid hazard. Those who answered yes were queried on the hazard cue. Those motorists who thought that the posted speed limit should be lower and those who had prior skidding experience at the site were more likely to perceive the site as a potential skid hazard. Younger drivers were also more likely to assess the site as potentially hazardous. At one site, fewer motorists assessed the site as a potential skid hazard when higher level signing conditions were displayed. However, specific signing characteristics of specificity and conspicuity were not statistically related to those responses. Those motorists in this sample who had skidded elsewhere on highway sections other than at curves were more likely to rate the site as a hazard.

Seventy percent of the 305 interviewed motorists assessed the sites as hazardous and cited the following cues:

1. Presence of the skid warning sign,
2. Sharp roadway curvature,
3. Appearance of the pavement,
4. Pavement superelevation (banking),
5. Pavement wetness,
6. Known accident history of the site,
7. Driving behavior of other motorists, and

8. Other reasons.

Responses were categorized by numbers and percentages of motorists who cited each cue according to site, pavement condition, and presence of a skid warning sign. The proportion of drivers who cited each cue remained fairly constant over all conditions. About one-third cited sharp curvature; about one-sixth cited driving behavior of other motorists; and almost one-third said that the site was not a skid hazard. Only 4 out of 305 motorists interviewed cited the skid warning sign as a cue of potential hazard.

For all response comparisons, the primary hazard cue was sharp roadway curvature. During wet pavement periods, some motorists' attention was diverted to pavement that was wet or looked slippery. Three of the four motorists citing the sign as their cue did so during wet pavement conditions. Specific sign conditions cited during wet pavement conditions were condition 2, the international symbolic shield used by itself; condition 4, the shield with flashing lights; and condition 6, flashing lights and the advisory speed limit. The SLOW WHEN WET panel was cited during the dry condition.

Contrasting cue responses between conditions with and without warning signs reveals minor differences. Significantly fewer motorists assessed one site (site 1) as a potential skid hazard while test signs were displayed. The data indicate that, without the presence of signing, a larger percentage of motorists cited the hazard cue as being roadway curvature or other driver's behavior, and all but 13 percent cited some cue of skid hazard. With experimental signing present, more diverse hazard cues were cited, but significantly more motorists reported no hazard. The emergence of more diverse cues during the presence of signing might indicate that motorists were more aware of various possible hazards. However, the concurrent increase in motorists' assessments that no hazard exists could indicate that the site is thought to be safer with the presence of signing. In either event, the effect was not repeated at site 3; therefore, no conclusive evidence was found to indicate that the signing had any impact on motorists' perception of skid hazard.

CONCLUSIONS

Summary and Findings

This field study investigated the driver's general awareness and his or her response to warning signs for the hazard of wet pavements subjected to high driver frictional demands. Three curved highway sections were treated by using five experimental signing conditions. Comparisons between all signs and the no-sign condition were made for wet and dry pavements. Normative driving behavior data were used to resolve time-of-day speed variations. Experimental signing conditions were made up of variations of the SLIPPERY WHEN WET symbolic sign, ranging from its use by itself to increasing levels of specificity and conspicuity to its use with flashing beacons and an advisory speed limit.

The primary measure of signing effectiveness was mean speed at critical curve locations. The highest quartile speed group (fastest 25 percent) of vehicles arriving in advance of the curve was selected as the target sample. Significant speed reductions at critical curve locations were observed to result from signing that employed flashing hazard beacons. Higher speed reductions generally resulted from the supplementary use of advisory speed limits. These observations took into account normal hour-to-hour speed variation. Three study sites were used to establish generalizability of results.

Questionnaire results were revealing in terms of motorists' responses to experimental signing. Vehicle speeds of interviewed motorists demonstrated that motorists who saw signing slowed down more than those who did not. Maximum speed decreases were observed at the most hazardous portions of curvature. Greater slowing was observed during use of higher level signing; sign conspicuity had a greater impact than specificity. The more familiar motorists were more likely to see the signs, and those with greater driving practice were more likely to read them. However, the experimental skid hazard warning signs were shown to have a marginal effect on motorists' verbal assessment of the site as a skid hazard.

Certain driver characteristics were linked to general perception of skid hazard. Younger drivers and those with prior skidding experience were seen to be more prone to assess test curves as potential skid hazards. Motorists who drive more kilometers per year exhibited higher speeds throughout the sites, but they were divided in their assessments of skidding potential. Female drivers were seen to be generally more sensitive to wet weather driving hazards because they gave lower estimates of safe wet pavement speeds, predominantly indicated that skid warning signs were helpful, and indicated a tendency to panic in the event of an unexpected skid.

Recommendation

Significant speed reductions observed at critical curve locations during conditions of wet pavements were shown to result from warning signs incorporating flashing beacons. This result must be regarded as sufficiently promising to suggest their operational use. It is to be emphasized, however, that responses were elicited from experimental signing installed immediately before rainfall rather than from permanent installations to which motorists had become accustomed. In addition, the experimental design incorporated in this study did not provide for a specific examination of novelty effect. Furthermore, the literature has shown poor driver responses to continuously displayed warning devices. Thus any recommendation for similar warning device usage must emphasize the need for activation of the flashing beacons at the onset of rainfall.

The recommendation for specific wording employed as part of the device stems not from the field observations of this study only. Advisory speed limit panels generally showed slight, although insignificant, improvements over other conspicuous signing used in the field evaluation. However, reviewed literature pertaining to accident liability has shown that use of the advisory speed limit sign is considered prudent on the part of highway agencies (18), and favorable accident rate effects have been shown to result from the use of advisory speed limits on curve warning signs (9). A documented technique to determine applicable wet weather speed limits is available (17).

The recommendation follows that activated warning signing be used as a skidding accident reducing countermeasure. Specifically recommended signing is that designated in the Manual on Uniform Traffic Control Devices (MUTCD) (20) as the SLIPPERY WHEN WET sign (W8-5) in conjunction with the advisory speed plate (W13-1) and rainfall activated hazard identification beacons (similar to that called out in section 4E of the MUTCD). The activation device should ensure that beacon flashing will terminate as the pavement becomes dry. Sign location with respect to the curve should be in accordance with current practice.

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Abridgment

Contributions of Psychological Set to Drivers' Route Choice Decisions

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A route diversion system involves the monitoring of two or more alternate routes to provide the driver with real-time information about the traffic conditions on each route (1). The real-time nature of the information is predicted on a sign format that allows message content to be periodically changed. This changing nature of message content, the lack of driver familiarity with this new type of sign, and the possible lack of driver familiarity with alternate routes might be considered as factors detracting from a driver's expectancy of the road ahead. One goal of this study then was to demonstrate that, according to the principles of expectancy as a component of psychological set, drivers with a greater familiarity of the road situation ahead would make route choice decisions significantly faster and would have a greater tendency to switch routes than would drivers with less familiarity.

Another aspect of psychological set is a driver's intention or readiness to respond in a certain way. A driver survey has shown that drivers rank travel time as most important for a trip to work and rank scenery as most important for a vacation trip (2, pp. 53-89). It appeared that, although many qualities of a desirable route existed, drivers valued some qualities more highly than others depending on trip purpose.

Because drivers ranked travel time as most important for business-related trips, it was hypothesized that, if drivers were told to imagine they were on a business trip, they would be more tense, would have more of an intention to "get there on time," and consequently would react more quickly to route choice situations than would those told to imagine that they were on vacation trips. It was also hypothesized that business drivers would choose the time saving route significantly more times than would vacation drivers. As a check on the validity of experimentally instilling trip purpose through instructions to the subjects, the results of the instilled trip purpose groups were statistically compared with results obtained by those with actual business and vacation trip purposes.

RESEARCH SETTING

The study took place at the Maryland House restaurant located on the John F. Kennedy Expressway (I-95), approximately 32.2 km (20 miles) north of its junction with the Baltimore Beltway (I-695). I-95 to Washington, D.C., is routed through the city of Baltimore and under the Patapsco River via the Baltimore Harbor Tunnel. An alternate route to the sometimes congested tunnel route is the Baltimore Beltway. The tunnel route is 27.3 km (17 miles) long, and the beltway route is 43.4 km (27 miles) long.

Experimentation took place in a mobile trailer parked adjacent to the Maryland House gift shop. One hundred naive volunteers participated in a stationary laboratory simulation of a route choice situation. The simulation technique consisted of having a subject respond to 12 color slides of roadway situations in which real-time route diversion signs were superimposed over actual signs in the original pictures. Each slide contained a view of the road ahead on a three-lane expressway and an overhead sign that informed the driver of conditions on each of two alternate routes. Subjects were asked to push one of two buttons that would indicate which route they would take. The dependent variables were decision time and route choice.

A 2 × 2 factorial design was employed with two types of psychological set, expectancy and intention, as the independent variables. Situational expectancy was represented by the amount of practice and situational information provided. The full information group was provided with full information about both alternate routes, including information on relative distances and tolls. After the initial inquiry, each full information group subject was given a written description of the existence of each alternate route and of the experimental task. When finished reading this, the subject was seated in the trailer and the experimenter read the procedural instructions. When this was done, the subject was given four practice slides with a description of each.

Members of the minimal information group, on the other hand, received no information about the specifics of the experiment after the initial inquiry; instead, they were merely told that they would be shown different ex-

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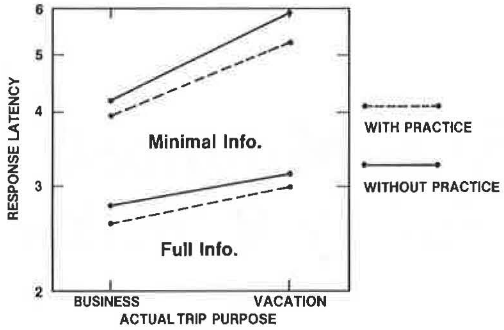
Figure 1. Information, practice, and actual trip purpose effects on response latency.



perimental signs to see which was the best. When seated in the trailer, each subject was told that pictures of different situations would be shown and that to each situation he or she must pick one or the other alternate routes. No mention of signs or types of signs was made, and no practice slides were given.

The second variable, intention, was represented by the trip purpose, business or vacation. The business condition was obtained by telling subjects to imagine that they were driving to see a client in Washington, D.C. For the vacation condition, the subjects imagined that they were headed to a beach near Washington.

RESULTS

The hypotheses that drivers' route choice preferences are significantly influenced by their expectancy of the situation and by their intention or trip purpose remain unsubstantiated. Although 74 percent of all the subjects preferred the tunnel route, there was no significant difference between those given practice and full information and those given no practice and minimal information. In like manner, no significance was obtained for route choice differences between either actual or instilled business trip purposes and vacation trip purposes.

In determining the relationship between a subject's route preference in the experimental situation versus the actual route choice situation, a person's experimental route preference in the mobile lab appeared to be very highly related [$\phi(84) = 0.37$, $\underline{p} < 0.001$] to a person's route choice in the actual, real-world situation. This result indicates that subjects most likely had brought their attitude or set into the experimental situation and were unable to respond differently. In this particular case, the drivers had already decided which route they would take, and this preformed intention was followed through in the experimental situation.

Figure 1 shows the significant response latency results. The hypothesis that response latency would decrease with increased expectancy (full information) was overwhelmingly supported [$\underline{F}(1, 96) = 68.5$, $\underline{p} < 0.001$]. This indicates that increased expectancy, although not affecting the decision of which route is taken, significantly affects the speed of that decision. By giving the subjects a preview of the types of signs they were to see, by allowing them to practice their responses, and by providing the subjects with full information concerning the alternate route system, the experimenter significantly increased the subjects' speeds of response in the experimental session.

With the data at hand, an attempt was made to equate the full and minimal information groups on the amount of task practice received even though the latter group received no formal practice session. To assess the effects of expectancy without the influence of the four practice slides given to the full information group, we adjusted the average scores of each subject to equate the groups on practice effects. Because those in the full information group had four practice slides, the last four latencies of each subject were eliminated from the group's averaging procedure. Because those in the minimal information group had no practice slides and because their first four experimental slides were equivalent to the practice slides of the full information group, the first four latencies of the minimal information group were eliminated from the group's averaging procedure. Both groups then were averaged among 8 instead of 12 latency scores/subject and were equated on this factor. With the practice effects accounted for in this manner, the decision times were considerably reduced; however, what was more important was that the amount of route information given to the subject remained a significant determiner of decision time.

The hypothesis that driver intention in the experimental setting will significantly influence reaction time was not verified. No significance was noted when subjects were told to imagine that they were on a business or a vacation trip. However, when subjects were regrouped according to their actual trip purpose, significant results were obtained [$\underline{F}(1, 60) = 5.00$ $\underline{p} < 0.05$]. These results indicated that those actually on a business trip tend to react significantly faster than those on a vacation trip. Because the correlation between age and trip purpose was insignificant, one cannot attribute the significant difference between vacationers and those on business to the possibility that vacationers consisted of older people who naturally reacted more slowly. The obvious conclusion then is that, with respect to the measure of reaction time, trip purpose cannot be simulated in the laboratory. Significant differences between those actually on business trips and those actually on vacation trips could not be replicated by instructions to the subjects.

The facilitative function of expectancy in the decision-making process found in this research strongly supports the model proposed by Allen, Lunenfeld, and Alexander (3). Because expectancy decreases reaction time and because expectancies can be structured potently for the navigational or macroperformance level of driving, the time saved in this level of performance provides for less interference in the levels of control and guidance and safer maneuvering can result. In addition, the results of this study have implications for the interpretation of past and future studies that require subjects to assume roles different from their roles before testing. Because there is no guarantee that instructions given to subjects will affect their behavior in the intended manner, experimenters must take heed when placing volunteers in hypothetical experimental situations.

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Analysis of Side-Mounted Turn Signal Safety Benefits

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A 1973 National Highway Traffic Safety Administration (NHTSA) Notice of Proposed Rulemaking would require that all passenger cars, multipurpose vehicles, trucks, and buses be equipped with side-mounted turn signals. It is evident from the side turn signal lamp photometrics specified in the notice that the signal is intended primarily to alert a driver overtaking in an adjacent lane that the vehicle displaying the signal is preparing to change lanes in his or her direction. The side turn signal would supplement the rear turn signal by providing a clear display to an overtaking driver who is too far forward with respect to the lead vehicle to be able to see its rear turn signals. Consideration of other driving situations revealed no commonly occurring set of vehicle relationships in traffic in which a side turn signal would provide a crucial message. However, because rear turn signals are visible through most of an overtaking maneuver and because, in any case, many drivers do not use turn signals when changing lanes, the safety benefit of side turn signals even in overtaking situations is not obvious. In accordance with this, an analysis was undertaken to obtain an estimate of the accident and dollar savings that might be realized from the installation of side-mounted turn signals on passenger cars.

An analytical model was developed that predicts the probability of an accident with and without a side turn signal given that the lead driver makes a blind lane change; that is, the decision to change lanes is independent of the presence or absence of an overtaking vehicle. Annual side turn signal benefits were then estimated by calculating the number of vehicles saved from being in accidents through provision of a side turn signal.

The analytical procedure involved three different tasks. First, an adjacent lane overtaking model was developed that defined the overtaking situations in which an accident would occur under each of several different environmental conditions. Next, a probability model was employed to estimate the accident likelihoods under each of these conditions. Finally, a survey of accident data yielded the relative accident frequencies of these conditions and also produced an estimate of the overall number of lane-change crashes expected to occur each year.

OVERTAKING MODEL

The essential features of the model and many of the assumptions are shown in Figure 1, which delineates the areas in closing rate and following distance space in which an accident can or cannot be avoided by braking should a driver make a blind lane change into the lane occupied by an overtaking vehicle. The ordinate is following distance measured from the front of the overtaking vehicle to the front of the lane-changing vehicle. Both vehicles are assumed to be 5.4 m (18 ft) long. The abscissa is closing rate, the speed of the overtaking car minus the speed of the lead car.

Braking

The normal reaction time curve a1 is a boundary condition representing the minimum following distance for each closing rate at which the overtaking car can avoid an accident by braking. This curve is a plot of the equation

$$D = (\Delta v^2/9.81\ g) + RT\Delta v \qquad (1)$$

where

D = following distance as previously defined in meters,
g = deceleration in g's as a fraction of the gravitational constant,
RT = overtaking car driver reaction time in seconds, and
Δv = closing rate in kilometers per hour.

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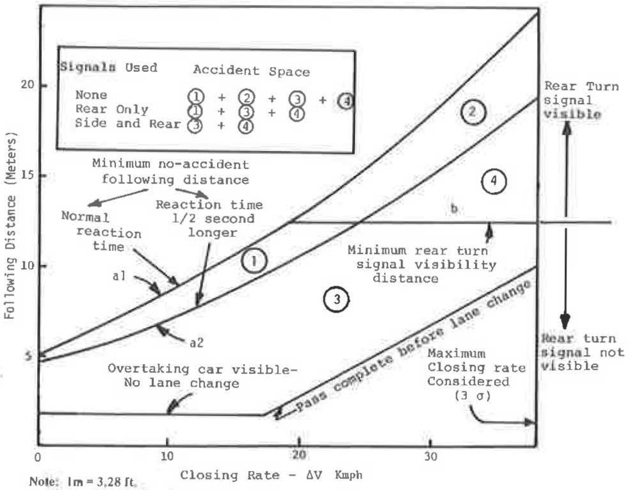
Figure 1. Combinations that will cause lane change accidents.



Note: 1m = 3.28 ft.
1 km/h = 0.621 mph.

Reaction Time and Effect of Turn Signals

The central premise in the analysis is that the effect of turn signals is to reduce driver reaction time to the start of a lane change by 0.5 s. This figure derives from the assumptions that the initial lateral displacement on the part of a lead car will not be interpreted by the following driver as the start of a lane change unless the lead car is displaying a turn signal. Curve a2 in Figure 1 is a plot of equation 1 with a 0.5-s shorter reaction time.

A reaction time distribution rather than a single value was used in the analysis. That is, accident probability computations were made for various reaction times and weighted by the relative probabilities of the reaction times. The distribution is $\log_{10}$ normal with a mean of 1.42 s and a standard deviation (σ) of the $\log_{10}$ reaction times of 0.4458. Four-tenths of a second is added to the distribution to represent foot movement time. For the purposes of the analysis, an additional 0.5 s of recognition time was added to the distribution to represent signal-absent reaction times, according to the previous discussion. The application of the distribution to the probability model is described further in a later section.

Rear Turn Signal Range

Line b in Figure 1 is a graph of $D = K$ where K = the minimum distance at which an overtaking driver can see the rear turn signals of the car in the adjacent lane. This distance depends on whether it is day or night and whether the overtaking vehicle is passing on the right or left side.

Accident Space

The accident space in Figure 1 is divided into four areas by line b and curve a2. Accidents above line b (areas 2 and 4) are those in which the lane change starts with the overtaking vehicle within the visible rear turn signal range of the lead car. In other words, these are accidents that will not be affected by the presence or absence of a side turn signal because the rear signal is visible. At lesser following distances, rear turn signals are assumed not to be visible, and this is the area in which a side turn signal might be of benefit. The effect of a turn signal, side or rear, is to reduce the total accident space; that is, the upper boundary becomes a2 rather than a1. Therefore, the area between a1 and a2 (area 1 plus area 2) represents the accident savings attributable to a turn signal. In particular, area 1 represents the savings in accidents attributable to a side turn signal; area 2 represents the savings attributable to a rear turn signal. If all current drivers used turn signals (rear only), then the total accident space can be represented by the sum of areas 1, 3, and 4. If no drivers use turn signals, then the total accident space is represented by the sum of all four areas.

Obviously, the outcome is dependent on the frequency of turn signal use. In a brief study conducted by the Ford Motor Company to establish turn signal use frequency, turn signals were found to be used at or prior to lane changing 42 percent of the time on freeways and 38 percent of the time on multilane streets and highways.

ACCIDENT PROBABILITY

The probability of an accident in a region N (where N is 1, 2, 3, or 4) of Figure 1 given a blind lane change is

$$P(N) = P(d)_{\Delta v,RT} \int_{\Delta v=0}^{\Delta v\ max} \int_{RT\ min}^{RT\ max} P(RT)\, P(\Delta v)\, d\Delta v\, dRT \qquad (2)$$

where

$d_{\Delta v,RT}$ = minimum no-accident following distance and

$P(d)_{\Delta v,RT}$ = probability that there is an overtaking vehicle in the adjacent lane with a following distance equal to or less than $d_{\Delta v,RT}$ at the start of the lane change.

The range of RT is $\pm 3\sigma$ and the upper bound on v is at 3σ. $P(d)_{\Delta v,RT}$ was computed by using an exponential expression for the distribution of headways. Numerical methods were used to approximate the integrals in steps of $\sigma/10$.

By changing boundary conditions to reflect the presence or absence of a side turn signal and the use or nonuse of turn signals, one can approximate the probabilities associated with the four regions in Figure 1. These are then inserted into the following equation to determine the proportion of accidents saved by the provision of a side turn signal:

$$P(S) = \frac{QP(1)}{(1-Q)\,[P(1)+P(2)+P(3)+P(4)] + Q[P(1)+P(3)+P(4)]} \qquad (3)$$

where Q = proportion of drivers using turn signals.

ACCIDENT DATA AND COSTS

About 0.77 million passenger cars are involved each year in same-direction crashes between vehicles. Based on National Safety Council and NHTSA data, the average cost per vehicle in a same-direction crash was estimated to be $690. An analysis of accident data files was performed to develop the distribution of these accidents across those environmental conditions that determine the values of some of the overtaking model parameters (K depends on whether it is day or night, braking deceleration depends on weather, and turn signal usage depends on the type of highway). To obtain an estimate of total percentage of accident savings, equation 3 was computed for each condition and the resulting values of P(s) were summed with appropriate weights.

ACCIDENT AND DOLLAR SAVINGS

The following tabulation gives the expected yearly benefits attributable to the introduction of a side turn signal system after complete installation of the device in the roadway system. The average benefits for the first 10 years of installation are presented, which may be a more representative assessment of the true benefit when one considers the long implementation lag times (the full life savings potential of any device is not reached in the early years because not all vehicles on the road are equipped):

Item	Accident Savings (vehicles)	Cost Savings ($)
Average annual savings after 100 percent introduction	9625	6 640 000
Average annual savings over 10-year introductory period	5066	3 500 000

According to the National Safety Council, 25.1 million vehicles were involved in accidents in 1974. As indicated in the previous tabulation, the introduction of side turn signals could reduce this figure by an average of about 5066/year over the 10-year introductory period. This reduction represents about 0.02 percent of the 1974 total of 25.1 million.

COSTS AND BENEFIT-COST RATIO

In 1973, the average cost of a side turn signal to the consumer was estimated to be $7.55. At the 1974 rate of sales (8.9 million passenger cars), the average annual cost of implementing side turn signals would be $67 million. The rate of the 10-year average annual benefits to average costs is $3.5 million/$67 million = 0.052. Estimates of benefit-cost ratios for certain Federal Highway Administration programs and high payoff vehicle safety standards range from 4 to 80. The side turn signal thus not only is an inefficient measure when considered on its own merits but also compares poorly with other highway and vehicle safety programs.

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A complete version of this paper is available from the authors.

Evaluation of an Accelerator Position Signal

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The vehicle rear lighting and signaling system plays a valuable role in promoting safe car following and in reducing the frequency of rear-end collisions. However, although the information currently presented on the rear of vehicles is valuable, it probably does not constitute the most useful information possible. In this respect, a number of studies have been conducted to evaluate additional forms of signals, such as coasting signals, to aid following drivers (1, 2).

One series of studies (3) found that an accelerator position signal (APS) system allowed drivers to detect coasting of a lead vehicle (which would be shown by the lighting of a yellow lamp) sooner than when such a signal was not given. Whenever the yellow signal appeared on the lead vehicle, it was coasting at the normal coasting deceleration for that vehicle, which means that the coasting signal never gave erroneous information.

The potential false alarms that can be given by a coasting signal were investigated by Mortimer (4). In that study, a motor-pool vehicle was driven for 3946 km (2452 miles) by various drivers and surreptitiously instrumented to measure the duration of coasting, the initial and final speed of each coasting maneuver, and whether the accelerator or brake was the control next used by the driver. The primary findings were that about 80 percent of the coasting durations were 2 s or less, about half were followed by braking, and fewer than 7 percent were less than 0.5 s and followed by braking. These data indicated that coasting durations are generally short and therefore involve a minor reduction in vehicle speed [in 90 percent of coasting events the vehicle slowed less than 6.4 km/h (4 mph)]. In addition, one cannot use the coasting signal to reliably infer that braking of the lead vehicle, especially moderate or severe braking, will follow. It was concluded that a coasting signal should not be given each time the accelerator is released except when the coasting duration exceeds about 5 s, a period during which a significant reduction in vehicle velocity could be expected to occur and that was usually followed by braking.

A further study of APS was recently completed. The rear lighting systems evaluated were the conventional system, consisting of one red lamp on each side of the vehicle that carried out presence (tail), stop, and turn functions, and the conventional system supplemented by an APS, represented by a vertical array of three centrally mounted lamps that indicated from top to bottom braking (red), coasting (yellow), and accelerator depressed (green blue).

These lighting systems were compared in tests consisting of (a) a driving simulator test in which drivers followed a lead vehicle that exhibited "normal" velocities and accelerations; (b) a driving simulator test in which the lead vehicle was revealed to the following car driver while exhibiting some unusual maneuvers, such as high decelerations or high closing velocities, as well as during normal accelerations, decelerations, and coasting or while maintaining a fixed speed; and (c) a road test in which the car-following behavior of naive drivers was surreptitiously recorded as they followed a test car on a two-lane road. A fourth evaluation was made in a structured road test in which subjects followed an APS-equipped car to determine whether they could intuitively comprehend the intended meaning of the APS's, to obtain their evaluations of its perceived effectiveness in a number of driving schedules that varied in the consistency of braking following coasting, and to obtain measurements of their relative frequency of accelerator releases and brake applications with respect to those of an experimenter driving the APS-equipped car.

In the interests of brevity, only the major findings of these studies will be presented here. The reader is referred to Mortimer and Sturgis (5) for a detailed account of the design, methodology, and analysis.

FINDINGS AND DISCUSSION OF RESULTS

Driving Simulator Studies

The results of the initial driving simulator study indicated no differences in drivers' ability to detect and identify stop and turn signals between the conventional system and

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that system augmented by the APS. It might have been expected that, if the yellow signal had the ability to alert drivers to impending braking, response times to stop signals would have been reduced. However, this was not found and confirms the contention of Nickerson and others (1) that such a meaning cannot be reliably inferred unless braking follows coasting on most occasions. APS might also have been expected to produce improved car-following performance, but none of the recorded measures (headway standard deviation, relative velocity standard deviation) indicated that this occurred.

The second simulator study, which was conducted to evaluate the rear lighting systems in situations that had a high predisposition for a rear-end crash to occur, showed one statistically significant difference between systems, but in a condition in which lead car speed remained constant and the green lamp of the APS was lighted throughout. Since this condition represented a positive initial relative velocity, there is no implication of a safety benefit for the APS.

Road Tests

The unobtrusive measurements of naive drivers who approached the test car from the rear and subsequently followed it on a two-lane road indicated some differences in their responses depending on whether the test car was coasting or braking. The following vehicle braked more frequently when the lead vehicle was braking than when the lead vehicle was coasting, which showed that the procedure has some degree of sensitivity in terms of measurable responses of following car drivers. On the first exposure of the following vehicle to a coasting lead vehicle displaying the APS, there was noticeable coasting of the following vehicle as measured by the significantly greater headways maintained with the lead car compared to when the lead car was displaying the conventional lighting system. However, this response to a change from the green to the yellow lamp of the APS was not noted on a second exposure to coasting of the lead car.

Although there was an indication that the standard deviations of headway and relative velocity were less when these drivers were following the test car equipped with the APS than when they were following the car with the conventional system, none of the differences proved to be statistically significant. This confirms the findings of the driving simulator tests that found no differences in a number of car-following measures and agreed with earlier studies (3) that also reported no benefits attributable to an APS in car following. In this test there were no differences between systems in the response of following drivers to braking lead vehicles, which would be expected because the braking signal is given by both systems.

In the structured driving study, 75 percent of the drivers were able to correctly infer the meaning of the APS signals. The drivers considered the signals of the APS to be useful, as shown by questionnaire responses. However, of major interest was a comparison of the effectiveness ratings made after conditions that differed both in the relative frequency with which braking followed release of the accelerator and in the duration of coasting events. These differences should have been reflected in the ratings of the consistency of the yellow signal in providing coasting and impending braking information. However, the mean ratings assigned to questions given at the end of these conditions did not differ, indicating that subjects did not perceive the fairly large differences in the coasting durations and relative frequencies of braking that were used. This suggests that subjective evaluations of the relative effectiveness of signals of the APS lack sensitivity.

By comparison, the frequency of accelerator releases and brake applications of the following car driver with respect to those of the lead car driver did reflect significant differences between driving cycles as measured by accelerator release ratios. The data show that, as the relevance of the yellow signal increased, in terms of long coasting durations and the likelihood of coasting being followed by braking, there was a relative increase of accelerator releases by the following car driver, indicating that the APS system encourages an increase in release of the accelerator by following drivers.

An earlier study (6) reported that after some time drivers tended to ignore coasting signals because they realized that they were of little relevance on most occasions. This appears to be an effect similar to that found in the current test.

For both the APS and the conventional system, the relative frequency of braking by the subjects was about the same, showing that, when more highly relevant information is provided (information on braking rather than coasting), the drivers responded consistently. This result was also unaffected by the schedule of APS signal presentations.

CONCLUSIONS

Clearly, to introduce a new rear signal that will frequently light and at the same time often be of no relevance to a following driver is undesirable. Such a new signal could be distracting and possibly lead drivers to pay less attention to other more important driving tasks as well as interfere with detection of the other important rear lighting signals. It has already been demonstrated that the ability to detect coasting of vehicles can be accomplished by drivers fairly well by using "primary" cues such as the change in the headway gap or visual angle subtended by the vehicle (2). Because coasting is not followed by braking in a sufficiently large proportion of cases to allow a coasting signal to alert drivers to braking and, more important, to alert drivers to moderate or severe braking (2), the only potentially useful information provided by a coasting signal would be to alert drivers to long coasting durations in the event that they are not detected by other means. For this reason, Mortimer (2) suggested that a coasting signal only be presented when coasting durations exceed about 5 s because then the change in speed of the vehicle could be substantial and bring about high relative speeds and changes in headway.

The findings of the current study have indicated scarcely any benefits attributable to an APS, although they have indicated at least two important undesirable characteristics of it: (a) an increase in the frequency of accelerator releases by following car drivers and (b) a frequently appearing signal on the rear of a vehicle that on most occasions provides no useful information to the drivers of following vehicles.

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Driver Perception of School Traffic Control Devices

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Field surveys were used to determine student and driver perceptions of traffic control devices. These consisted of two structured surveys—a student survey and a driver survey. Interviews were conducted with approximately 1000 students (kindergarten and third, sixth, and eighth grades) and some 400 passing motorists at school locations in New York, Maryland, and Virginia.

Driver responses were evaluated based on driver recognition of existing signing and behavioral modifications as evidenced by a change in speed. Covert use of radar hand guns was employed to measure driver performance and to provide a comparison with the driver interview responses. Drivers were not observant of school advance warning and crosswalk signs, and, in general, the only school signs perceived were active signs with flashing lights. These did not necessarily modify driver behavior or reduce speed to the level indicated on the sign.

The student surveys are not addressed within this paper. Readers are directed to the study final report for details of the student survey (1).

This paper discusses the design of the survey, the administration of the survey to the motorists, and general findings related to driver behavior (speed), signing, and other site specific factors. The major task of the project related to the driver was the assessment of driver perception, attitudes, and behavioral changes when drivers approached and passed through a school zone.

To assess any changes in driver behavior, we incorporated two methods of approach into the study design. The first method was the covert measurement of vehicle speeds within school zones by use of radar speed guns (under children present and children not present conditions). The second method of data collection was through interviews with the drivers of these vehicles immediately after they passed through the school zones. A survey format using recall (free response) rather than recognition (multiple choice) items was designed to secure the desired information without prompting the driver.

DATA COLLECTION METHODOLOGY FOR SPEED MEASUREMENT

Objective measures of vehicle speeds and vehicular and pedestrian activity in the school areas were used. Observers stationed unobtrusively on and around school grounds took pedestrian and vehicle counts a few days before data collection. This permitted identification of any unique occurrences on the day of the driver survey administration.

Individual vehicle speeds were matched with their corresponding questionnaires to allow comparisons between high- and low-speed groups and between driver's estimate of speed and actual speed. The measurement instrument was a radar speed gun, a radar device that can be aimed at moving vehicles as they pass. Use of the radar guns provided the opportunity for observers to obtain speed readings at several points on the roadway while remaining at a single observation point. Testing and calibration revealed that the gun should be aimed at an angle of less than 15 deg because measurement error increased with increasing angle of aim. At 15 deg, the error was about 3.5 percent.

The location of the radar device and the number of speed measures taken were, of course, site dependent. At two of the school sites, three measures of speed were taken. The first reading indicated the driver's speed well before the school zone. The second measure was taken just as the driver entered the zone. The final measure indicated the driver's speed within the zone (usually at a crosswalk). The location of a traffic signal at one site allowed only two meaningful speed measurements: before the school zone and entering the zone. In New York, heavy traffic volume did not permit the collection of speed data on specific vehicles; therefore, the general speed of the traffic stream was determined.

The speed measures were taken on a sample of vehicles and manually recorded. The drivers of these vehicles were stopped by a police officer located downstream and were interviewed. Vehicles were randomly

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selected whenever an interviewer was free.

RESULTS

Driver Survey Responses

An attempt to tap the level of awareness of the drivers about the school zone was made early in the interview when drivers were asked whether they had changed their driving behavior when they drove through the area. About 22 percent replied that they had. When asked why, about 40 percent of those drivers mentioned the school zone. Thus about 8 percent of the drivers specifically mentioned the school zone.

A check was made of those drivers who said that they had modified their behavior. Half of these drivers indicated that the way they drove differently was by slowing down (the other half did not specify how they had varied their driving). It was hypothesized that the radar-obtained speed for these drivers should be significantly different from that of the remainder of the driver population. However, a statistical test indicated no significant speed difference between the two driver populations. The motorists who said that they had not changed their driving behavior were then asked if the area was special in any way. Forty-three percent of those asked said that it was; of these, 47 percent said that it was a school zone. Thus about 20 percent of the driver sample when prompted recalled that the area was a school zone. Therefore, slightly more than one-fourth of the drivers mentioned the school zone before it was specifically brought up by the interviewer. About 7 percent of the 348 drivers at the four survey sites responded negatively when asked, Is this a school zone? Five percent did not respond or indicated that they did not know. The total driver sample was generally familiar with the school areas; 67 percent lived 8 km (5 miles) away or less and 70 percent drove past the school at least once per day.

The drivers were asked whether they had seen any school-related signs in the school zone. Sixty-six percent responded affirmatively. (Thirty-three percent who had passed at least one sign and, most often, two signs responded negatively.) They were then asked what the sign looked like. They were shown a 28 by 35.6-cm (11 by 14-in) page containing six photographs of school-related signs. The signs shown and their positions on the paper were varied at each site. Figure 1 shows the distribution of the sign recognition responses of the drivers. The shaded boxes represent the signs the drivers passed in their direction of travel. The only signs indicated by more than half of the drivers' responses at the two sites where they were present were the active (flashing) signs. Less than half of the responses of the entire sample correctly identified the existing signs. Forty-seven percent of the responses at site 14 indicated a sign that they had not passed in the school zone but would be aware of if they lived in the area.

At site 10, the flashing light was on for about half of the driver interview period (38 out of 74 drivers). This permitted a comparison of driver perception of signing responses by using the activation of the sign as a variable. If we consider only the beacon sign, we can see that activation dramatically increases driver recognition of the sign:

	Beacon On		Beacon Off	
Response	Number	Percent	Number	Percent
Right	31	82	20	56
Wrong	7	18	16	44
Total	38	100	36	100

The sign-related observations at the four driver survey sites can be described as follows:

1. Each of the sites was marked with either one or two school warning signs or speed signs or both;
2. Most drivers (89 percent) traveled past the signs one or more times a week, and most drivers (66 percent) reported seeing a school-related sign as they drove through the school zone; and
3. Less than half of the total responses correctly identified the signs that were present, and the type of sign most frequently identified was the flashing school speed sign.

Speed—Signing and Children's Presence

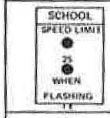
A driver's speed through the school area is generally a product of recognition of a potential hazard to self or to the young pedestrians and a determination of what is a reasonable speed for the traffic and environmental conditions. Drivers who responded to the survey tended to emphasize their caution and their relatively slow speeds through the school zone. The radar speed measurements taken at the school zones do not verify these responses. In a comparison of all the survey sites, the drivers indicated that they were aware of passing through a school zone. Seventy-two percent said that they were driving at or under the legal speed limit. More than half (64 percent) correctly identified the legal speed limit through the zone. Eighty-five percent of the drivers whose speeds were obtained by radar were exceeding the legal speed limit. These drivers exceeded the speed limit by approximately 16 km/h (10 mph).

Several speed comparisons were made at specific sites. In one instance, this reflected the desire of the local traffic engineer for a comparison of speeds in the school area for residents and nonresidents. [Residents live less than 3.2 km (2 miles) from the interview site.] It is interesting to note that familiarity with the area did not relate to observed speed through the school zones. The findings at the Howard County, Maryland, site indicate that local drivers travel at about the same speed as do nonresidents but are more aware of signing and children on their way to school. Increased awareness of the school zone did not cause residents to drive significantly slower than nonresidents in the school area. Increased recognition of the existing signs at this site may be due to the drivers' general familiarity with the area. Weight is given to this argument by the fact that 47 percent of the responses given to the signing question at this site indicated recognition of a sign not driven past but located elsewhere in the general area.

Although drivers generally perceived the active signs with flashing lights, these did not necessarily modify driver behavior or reduce speed to the level indicated on the sign. A flashing sign during school hours, students on the sidewalk, a wide street, and long sight distances reduced speed only slightly (school site 2). A similar sign during the same hours, students present, and a curving uphill road with poorer sight distance produced a significant speed reduction (school site 10). Obviously, the effectiveness of signing has something to do with the driver's perception of it as a credible indicator of a potentially unsafe situation.

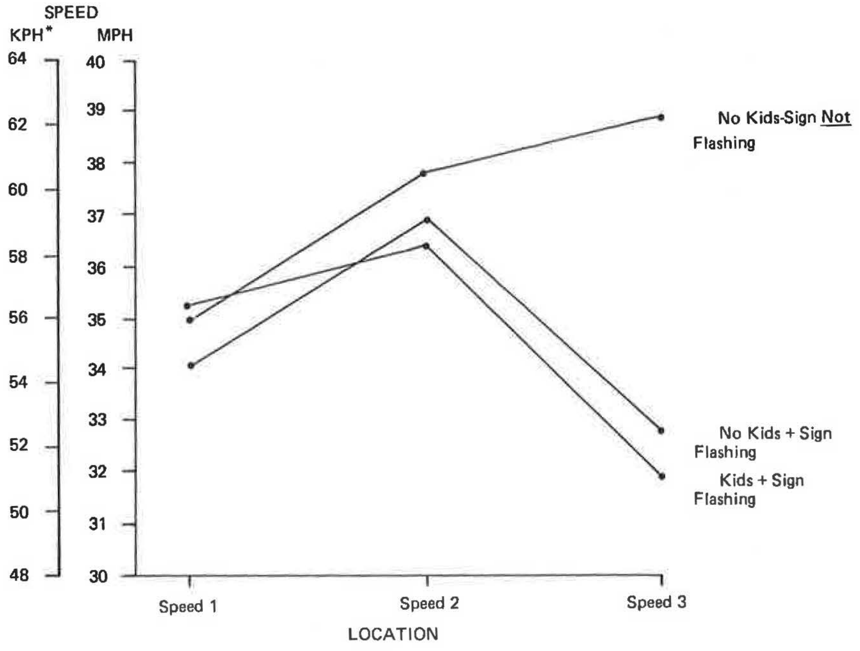
The driver at school site 10 is driving in a rolling terrain and cannot see the school or the crosswalk when the school flashing speed limit sign is observed. Between speed one and speed two, under all conditions, the driver is accelerating after coming down from a rise (even though the road is curved). Figure 2 shows the measured speeds at these locations. The drivers' speeds

Figure 1. Distribution of sign recognition responses of drivers.

SIGNS	FairFax County, Va. 10	Howard County, Md. 14	Brooklyn, N.Y. 11	Falls Church, Va. 2
	6%	4%	10%	8%
	12%	18%	21%	2%
	6%	13%	6%	0%
		14%		
	10%		27%	16%
	59%	5%	4%	
			31%	
				64%
	8%	 * 47%		11%

* The Photo of this Sign was Only Shown to Drivers at Site 14

Figure 2. Driver speeds measured by covert radar through school site 10.



at the second speed location showed no significant decrease even though there is a school advance sign at this location. As Figure 2 illustrates, when the sign is not flashing, the drivers' speeds show no significant decrease (at the third speed location from the advance school sign past the school speed sign to the school crosswalk).

There is a statistically significant decrease in speed 3 when the sign is flashing as opposed to when it is not. This significant reduction in speed occurs whether children are present or not. The speed limit in the area is 56 km/h (35 mph) and is reduced to 40 km/h (25 mph) when the beacon is flashing.

ACKNOWLEDGMENTS

This paper relates to one area of a study, School Trip Safety and Urban Play Areas, performed by BioTechnology, Inc., for the Federal Highway Administration under contract DOT-FH-11-8126. We wish to thank the individuals in the school systems associated with the 14 schools and the police of the four jurisdictions that made up the field survey sites. Without their cooperation, the study could not have been conducted. We wish to thank Wallace G. Berger of the U.S. Senate staff (formerly of BioTechnology, Inc.) and John C. Fegan of the Federal Highway Administration for their suggestions during the conduct of the study. The views expressed in the paper are ours and do not necessarily reflect the views or the policies of the Federal Highway Administration or the U.S. Department of Transportation.

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Abridgment

Evaluation of Selected Messages and Codes for Real-Time Motorist Information Displays

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As a part of an overall freeway information and control system in the Gulf Freeway corridor in Houston, Texas, the Texas Department of Highways and Public Transportation (formerly the Texas Highway Department) installed three lamp matrix changeable message signs in the fall of 1973. These signs were installed as a result of recommendations from a previous systems analysis study by Messer, Dudek, and Loutzenheiser (1). One of the major objectives of the project was to evaluate the understandability and usefulness of the real-time visual information displays. Questionnaire responses were used to evaluate existing and potential improvements in traffic operations and to evaluate the communicative nature of the messages employed. This paper addresses the results obtained in the questionnaire surveys and the inferences that may be drawn from them.

PROJECT DESIGN

The three changeable message signs were installed adjacent to the Gulf Freeway; one large sign (sign A) was adjacent to the freeway main lanes, and one smaller sign (sign B or C) was at each of two major entrance ramps. Because of unexpected circumstances, data obtained applied largely to the freeway sign.

Each sign had three lines of matrix insert. The top line carried the fixed message, FWY CONDITION, which was illuminated whenever the sign was turned on. Adjacent to the fixed message was a single changeable lamp module capable of displaying any single alphanumeric character. The two lower lines of each sign were designed to be capable of displaying any one of three preselected messages.

An initial step in sign design was the development of the required messages. An extensive study of driver information needs and preferences was conducted by Dudek, Messer, and Jones in 1970 (2, 3). That study revealed that qualitative measures (location and length of congestion and degree of congestion) were preferred to quantitative measures (average speed and travel time). On this basis, messages were selected to reflect these qualitative measures (Table 1). To supplement the degree of congestion descriptors (OK, SLOW TRAFFIC, LANE BLOCKED), a series of letter grades forming a rating scale was developed (Table 1). These letter grades were designed to correspond to certain freeway conditions and were displayed on the same line with FWY CONDITION.

The letter-grade rating scale was used to determine whether a simple display could be used to convey the message of the various traffic states. If the letter grades were readily understood, then the cost of a display could be reduced. The letter grades chosen were standard academic grades. The research staff reasoned that the grades would be more readily understood than a number scale.

STUDY DESIGN

Questionnaires designed to measure motorists' attitudes regarding the changeable message signs were distributed to motorists observed passing the freeway sign. These questionnaires were patterned after questionnaires developed in previous research studies conducted on the Gulf Freeway (4) and were distributed under various sign message and traffic flow conditions. A large volume of data was obtained from the three sets of questionnaire studies conducted; additional results are reported in another publication (5).

EVALUATION OF STUDY RESULTS

Motorist Diversion

Several questions on the distributed questionnaire were diversion-related. A total of 428 respondents (69 percent of the total) understood the sign. Eighty-two percent of those drivers (57 percent of the total) indicated that they used the information. Only 12 percent of the total respondents understood the signs but did not use the information.

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

Table 1. Messages used on Gulf Freeway changeable message sign system.

Sign	Information on Congestion	Location and Length of Congestion	Motorist Guidance	Letter Grade Rating Scale
A (On Freeway)	OK SLOW TRAFFIC LANE BLOCKED	3 MI. AHEAD 2 MI. AHEAD 1 MI. AHEAD	KEEP LEFT KEEP RIGHT	A, B, C, D, F, X
B (Griggs Entrance Ramp)	OK SLOW TRAFFIC LANE BLOCKED	3 MI. AHEAD 2 MI. AHEAD 1 MI. AHEAD	USE FRONTAGE ROAD	A, B, C, D, F, X
C (Telephone Entrance Ramp)	OK SLOW TRAFFIC LANE BLOCKED	3 MI. AHEAD 2 MI. AHEAD 1 MI. AHEAD	RAMP CLOSED USE NEXT RAMP	A, B, C, D, F, X

In general, responses to the diversion-related questions showed that the majority of the motorists desired the information and found it useful but that a smaller proportion actually used it to opt for an alternative route. These responses seem realistic and to be expected given the quality of alternate routes available inbound from the sign location.

Sign Design and Communications

Several questions were included to determine whether the sign (and message) actually communicated the intended meaning and whether improvements could be made. A vast majority of the respondents indicated that all of the freeway condition messages were useful. Especially important was the 94 percent affirmative response to the usefulness of lane blocked message. Nearly 200 of the respondents who indicated that the lane blocked message was useful had never seen it displayed, indicating that motorists in general desire this information. The 83 and 90 percent affirmative responses to the usefulness of the off-peak OK and slow traffic messages respectively indicate a confirmation of the hypothesis of the desirability of positive signing.

One of the primary objectives of the study was to determine whether the motoring public would learn the freeway condition and letter grade relationship without an educational program. Under the conditions in which the study was performed, the public as a whole did not learn the relationship. Responses showed that the motorists did not understand the letter grade rating scale. Current Texas Transportation Institute research indicates that the lack of anchoring may have caused driver confusion. Anchoring implies defining the range of scale so that drivers are fully aware of the limits. Because only one letter grade was displayed at a time, the motorist had no way of knowing whether the scale was 6 letters long or 26 letters long. Therefore, there was no way of knowing whether FREEWAY CONDITION C was midway between free flow and heavy congestion (as was the case) or whether it was very near free flow (as would be the case in an A through Z scale). This problem could be alleviated in future installations by appropriately anchoring the scale on the sign.

SUMMARY

The results of this study suggest that changeable message signs may be an effective tool for communicating with urban freeway drivers. Through motorist diversion, they contribute to the reduction in overall delay to the motorist as well as the reduction in total demand on the freeway. Especially important was the significantly positive reaction to the signs and toward the Texas Department of Highways and Public Transportation for their attempts at reducing congestion. Five specific findings are drawn from the results of this research. First, the freeway sign was visible and had a high target value (96 percent of the motorists responding to questionnaires had seen the signs). Second, a majority of motorists understood the signs and the several messages. Of those who understood, 82 percent used the information. Third, the motoring public did not satisfactorily learn the letter grade and freeway condition relationship. Lack of anchoring of the rating scale may have been a contributing factor. Fourth, a majority (78 percent) of the respondents rated the system useful or very useful, including a slight majority (51 percent) who indicated that the system could be improved. Fifth, the analysis of motorist comments revealed that the indication of which lane is blocked when LANE BLOCKED is displayed is highly desirable.

ACKNOWLEDGMENTS

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We wish to express our appreciation to R. G. Biggs and W. A. Cowan of the Texas Department of Highways and Public Transportation for their assistance throughout the conduct of the research. We also wish to acknowledge W. R. McCasland and G. P. Ritch of the Texas Transportation Institute for their assistance throughout the project, R. D. Huchingson of the Texas Transportation Institute for his assistance in the development of the questionnaires, and Richard Fullerton of the Texas Transportation Institute for his coordination of questionnaire studies and data collection.

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Abridgment

Driver Expectancies at Freeway Lane Drops

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Motorists frequently encounter situations on high-speed freeways where the lane that they are driving on and, in some cases, the route that they are following are not continued on the through lanes beyond an interchange. It is currently believed that, in these situations, driver expectancies of interchange configuration may be violated for at least two basic reasons. First, the driver may expect an option to continue through an interchange when, in fact, remaining in a lane forces an exit. Second, the driver may have false expectancies regarding the facility and route relationship. That is, he or she may expect a major route to continue on a facility when it does not. In the interest of gaining information on how current and variations of current forms of signing affect drivers' expectancies in situations where expectancies are violated, two experiments were undertaken. Both were conducted in the Human Factors Laboratory at Fairbank Highway Research Station, which is part of the Traffic Systems Division, Office of Research, Federal Highway Administration.

DESIGN OF EXPERIMENT 1

Experiment 1 included a consideration of the extent to which variations in sign characteristics affect expectancy. Four exit panel messages were compared. They were MUST EXIT, EXIT ONLY, ONLY, and EXIT LANE. These messages were also compared to panels that had no message but did have a directional arrow. Also considered were the effects of sign position (whether the sign was positioned over the right or left lane). Expectancies were divided into those regarding interchange geometrics and those relevant to routes and destinations.

Twenty subjects participated in the experiment. Each subject was seated in a chair and faced a rear projection screen. To measure geometric expectancies as dependent on exit direction messages, eight 35-mm slides depicting a three-lane Interstate highway with different exit sign messages were randomly presented to the subject (Figure 1). Immediately after each slide presentation, a slide of five geometric configurations was presented (Figure 2). The subject was instructed to choose the geometric configuration that he or she would expect to see at the approaching exit as determined by the message content and the positioning of the sign previously presented. The subject then verbally indicated the relative certainty of his or her response on a five-point scale. The experimenter recorded the subject's choice, response time (the time between the slide presentation and a subject response), and certainty for each trial.

A second slide set was presented to the subject to identify his or her route and destination inconsistencies as applied to choice of appropriate path at exits. The subject was first given instructions regarding the route to follow and destination. A slide of the highway with the exit approach sign that contained route and destination information was presented and was immediately followed by the presentation of a slide with four route and destination combinations. The subject indicated his or her expectancy of the route and destination combinations and verbally indicated the certainty of the response after each trial.

RESULTS OF EXPERIMENT 1

The results of experiment 1 indicate the superiority of the MUST EXIT and EXIT ONLY panels in terms of the data collected. This is especially apparent in the geometric portion of the study. The results of geometric accuracy seem to indicate not only that a worded exit message appears to convey a more definitive message to the driver regarding interchange geometrics but also that a great disparity exists between the psychological meaning of the words chosen. The words "must" and "only" evidently have a large influence on the accuracy of driver choices for lane drop geometrics. The other worded exit panels, although significantly improving accuracy choices over panels containing arrows, were not significantly different from one another. This would imply that there may be other words whose psychological impact is strong enough to substantially increase the accuracy of drivers' predictions. Of course, there may

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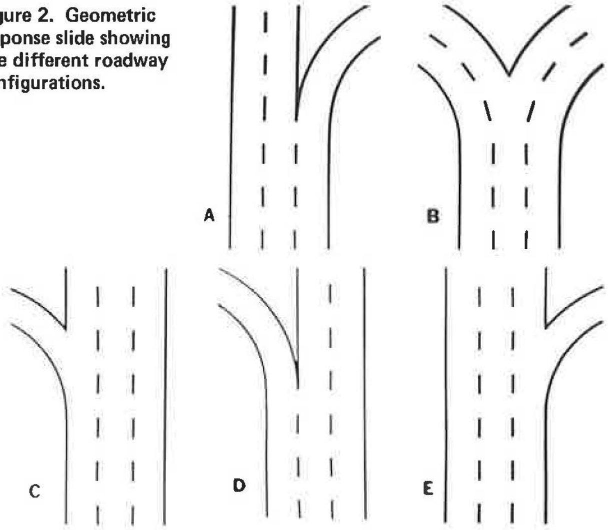
Figure 1. Stimulus slide showing roadway scene and exit direction sign.

Figure 2. Geometric response slide showing five different roadway configurations.



be symbols or combinations of words and symbols that also would be effective.

The results of the route and destination portion of experiment 1 are fairly inconclusive. The MUST EXIT panel had a significant advantage in influencing correct judgments for reaching a destination. There appears to be no obvious explanation for this effect. The MUST EXIT panel was significantly better than all other panels for latency, and there were no significant differences between the panels for the certainty measure.

Each subject, after the experimental sessions, was asked to interpret the meaning of the panels. Between 90 and 95 percent of the subjects made correct judgments for MUST EXIT and EXIT ONLY panels respectively and only 50 to 65 percent chose correctly for the ONLY and EXIT LANE panels respectively.

Exit panels, in general, appear to be more effective in influencing interchange geometric expectancies of the driver and appear to have little effect on route and destination expectancies. It may be that, in situations where the route leaves the facility, the facility leaves the route, and so forth, this information could be more meaningfully conveyed by some alternate information source.

DESIGN OF EXPERIMENT 2

In experiment 2 the MUST EXIT and EXIT ONLY panels were retained, and, for comparison, a no panel condition was included. Sign position was also retained. The third consideration dealt with the effects of diagrammatic signs. Diagrammatic signs and major splits were included in the design to (a) contrast the diagrammatic sign efficiency with the efficiencies of conventional signs at exit configurations and (b) test the effectiveness of exit panel messages when used in conjunction with diagrammatic sign content. The procedure for experiment 2, with the exception of the slides presented, was the same as that for experiment 1.

RESULTS OF EXPERIMENT 2

The effects of the exit panels as used in the exit lane drop situations were clear cut. The primary element that influences the expectation of a lane drop configuration at exits seems to be the presence or absence of an exit panel message. In experiment 2, no significant differences were found between MUST EXIT and EXIT ONLY panels for any measures. The inclusion of either panel on a sign yielded significantly better results than a sign with no exit panel at all. The advantages of the panels were particularly notable when they were used in conjunction with conventional signs, although the diagrammatic sign performed equally well whether an exit panel was present or not. Because a portion of the content of a diagrammatic sign is essentially a diagram of the interchange configuration, drivers may require no information other than that provided by the diagram to identify a lane drop situation. The conventional sign, on the other hand, does not have this advantage; therefore, an additional exit panel may be needed to inform the driver of the impending dropped lane.

The use of exit panels at major split configurations is contraindicated. The only significant results regarding panels as split configurations were found in the certainty measures where no panel yielded more assured responses than either MUST EXIT or EXIT ONLY. At the same time, on every measure, the diagrammatic signs proved to be significantly better than the conventional signs at the split configurations.

Although diagrammatic and conventional signs at exit lane drop configurations yielded comparable results on both certainty and lane drop expectation measures, there was a significant difference in the reaction time measure and diagrammatic signs yielded quicker responses. This may result from the nature of the diagrammatic sign, which requires for geometric purposes symbol matching rather than word interpretation. The relatively shorter time for matching compared with that for interpretation could easily yield a similar relationship between the respective reaction times without reducing the comparability of certainty and expectation scores.

Reaction times were shorter for signs indicating a left exit than for those indicating a right exit. It is interesting to note that more drivers indicated that they expected a lane to be dropped at a left exit than at a right exit. This tendency is not present for driver expectations at split configurations. Although drivers are not generally thought to expect lane drops, it may be that, when a left hand exit is known in advance, a lane drop is more likely to be expected.

CONCLUSIONS

In general, the data indicate that the selection of exit panels for specific applications should be influenced by the type of sign selected (diagrammatic or conventional) and the direction in which the exit diverges from the roadway (EXIT ONLY panels are superior to MUST EXIT panels at left exits). Based on the research to date, it seems clear that exit panels significantly improve the correctness of driver expectations of freeway interchange geometrics in terms of lane drop configurations. Of all messages tested, the MUST EXIT and EXIT ONLY panels were the most helpful in correctly influencing expectations. The difference in efficiency of these messages seems small, and probably either one could be adopted. In the interest of improving the accuracy of driver expectancies, it would seem that only one exit panel message should be used.

Diagrammatic signs appear to have influenced expectancies favorably, but the cost factors associated with installing this type of sign where conventional signs now exist may make their use prohibitive in the near future. Exit panels affixed to existing conventional signs may offer a sufficient short-term solution.

Analysis and Design of Freeway Incident Response Systems

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Described in this paper is the development of a two-phase procedure for the optimal design of nine specific types of a freeway incident response system. As a basis for analysis, individual system components were classified into three groups according to their functions and design variables: (a) detection, (b) service, and (c) detection and service. Mean response time was selected as the measure of system effectiveness. In the first phase, steps leading toward the optimal disposition of a given number of detection or service units or both in the service area were developed for each component group. The relationship between mean response time and component design variables was first derived. Mathematical programming techniques were then used to determine the optimal component design that minimizes the mean response time. The optimal allocation of a given resource (e.g., annual budget) among competing components of a total system was determined in the second phase by using the results from the first phase. Based on component interactions, the relationship between mean system response time and the response times of individual components was formulated as the objective function of a resource allocation problem. For a given resource, the optimal component integration for a specific type of system was generated by solving this problem. Potential applications of this two-phase procedure in system design and in evaluating alternative system types were demonstrated by numerical examples. Although analysis results and conclusions were limited to the specific types of systems and the hypothetical input data considered in this study, the methodology is general and can be applied to the planning and design of other types of systems not considered here.

On urban freeways carrying heavy traffic, a reduction in roadway capacity due to traffic incidents usually results in traffic congestion. Such congestion not only results in delay to the motorists affected by the incidents but also may cause secondary incidents and delay in treating injured victims. Because of the nature of limited access to nearby service areas from a freeway facility, special problems also arise from the difficulty of summoning aid to the incident site. In view of the adverse effects of traffic incidents, it is evident that there exists the need for a highly responsive and controlled emergency detection and roadside service system to guarantee minimum delay and maximum safety to all motorists.

A traffic incident response system is a multicomponent system for the rapid and adequate response to traffic incident needs. Each component consists of specific hardware and attendant units designed to perform the function of incident detection or service or both. The efficiency of such a system depends not only on the hardware sophistication of its component units but also and, what is more important, on the quantitative mix of different types of component units in the total system and the physical disposition of such units in the service area. A recent review of traffic incident response systems revealed that most of the systems now in operation were developed with limited advance planning and design. Thus, even with current technology, the incident needs conceivably could have been better served if the proper mix of component units and their disposition in the service area had been well reflected in the system design. It is with such a realization that the Institute of Transportation and Traffic Engineering at the University of California, Berkeley, undertook a research study, sponsored by a U.S. Department of Transportation (DOT) university research grant, on the optimal design and operation of freeway detection-service systems (1). Presented in this paper is a particular phase of this research project that gives emphasis to the development and demonstration of an analytical procedure for the optimal allocation of specific hardware and attendant units among various components of an incident response system and their optimal disposition in the service area. This particular phase of research covers four major areas: (a) identification of system components and alternative types of systems selected for detailed study, (b) discussion of system design considerations, (c) analysis and design of system components, and (d) optimal integration of system components in a total system. Many valuable results from previous studies and publications have been used in this study (1, 2, 3, 4, 5, 6, 7, 8, 9, 10).

IDENTIFICATION OF SYSTEM COMPONENTS AND ALTERNATIVES

The study began with a review of the state of the art in traffic incident detection and service techniques and covered the use of ground and aerial patrol units, passing

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motorists, citizens band radios, observers, television cameras, electronic detectors, telephone units, call-box units, stationary police and service units, fire trucks, and ground and aerial medical response units. Among the many types of incident detection and service components, six were selected for detailed study: emergency telephone, call box, police patrol, stationary police, service patrol, and stationary service. Emergency telephone units are those installed on both sides of the roadway at specific intervals to provide direct voice communication between the user and the service dispatcher for the report of incidents and request for needed services. Call-box units are coded roadside radio units for the transmission of incident service requests. The user pushes one or more of the buttons on the unit for the required services and transmits a digitally coded signal to the dispatch center where the signal is decoded and information on calling locations and requested assistance is printed on a tape. Police patrol or service patrol units are specially equipped vehicles moving along the roadway in designated patrol beats. A patrol unit can detect an incident on its patrol route or can be dispatched to the incident site to render required service or evaluate service needs. Stationary police or stationary service units are specially equipped vehicles stationed at strategic locations along the roadway. When an incident occurs, stationary units can be sent by the dispatch center to the incident site to provide needed services or evaluate service needs; these units do not detect incidents.

Within the resource limitations of this study, these six system components were selected for detailed analysis because their effectiveness is particularly sensitive to changes in system design configuration (number of component units and their disposition in the service area); therefore, they are more relevant to the study objective. Although fire fighting and medical response are both important services to traffic incident needs, they were not included in this study mainly because they are part of the overall fire or medical emergency response system for the community. In the analysis and design of these components, consideration should be given to the overall fire and medical service needs of the community, not only to the needs of traffic incidents. Furthermore, past experience has indicated that the frequency of these needs in a traffic incident situation is very low when compared with the frequency of other types of service needs. The inclusion or exclusion of these components in the design of an incident response system will not significantly affect the design of other system components.

Based on logical combinations of the six selected components, nine alternative types of incident response systems were identified by number as shown by the data given in Table 1. In the nine system alternatives considered, the telephone or call box is considered to be the detection component that performs the function of incident detection only. Stationary police and service units are considered to be the service components that render needed services but do not detect incidents. Police and service patrol units can perform the dual function of detection and service and are considered to be the detection and service components. A system alternative can have two different types of components for the same function, such as call boxes together with police or service patrol for incident detection. But different modes of operation of the same type of service are not considered in a system alternative. That is, if the police patrol is used as the detection and service component, stationary police will not be considered in the same system alternative.

SYSTEM DESIGN CONSIDERATIONS

Several external factors influence the optimal design configuration of an incident response system: response process, system objectives, effectiveness measures, incident characteristics, roadway features, and traffic conditions. From the system design point of view, these factors define the conditions for which an incident response system is to be designed and therefore are the input to the design process.

The response process represents the individual activities of various system components in performing their assigned functions and their relationships on the time scale as shown in Figure 1. In general, all of these activities are coordinated at a communication or service dispatch center that receives calls for assistance and dispatches the required service units to the incident scene. The returning of a service unit to its base station was not considered a part of the response process because, with two-way communications, the service unit is available for the next incident as soon as it completes the current service.

Possible objectives of an incident response system were identified and analyzed from the viewpoints of two recipient groups: stranded motorists directly involved in a traffic incident and passing motorists affected by a traffic incident. Based on an analysis of the relationships between alternative objectives, a single objective of rapid detection and service response to an incident was selected as the representative objective for the design of the nine system alternatives considered in this study.

Various forms of system effectiveness measures were considered. Their measurability and reliability were analyzed. Based on the selected system objective, the effectiveness of individual system components and the total system was expressed by the mean response time to an incident. According to Figure 1, the mean response time of a detection component is the mean detection time; that of a service component is the mean service response time; and that of the total system is the mean system response time, which is the sum of mean detection time and mean service response time.

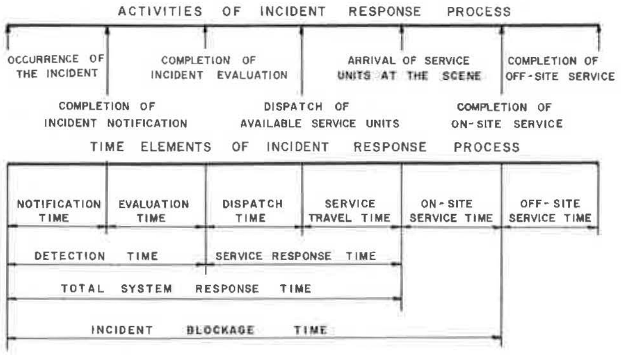
One major input to the design process is the information on when and where traffic incidents occur. Such information usually is generated from the historical incident data for the service area under consideration or can be estimated by using various incident prediction models. Although the generation of incident data was not a subject of this study, a statistical analysis on a set of real-world incident data from the San Francisco-Oakland Bay Bridge was performed to gain a better understanding of traffic incident distribution with respect to time and space and the possible influence of traffic flow conditions and roadway geometric features on such distribution. Within the limits of the uniqueness of the data and its sample size, it was found that, for a 30-min interval, incident distribution can be approximated by the homogeneous Poisson distribution and the influence of both traffic flow condition and geometric feature on incident distribution was significant. Although the bridge incident data may not be typical of freeway incidents, the analysis provided useful insight into the formulation of a basic procedure for the design of incident response systems that is sensitive to the varying conditions of both traffic flow and roadway geometric features.

The frequency distribution of incident service needs was investigated to provide input data for the proper mix of various components in the total system. Four major types of service needs were identified: (a) service (mechanical repair, tire repair, gas, oil, water, and other nonemergency services); (b) police, (c) medical,

Table 1. System alternatives considered.

	Stationary Service Component		Service Patrol Component	
Detection Component	Stationary Police	Police Patrol	Stationary Police	Police Patrol
Telephone	1	2	3	—
Call box	4	5	6	—
Police patrol	—	7	—	9
Service patrol	—	—	8	9

Figure 1. Incident response process.



and (d) fire. Among these four types of needs, service was found to be the most frequently needed.

Major roadway characteristics are the boundary of the service area, the geometric features in the service area such as grades and service routes, the locations of on and off-ramps, and the locations of feasible candidate sites for the disposition of detection and service units. These characteristics not only influence the incident distribution but also determine the feasibility of different types of system components and their operational procedures. In this study, the service area of a response system was defined as the two-way linear section of a freeway. The subsections between consecutive on and off-ramps were considered to be the subservice areas and were treated as the basic design units. However, the actual length of the freeway section and other roadway characteristics can vary depending on the service area under consideration and should be specified by the system designer as input to the design process.

Another important input item is the traffic flow or travel time information for the service area. Traffic flow not only influences the incident distribution but also has significant effect on the delay to passing motorists and the travel time of incident response units. The traffic performance under incident condition is itself an interesting subject to study. Several analytical procedures are available for the calculation of travel time and delay under varying traffic demand and capacity situations such as the FREQ model (2), the flow-dependent travel time function (3), and, under certain assumptions, the tandem queuing model. However, a detailed study on this subject is beyond the scope of this study and empirical travel time data or data from separate analysis by the above methods were assumed to be available as input to the system design process.

ANALYSIS AND DESIGN OF SYSTEM COMPONENTS

Conceptually, the optimal design of an incident response system was approached in two phases. The first phase involved the determination for each selected system component of the optimal design configurations (the optimal disposition of component units in the service area) of given levels of component units. By using the results from the first phase as input, we determined the optimal allocation of a given resource among competing components of a total system in the second phase.

To accomplish the first phase, the design variables of each selected component were first identified. For each selected component, a relationship between the mean component response time (the selected effectiveness measure for the component) and its design variables was developed, and the effect of changes in design variable values on component effectiveness was investigated. For a given level of component units, the optimal design configuration of a component is characterized by the set of design variable values that minimizes the mean component response time. The analysis of individual components was performed for three component groups: (a) detection components, (b) service components, and (c) detection and service components. Each of the six selected basic components of an incident response system was classified into one of these three groups according to its functions in incident response and its design variables. As a basis for the analysis, the service area of each system component is a section of urban freeway of length L, which consists of n subsections (roadway segments between consecutive on and off-ramps); each has length ℓ_i $(i = 1, 2, \dots, n)$. Also all system components were analyzed for a specific time period t during which the incident intensity in each subsection λ_i is considered to be known.

Detection Components

System components of this group consist of discrete communication units (telephones or call boxes) that are installed along the freeway at specific intervals and are connected to the communication or service dispatch center by means of communication links. The design variables of a detection component are the spacings between detection units in different subsections of the freeway facility under consideration. Although the unit spacings in different subsections may not be the same because of varying incident intensities, the unit spacing within a subsection was assumed to be uniform.

The effectiveness of a detection component is measured by the average time required to complete the incident reporting following the occurrence of an incident or the mean notification time as shown in Figure 1. The notification time is the sum of three time elements: recovery time, walking time, and communication time. Recovery time is the time needed by those involved in the incident to react to the situation. It includes the initial examination of the incident situation and self-help by the stranded motorist before he or she decides to use the communication units to call for help. The duration of this time period may vary from less than 1 min to more than 30 min depending on when the stranded motorist decides to call for help. An average of 1.5 min was assumed in the analysis. The walking time is the time required of the stranded motorist to walk from the incident site to the nearest call unit. Because call units are usually installed on both sides of the roadway, the walking distance can be assumed to be the linear distance parallel to the roadway alignment. Based on an assumed walking speed, the mean walking time is a function of the spacing between detection units. The communication time is the time needed to complete the incident report after the call unit is activated. For the call-box unit, the transmission and decoding of the radio signal can be considered instant; therefore, the communication time was assumed to be zero. For the telephone component, however, an average of 1 min was assumed.

Among the three elements of the incident notification time, only the walking time is influenced by the spacing between detection units and the location of the incident. If we assume that the distribution of incident location is also uniform within a subsection, the maximum distance between an incident and the nearest detection unit is one-half of the unit spacing and the average distance is one-fourth of the unit spacing. Based on these considerations and use of the incident intensity in each subsection as the weight, a relationship between the mean notification time of a detection component and its design variables was developed:

$$\overline{t_n} = \overline{t_x} + \overline{t_z} + \sum_{i=1}^{n} (\lambda_i \times s_i) \Bigg/ \left(\sum_{i=1}^{n} \lambda_i \right) \times 4v \qquad (1)$$

where

$\overline{t_n}$ = mean notification time,
$\overline{t_x}$ = mean recovery time,
$\overline{t_z}$ = mean communication time,
s_i = unit spacing in subsection i, and
v = mean walking speed.

Because both the mean recovery time and the mean communication time are independent of the design configuration of a detection component, the mean notification time varies with the unit spacing in each subsection. For a given total number of detection units in the service area K, the optimal design configuration of a detection component is the unique distribution of K units along the freeway section that yields minimum mean notification time. This unique distribution can be generated by solving the following optimization problem:

$$\text{Minimize } \overline{t_n} = \overline{t_x} + \overline{t_z} + \sum_{i=1}^{n} (\lambda_i \ell_i / k_i) \Bigg/ \left(\sum_{i=1}^{n} \lambda_i \right) \times 4v \qquad (2)$$

subject to $\sum_{i=1}^{n} k_i = K$ where k_i = number of detection units in subsection i.

An algorithm, DETECT, was developed to solve this optimization problem. By solving the problem for different levels of component units (different values of K), we determined an optimal relationship between level of component units and component effectiveness. Such a relationship was used as an essential input to the optimal allocation of available resources among various components of an incident response system in the second phase of the design process.

Service Components

System components of this group consist of service units (police or service vehicles and their attendants) stationed at strategic locations (base stations) along the freeway section. In an incident situation, service units are dispatched by the communication center to the incident site to provide needed services or to evaluate the incident service needs; but service units do not detect incidents. Two distinctive service dispatch policies were analyzed. The dispatch policy adopted in this study was that the entire service area of the service component is divided into several nonoverlapping service beats (subsections of the freeway section) according to the size of the service area, total number of service units available, and certain desirable constraints on incident service response time. Service units assigned to a particular service beat respond only to the incidents occurring in that beat and always return to the same base station after rendering the needed service.

The design configuration of a service component is characterized by four variables: (a) number of service beats in the service area, (b) size of each service beat, (c) location of the base station for each service beat, and (d) number of service units in each service beat. Under the system objective and selected effectiveness measure, the optimal design of a service component for a given total number of service units is characterized by the best combination of these four variables that yields the minimum mean service response time.

The mathematical relationship between the mean service response time and these four design variables was derived and expressed as the objective function of an optimization problem by treating the service component as an M/G/N queuing system. To find a practical solution to this optimization problem, we investigated the sensitivities of the two elements of the mean service response time (mean travel time and mean dispatch time) to changes in design variable values. The mean travel time was influenced only by the number of service beats, their size, and the locations of their base stations; the mean dispatch time was mostly influenced by the number of service units in each service beat.

Based on these findings, the optimal design of a service component was approached in two steps. The first step is to perform the optimization with respect to the mean travel time under the desirable constraints on the number and size of the service beats in the service area. The output from this step is the best combination of the number of service beats, the size of each service beat, and the location of each base station among a set of candidate sites, which yields the minimum mean travel time for all service units in the service area. After the output from the first step is used as the given condition, the second step is to optimize the distribution of a given total number of service units among individual service beats so that the mean dispatch time of the service component is minimized.

In generating the optimal design of a service component, we also considered several design and operational aspects. First, not every point in or near the service area of the component is economically or practically feasible as a base station for service units. Therefore, the selection of station locations was made from a set of finite and predetermined candidate sites that are considered to be feasible for such a purpose. Second, for economic reasons, it is desirable to minimize the number of base stations for a service area; however, for operational efficiency it is also desirable to have smaller service beats and hence more base stations in the service area. The approach used in this study to compromise cost and operational efficiency is to minimize the number of service beats subject to the constraint that the maximum service travel time in a service beat be below a certain acceptable value. Therefore, the minimum number of service beats in the service area was determined by a predetermined value on the maximum service travel time in each service beat. Finally, the maximum number of service beats is restricted by the smallest of the total number of service units available and the total number of freeway subsections in the service area. All of these considerations were entered into the optimization procedure as constraints.

An algorithm, SERVICE, was developed for the application of the two-step optimization procedure. By repeated application of this algorithm to different levels of total given service units, an optimal relationship between number of service units and minimum mean service response time was developed. Such a relationship served as the basic input to the optimal allocation of resources among competing components of an incident response system.

Detection and Service Components

System components of the detection and service component group consist of police patrol and service patrol units that move along the freeway for incident detection or service or both. The merits of two different patrol strategies (one with overlapping patrol beats and the other with nonoverlapping beats) were analyzed. The patrol strategy with nonoverlapping patrol beats was assumed in this study for the analysis and design of detection and service components.

The incident response time of a detection and service component was analyzed for two cases: (a) when a patrol unit detects an incident on its patrol route and (b) when an incident is detected by some other means and a patrol unit is dispatched to the scene to render required service or evaluate service needs. For both cases, the detection time (the time period from occurrence of an incident to arrival of a patrol unit at the scene) was found to be the most representative and crucial measure of the effectiveness of a detection and service component. Therefore, for a given total number of patrol units in the service area, the design configuration of a detection and service component was analyzed under the objective of minimizing the mean detection time.

The detection time of a patrol unit in a patrol beat is a function of the time headway between patrol units in that beat and is influenced by the following factors:

1. Length of patrol beat,
2. Prevailing traffic condition in the patrol beat for the time period under consideration,
3. Incident intensity in the patrol beat,
4. Number of patrol units assigned to the patrol beat, and
5. Service time of individual incidents served by the patrol units.

Factors 1 and 2 determine the travel time of a patrol unit to complete a patrol loop without interruption for incident detection or service or both. Factors 3 and 4 determine the frequency of interruptions that a patrol unit may encounter during a patrol loop. Factor 5 determines the duration of each such interruption or the delay to a patrol unit due to incident detection or service or both. Based on their influence on mean patrol headway, a mathematical relationship between the mean detection time of a detection and service component and these factors was derived. The optimal design of a detection and service component for a given total number of patrol units was then approached by solving an optimization problem for which this mathematical relationship is the objective function.

For the solution of this optimization problem, an algorithm, PATROL, was developed. For a given number of patrol units in the service area, the algorithm determines the number of patrol beats, the best partition of the service area into such patrol beats, and the best allocation of given units among patrol beats so that the mean detection time of the detection and service component is minimized. A numerical application of the algorithm indicated that both the optimal partition of the service area and the allocation of patrol units among patrol beats vary with the total number of patrol units available in the service area.

OPTIMAL INTEGRATION OF SYSTEM COMPONENTS

The second phase of the system design process involved the optimal integration of individual system components in a total system for a given resource. The optimal integration of system components was treated as a resource allocation problem in which the given resource was allocated, in terms of hardware and attendant units, to individual components of an incident response system. The allocation is such that the resulting mean response time to an incident of the total system is minimized. To accomplish this second phase, the interactions among individual components in a total system and the mean response time of the total system to each of the three different types of incidents were analyzed.

1. Incidents requiring the response of a police unit only,
2. Incidents requiring the response of a service unit only, and
3. Incidents requiring the response of both police and service units.

Based on results from the analysis of component interactions in a total system, a mathematical relationship between the mean system response time and the mean response times of individual components was derived for each of the nine system alternatives considered in this study. By using these relationships as the objective functions and the optimal relationships between component units and the mean response time of individual components developed in the first phase as the return functions, we developed the specific forms of the resource allocation problem for the nine system alternatives. An algorithm, ALLOCATE, was then developed for the solution of these resource allocation problems. With the application of this two-phase procedure, the best design configuration of a specific system alternative for a given resource can be determined in terms of the proper amount of hardware and attendant units assigned to each system component and their best disposition in the service area.

The two-phase procedure is a useful tool not only in system design but also in system planning and evaluation. Its potential applications were demonstrated in several numerical examples. The service area assumed for the numerical examples was an 8-km-long (5-mile-long) urban freeway with five 1.6-km-long (1-mile-long) subsections. Input data on incident intensity, candidate sites for service units, travel times between incidents and service unit bases, distribution of service needs, and the like were either generated from actual observations or assumed for the purpose of illustration. The cost data used were developed from the cost information collected from eight different toll authorities and highway agencies for an earlier study (3). Costs included both capital and operating costs and were expressed annually based on assumed lives of different types of hardware and the pay scale of various service personnel. Because the cost and other input data used in the numerical examples are not typical and were used only to demonstrate the potential applications of the analytical procedure developed in this study, the results and conclusions from such applications, as described below, can only be interpreted within the limits of these data.

To illustrate its use in system design and evaluation, the two-phase procedure was applied to each of the nine system alternatives considered in this study under the constraint of an assumed annual resource of $300 000. As a result of this application, the number of hardware and attendant units assigned to each system component, the mean system response time, and the actual annual cost under the ceiling of the given resource were determined for each system alternative as given in Table 2. Based on Table 2, the merits of the nine alternatives were evaluated by using two different criteria: mean system response time and effectiveness-cost (E/C) ratio. The E/C ratio was defined as the number of minutes saved in mean system response time, when compared to a hypothetical system that has zero annual cost and a mean system response time of 30 min, for every thousand dollars invested annually. The results of this evaluation are given in Table 3. Except for alternative 9, the two criteria resulted in the same ranking of alternatives.

To demonstrate another potential application, the procedure was used to evaluate relative effectiveness of different types of system components for four selected cases.

1. Telephone versus call box,
2. Police patrol versus stationary police,
3. Service patrol versus stationary service, and
4. Police patrol and stationary service versus service patrol and stationary police.

For each case, the mean system response times and the E/C ratios of the system alternatives that have identical other components (alternatives 1 and 4 in the first case) were calculated based on an assumed common number of component units for each system component. The assumed number of detection units for a telephone or a call-box component was 20. The number of vehicles and attendant units assumed for a police patrol or a service patrol component and for a stationary police or a stationary service component was 2. The results of this sensitivity analysis are as follows for case 1, telephone versus call box:

Other Common Components of System	Mean System Response Time (min)		E/C Ratio	
	Telephone	Call Box	Telephone	Call Box
Stationary police + stationary service	8.40	11.11	0.085	0.075
Police patrol + stationary service	7.34	11.54	0.087	0.072
Stationary police + service patrol	7.78	8.61	0.084	0.081

For case 2, police patrol versus stationary police, the results are as follows:

Other Common Components of System	Mean System Response Time (min)		E/C Ratio	
	Police Patrol	Stationary Police	Police Patrol	Stationary Police
Telephone + stationary service	7.34	8.40	0.087	0.085
Call box + stationary service	11.54	11.11	0.072	0.075
Service patrol	7.90	8.61	0.085	0.084

For case 3, service patrol versus stationary service, the results are as follows:

Other Common Components of System	Mean System Response Time (min)		E/C Ratio	
	Service Patrol	Stationary Service	Service Patrol	Stationary Service
Telephone + stationary police	7.78	8.40	0.084	0.085
Call box + stationary police	8.61	11.11	0.081	0.075
Police patrol	7.90	11.54	0.085	0.072

For case 4, police patrol and stationary service versus service patrol and stationary police, the results are as follows:

Other Common Components of System	Mean System Response Time (min)		E/C Ratio	
	Police Patrol and Stationary Service	Service Patrol and Stationary Police	Police Patrol and Stationary Service	Service Patrol and Stationary Police
Telephone	7.34	7.78	0.087	0.084
Call box	11.54	8.61	0.072	0.081
—	11.54	8.61	0.072	0.084

Within the limits of the unique conditions pertaining to the service area and the number of component units assumed for the analysis, four observations were made.

1. The telephone was more effective than the call box as a detection component in all three system alternatives investigated.
2. The police patrol was more effective than the stationary police when the telephone component or service patrol component was present. But police patrol was less effective when the call box was used as the detection component because an on-site evaluation by a police patrol unit was assumed and, for the same number of police units assumed in the analysis, the police patrol had longer mean response time than the stationary police had. When the number of police units in the service area increases, police patrol may become more effective than stationary police for this particular case.
3. Considering the mean system response time, service patrol was more effective than stationary service in all three alternatives investigated. Service patrol was also more effective than stationary service with respect to the E/C ratio in two alternatives. However, with telephone and stationary police as the common components, the two systems had nearly the same E/C ratio.
4. Police patrol plus stationary service was more effective than service patrol plus stationary police when the telephone was used as the detection component. But when the call box was used as the detection component or when there were no discrete detection units in the system, service patrol plus stationary police was more effective.

For the purpose of investigating the effect of different levels of resource on system effectiveness, the two-phase procedure was applied to each of the nine system alternatives at six additional levels of annual resource constraint in $50 000 increments ($350 000, $400 000, $450 000, $500 000, $550 000, and $600 000). For each annual cost constraint investigated, mean system response times for the nine system alternatives were calculated. The relationship between mean system response time and level of cost constraint for each system alternative is shown in Figure 2. Because component units were allocated in integer numbers, the data points in Figure 2 may not match exactly with the assumed levels of cost constraint but rather indicate the actual annual system cost under each cost level. Based on Figure 2, three observations can be made.

1. For all nine system alternatives investigated, mean system response time decreases as cost level increases, but at a decreasing rate.
2. The relative effectiveness of different system alternatives is not uniform at all cost levels investigated. For example, at a cost level below $300 000, alternative 2 has the least mean system response time

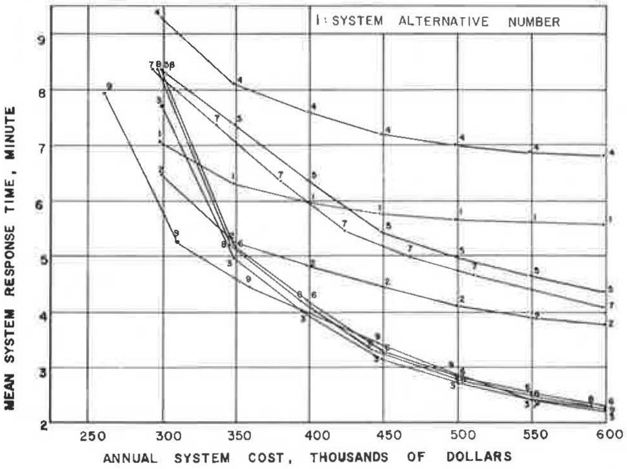
Table 2. Allocation of given resource among system components.

System Alter-native	Number of Hardware and Attendant Units Allocated: Call Box	Tele-phone	Police Patrol	Service Patrol	Sta-tionary Police	Sta-tionary Service	Mean System Response Time (min)	Actual Annual System Cost ($)
1		27			2	3	7.04	299 770
2		15	2			3	6.49	299 650
3		87		2	2		7.69	299 370
4	36				3	2	9.32	299 850
5	15		3			2	8.37	299 600
6	9			2	3		8.37	299 960
7			3			2	8.37	293 000
8				2	3		8.37	296 000
9			2	2			7.90	261 000

Table 3. Comparison of system alternatives.

System Alter-native	Mean System Response Time (min)	Annual Cost ($)	Savings in Mean System Response Time (min)	E/C Ratio	Rank: Based on Response Time	Rank: Based on E/C Ratio
1	7.04	299 770	22.96	0.077	2	3
2	6.49	299 650	23.51	0.079	1	2
3	7.69	299 370	22.31	0.075	3	4
4	9.32	299 850	20.68	0.069	9	9
5	8.37	299 600	21.63	0.072	7	7
6	8.37	299 960	21.63	0.071	8	8
7	8.37	293 000	21.63	0.074	5	5
8	8.37	296 000	21.63	0.073	6	6
9	7.90	261 000	22.10	0.085	4	1

Figure 2. Mean system response time at given levels of annual cost constraint.



of all nine alternatives, but its rank drops to fourth at cost level $350 000. For cost levels beyond $300 000, alternative 3 has the least mean system response time of all nine alternatives. The range of the mean system response times for alternatives 3, 6, 8, and 9 is small, but they are significantly less than those of the other five alternatives considered. This indicates that systems with telephone or service patrol units or both are generally more effective. This may be expected because both telephone and patrol units are more effective detection units and the need for service units is more frequent than for police units.

3. Considering the mean system response time, alternative 4 is the least effective system of all nine alternatives at all cost levels investigated. This indicates that, when call boxes are used as detection units, systems with patrol units are always better than systems with stationary units only.

In addition to these observations, this type of analysis can be very helpful for system planning in two other respects. It provides useful data for the proper selection of system alternatives when an increase in future funding level is anticipated. Also the analysis can be helpful in estimating the required funding level for the desired level of system effectiveness.

SUMMARY

Presented in this paper is a summary description of the development of a two-phase procedure for the analysis and design of freeway incident response systems. The first phase gives emphasis to the analysis of individual system components. For six selected types of components, specific relationships between component effectiveness and their design variables are developed and the effect of changes in component design on component effectiveness is analyzed. The second phase gives emphasis to the analysis of component interactions in a total system. For nine selected system alternatives, the relationships between total system effectiveness and effectiveness of individual components are derived, and steps for the optimal integration of system components in a total system are developed. The usefulness of this procedure in several aspects of system planning, design, and evaluation is illustrated by a set of numerical examples. Although the study results are only applicable to the specific components and system alternatives considered in this study and represent the analytical outcome of a set of assumed input data, the methodology used is general and can be applied to a range of real-world situations or can be expanded to include other types of system components not analyzed in this study.

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Improving Commercial Radio Traffic Reports in the Chicago Area

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An operational computerized traffic report network based on electronic freeway surveillance and designed to improve commercial radio traffic reports is described. The report network was implemented after a comprehensive home-interview survey was conducted in the Chicago area to determine motorists' attitudes toward driving information. An analysis of that part of the survey related to the commercial radio traffic report is presented. Questions were analyzed to determine the potential of radio reports, the effect of radio reports on diversion, and the importance of various types of information. Expressway drivers found commercial radio traffic reports slightly more useful than did nonexpressway drivers. Information was more important for the trip to work than for the trip home. Also drivers indicated that they diverted to alternate routes because of radio traffic reports.

A driver information system is an integral part of an urban corridor traffic management system. The ideal information system should be able to provide the driver with pertinent information at any point in time and space from origin to destination. An existing means that can provide the urban driver with continuous information at practically any point along a journey is the commercial radio.

In 1969, the Chicago Area Expressway Surveillance Project, Illinois Department of Transportation, conducted a home-interview survey to determine driver behavior and attitudes toward driving information (1, 2, 3, 4). The analyses in this report are based primarily on two series of questions from the survey pertaining to radio traffic reports. The specific objectives were to determine

1. The potential of commercial radio traffic reports as a workable component of a driver information system;
2. The effect of commercial radio traffic reports on the driver's choice of route, time of trip, and the like;
3. The importance and kind of information drivers should receive from commercial radio reports; and
4. The difference in attitude toward commercial radio between expressway and nonexpressway drivers.

In the overall home-interview survey, 732 usable interviews were obtained; 417 of the respondents were expressway drivers (drivers making some portion of their trip on an expressway) and 315 were nonexpressway drivers. The survey was primarily concerned with the home-to-work commuting trip. Frequency of certain behavior, or the importance of some aspect of driver information, was obtained by using the scales shown in Figure 1.

A chi-square analysis was conducted to find whether there was a significant difference between the responses of expressway drivers and the responses of nonexpressway drivers to 34 questions from the survey (5). Where a statistically significant difference was found, expressway and nonexpressway drivers are identified; otherwise, the term "drivers" is used.

In addition to analyzing survey questions, the report concludes by describing an operational computerized traffic report network implemented to improve commercial radio traffic reports.

COMMERCIAL RADIO USAGE

Coverage

Ninety-nine percent of the drivers interviewed responded that they have radios in working condition in their homes. Ninety-four percent have radios in working condition in the cars that they drive to and from work.

The following tabulation shows that, most of the time, drivers choose a route even before leaving home or work (ranges are due to data grouping in analyses):

Time	Average Frequency (%)
Before leaving home	80 to 85
After leaving home	15 to 17
Before leaving work	77 to 81

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Furthermore, as shown in Figure 2, more than two-thirds of the drivers always choose their routes to work before leaving home, and only 7 percent always choose their routes after they are on the road system. For the trip home from work, 64 percent of the drivers always choose routes before leaving work and 11 percent always choose routes after they are on the road system.

The evidence indicates that most drivers make route choices at the beginning of a trip. Research by Dudek, Messer, and Jones (6) reported that 42 percent of the Texas drivers interviewed prefer to receive real-time freeway information at the beginning of a trip and that 92 percent prefer the information before they enter the freeway.

For the trip home from work, the availability of radios at work is definitely less than that at home. However, 94 percent of the drivers could theoretically receive information from their car radios before entering the road system.

Degree of Listening to Traffic Reports

Table 1 gives the frequency for expressway and nonexpressway drivers at which a driver is expected to have his or her radio on or is expected to be intentionally listening to traffic reports while at home before leaving for work, driving home from work, or driving to work. In general, expressway drivers listen to more of the traffic reports than the nonexpressway drivers do. This is probably because most traffic reports by Chicago area stations are primarily concerned with expressway conditions. The same reasoning accounts for the fact that more of the expressway drivers always intentionally listen to the reports as shown in Figure 3. When drivers who never listen to radio traffic reports were asked why, 66 percent of the drivers indicated that the reports did not provide information concerning their routes to work and 62 percent indicated a lack of information concerning their routes to home. No data were available on how many of those that listen hear what they want and need to hear.

The data also indicate that drivers listen to more traffic reports during the trip to work than either before leaving home or during the trip home. Before starting the trip to work, most drivers want the most timely information that can be obtained and therefore intentionally listen to the traffic reports broadcast just before they leave their homes. While on the road, drivers want to be aware of any new developments in traffic conditions. Conditions are not so important on the way home because arrival times at home are not so critical as arrival times at work. On a scale of 100 (Figure 1b), drivers indicated an average importance of 68 for arriving at work at specific times and an average importance of only 35 for arriving at home at specific times.

Use of Comparable Alternative

Any alternative to commercial radio must be capable of providing traffic information at the beginning of a trip before drivers enter the road system. Information provided at the beginning of a trip will produce the best results in aiding the drivers in route choices and is therefore most effective in redistributing road demand.

When asked how often they would phone a traffic information center that could provide information about their routes to or from work, only 6 percent of the expressway drivers and 4 percent of the nonexpressway drivers indicated that they would always call the information center before starting their trips to work as shown in Figure 4. Even less would always call before leaving work. The following tabulation shows that nonexpressway drivers would call the information center about once every 5 days before going to work and about once every 7 days before leaving work (ranges are due to data grouping in analyses):

	Average Frequency (%)	
Time	Expressway Drivers	Nonexpressway Drivers
Before leaving for work	18 to 29	12 to 21
Before leaving for home	12 to 21	7 to 15

Expressway drivers indicated that they would phone more often—about once every 4 days before going to work and about once every 6 days before leaving work.

EFFECT OF TRAFFIC REPORTS ON DIVERSION

Because one of the main purposes of a driver information system is to redistribute the demand on the road system when warranted, the diversion characteristics of the drivers are necessary elements for an evaluation of the information system.

Diversion Due to Observation of Congestion

Drivers who encounter congestion on the way to work divert once out of five times as shown by the data given in Table 2. Figure 5 shows that 64 percent of drivers divert at least some of the time. Thirty-six percent of the drivers never divert and 6 percent always divert. For the trip home, the frequency of diversion is slightly less than that while traveling to work because arrival times at home are not as critical as arrival times at work.

Diversion Due to Radio Reports of Congestion

A radio traffic report of congestion causes 10 percent of the expressway and 8 percent of the nonexpressway drivers to always change routes before they encounter congestion on their routes to work. Figure 6 shows that 54 percent of the expressway drivers and 32 percent of the nonexpressway drivers indicate that they divert some of the time.

For the trip home from work, 6 percent of the expressway drivers and 7 percent of the nonexpressway drivers always change routes because of a congestion report. Expressway drivers are expected to divert once every four times while going to work. Nonexpressway drivers divert once every six times.

Diversion Due to Radio Reports of Accident

A radio report of an accident causes 12 percent of the expressway drivers to always change routes on the way to work. Expressway drivers are expected to divert once out of three times because of radio reports while on the way to work. Nonexpressway drivers are expected to divert once every four times while on the way to work.

When drivers were asked why they did not divert more often, 28 percent indicated that they did not know of any acceptable alternate routes and 22 percent indicated that they did not know the conditions on other routes.

IMPORTANCE OF INFORMATION

The respondents were asked to indicate how important it is for them to know traffic and road conditions to help them decide which routes to drive and what times to start their trips. The data given in Table 3 show that,

Figure 1. (a) Frequency and (b) importance scales.

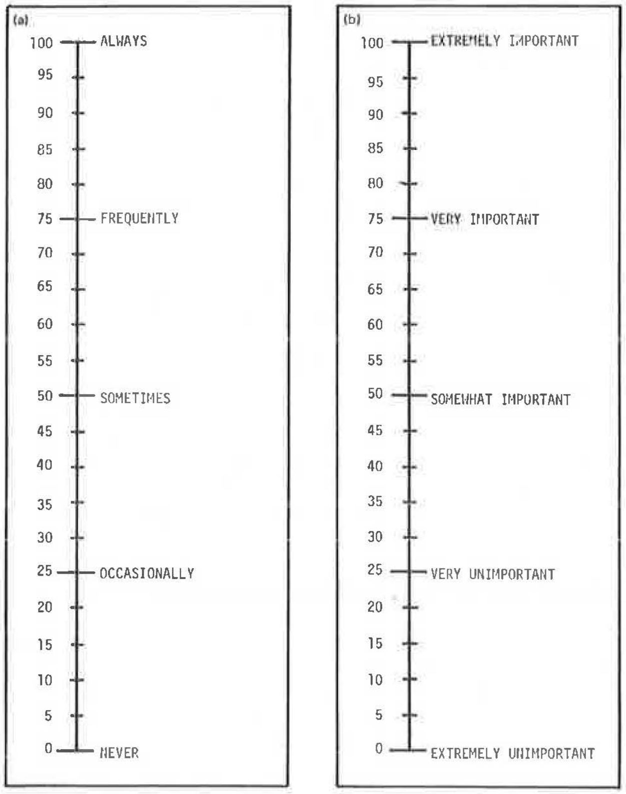


Figure 2. Drivers who choose a route before or after starting a trip.

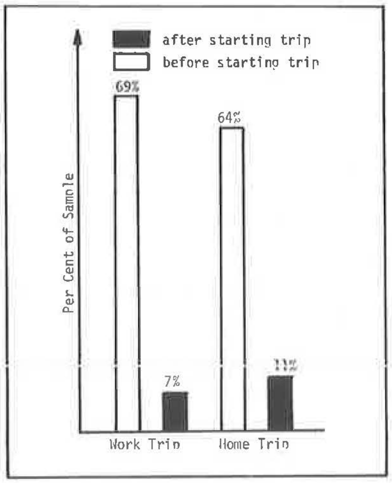


Figure 3. Drivers who always intentionally listen to radio traffic reports.

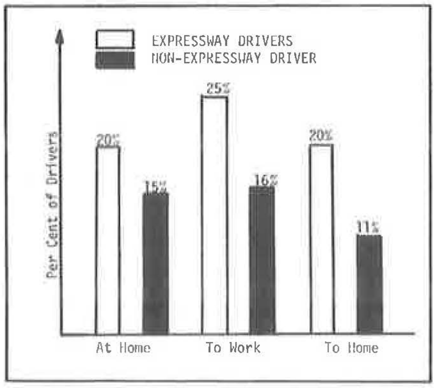


Table 1. Average frequency of radio use.

Drivers	Radio On (%)	Driver Intentionally Listening to Traffic Reports (%)
Expressway		
At home	58 to 65	32 to 39
To work	78 to 83	39 to 47
To home	76 to 81	32 to 40
Nonexpressway		
At home	55 to 62	24 to 31
To work	70 to 76	26 to 34
To home	68 to 73	20 to 27

Note: Ranges are due to data grouping in analyses.

Figure 4. Drivers who indicate that they would always phone an information center.

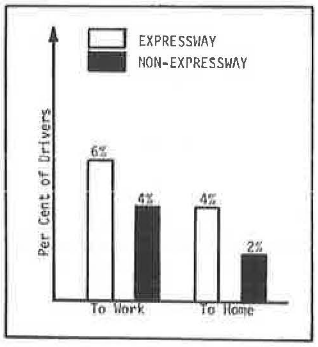


Figure 5. Drivers who divert at least some of the time on the way to work.

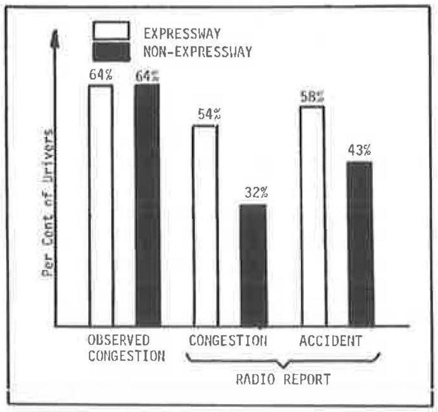


Table 2. Average frequency of route diversion.

Drivers	Observed Congestion (%)	Radio Report of Congestion (%)	Radio Report of Accident (%)
Expressway			
To work	16 to 27	21 to 30	26 to 35
To home	14 to 25	17 to 26	24 to 33
Nonexpressway			
To work	—[a]	14 to 19	23 to 28
To home	—[a]	13 to 19	19 to 25

Note: Ranges are due to data grouping in analyses.

[a] No significant difference.

in all cases, both expressway and nonexpressway drivers indicated that information was slightly less important for trips home from work. Expressway drivers also felt that information was slightly more important than nonexpressway drivers did.

Information about road conditions is more important than information about traffic conditions to both expressway and nonexpressway drivers. Information is equally important in aiding drivers to decide which routes to drive or what times to drive except for the nonexpressway drivers' trips to work where traffic conditions are more important for departure times than for route choices.

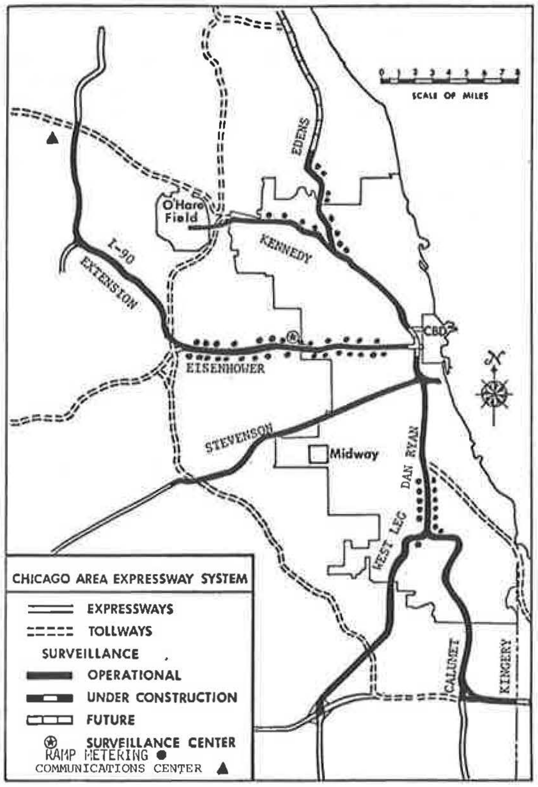
Commercial radio reports are usually consistent in the manner in which road condition information is given to drivers. However, inconsistencies do exist in conveying traffic conditions. Research has indicated that most drivers prefer to know the location, length, and degree of congestion as an indicator of traffic conditions (3, 6). Maximum effects can probably be achieved if commercial radio reports consistently convey that kind of information.

Table 3. Average importance of road and traffic conditions for route choice and starting time decisions on commuting trips.

	Traffic Conditions		Road Conditions	
Drivers	Route to Take	Time to Leave	Route to Take	Time to Leave
Expressway				
To work	40 to 52	37 to 48	51 to 61	55 to 66
From work	30 to 42	27 to 39	42 to 54	40 to 52
Nonexpressway				
To work	28 to 38	31 to 41	41 to 50	54 to 63
From work	20 to 30	17 to 28	33 to 43	35 to 45

Note: Values are from importance scale in Figure 2. Ranges are due to data grouping in analyses.

Figure 6. Electronic surveillance and control network for Chicago area expressways.

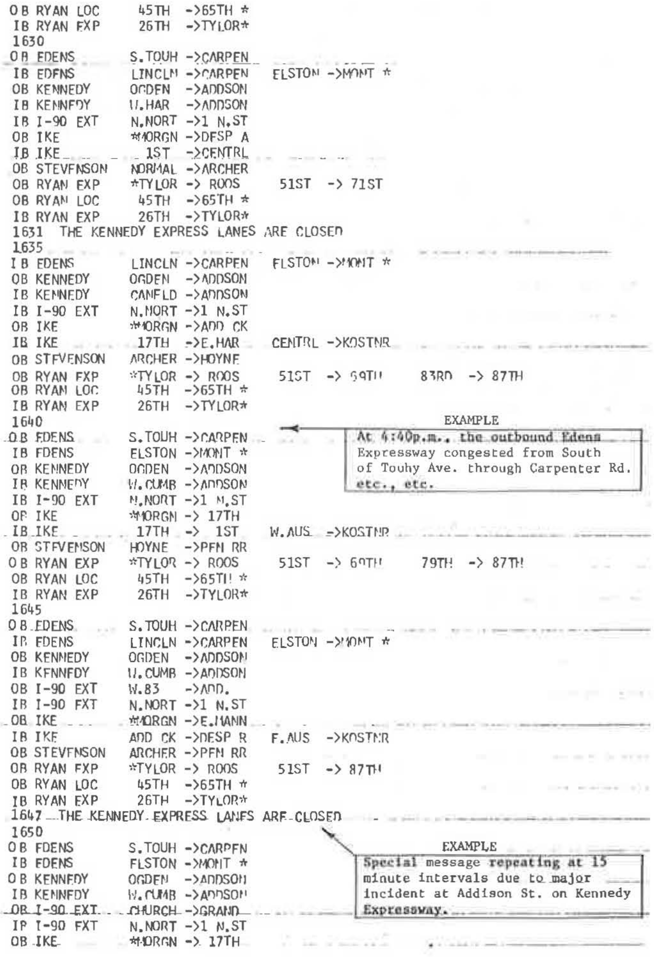


SUMMARY OF RESEARCH FINDINGS

This research was concerned with the analysis of attitudinal survey data to determine the potential of the commercial radio traffic report and the effect of the radio report on drivers' behavior. The results from the analyses of questions, which reflect the prevailing conditions in the Chicago area at the time of the survey, are as follows:

1. Commercial radio can reach almost all potential users of an information system;
2. Commercial radio can provide information when and where drivers want information;
3. Most drivers make route choices at the beginning of a trip;
4. Many drivers always listen to traffic reports, and most listen some of the time;
5. Drivers listen to radio traffic reports more often than they would telephone for traffic reports;
6. Radio traffic reports cause many drivers to divert all of the time and most drivers to divert some of the time;
7. Drivers regard both traffic conditions and road conditions as important in helping them decide what time to start a trip and which route to drive;

Figure 7. Typical traffic congestion report provided on computerized network.



```
OB RYAN LOC     45TH  ->65TH *
IB RYAN EXP     26TH  ->TYLOR*
1630
OB EDENS       S.TOUH ->CARPEN
IB EDENS       LINCLN ->CARPEN   ELSTON ->MONT *
OB KENNEDY     OGDEN  ->ADDSON
IB KENNEDY     W.HAR  ->ADDSON
IB I-90 EXT    N.NORT ->1 N.ST
OB IKE         *MORGN ->DESP A
IB IKE           1ST  ->CENTRL
OB STEVENSON   NORMAL ->ARCHER
OB RYAN EXP    *TYLOR -> ROOS     51ST  -> 71ST
OB RYAN LOC     45TH  ->65TH *
IB RYAN EXP     26TH  ->TYLOR*
1631  THE KENNEDY EXPRESS LANES ARE CLOSED
1635
IB EDENS       LINCLN ->CARPEN   ELSTON ->MONT *
OB KENNEDY     OGDEN  ->ADDSON
IB KENNEDY     CANFLD ->ADDSON
IB I-90 EXT    N.NORT ->1 N.ST
OB IKE         *MORGN ->ADD CK
IB IKE          17TH  ->E.HAR    CENTRL ->KOSTNR
OB STEVENSON   ARCHER ->HOYNE
OB RYAN EXP    *TYLOR -> ROOS     51ST  -> 59TH     83RD  -> 87TH
OB RYAN LOC     45TH  ->65TH *
IB RYAN EXP     26TH  ->TYLOR*
1640                                            EXAMPLE
OB EDENS       S.TOUH ->CARPEN  <-----  At 4:40p.m., the outbound Edens
IB EDENS       ELSTON ->MONT *          Expressway congested from South
OB KENNEDY     OGDEN  ->ADDSON          of Touhy Ave. through Carpenter Rd.
IB KENNEDY     W.CUMB ->ADDSON          etc., etc.
IB I-90 EXT    N.NORT ->1 N.ST
OB IKE         *MORGN -> 17TH
IB IKE          17TH  ->  1ST    W.AUS  ->KOSTNR
OB STEVENSON   HOYNE  ->PEN RR
OB RYAN EXP    *TYLOR -> ROOS     51ST  -> 69TH     79TH  -> 87TH
OB RYAN LOC     45TH  ->65TH *
IB RYAN EXP     26TH  ->TYLOR*
1645
OB EDENS       S.TOUH ->CARPEN
IB EDENS       LINCLN ->CARPEN   ELSTON ->MONT *
OB KENNEDY     OGDEN  ->ADDSON
IB KENNEDY     W.CUMB ->ADDSON
OB I-90 EXT    W.83   ->ADD.
IB I-90 EXT    N.NORT ->1 N.ST
OB IKE         *MORGN ->E.MANN
IB IKE         ADD CK ->DESP R   F.AUS  ->KOSTNR
OB STEVENSON   ARCHER ->PEN RR
OB RYAN EXP    *TYLOR -> ROOS     51ST  -> 87TH
OB RYAN LOC     45TH  ->65TH *
IB RYAN EXP     26TH  ->TYLOR*
1647  THE KENNEDY EXPRESS LANES ARE CLOSED
1650                                    \      EXAMPLE
OB EDENS       S.TOUH ->CARPEN          Special message repeating at 15
IB EDENS       ELSTON ->MONT *          minute intervals due to major
OB KENNEDY     OGDEN  ->ADDSON          incident at Addison St. on Kennedy
IB KENNEDY     W.CUMB ->ADDSON          Expressway.
OB I-90 EXT    CHURCH ->GRAND
IB I-90 EXT    N.NORT ->1 N.ST
OB IKE         *MORGN -> 17TH
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8. Information is required more and used more for the trip to work than for the trip to home;
9. Expressway drivers find commercial radio traffic reports slightly more useful than nonexpressway drivers do;
10. Currently, only commercial radio can and does provide information to most drivers before they begin a trip; and
11. The commercial radio traffic report is an effective component of any driver information system.

Even though the questionnaire survey indicated that the commercial radio traffic report is a useful and effective component of a driver information system, motorist responses also identified where improvements could be made in the Chicago area reports available at the time of the survey.

More Routes Could Be Covered

Sixty-two to 66 percent of those drivers who never listen to traffic reports do not listen because reports do not provide information about their routes. Forty-two to 50 percent do not change routes because of a lack of information about alternate routes. Increasing the route coverage could attract more listeners and increase diversion and spread traffic demands.

Reports Could Be More Accurate and Timely

Eight to 11 percent of the drivers never listen to reports because previous experience has led them to believe that reports are either inaccurate or not current. Reporting traffic conditions in a consistent manner could decrease the possibility of driver misinterpretation of information and would improve driver opinion of accuracy. Supplementing regular traffic reports with traffic bulletins to keep drivers informed of new developments could help improve the timeliness of traffic reports.

More Radio Stations Could Provide Traffic Reports

Although most drivers listen to radio stations that report traffic conditions, more drivers could be reached if additional stations provided traffic reports.

IMPROVING CHICAGO AREA TRAFFIC REPORTS

For the past several years, the preceding three potential areas for improving traffic reports have been affected by the expressway driving information obtained by the Illinois Department of Transportation particularly through its growing electronic surveillance network. Historically, several Chicago area radio stations have provided public service traffic reports based either on private ground and helicopter surveillance (since 1958) or on information obtained through the department or from various other sources and techniques (7).

With expansion of the electronic expressway surveillance network (Figure 6), several radio stations regularly requested the current traffic conditions depicted on the traffic status displays located in the Illinois Department of Transportation Surveillance Center in Oak Park as well as those in the Illinois Department of Transportation Communications Center in Schaumburg (8). The surveillance center prepared for directly outputting basic computer-generated traffic information on a remote teleprinter network serving commercial radio stations or other interested users (9, 10, 11). Such communications appeared to have a great potential for improving the timeliness, accuracy, and quality of expressway traffic reports particularly because the electronic surveillance covers major routes [currently operational for 360 directional roadway km (224 miles) at 0.8-km (0.5-mile) intervals in real time] and is not limited by the frequency and constraints of other coverage methods.

In March 1974, the department notified Chicago area radio and television stations of the availability of a teleprinter service consisting of receive-only, computer-generated traffic reports as often as every 5 min when applicable that listed only the significant expressway congestion areas. On a continuous 24-h/day basis, this report prints out the location limits when two or more adjacent, or once-removed, expressway main-line surveillance stations are congested, based on 5-min average lane occupancy readings of 30 percent or more (Figure 7). Special messages can be added to the computer-generated report through cathode ray tube keyboard entry at the surveillance center. Each radio station or other user provides its own teleprinter or other compatible terminal, modems, and leased phone line for hookup with the expressway surveillance computer.

Thus far, four of the major regional AM radio stations are using the computerized traffic report service as a continual source of motorist information. Some of these users relay traffic information to affiliated FM or television stations. Some nonusers phone either of the two department locations for the information particularly if their traffic report broadcasts are infrequent or if their broadcast range is highly localized. (There are nearly 40 AM radio stations, nearly 40 FM stations, and 8 TV stations in the Chicago metropolitan area.) Other nonusers monitor reports broadcast by radio stations with direct information sources.

Each radio and television station providing traffic reports adapts the information base to suit its particular programming format and audience. Some read the latest computerized printout; others modify or expand the information. One uses two helicopters to cover additional routes or to concentrate on special problems. One provides supplementary travel times and airs a minimum of 33 daily rush-period reports.

The Chicago area experience demonstrates that large-scale, real-time, freeway surveillance systems can be used to supply timely and accurate traffic reports to commercial radio stations and other users. The degree to which the availability of current commercial radio traffic reports affects driver attitudes and behavior could be the subject of a follow-up study.

ACKNOWLEDGMENT

The contents of this paper reflect the views of the authors who are responsible for the facts and accuracy of the data presented.

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Abridgment

Simulation of Operation of Disabled Vehicle Location and Aid Systems on Limited-Access Highways

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The operation of alternative disabled vehicle aid and location systems for use on limited-access highways has been examined by digital computer simulation. Characteristics of disabled vehicles input to the simulation programs were obtained from studies carried out on British motorways and reported to the 1975 Annual Meeting of the Transportation Research Board.

Three location systems have been studied: the emergency telephone system currently in use on British motorways, the service patrol, and the "flash" system.

The simulation models reproduced real-life breakdowns for any highway and the operation of a disabled vehicle location and aid system whose characteristics were input into the simulation model. These characteristics include

1. Length of highway being simulated,
2. Period of real time for which simulation is required,
3. Hourly traffic volumes and proportions of goods vehicles,
4. Distribution of types of faults and disablement probabilities,
5. Speed-flow relationships for highway, and
6. Operating details of disabled vehicle location and aid systems.

Output from the models included

1. Time and position of each breakdown,
2. Type of vehicle involved and disabling fault,
3. Time required to detect an incident, and
4. Time required to bring aid to the disabled vehicle.

Validation of the breakdown procedure of the simulation models was achieved by the ability of the program to reproduce the observed pattern of vehicle disablements on a section of the M1 motorway in Yorkshire, England. Given the necessary input data, the models were able to reproduce realistically the pattern of vehicle disablements that occur on a real highway. If the characteristics of any disabled vehicle location and aid system are known, one can evaluate its effectiveness without actual implementation of the system.

In the simulated emergency telephone system, detection is performed by the disabled motorist and detection time is assumed to be a function of the distance to an adjacent emergency telephone. Aid to disabled motorists was provided by private garages contacted by the emergency telephone control center. Input to this model was a list of garages able to provide assistance, their location in relation to the highway, and details of the hours during which they operate. On receipt of a call for aid, the model selects the garage nearest to the disabled vehicle that is able to respond to the call for aid. Monte Carlo processes are used to model the time required by a garage to turn out on receipt of a call.

The service patrol system as simulated both detects disabled vehicles and offers limited aid to the motorist in the form of gasoline, water, oil, first aid equipment, and emergency warning signs. Each patrol is allotted a beat of 16 km (10 miles) and travels at the prevailing roadway speed. If the patrol cannot give aid, then the disabled vehicle is further delayed until aid requested from a private garage by the control center near the service patrol arrives.

The flash system investigated was that designed and developed by the Airborne Instruments Laboratory. Evaluated on the cooperative motorist concept, it allows drivers who sight a disabled vehicle to summon aid by flashing their lights at one of a series of electronic detectors situated at the roadside.

The simulation model assumed that the time required to detect a disabled vehicle was composed of two elements: (a) the time required for a passing vehicle to detect the disabled vehicle and (b) the travel time of the detecting vehicle before it reached the detector.

Operation of the systems was simulated for the traffic flow conditions that occurred on the M1 motorway for a total of 7 Fridays between 6:00 a.m. and 10:00 p.m. The average waiting time required to locate and provide aid to disabled vehicles under these traffic conditions was

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determined from the simulation models. For the system characteristics input into the simulation models, the flash system produced the shortest average waiting time, the emergency telephone system produced greater delay, and the service patrol produced the greatest delay.

This study has developed computer simulation models that can reproduce the pattern of breakdowns on a typical section of the British motorway system. The operation of three location and aid systems also can be simulated by using assumed system characteristics.

Michigan Emergency Patrol, a Major Motorist Communications Project That Uses CB Radio

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The use of citizens band (CB) radios by the motoring public has increased substantially in recent months. Two previously reported programs demonstrated that CB could be used to fulfill many of the legitimate communications and real-time information needs of the traveling public. An intensive CB monitoring program in a major urban area, the Michigan Emergency Patrol, has handled more than 400 000 calls in the past 5 years. The wealth of experience gained from this program provides useful insights for those planning similar programs elsewhere. A recently established rural-area CB monitoring program being conducted by a state police agency has enjoyed a tremendous public relations success with all segments of the driving public and should encourage other states to implement similar wide-area programs. Based on the experiences of these four programs, a number of recommendations can be made for future system design.

The creation of the citizens radio service (CRS) and especially the allocation of certain radio frequencies in the 27-MHz band to class D of the CRS [commonly known as citizens band (CB) radio] have resulted in the installation of communications transceivers in many vehicles operated by the general motoring public. The potential for using such facilities for motorist assistance and highway emergency communications has been recognized in the formation of hundreds of volunteer groups of CB licensees, many of whom are affiliated with such national organizations as Radio Emergency Associated Citizens Teams (REACT) and Affiliated League of Emergency Radio Teams (ALERT). Most of these groups participate in and coordinate local efforts to monitor national CB emergency channel 9 (27.065 MHz) to relay reports of highway emergencies from the motoring public to the proper local authorities and to give general informational assistance to that public. The evolution of these coordinated monitoring efforts and some proposals for enhancing such activities have been the subject of papers previously published by the Highway Research Board, now the Transportation Research Board (1, 2, 3).

Within the past 2 years, the use and popularity of CB radio have increased substantially. CB manufacturers have not kept up with consumer demands for these transceivers. The Federal Communications Commission (FCC) has experienced a dramatic increase in the number of CB license applications, from a monthly average of about 30 000 in late 1974 (already double that of 1972) to more than 500 000 in early 1976. Two general reasons can be cited for this recent increase in CB licensing and usage. First, the motoring public has come to recognize the considerable value of such a mobile, two-way voice telecommunication resource, especially for communicating with other motorists and public safety authorities directly or through cooperative citizens' monitoring stations. Even the occasional abuse of this resource has not seriously detracted from the enthusiasm expressed by many public safety agencies for the increased capability of communicating with the general public that CB radio provides (4, 5). Second, the FCC has taken certain actions (to reduce CB licensing fees, liberalize and simplify operating regulations, and increase enforcement efforts against violators and unlicensed operators) that have increased the popularity of CB and its proper use.

The net effect of this increased CB radio usage has been to create a capability for a motorists' aid and communications system. Numerous authors have established the legitimacy and necessity for just such a system and have decried the lack of a national program to accomplish this goal (6, 7, 8). In an internal report, the U.S. Department of Transportation also recognizes both the need for such an aid and communications system and the possibility that CB radio can fulfill that need to at least a limited extent (9).

SUMMARY OF TWO PREVIOUSLY REPORTED PROGRAMS

Two programs that use CB radio have been previously discussed in papers presented to the Highway Research Board, and are summarized below.

Ohio REACT Program

The Ohio REACT program was established in 1970 to determine the potential of a voluntary citizens' monitoring program to meet the motoring public's emergency and assistance communications requirements on a statewide

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Publication of this paper sponsored by Committee on Motorist Services.

basis (3, 10). A special attempt was made to recruit and train volunteers for this program, to develop good working relationships with local public safety authorities, and to collect information on program activities as a guideline for the implementation of similar programs elsewhere.

In a more detailed statistical evaluation (11, 12), four call-profile trends of communications logged by the Ohio REACT program were noted.

1. Calls regarding reports of accidents constituted the largest category. However, the growth rate for such calls was below that of other types.
2. Calls regarding stalled vehicles constituted the second largest category. The growth rate of this category was average for the overall system growth.
3. Calls containing requests for information constituted the third largest category. This growth rate also was typical for the overall system.
4. After the first 3 months of operation, the total number of calls failed to follow a consistent growth pattern. This was probably due to a lack of expansion in the coverage hours or service area of operation.

The original sources (3, 10) are substantially more detailed than the discussion presented here and contain valuable information pertaining to hours of coverage, hours of calls reported, and participation by the individual volunteer teams.

The Ohio REACT program, despite considerable dedication from some of its participant teams, demonstrated that a geographically and temporally comprehensive monitoring program could not be developed and maintained on a statewide basis by relying solely on citizen volunteers operating from their own homes. Individual team participation was somewhat irregular, the variation in numbers of calls received by the different teams was substantial, and coverage of the state's extensive rural areas was spotty at best (12). What the Ohio REACT program did establish, however, was that a close and favorable working relationship between citizen volunteer monitors and public safety authorities could be developed, despite certain previous negative experiences of those authorities with the vigilant type of CB organizations.

After termination of the Ohio REACT program in 1972, the individual Ohio State Highway Patrol (SHP) posts were equipped with CB transceivers for monitoring CB emergency channel 9. More recently, the individual patrol vehicles of the Ohio SHP have begun to be equipped with such transceivers as well. The intent of these efforts has been to provide a greater coverage in Ohio's rural areas, especially those near Interstate highways and other primary routes. Data on these Ohio SHP and later urban-oriented REACT efforts are not currently available.

Detroit KUY Program

The Department of Streets and Traffic of Detroit, Michigan, established a CB monitoring program in 1966 to determine the utility of CB in collecting information of interest to that government agency (13). This program became known as the KUY program, after the call sign of the original, specially licensed system (KUY 3173).

CB transceivers were installed in the personal vehicles of a number of city government and private industry employees, as well as in some official city government vehicles. The persons using these mobile units, most of whom had not previously been familiar with CB radio, were instructed in the proper operation of CB units and were requested to contact the KUY base station only to report situations involving emergencies or unusual conditions that impaired safe and efficient traffic flow. This communications system was not intended for normal dispatch and business operations, nor was it originally intended to serve as a general motorists' communications facility. Although the program did not solicit participation by the general CB motoring public, that public had become the primary users of the system within 6 months.

In a more detailed statistical evaluation (11, 12), three call-profile trends were noted.

1. Calls regarding stalled vehicles constituted the largest single category for the first 2 years but then declined during the remaining 3.5 years of program operations.
2. Calls requesting information constituted the second largest category for the first 2 years but then surpassed stalled vehicle reports and soon accounted for about half of all calls handled.
3. Calls pertaining to accident reports constituted the third largest category.

Additional information is available on the disposition of calls from the KUY dispatcher to the Detroit police department, on the awareness of the Detroit CB licensee public about the KUY program, on the theoretical savings in detection time of major freeway incidents by use of the KUY system, and on the social and cost-effectiveness implications of the system (14).

The fundamental orientation of the KUY program was to serve as an information collecting system for the various functions (police, fire, road repair, and the like) of the city of Detroit. Therefore, some types of basic motorist aid communications (for instance, requests for service trucks for disabled vehicles not actually blocking a traveled portion of a roadway) were discouraged or just not handled. The KUY network (including remote receivers and transmitters, when fully operational) was intended to cover only the immediate Detroit freeway system. In reality, that network suffered from a lack of adequate coverage on certain Detroit freeways, a very poor coverage on Detroit's nonfreeway streets, and a total lack of coverage on freeways in the metropolitan area outside the immediate Detroit city limits. The remote transceivers became subject to increasing failure toward the end of the KUY program, and the hours of operation became quite irregular.

The tremendous public success of the KUY program ironically was also partially to blame for its failure. The user public had come to expect a considerable operational regularity and dependability and a responsiveness to a wide range of their legitimate communication needs. When those expectations grew beyond the capabilities of the program, an alternative program, the Michigan Emergency Patrol (MEP), was developed by members of that user public.

MICHIGAN EMERGENCY PATROL

MEP was formed in 1967 by citizen volunteers to supplement the operation of the KUY program. In late 1970, MEP moved to a central office and transceiver facility atop one of Detroit's tallest buildings. From there, a monitoring coverage superior both in range and in saturation to that of KUY's multiple-remote system was attained. MEP's immediate expansion in number of calls over that handled by KUY was due to this superior location and to a willingness to respond to a wider range of motorists' communication needs. In addition, MEP's association with several area commercial radio stations resulted in a network for the rapid dissemination of road and traffic information to the general driving public.

Statistical Trends

In a more detailed statistical evaluation (11, 12), eight call-profile and operations trends have been noted for MEP.

1. The volume of calls in all categories has been larger (in most instances considerably larger) than in the respective categories of either the Ohio REACT or KUY programs.
2. Calls requesting information have constituted the largest single category. The percentage of these calls has demonstrated slight seasonal fluctuations, increasing in late winter and spring. Operational problems have arisen from the large number of these information-request calls.
3. Calls providing general information (reports on traffic, weather, and road conditions) to the MEP base constitute the second largest category. No consistent seasonal trends have been noted.
4. Calls reporting stalled vehicles have constituted the third largest category. There has been a slight increase in the number of these calls during the winter months.
5. Calls pertaining to accident reports have constituted the fourth largest category; no seasonal trends have been found.
6. The percentage of improper requests (as defined by FCC regulations) grew initially but then tapered to zero. Unidentified and deliberately interfering transmissions (dead carriers, whistling, music, and the like) have not been logged.
7. The month-to-month regularity of system growth and development (or user familiarization with services rendered) had begun to stabilize by early 1974. The tremendous growth in popularity of CB, which began in mid 1974 and continues now, has upset that stability somewhat, however.
8. Ambient-weather and day-of-week factors have had a significant impact on call profiles. A particularly notable increase in information requests coincided with every heavy snowstorm that occurred during a nonholiday workweek. These weather factors also increased the total number of calls handled.

A wealth of additional information is available about the specific nature of the calls, their time of day and day of week, the identity and location of the callers, and ambient-weather and traffic conditions.

Problems Encountered

Like the Ohio REACT and KUY programs, MEP has encountered six problems that should be expected to beset any intensive CB monitoring project. First and foremost, ambient radio frequency noise and adjacent-channel "bleedover" difficulties are exacerbated by MEP's relatively high antennas and urban location. Receiver redesign and use of special audio filters are being investigated as possible cures.

Second, and related to the first item, the discrepancy between "talk-out" range (base to mobile unit) and "talk-back" range (mobile unit to base), the former invariably being greater, is being countered by the planned installation of additional remote receivers. Although this would seem to follow the example set by the predecessor KUY program, the receivers will be located much further out in the tricounty metropolitan area and will be of the improved design just mentioned.

Third, recurrent but unintentional cochannel interference from distant base stations whose transmissions can easily overwhelm those of much closer mobile units is being countered by careful receiver antenna installation and orientation for directional (nulling) effects. Similar interference from closer in stations has not developed.

Fourth, deliberate interference is occasionally encountered. This type of interference is probably caused by malcontents who view MEP as an authority figure because of its close interaction with the public safety authorities and its insistence on callers' strict adherence to FCC operating regulations, or by the inevitable misfits who delight in causing hardship and grief. Fortunately, the general CB user community sees such a benefit deriving from the MEP program that considerable peer pressure can be brought against those responsible for this misconduct.

Fifth, the high level of training and commitment required of the MEP base operators has created a high personnel turnover and has hampered recruitment. The 30 to 35 person-h/weekday, or 200 to 225 person-h/week, logged at the MEP base are split disproportionately among the 30 most active and 60 less active MEP members; the average member contributes 4 to 6 h/week of operating time.

Sixth, the large volume of radio traffic being handled on channel 9 by MEP is causing increasing frequency congestion especially during the morning and afternoon rush hours. So many callers are at times trying to reach MEP that the more distant mobile units, including those with urgent traffic, cannot get through. Over short periods of time (3 to 4 min), calls are handled as frequently as 3 to 5/min. More than 60 calls/h and 600 calls/day have been received on occasion. Sometimes six or more callers wait after having been acknowledged and asked to stand by to allow completion of earlier or more urgent communications.

To combat this overcrowding, MEP has implemented five programs over the last 4 years.

1. Callers at other base stations have been asked to use the telephone instead of the CB system. This program was extended beyond the rush-hour periods and is now followed by most callers around the clock.
2. During those rush hours with inclement weather, callers have been asked to refrain from placing any calls not pertaining to immediate emergencies, even though such calls are permitted by FCC regulations. These requests have generally been honored by a user public not otherwise known for such restraint.
3. The issuance of traffic advisories to subscribing commercial radio stations has been expanded. (Each advisory currently goes to six stations.) In 1975, more than 14 500 such advisories were issued, probably more than three-fourths during the weekday morning or evening rush hours, or an average of one for every 6 min (as needed to convey information on new reports or to modify old reports).
4. Requests for information on road, traffic, and weather conditions ("10-13s") have been answered, but the callers have been asked to telephone the MEP base before starting the trip next time. Special telephone lines have been installed along with automatic answering and message delivery equipment. During 1975, half again as many of these 10-13s were actually handled by MEP as were logged on the air (50 000) because of the use of this phone system.
5. In response to 10-13 requests, MEP operators have occasionally summarized briefly the conditions on all major routes within the tricounty metropolitan area. Potential callers and callers on the line have been saved time by this process. As many as six previously unrecognized callers have been heard to acknowledge receipt of such a single summary, and then to sign off.

Many drivers regularly traveling through the Detroit area are known to monitor channel 9 continuously, especially when they are out of range of their home or office base stations, just to keep abreast of developing traffic situations.

Since early 1975, both the number and percentage of 10-13s have again increased. This is felt by experienced MEP staff to reflect the growing popularity of CB radio usage among the general public and thus the presence of many new callers who may not be initially familiar with MEP's preferred operating style. In addition, 1975 saw a general increase in driver confusion and traffic congestion that resulted from detours around Detroit's most comprehensive expressway repair and reconstruction program in years.

MEP Program Summary

The MEP program has demonstrated that a comprehensive CB motorist aid system can succeed in a major metropolitan area and that the citizen users of such a service will respond intelligently to the problems that inevitably arise.

MEP is basically a bidirectional information processing system. To collect information, one needs input from the metropolitan area CB motoring public. Such incoming information calls now constitute about one-sixth of all calls handled and are MEP's lifeline to the real and changing world. However, for that public to be willing to give such information, something must be available in return—an overview of the cumulation of these reports.

Some of these 10-13 requests may be merely radio checks, which are highly undesirable on an emergency channel and are prohibited by FCC regulations. Although these must be minimized, banning all 10-13s would disallow something that indeed reflects a legitimate communications need. To implement other means to perform this information distribution function (alternative CB channels, commercial broadcast radio, telephone recordings, changeable message signs, the new travelers information service radio system adjacent to the AM broadcast band) would be preferable.

The MEP program has been extended beyond what would seem reasonable for a strictly volunteer effort. A more accurate description is that MEP is considered by the user public, the local public safety authorities, and the subscribing commercial broadcast media as a professional organization that happens not to pay its staff. Similar projects elsewhere that have attempted to emulate the MEP program have not succeeded. They have lacked a general appreciation of the importance of a substantial and committed administrative structure. MEP enjoys such a supporting group, representative of a broad range of capabilities and community interests. Indeed, some of its members had little previous experience with CB radio and rarely operate the MEP base station but nevertheless contribute invaluable services and administrative expertise to the organization.

Although mindful of the burden of present commitments, MEP is undertaking an ambitious expansion project. After more detailed evaluations of operator-loading and other personnel problems and of multiple-site frequency congestion problems and after discussion with the FCC regarding special licensing for remote transmitting facilities, extension of the current coverage into nearby communities is anticipated. The long-term goal is a coordinated, central office operating facility serving the southeastern quarter of Michigan's lower peninsula.

MISSOURI STATE HIGHWAY PATROL CB PROGRAM

The Missouri State Highway Patrol has recently implemented a program that deserves a brief mention here. The Missouri SHP has equipped its posts and patrol vehicles with CB radios capable of simultaneously monitoring national CB emergency channel 9 and one other (selectable) channel. The thrust of this effort has been toward vehicular installations because Missouri has relatively few SHP posts statewide and must rely on patrol vehicle usage of CB to achieve the desired coverage.

Although the Missouri program has been fully operational only since August 1975, their comprehensive statistical logging has provided some valuable insights into the operation and evolution of the project. From logging information distributed by the Missouri SHP, four trends are noted.

1. Within the first 6 months of operations, calls containing requests for information or directions have more than tripled in number and doubled in percentage of total calls received. This is the largest of all individual call categories now, although it has begun to subside somewhat.
2. Stalled and disabled vehicle reports constitute the second most common type of call, averaging about one-fifth of all calls.
3. Reports of dangerous driving behavior (wrong-way driving, driving while impaired, speeding) are the third most frequent type of call, averaging about one-seventh of all calls. This category reflects an emphasis in the Missouri program on collecting information from the motoring public concerning observed driving violations.
4. A substantial monthly fluctuation in total number of calls received exists and possibly is attributable to ambient weather variations.

Additional information is available from the Missouri program reports including information on type of roadway (Interstate versus non-Interstate), type of violation and action taken, and whether the reported incident was located.

Two long-term problems with the Missouri program can be anticipated, although neither has yet become serious. First, a conflict may develop between the type of service that the CB motoring public may come to desire and the type that the Missouri SHP is willing and able to provide. The program could become bogged down by an excessive number of requests for information, directions, or nonemergency message transfers. Although these are not unreasonable requests for a comprehensive motorist communications system, they should be directed instead to local citizen volunteers on nonemergency channels. Furthermore, the CB motoring public will have to recognize that immediate Missouri SHP response to all reports of potential or even existent emergencies may not always be possible because of more urgent incidents elsewhere or the unavailability or inopportune location of personnel. Second, even the equipping of all Missouri SHP vehicles with CB radios cannot provide 100 percent monitoring coverage. The active involvement of citizen volunteers (and the relatively greater monitoring coverage provided by their base station antennas) will be necessary and desirable.

The Missouri SHP justifiably considers its CB program to be a tremendous success. Its public relations value alone has had a substantial positive impact on that state's driving public—both the local citizenry and transients. The comprehensive documentation of the operations of this program will provide a wealth of information on its cost effectiveness (time and lives saved, for

Table 1. Summary of logging reports for the four programs.

Program	Emergencies		Incoming Information	Information Requests	Miscellaneous
	Existing	Potential			
Ohio REACT	27.0	38.1	6.9	17.0	15.3
Detroit KUY	14.9	33.3	–	46.4	5.4
Detroit MEP	7.6	12.9	16.8	55.0	7.6
Missouri SHP	13.7	40.9	5.4	31.4	8.7

Note: Values are average monthly percentages of calls in busiest semiannual period for each program.

instance). Many other states are considering shifting budgetary priorities or soliciting state or federal financial support to create similar programs and are closely following and will benefit from the experience of the Missouri SHP program.

COMPARISON OF THE FOUR PROGRAMS

Radio communications between the general public and the agencies or groups that conduct each of the four CB monitoring programs have usually been initiated by the public. Therefore, the respective user public's image or perception of the utility and purpose of each of the programs is reflected in the relative distribution of calls logged in each of the various categories, the call profile.

A CB motorist communications system can be of most obvious and valuable benefit in reporting highway emergencies such as accidents to which the public safety authorities must immediately respond. Each of the four monitoring programs described previously has given highest priority to such emergency calls. However, as long as all those emergencies that could have been reported were reported as expeditiously as possible, the nature and extent of the nonemergency traffic handled are more indicative of the public's conception of the image or utility of the respective monitoring program.

For this reason, and to simplify comparison of the four programs, representative logging data from each are given in Table 1 in five summary categories. The average number of monthly calls based on busiest semiannual period for each program is as follows:

Program	Number	Program	Number
Ohio REACT	1216	Detroit MEP	8276
Detroit KUY	952	Missouri SHP	9101

The existing emergencies category includes all reports of accidents, fires, medical emergencies, and other conditions purporting to need an immediate response from the appropriate public safety authorities. The potential emergencies category includes all reports of disabled or abandoned vehicles, debris, malfunctioning traffic control devices, dangerous driving, and other conditions that need subsequent attention from some public safety authority or service or might result in some situation in the existing emergencies category if not corrected. (Because disabled vehicles on the roadside are a distinct traffic hazard, requests for service or assistance for such is included here.) The incoming information category includes all other reports that are relayed to the public safety authorities or are of interest to the general motoring public. The information requests category includes all requests for information (as distinct from service or physical assistance), such as those on traffic conditions, directions, and the like. The miscellaneous category includes all contacts not clearly falling within one of the other categories.

In the original data sources, much more detailed breakdowns of these summary categories are available. Readers are cautioned to distinguish between reference to the individual categories mentioned previously in this paper and subsequent reference to the five summary categories.

The busiest semiannual periods for the four programs, on which the information given in Table 1 is based, were August through September 1975 for the Missouri SHP program and the last complete periods for the Ohio REACT and MEP programs. The last period was not the busiest for the KUY program because MEP had already captured most of its calls.

For the KUY program, the busiest semiannual period was also the most stable (in terms of month-to-month variations in total number of calls) before MEP operations started. For MEP, the last and busiest period was not the most stable because of the increasing number of new users. For the Ohio REACT program, system growth had stabilized and even declined; however, evaluation of the long-term monthly deviations is not possible because of insufficient data. The Missouri SHP program is too young for a meaningful analysis of monthly variations.

Of all calls handled by the Ohio REACT program, the data given in Table 1 show that almost two-thirds pertained to existing or potential emergencies. This program had the apparent image of serving primarily as an emergency communications system. Yet, the total number of calls logged indicated that, for a statewide system, it was not an efficient large-scale means of reporting highway problems. A primary factor in this inefficiency was the somewhat haphazard nature of monitoring coverage that is inherent in such a volunteer system. Also, these data come from early 1972, long before the current explosion of CB popularity; user density (both mobile units of the general public and monitoring base stations) was much lower than would be found today.

The Ohio REACT program image is thought to be rather typical for REACT type of operations (volunteer home monitoring) elsewhere. (In the Ohio REACT program, unlike in the others discussed here, the call categories employed were not mutually exclusive. A particular call could have been credited to several appropriate categories. Therefore, the sum of percentages in Table 1 is greater than 100.)

The KUY program, designed as an information collection resource for the government agencies of the city of Detroit, nevertheless developed an image of being able to provide information to the CB motoring public. The data given in Table 1 show that about half of all calls pertained to existing or potential emergencies but that about another half were information requests. No logging category was apparently felt to be needed for general (nonemergency) incoming information. Compared with that of its successor (MEP), the public image of KUY was still substantially more identified with serving the motoring public's emergency communications needs.

The emergency reports handled by the MEP program have always been greater in number but smaller in percentage of total calls than those handled by KUY during its busiest periods. Some of this can be attributed to the somewhat larger service area of MEP. In the last 5 years, the number of MEP emergency reports has increased at a rate only about one-fourth as great as the increase in nonemergency calls. Such emergency reports now constitute about one-fifth of all traffic handled. However, this does not mean that MEP is derelict in its attention to emergency traffic. Rather, it indicates that very few major freeway incidents or hazardous conditions escape their attention. (The number of reports cannot exceed the number of incidents because subsequent reports of the same condition are logged instead as incoming information.) A greater image of information resource is undoubtedly attributed to MEP by its user public, and a greater effort is made to keep that information current than is found with other CB monitoring programs.

The Missouri SHP program exists in a different user environment altogether. In Detroit, extensive monitoring of channel 9 is done by the transient driving population. In Missouri, undoubtedly the bulk of CB users are usually monitoring and frequently conversing on other channels, switching to channel 9 to summon help or report hazards or violations. The program monitors have dual-channel, simultaneous-monitoring capabilities, and presumably do listen to and probably occasionally engage in informal communications on other channels. (MEP operates only on channel 9.)

In Missouri, an extensive amount of information on road conditions would be available directly from other motorists. In all likelihood, the CB motoring public would become more dependent on the Missouri SHP for road information primarily during times of inclement weather, when other road users normally having that information are less numerous, less available (more preoccupied by driving tasks), or less likely to have traveled from as far away.

In additional, informal comparisons of the MEP program with current volunteer efforts in other major urban areas, the considerable benefit of coordinating or collocating all monitoring from a single office has been observed. A multiplicity of uncoordinated monitoring efforts, even though technically easier to accomplish because centralized advantageous transceiver locations or remote operations can be avoided, is wasteful of volunteer personnel and has led to other operational difficulties exacerbated by the inevitable petty jealousies between the competing volunteer organizations. In concentrated urban areas, no reasonable alternative to a central monitoring point is envisioned if efficient operations are to be accomplished.

In summary, in the three programs discussed in this paper that have more than a year's experience apiece, a greater percentage of all calls concerned nonemergency reports or requests as users became more familiar with the potentials of the communications service provided by the monitoring agencies or groups. Although the number of reports of accidents and other existing or potential emergencies rose (except in Ohio), this increase was not as large as overall system growth. The same pattern would be expected to develop in Missouri as well, although this program seems determined to avoid the saturation and distraction problems encountered by MEP.

CONCLUSIONS

Citizens band radio offers a here-and-now capability that, despite its limitations, can serve to partially fulfill the legitimate communications and information needs of the traveling public. The recent phenomenal growth in CB usage and popularity has created a broader base for participation by the traveling public and ensures that its use for highway safety will be with us for some time to come.

Use of CB for communications pertaining to transportation safety and other aspects of motorists' real-time information and assistance needs will be shaped in part by the image of the services rendered and the groups or agencies providing such services. In an urban environment, the MEP and KUY programs have demonstrated that such services can and should extend beyond a mere capability of relaying reports of highway emergencies to the appropriate public safety agencies for their response. Furthermore, the demands placed on such an urban communications program can be expected to vary with such factors as time of day, day of week, month of year, weather, and road obstacles and detours.

A motorists' communications system built on a strictly volunteer structure will be prone to certain variations in hours of service and range of coverage. On the other hand, a governmentally sponsored service without a substantial institutional commitment to its successful operation, or with a narrowly defined and self-serving goal, may not fare much better.

Despite certain common impressions regarding CB radio, self-restraint and a certain degree of self-policing (peer pressure) from within the CB user community can probably be expected, but only if the benefits to be derived are readily immediate and obvious to that user group. The cooperative suppression of 10-13 calls to MEP during times of high vehicular density and inclement weather (when presumably such information on road conditions would be of greatest use to the motoring public) in deference to more urgent communications supports this observation.

A continuing two-way flow of information on road and traffic conditions is desirable. Information is necessary not only about the initial occurrence of some accident or blockage but also about its continuing and changing existence and subsequent removal. In a comprehensive urban communications system, demands and priorities may dictate that the redistribution of such information should be accomplished by means other than national CB emergency channel 9. For instance, it should be accomplished on other channels or by the commercial broadcast media. In addition, use of such media provides an access to a larger driving public than that which could be reached if only CB were used.

Motivations for system use are important. Certain inherent rewards exist for participation in such a communications network. The "first-person" benefits, namely those in which the caller is directly involved in the incident (accident, breakdown, traffic tie-up, and the like), are direct and tangible, such as in time saved in securing an ambulance or tow truck. However, there are also "second-person" benefits, such as a person's natural gratification in hearing his or her own report of an incident being relayed to others on CB or especially on commercial broadcast radio. Even completely without external reinforcements, good samaritan motivations are not uncommon.

The MEP and Ohio REACT programs demonstrate that the problems of interfacing volunteer efforts with existing safety agencies, of getting legitimate acceptance by and recognition from such agencies, are resolvable. Although these problems are beyond the scope of this paper, it is noteworthy that many observers of the CB radio and public safety communities consider them to be the most difficult for volunteer CB monitoring programs.

The public relations value of direct public-safety-agency involvement in a CB monitoring and communications program has been amply demonstrated by the success of and citizen response to the Missouri SHP program.

RECOMMENDATIONS

Pending the creation of a dedicated or a more comprehensive motorists' communications radio service by the FCC, certain procedures can be recommended for those groups or agencies considering establishing CB monitoring programs.

New systems should especially emphasize rural coverage because, in those areas, the fewest alternative communications resources (telephones, passers-by, etc.) currently exist and the death and injury rates from highway accidents are highest.

Those systems designed to serve populous urban areas should attempt to use a separate CB channel for the more routine motorist communications functions (10-13s and other nonemergency reports and requests). In some major metropolitan areas, perhaps several channels may need to be used for these and other functions. (The FCC is currently considering a proposal to allocate additional channels to CB radio for class D operation.)

Greater encouragement should be given to the use of simultaneously monitoring multiple-channel receivers, especially by those public safety agencies that permit or encourage their employees to use CB for communications directly with the general public from agency-owned vehicles. This would enable a continuous watch on national CB emergency channel 9 regardless of whatever other channel was being monitored by those employees.

Careful consideration should be given to the desired system image, and to the services that would or would not be provided by the respective agency or group. If time and resources permit, the continual updating of information on highway incidents by subsequent or on-scene observers and the dissemination of any pertinent advisories to the motoring public via CB, commercial broadcast radio, and other means are recommended. Some continuing effort at public education and familiarization with this system image should be anticipated.

The potentials for volunteer contributions (personnel, experience, and even hardware resources) should be recognized. Especially the spontaneity and enthusiasm of community-service-minded volunteers should be combined with the professionalism, discipline, and administrative stability of current public safety operations. The resulting CB communications system should have both a public involvement and accountability and a substantial institutional commitment to success. Furthermore, other community resources, such as the print and broadcast media, should be used.

In those communities where the establishment of a comprehensive CB communications system is undertaken by citizen volunteers without the active involvement and financial support of the local public safety community, particular care must be given to such administrative details as fund-raising and coordination of services, personnel, and other resources. The record of accomplishment of such independent efforts is not good especially because of an overabundance of enthusiasm hampered by an inadequacy of patience and administrative and organizing talents.

Creation of new programs should be accompanied by a careful analysis of the needs of the CB user public to be served. For instance, the availability of alternative routes and the proportion of transient drivers who are not likely to be familiar with them need to be determined.

Care must also be taken not to encourage the development or perpetuation of cliquish or "toy cop" groups. Participation by the public (reporting highway incidents, requesting service vehicles, and the like) must be completely open to all regardless of group affiliation or area of residence. System operations should not prerequire knowledge of specialized codes or ciphers. Burgeoning CB popularity means that a large number of novices will exist whose familiarity even with the time-worn "10-codes" may be minimal and for whom the example of clear and simple language should be a welcome relief from the affected mannerisms too often encountered on the other, nonemergency channels.

The designers of subsequent comprehensive systems are encouraged to consider a cellular type of coverage similar to that proposed for the new 900-MHz land-mobile networks. The larger the individual exclusive operating cells become, the larger the areas without service would be when hardware components fail or interference is encountered. Conversely, the smaller the individual operating cells can be made, the greater is the chance that communications could be accomplished even in the presence of such interference. If multiple or redundant coverage zones are used (this would be desirable), then real-time central office coordinating of their coverages would be essential.

Subsequent regulatory changes to CB radio should be undertaken with input both from transportation specialists familiar with the legitimate real-time information and communications needs of the traveling public and from communications specialists familiar with hardware and system design, radio frequency spectrum performance and allocation, and current CB user behavior.

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