

STATE OF THE ART RELATED
TO REAL-TIME TRAFFIC INFORMATION
FOR URBAN FREEWAYS

by

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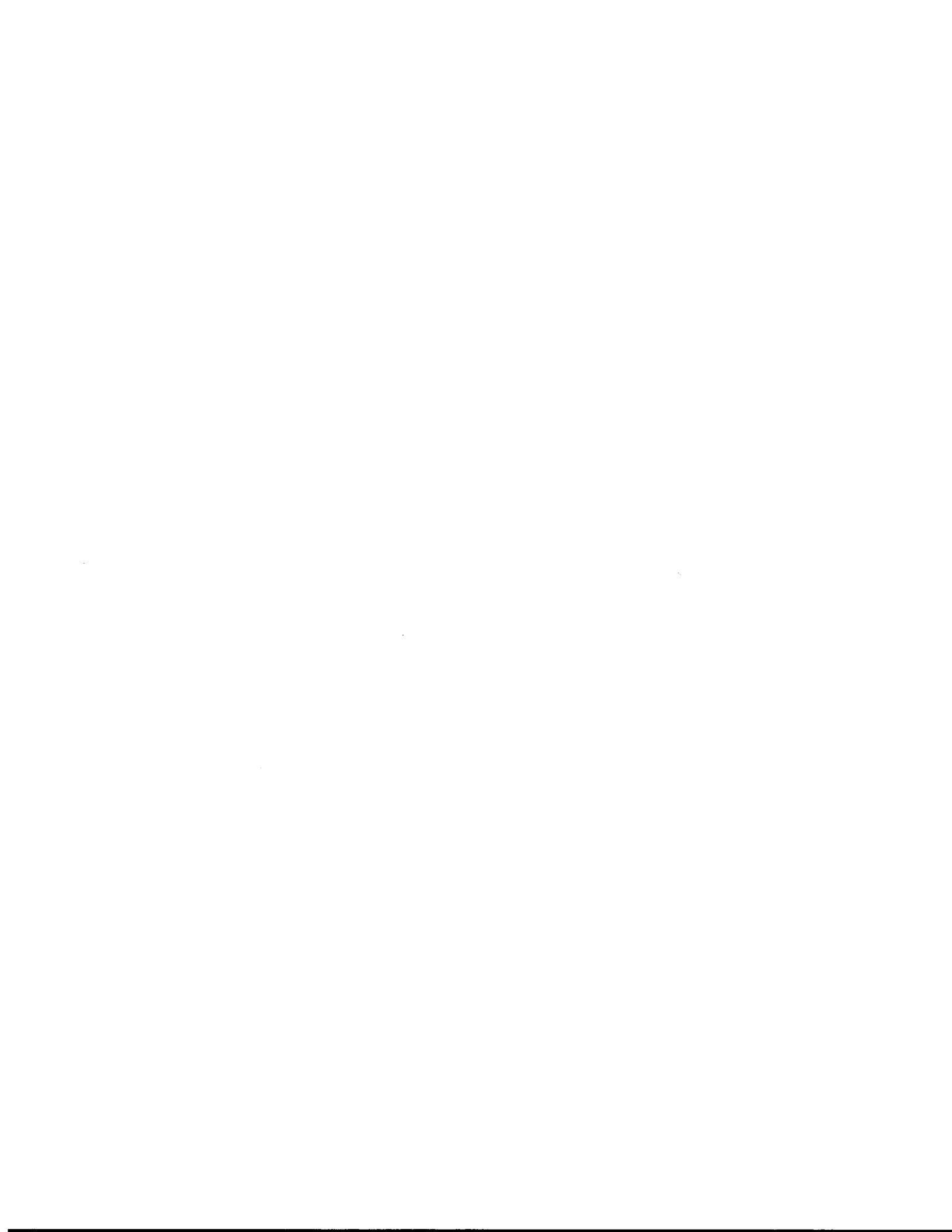
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ABSTRACT

An examination of the state of knowledge was conducted for the purpose of evaluating methods of providing the urban freeway driver with real-time traffic information. Visual and audio methods of communication were considered to be most feasible for implementation. The state of the art was therefore focused on systems requiring the use of these two methods.

The report presents a comprehensive review of existing and proposed systems which are capable of communicating with the driver while he is in his vehicle. The systems were classified according to whether they displayed or provided information to the driver external to the vehicle (external system) or within the vehicle (on-board system).

DISCLAIMER

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

SUMMARY

An examination of the state of knowledge was conducted for the purpose of evaluating methods of providing the urban freeway driver with real-time traffic information. This report presents a comprehensive review of existing and proposed systems. The systems were classified according to whether they displayed or provided information to the driver external to the vehicle (external system) or within the vehicle (on-board system).

From the evaluation presented in the report, the following findings may be drawn:

1. Based on the criterion that a system be designed for immediate and practical implementation, changeable message signs offer promise as one effective method of communicating with the urban freeway driver in real-time. Additional research would be necessary to better define the informational and the visual display requirements for effective system design.
2. The effectiveness of traffic radio reports in urban areas is not completely known, due to the lack of quantified data for evaluation. One study, which provided guidance information on varying degrees of advance and exit information, indicated that a radio-signing system which provides the necessary information where needed can be effective and, at the same time, avoid extensive over-signing. Additional

research is needed to fully define the application of commercial radio to real-time freeway information for urban areas.

3. Results of studies relating to changeable lane control signs indicate that these signs appear to be effective when freeway traffic volumes are light to moderate. The effectiveness is reduced considerably when the freeway demand is greater than the capacity of the obstructed section.
4. Results of studies relating to the use of variable speed signs indicate that, generally, this type of device is not effective in controlling freeway traffic.
5. The experiences with diagrammatic type changeable message signs seem to be varied. Studies in Chicago indicated that these types of signs had no measurable effect upon the daily distribution of expressway-bound traffic. Conversely, research in Detroit indicated a definite response to the signs.
6. Very limited work has been done to evaluate driver preferences for visual information displays directed at providing the driver with real-time information. Results of one study indicated that 1) drivers prefer that information about freeway traffic conditions be displayed at all times, 2) drivers prefer to receive information regarding the occurrence of an accident during the peak periods, and 3) quantitative information in terms of delay and travel time were not desired by the drivers.

Recommendations For Implementation

Based on the findings of this report, the following recommendations are offered:

1. Changeable message signs and signals external to the vehicle and on-board audio systems employing the use of the car A.M. radio and citizens band radio should be further evaluated as alternatives for providing real-time freeway traffic information to the motorists in urban areas.
2. Requirements for real-time communication need to be defined. These requirements must be responsive to the needs of the motoring public. Freeway drivers, therefore, should be allowed to provide inputs toward the development of these requirements.
3. Studies should be conducted to evaluate driver preferences for diagrammatic type of changeable message signs in comparison to other alternatives.
4. Driver preferences for real-time freeway traffic information should be further evaluated.

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INTRODUCTION

The basic methods which conceivably can be used to transmit information to the driver are visual and audio. The driver normally receives information by other sensory processes, all of which provide some input to the driving task. However, in terms of a realistic, implementable real-time freeway communication system, the above two are most meaningful. The state-of-the-art will, therefore, be focused upon systems requiring the use of these two senses.

This report is concerned with communication with the driver in his vehicle and does not consider systems that require him to leave the vehicle. Consequently, systems such as emergency call boxes have not been reviewed as part of this undertaking.

To facilitate this presentation, real-time communications was further classified according to the location, relative to the vehicle, where information is displayed or presented to the driver - that is, whether the information is presented external to the vehicle (external system) or within the vehicle (on-board system).

EXTERNAL VISUAL SYSTEMS

Signals

Traffic signals which regulate traffic at intersections have long been a method of communicating with the motorist in real-time. The three basic standardized colors of red, amber and green provide messages which are clearly understood. Laws governing driver compliance

with the signal have made this device effective.

Modern-day use has also found this device to be an effective means of regulating ramp traffic entering a freeway (1-5). Entrance ramp traffic is metered with this device to prevent freeway congestion and to ensure stability of flow during the peak periods.

Due to wide public acceptance and compliance with traffic signals, it would appear that the application of this device might offer possibilities for displaying some types of freeway traffic information in real-time.

Flashing amber or red beacons have also been used successfully in several applications within the highway environment. The effectiveness of this type of device from other experiences lends itself to possible application for real-time freeway communication.

Changeable Message Signs

General - Changeable message signs provide another means of communicating with freeway motorists. These devices present messages with varied configurations of displays, in which information is provided by the use of words or symbols which are visible when a particular message applies. The manner in which messages are displayed varies according to the manufacturer of each particular product (6).

In this report, changeable message signs are defined as any visual word or symbol presentation that can be electronically or mechanically changed when conditions warrant. This group includes signs which may only contain one message but which can either be

visible (on) or blanked-out (off).

Communication On The Freeway - Research involving the provision of traffic information to freeway drivers using changeable message signs has been rather limited. One of the first large-scale experimental systems in the United States made use of a series of overhead lane control signs (Figure 1) and overhead variable speed control signs (Figure 2) installed on 3.2 miles of the John C. Lodge Freeway in Detroit as part of the National Proving Ground traffic control system (7). Freeway conditions were monitored by observers via closed circuit television. The lane and speed signs were illuminated based on the observers' evaluations of freeway conditions.

The purpose of the lane control signs was to inform the freeway motorists whether the lanes ahead were open or closed. A green arrow over a lane indicated that the particular lane was clear of any physical obstruction, while a red "X" warned of a lane blockage. The intent was to give advance warning to the motorists so that they could move out of the blocked lane as soon as possible.

The variable speed control signs had two primary purposes:

- 1) to warn motorists on the freeway of a shock wave ahead so that they could begin to decelerate before actually reaching the congested areas, and
- 2) to encourage the motorists leaving a congested area to increase their speed to help disperse the congestion. One of three speeds (25, 40 or 55 mph) could be displayed on a matrix-type sign.

Clinton (8) conducted before-and-after studies to evaluate the effect of lane control signs on the lane change rate. He observed

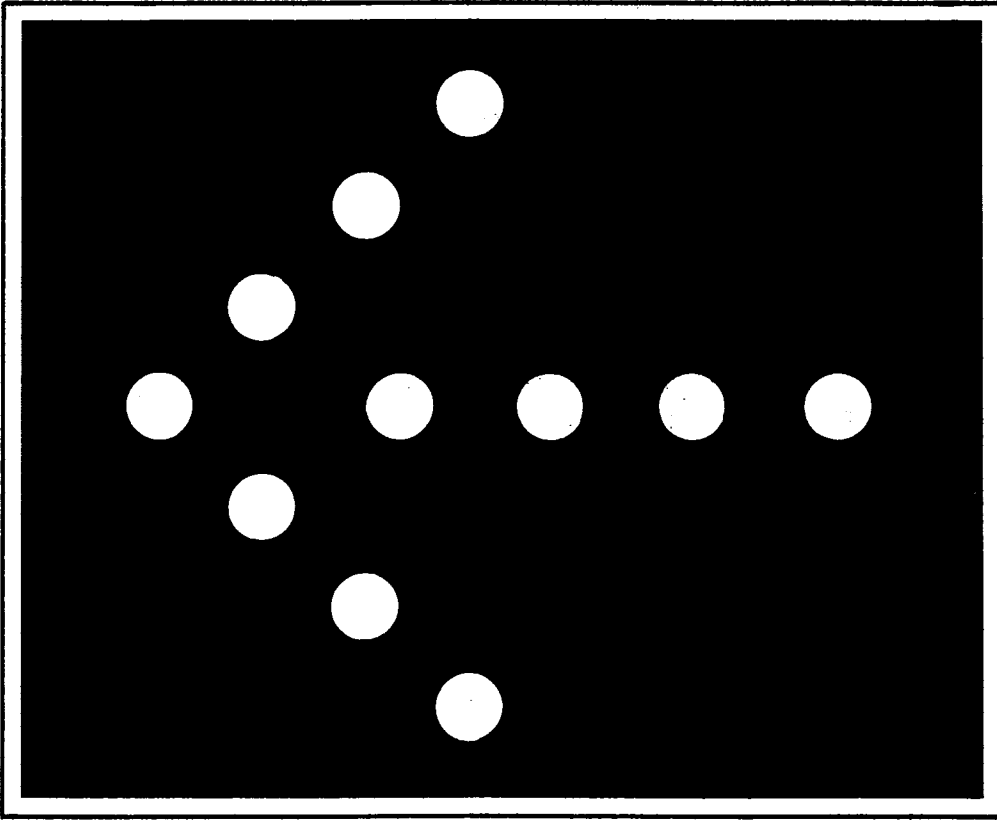
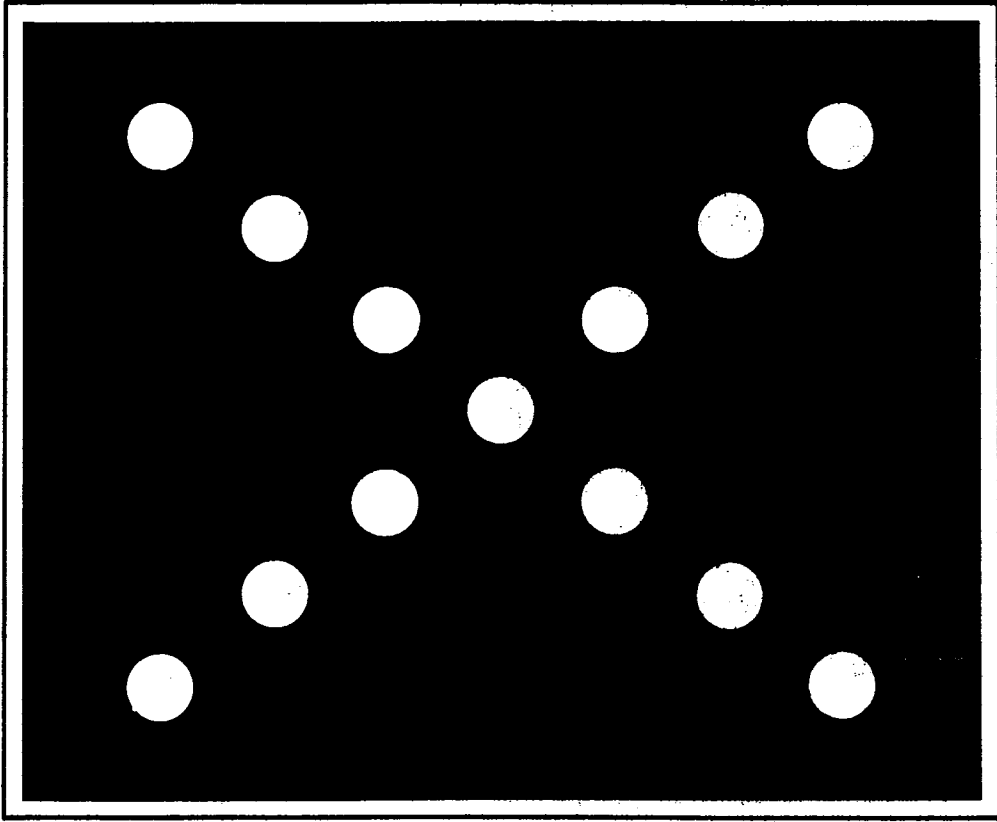


FIGURE 1 - LANE CONTROL SIGNS - DETROIT (7)

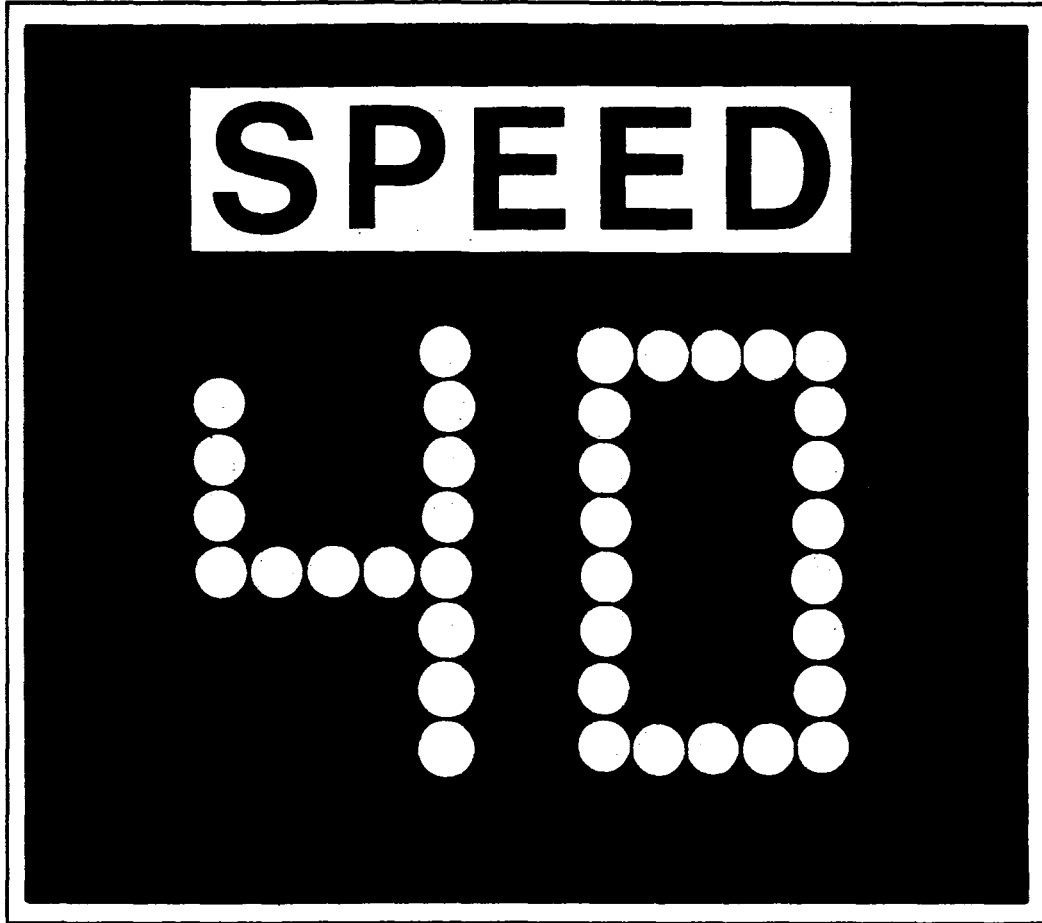


FIGURE 2 - VARIABLE SPEED CONTROL SIGN - DETROIT (7)

that they had no appreciable effect on the average lane change rate. Initial observations made by Dudek (9) of the effectiveness of the signs indicated that they were effective during the off-peak period in clearing the lane in which an incident had occurred.

In a more comprehensive study, Gervais (10) evaluated the operational benefits of these signs. Observations were made and data were collected from the television control center of the project. In addition, 16mm films were taken from a high vantage point near the freeway. The specific characteristics studied included the following: 1) volume, 2) speed, 3) lane occupancy, 4) lengths of back-ups, 5) vehicle delay, 6) number of trapped vehicles and 7) lane changes. The purpose of this study was to measure the comparative effectiveness of conventional methods of closing a lane (flasher trailer, cones, road signs, barricades, etc.) as opposed to utilizing the lane control system. Lane closures were staged on the John C. Lodge Freeway in the southbound and northbound direction, having four- and three-lane sections, respectively.

The results of the experiment revealed that a definite and considerable improvement in freeway operation was realized utilizing the lane control signs. Some of the results of the study were as follows:

1. Lane changing was initiated farther in advance of the lane obstruction.
2. Traffic volumes past the obstruction increased significantly, provided traffic demands were high.
3. When traffic demand was moderate, speed past the incident remained near the optimum, while stoppages were minimized or eliminated.

4. The rate of vehicles trapped behind the obstruction was reduced.

Further evaluations by the Texas Transportation Institute and reported by Wattleworth, et al. (11) revealed that the effectiveness of the overhead lane control signs appeared to be a function of the freeway demand. The effectiveness was reduced considerably when the freeway demand exceeded the capacity of the obstructed section.

In general, overhead lane control signs appear to be effective for light to moderate traffic conditions on the freeway. When the traffic demand becomes very high, the motorists are presented limited opportunity to change lanes into one displaying a green arrow, particularly when the "open" lanes are heavily congested due to the obstruction downstream. When vehicles do leave the affected lane, the appearance of a congestion-free, relatively faster-moving lane becomes enticing to those motorists trapped in a stop-and-go situation. Consequently, the tendency to use the blocked lane increases, rendering the overhead sign ineffective.

Results of studies relating to the use of variable speed signs indicate that this type of device is not effective. The Texas Transportation Institute measured the response of motorists to this type of sign on the John C. Lodge Freeway (11). The results of the evaluations indicated that the motorists did not decrease their speeds to coincide with the posted speed unless there was an apparent reason to do so. This would imply that the motorists did not consider the changeable speeds to be regulatory. It was suggested that other messages might

provide a more direct advance warning to the motorists.

Although the studies on variable speed message signs conducted by the Texas Transportation Institute were of limited scope, research conducted by the California Transportation Agency (12) to develop means of giving advance warning to motorists driving under reduced visibility conditions tended to substantiate the findings. The following conclusions were drawn by the California Transportation Agency regarding the effectiveness of variable speed signs on both expressways and freeways:

1. In all cases on the expressways and with low volumes (day and night) on the freeways, posted speeds effect a reduction in both mean and the 85th percentile speeds (generally 5 to 10 mph).
2. Posted speeds less than 35 to 40 mph have little additional effect in reducing speeds.
3. Drivers tend to drive at speeds higher than the posted or the safe speed in fog.
4. Based on a limited test, very little difference was found in the effectiveness of regulatory and advisory speed limit signs.

A similar experimental system for fog warning has been installed in north-central Oregon on a 6-mile section of Interstate Route 5 (13). Fog warning is given by a series of six variable message and speed signs. Twenty-four hour radio contact between police mobile units on the freeway and the office of the state police in Albany is used as an early-warning system on which decisions are based to activate the signs if there are indications of a critical fog. The signs are remotely controlled from the Albany office. The researchers indicate that preliminary observations, as well as initial reports from the state police, seem to be quite favorable, although no actual field

measurements have been made. Additional planned instrumentation will eventually make the system fully automatic.

Communication On The Frontage Roads and Arterial Streets - Research involving display of real-time information to potential freeway drivers on arterial streets has also been very sparse. The Chicago Area Expressway Surveillance Project conducted experiments with a prototype sign to inform the motorists on the arterial streets of freeway and entrance ramp conditions. These experiments have been documented by Hoff (14). The sign was illuminated when conditions on the freeway and entrance ramps reached critical levels. Both the freeway and ramp traffic characteristics were measured by detectors which transmitted information to a computer. The computer in turn activated the sign when critical freeway parameters were reached.

The staff of the Chicago Area Expressway Surveillance Project considered several changeable message sign designs. The researchers felt that the state of the technology at the time limited feasible designs to those which presented the traffic information visually. Among these designs were the following: a sign which used words to describe the traffic conditions at the ramp and on the expressway; a matrix of lights which would change color to reflect the traffic conditions; a sign giving probable values of delay at each ramp and traffic conditions at certain locations.

Individuals having experience in the communication of information to drivers were consulted. Based upon these discussions and the judgment of project personnel, a sign design containing a map panel

with colored arrows was selected for further investigation (Figure 3). Each controlled ramp and each freeway detector within the area depicted by the map panel were represented by a changeable color arrow. The arrow reflected traffic conditions by displaying one of three colors (red, yellow, green). Two successive ramp locations and their associated mainline locations were displayed on each sign. The researchers felt that, by presenting the information concerning the closest westbound entrance ramp and the next closest westbound entrance ramp, the driver could choose between at least two alternatives. A white band, representing the expressway, was located vertically on the signs used on the east-west arterials and horizontally on the signs used on the north-south arterials. Thus, the direction of travel of the expressway with respect to the direction of travel of the motorist was explicit.

Initially, some consideration was given to the use of separate lights instead of a single arrow, at each indicated location, but this idea was thought by the researchers in Chicago to be too similar to traffic signals and could possibly cause some degree of driver confusion, resulting in hazardous maneuvers. Therefore, it was felt necessary to develop a method to project three separate colors through one arrow-shaped opening in the sign.

Four light sources were assembled and evaluated: 1) a three-lamp direct lighting system, 2) a neon gas interwoven tubing system 3) a three-lamp reflected lighting system, and 4) a single lamp with a three-color rotating wheel system. When all of these sources were

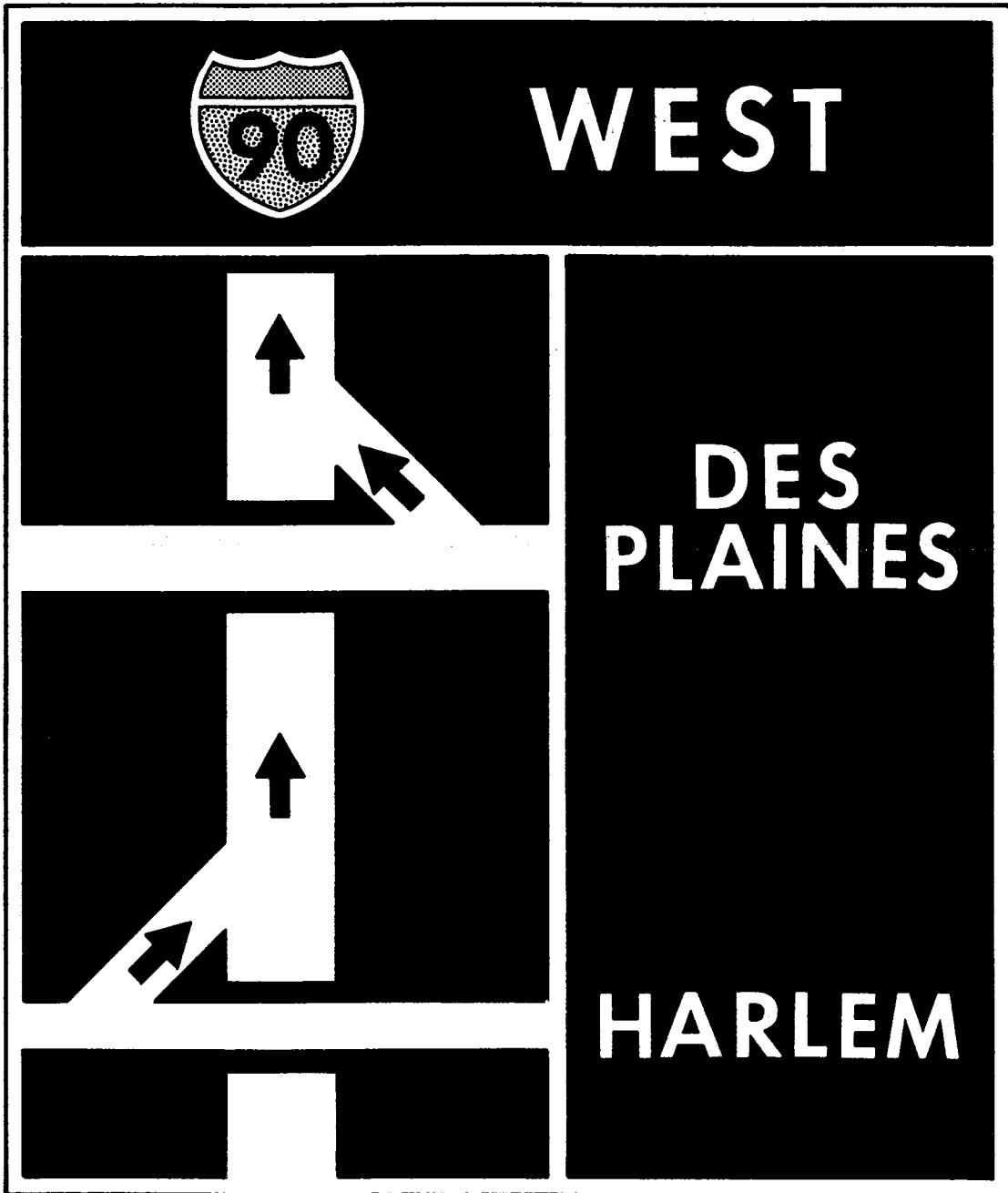


FIGURE 3 - FREEWAY INFORMATION SIGN - CHICAGO (14)

viewed in bright sunlight, only the single-color wheel system provided a conspicuous difference between colors, and was therefore selected.

The sign face was rectangular, 7 1/2 feet high and 6 feet wide, with white letters on a green background. The signs and explanatory legend signs were located 300 feet in advance of the intersections. Each sign was externally illuminated during darkness by fluorescent lighting which was controlled by a photocell.

The results of evaluation studies indicated that the information signs did not have a measurable effect upon the daily distribution of expressway-bound traffic. Hoff (14) noted that the results did not necessarily imply that the concept of presenting expressway traffic information on arterial streets was invalid. He suggested that if the driver does not understand the significance of the map and symbols used on the sign face, then any information presented would be ignored or misused.

The inconclusive results of the study prompted the researchers in Chicago to determine driver comprehension and usage of the signs through a questionnaire study. When motorists were queried as to their use, a large proportion indicated that they did use the signs. Hoff noted that divergent results had emerged. In addition, one of the most frequent comments regarding the signs was that they were difficult to understand while dri

Additional studies involving the provision of traffic information on the frontage roads and on the arterial streets were conducted by the Texas Transportation Institute in the Lodge Freeway corridor

and were reported by Courage (15). Signs designed to convey the traffic characteristics on the entrance ramps were installed at two entrance ramps on the frontage road and at two locations on a parallel arterial street where drivers must make a decision whether to turn to use the freeway. The signs were controlled directly by a computer which received information from ramp detectors. The detectors were installed at the tops of metered ramps and interrogated by a digital computer to determine whether or not a ramp queue existed. The traffic parameter measured was the detector occupancy (percentage of time in which a vehicle presence was indicated) calculated at one-minute intervals.

Figure 4 shows the ramp information signs described above. The downstream ramp conditions were depicted by different colors of internal illumination behind the symbols. A red display referencing a particular ramp indicated "delay," while a green display indicated "no delay." Thus, the driver waiting in line to enter the freeway was advised if conditions on a downstream ramp warranted abandonment of his position to gain more favorable access downstream.

In addition to the above signing, six existing blank-out signs, which were originally installed as ramp closure signs in connection with previous research, were modified to display the message FREEWAY STOPPED AHEAD upon activation when freeway conditions warranted. These signs are shown in Figure 5.

An input-output analysis indicated a net increase in freeway travel of approximately 476 vehicle miles per day due to the signs.

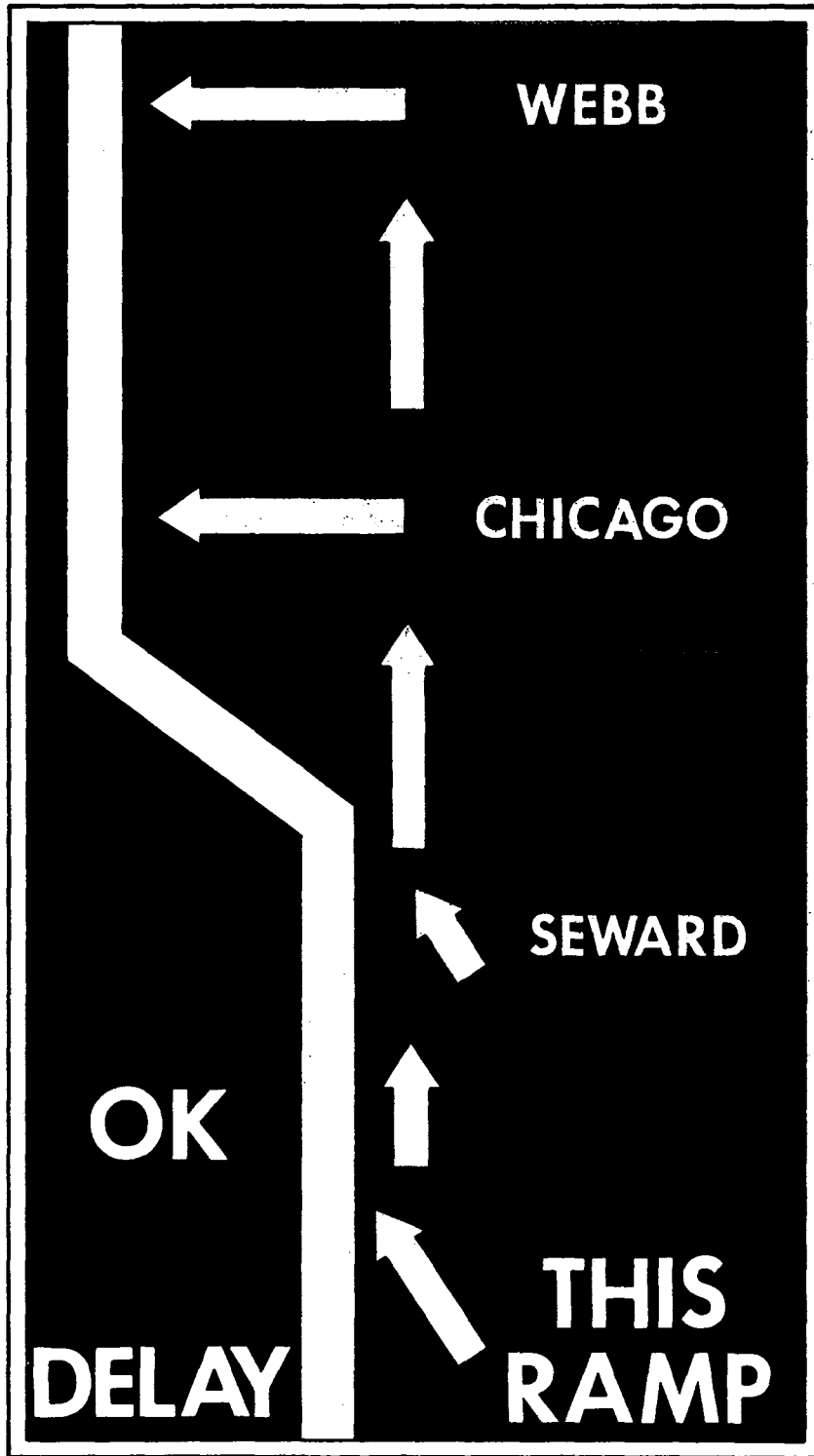


FIGURE 4 - FREEWAY RAMP INFORMATION SIGN - DETROIT (15)



FIGURE 5 — 'FREEWAY STOPPED AHEAD'
SIGN — DETROIT (15)

This was converted into an estimated travel time saving of 3,000 vehicle hours per year.

The direct travel time saving due to earlier satisfaction of demand at the ramp signals amounted to approximately 163 vehicle hours per day, or 41,000 per year. Assuming a 10-year life for the sign units, the total annual cost of adding the information system to the existing surveillance and control facilities was estimated to be approximately \$4,180. The cost/effectiveness ratio associated with this system was estimated to be about 10 cents per vehicle hour saved.

Some of the conclusions of the study were as follows (15):

1. The above figures were believed to represent a realistic interpretation of the study data. Courage believed, however, that there were a number of factors which should be borne in mind in assessing the system.
 - a. While response to the sign messages was apparent, the extent of the real-time response (as opposed to a permanent change in patterns of ramp usage) was not known.
 - b. The frontage road on the Lodge Freeway is a well-defined portion of the corridor. In other areas of the corridor (or in other corridors), the probability of success is likely to be much lower where the alternate surface route is not so clearly established.
 - c. The information system described can be considered only in the context of an addition to an existing surveillance and control system. The cost figures used involved only the incremental cost of installing and operating this additional system.
 - d. While the cost/effectiveness ratio was favorable, the actual travel time saving was relatively small. Furthermore, this saving was likely to be reduced under a fully operational ramp metering system after the queueing patterns have completely stabilized.
2. In the study time available, it was not possible to collect sufficient data to separate the benefits of the freeway

information signs from the ramp information signs, nor was it possible to study, in sufficient depth, the operation of this system during capacity-reducing incidents on the freeway. No specific conclusions on this subject could therefore be offered.

The signs used in the experiments conducted by the Texas Transportation Institute have since been modified (Figure 6). Additional signs for route diversion have also been placed within the Lodge Freeway study corridor and are being evaluated by the University of Michigan as part of NCHRP Project 20-3. A questionnaire has been developed to evaluate the new ramp information signs.

The experiences in the United States with diagrammetric type changeable message signs seem to have varied. Hoff (14) observed that these types of signs had no measurable effect upon the daily distribution of expressway-bound traffic in Chicago. On the other hand, Courage (15) reported a definite response to the signs in Detroit. It is difficult to determine why the differences did exist. The fact that the signs in Detroit were placed on the frontage road may perhaps have contributed to a more effective response on the part of the motorist.

Neither study evaluated driver comprehension of the diagrammetric changeable message sign. Hoff, however, speculated that the drivers may not have understood the significance of the map and symbols used on the sign face. The University of Michigan is evaluating driver comprehension of this type of sign for a single case. Results of the study are not yet available. It appears that some laboratory experimentation would be desirable to fully evaluate driver comprehension

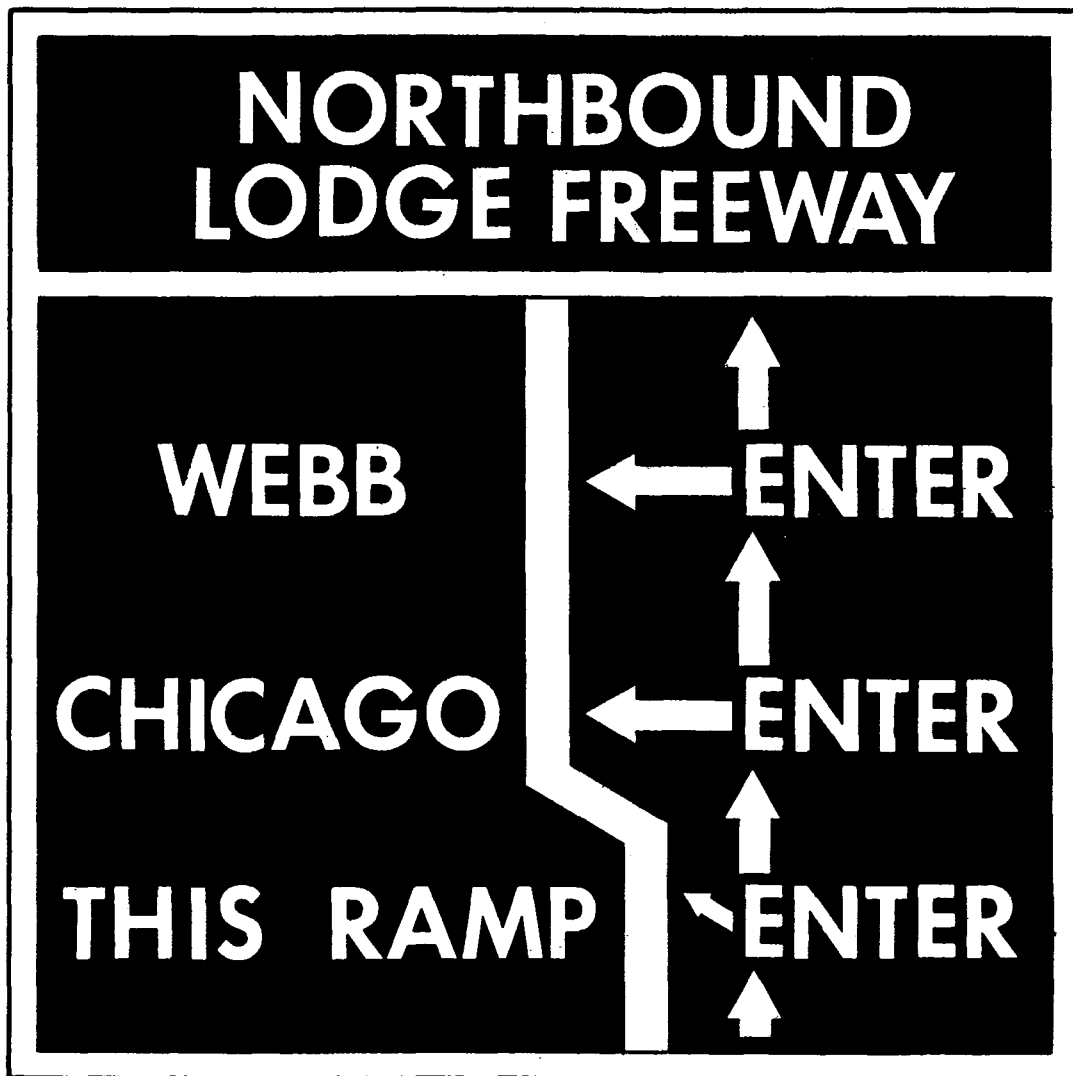


FIGURE 6 — REVISED FREEWAY RAMP
INFORMATION SIGN — DETROIT (15)

of diagrammatic changeable message signs, and to evaluate the preference of this design in comparison to other alternatives, such as the use of word messages, to name one.

Systems in Foreign Countries - In Germany, a pilot surveillance and driver communications system has been installed on a 20-mile stretch of highway between Weyarn and Munich (16). This section of highway is monitored using closed circuit television. Remotely controlled speed signs and alternate routing signs are activated as needed. The basic emphasis is to create a speed funnel by systematically changing regulatory speed signs, in an attempt to control the speeds of the vehicles approaching a congested area. When accidents occur and the capacity of the highway is reduced, the drivers are encouraged to use alternate routes to Munich. Standard traffic signs and signals, which are specified in the German Highway Code and with which all motorists are familiar, are imprinted on scroll type changeable message displays (Figure 7).

This pilot system was designed to relieve traffic congestion on one of the most heavily travelled highways in Germany. Specifically, it was expected to utilize the roadway capacity to an optimum degree and to reduce the considerable number of accidents that occur on the highway. The final construction stage of the system will provide fully automatic operation, where traffic entering the highway would be registered by vehicle detectors and evaluated by a computer which would then automatically control the changeable signs. To the author's knowledge, this system has not yet been evaluated.



FIGURE 7 - VARIABLE SPEED CONTROL - GERMANY (16)

In 1966 the Minister of Transport, United Kingdom, announced a proposal to equip a 1,000-mile network of highways with remotely controlled signal systems aimed at reducing accidents and securing safer all-weather driving conditions (17). These signals will gradually replace temporary flashing amber warning lights which were installed in 1965.

Earlier, two trial systems - both centrally controlled - had been tested, one on a rural highway (M5) and one on an urban highway (M4). Both of these trial systems used worded signs which were controlled from the police stations. The signs consisted of neon tubing with the general legend "M4 CLOSED - USE A4." These signs were found to suffer from several disadvantages:

1. They could only be used for emergencies sufficiently serious for the highway to be completely closed.
2. Many drivers ignored them since they were only advisory in nature.
3. The time to replace broken or faulty signs was considerably long since each sign had to be individually fabricated.

Signs were placed on the rural highway at two-mile intervals on 24 miles of the roadway. Seventeen of the 22 signs used 75-watt metal filament lamps with special lenses, and the remaining five had neon tubing. Each sign contained alternative legends - SKID RISK, ACCIDENT and FOG. One or more of these legends can be displayed at a time. They were always accompanied by the word SLOW. For example, if an accident occurred during fog, SLOW, together with ACCIDENT and FOG, would appear on two or more signs in advance of the accident.

Flashing amber beacons were displayed on the signs when they were in use. These signs were about 11 feet wide and were mounted behind the shoulder with the tops above the roadway surface.

Consideration of the two trial systems indicated to the researchers in the United Kingdom that the requirements for communicating the nature of the emergency and its severity are such that the dimensions of the sign become impractical for highway use. Those on M5 did not indicate the severity and only showed three of the possible situations which could occur. Accordingly, for the permanent systems, the researchers adopted the alternative of telling the motorist what action is required of him, namely, the appropriate speed and/or which lanes to use.

The design of these new signals (Figures 8 & 9) was governed by the following conditions:

- 1) Conspicuity - This has been accomplished by using four amber lights which flash in pairs to attract drivers' attention to the fact that the signs are in use. The flashing is in the vertical direction, comparable to temporary warning lights.
- 2) Adaptability - The use of a 13 x 11 lamp matrix allows the presentation of a wide variety of symbols. For simplicity of control, the number of symbols has been limited to 16, but changes within this number can be made easily.
- 3) Economy - All variants of the basic signal (for urban and rural use) are assembled from the same components, thus deriving the benefits of large-scale production.
- 4) Reliability - There are no moving or exposed corrodible components. Both the matrix indicator and the lights are sealed in weatherproof compartments. The indicator can be removed from the signal and replaced with a new one in less than one minute without the aid of tools, thus creating a minimum of maintenance work on the highway.

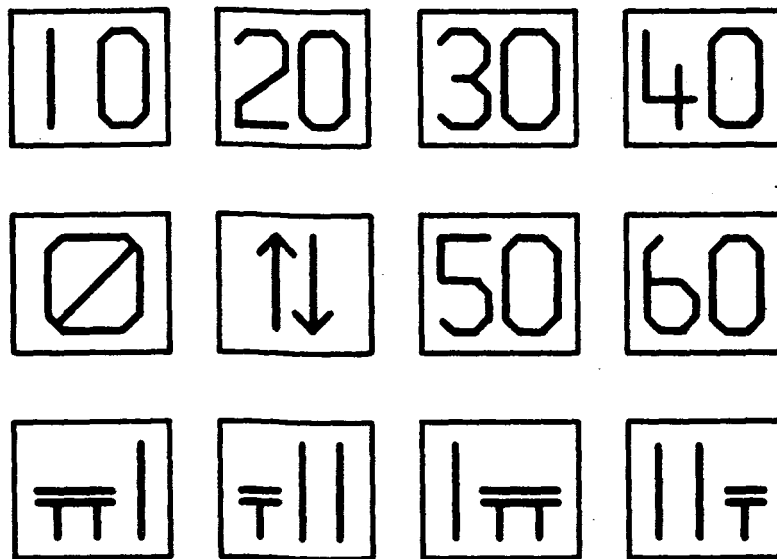
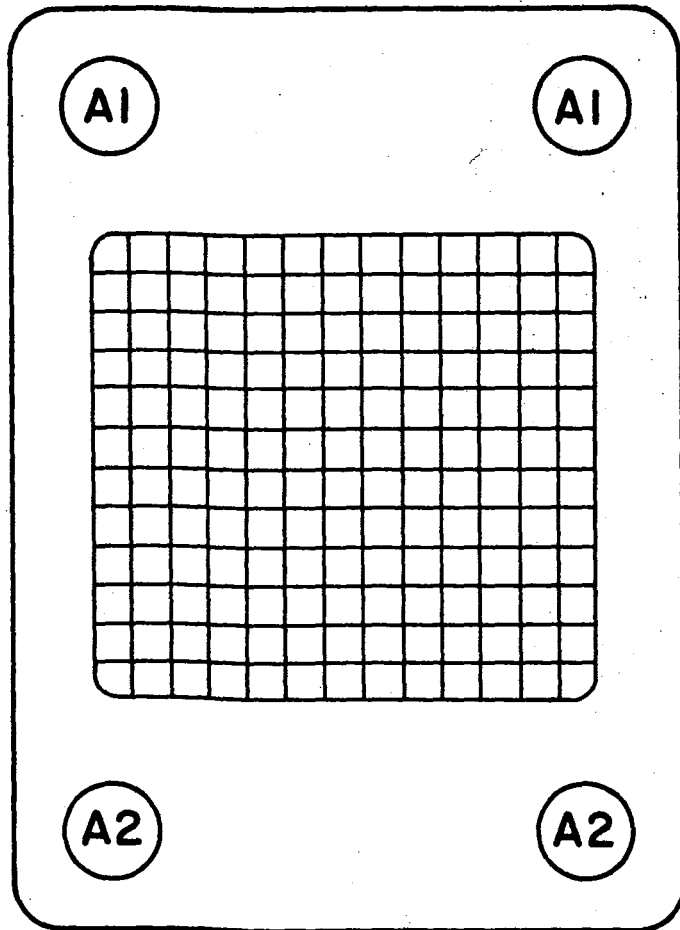


FIGURE 8 - POST MOUNTED CHANGEABLE MESSAGE WITH LEGENDS - UNITED KINGDOM (17)

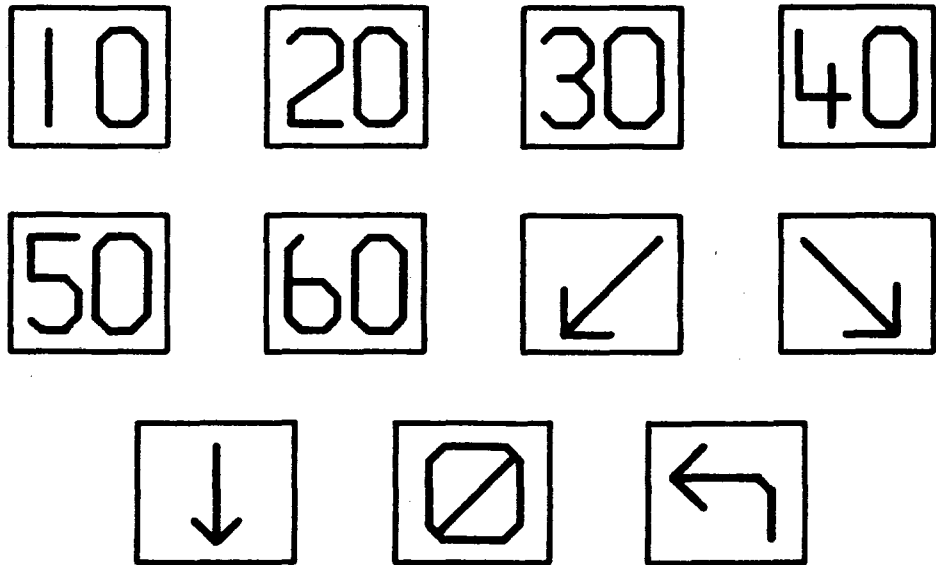
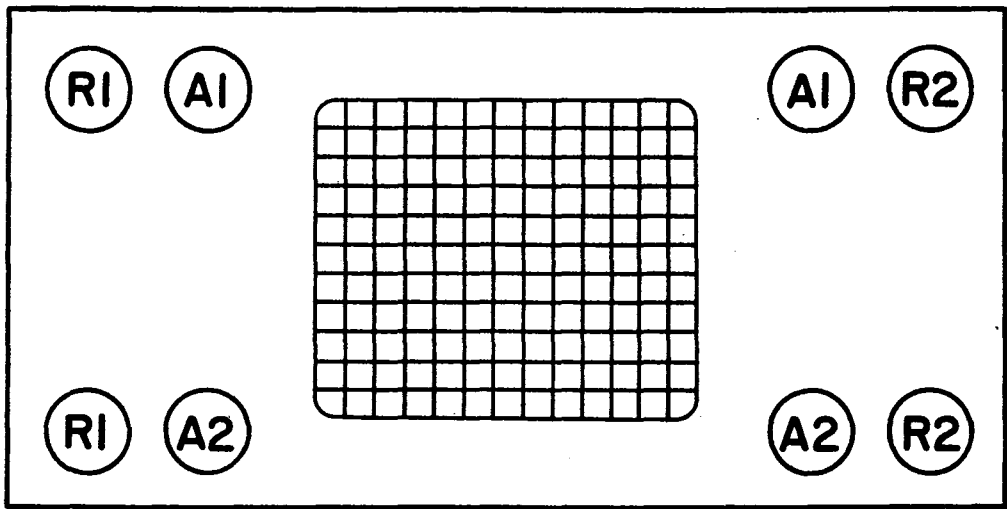


FIGURE 9 - OVERHEAD MOUNTED CHANGEABLE MESSAGE SIGN WITH LEGEND - UNITED KINGDOM (17)

The urban signals used on M4 also include four red lights which can be flashed horizontally in pairs when it is necessary to stop motorists. The lamps in the indicator matrix can be dimmed at night by appropriate control from the central computer. Heaters can be switched on to prevent the indicators from icing in cold weather.

The general aim of the surveillance system is to give an early warning to the central control of any material change in the traffic flow resulting from accidents, breakdown or congestion; to enable the police, by means of closed circuit television, to ascertain the possible cause of the trouble; to enable them, by remotely controlled signals, to influence the traffic flow to prevent accidents or to control queues; and to take quick action by calling patrols, ambulances, fire engines, etc., to deal with the cause of the trouble. Information regarding the evaluation of this system is not available.

Studies Relating To Information Requirements - Heathington, et al. (18) studied driver preferences for alternative visual information displays directed at providing real-time information to the freeway driver. Several traffic information descriptors were evaluated through a home questionnaire survey in the Chicago metropolitan area. Specifically, seven descriptors at the level of heavy congestion, six at the level of moderate congestion, and six at the level of no congestion were evaluated. The descriptors were classified as follows: 1) descriptive information, 2) quantitative information, and 3) no information. These descriptors are presented in Table 1.

The method of paired comparisons was used to evaluate the

TRAFFIC INFORMATION DESCRIPTORS EVALUATED
FOR VISUAL INFORMATION DISPLAYS (18)

Heavy Congestion

Speed 5 to 15 mph - next 3 miles

Heavy congestion - next 3 miles

Stop and go traffic - next 3 miles

Extra delay 10 to 20 minutes - next 3 miles

Accident - heavy congestion - next 3 miles

Travel time 15 to 25 minutes - next 3 miles

Blank sign

Moderate Congestion

Speed 20 to 30 mph - next 3 miles

Moderate congestion - next 3 miles

Heavy, steady, traffic flow - next 3 miles

Extra delay 0 to 10 minutes - next 3 miles

Travel time 5 to 15 minutes - next 3 miles

Blank sign

No Congestion

Free-flowing traffic - next 3 miles

Uncongested - next 3 miles

Extra delay 0 minutes - next 3 miles

Speed 45 to 55 mph - next 3 miles

Travel time 3 to 8 minutes - next 3 miles

Blank sign

TABLE 2

P'_{JK} MATRIX FOR HEAVY CONGESTION (18)

(The percentage of the time descriptor J is preferred over descriptor K)

		J DESCRIPTORS						
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
K DESCRIPTORS	1	-	47.59	46.32	36.97	66.71	26.49	13.31
	2	52.41	-	46.74	37.11	77.05	33.29	13.74
	3	53.68	53.26	-	32.86	70.82	33.43	17.71
	4	63.03	62.89	67.14	-	76.35	41.08	22.95
	5	33.29	22.95	29.18	23.65	-	28.05	12.46
	6	73.51	66.71	66.57	58.92	71.95	-	29.32
	7	86.69	86.26	82.29	77.05	87.54	70.68	-

Descriptors

1 = Speed 5 to 15 mph - next 3 miles

4 = Extra delay 10 to 20 minutes - next 3 miles

2 = Heavy congestion - next 3 miles

5 = Accident - heavy congestion - next 3 miles

3 = Stop and go traffic - next 3 miles

6 = Travel time 15 to 25 minutes - next 3 miles

7 = Blank sign

TABLE 3

P'_{JK} MATRIX FOR MODERATE CONGESTION (18)

(The percentage of the time descriptor J is preferred over descriptor K)

		J DESCRIPTORS					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
K DESCRIPTORS	1	-	44.33	41.93	27.20	21.25	18.98
	2	55.67	-	52.97	37.82	37.82	23.37
	3	58.07	47.03	-	28.75	27.20	24.50
	4	72.08	62.18	71.25	-	49.72	29.18
	5	78.75	62.18	72.80	50.28	-	37.68
	6	81.02	76.63	75.50	70.82	62.32	-

Descriptors

1 = Speed 20 to 30 mph - next 3 miles

4 = Extra delay 0 to 10 minutes - next 3 miles

2 = Moderate congestion - next 3 miles

5 = Travel time 5 to 15 minutes - next 3 miles

3 = Heavy, steady traffic - next 3 miles

6 = Blank sign

TABLE 4

P'_{JK} MATRIX FOR NO CONGESTION (18)

(The percentage of the time descriptor J is preferred over descriptor K)

		J DESCRIPTORS					
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
K DESCRIPTORS	1	-	43.06	18.98	57.08	27.62	35.98
	2	56.94	-	21.81	58.22	26.06	33.43
	3	81.02	78.19	-	79.75	46.03	35.84
	4	42.92	41.78	20.25	-	20.40	20.96
	5	72.38	73.94	53.97	79.60	-	43.06
	6	64.02	66.57	64.16	79.04	56.94	-

Descriptors

1 = Free-flowing traffic - next 3 miles

4 = Speed 45 to 55 mph - next 3 miles

2 = Uncongested - next 3 miles

5 = Travel time 3 to 8 minutes - next 3 miles

3 = Extra delay 0 minutes - next 3 miles

6 = Blank sign

information preferred by the survey participants. The P'_{JK} matrices for heavy congestion, moderate congestion, and no congestion are reproduced in Tables 2, 3 and 4, respectively. These tables list the percentage of time that each descriptor J was preferred over descriptor K at a given level of congestion. To explain the tables, reference is made to Table 2. For this case, descriptor 1 (speed 5 to 15 mph - next 3 miles) was preferred over descriptor 2 (heavy congestion - next 3 miles) 52.4 percent of the time. Descriptor 7 was generally the least preferred descriptor. The P'_{JK} matrix was further used to develop a ranking (scaling) of the descriptors for each level of congestion. The individual scale values for each descriptor are shown in Figures 10, 11 and 12.

From the analysis of the P'_{JK} matrices and the developed scales, Heathington reached the following conclusions:

1. For all levels of congestion, traffic information was preferred over no information about traffic conditions.
2. For the level of heavy congestion, information relative to an accident having occurred was the most preferred descriptor of the total sample.
3. The descriptor "speed" ranked second to the accident descriptor for the level of heavy congestion and was the first choice for the other two levels of congestion.
4. The two quantitative terms "delay" and "travel time" had relatively low scale values and were simply not desired by the respondents.
5. The two descriptive terms (excluding the accident descriptor) were scaled fairly high, but were less desirable than the term "speed."

The study by Heathington, to the author's knowledge, is one

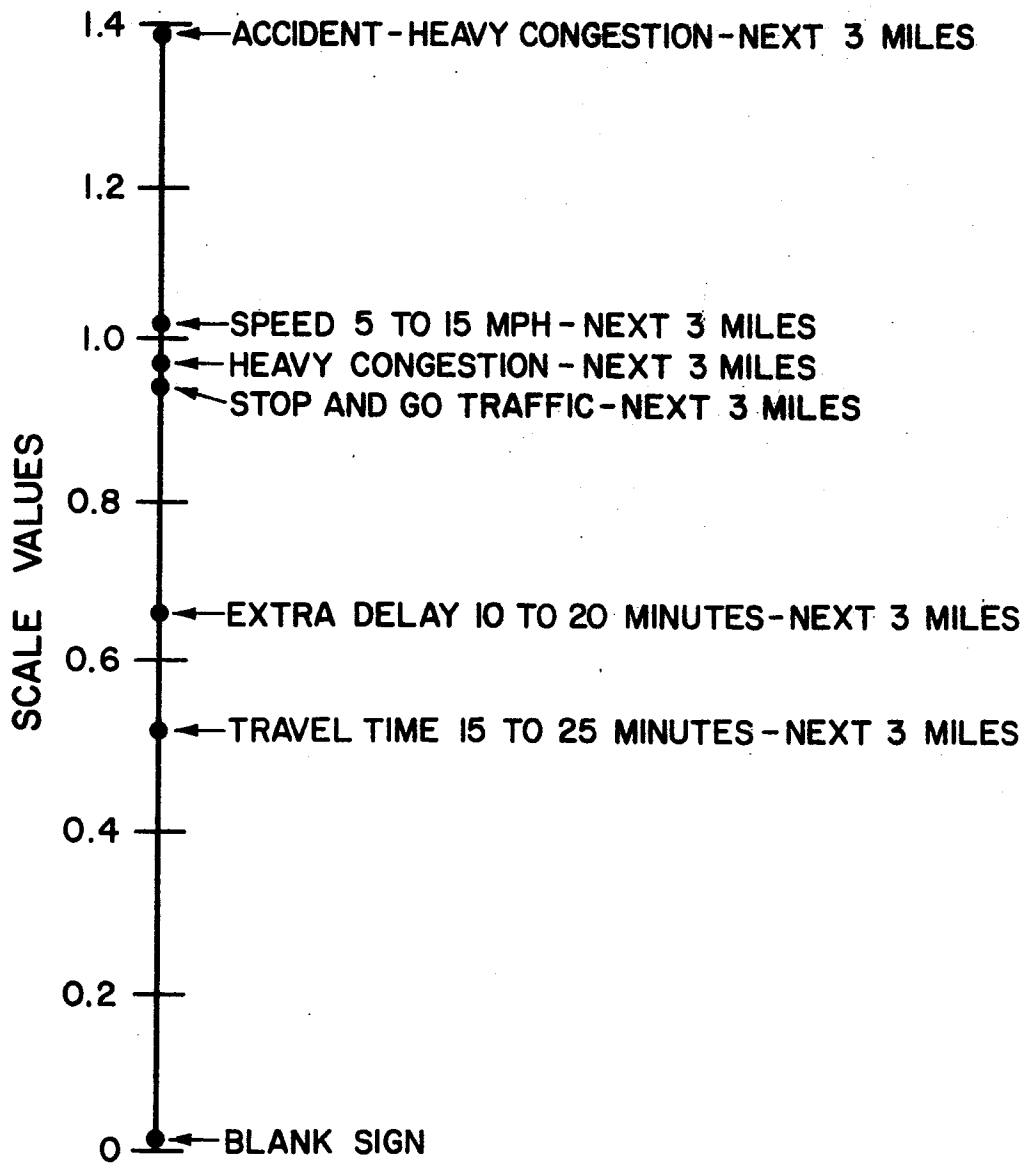


FIGURE 10 - SCALING OF DESCRIPTORS FOR HEAVY CONGESTION (18)

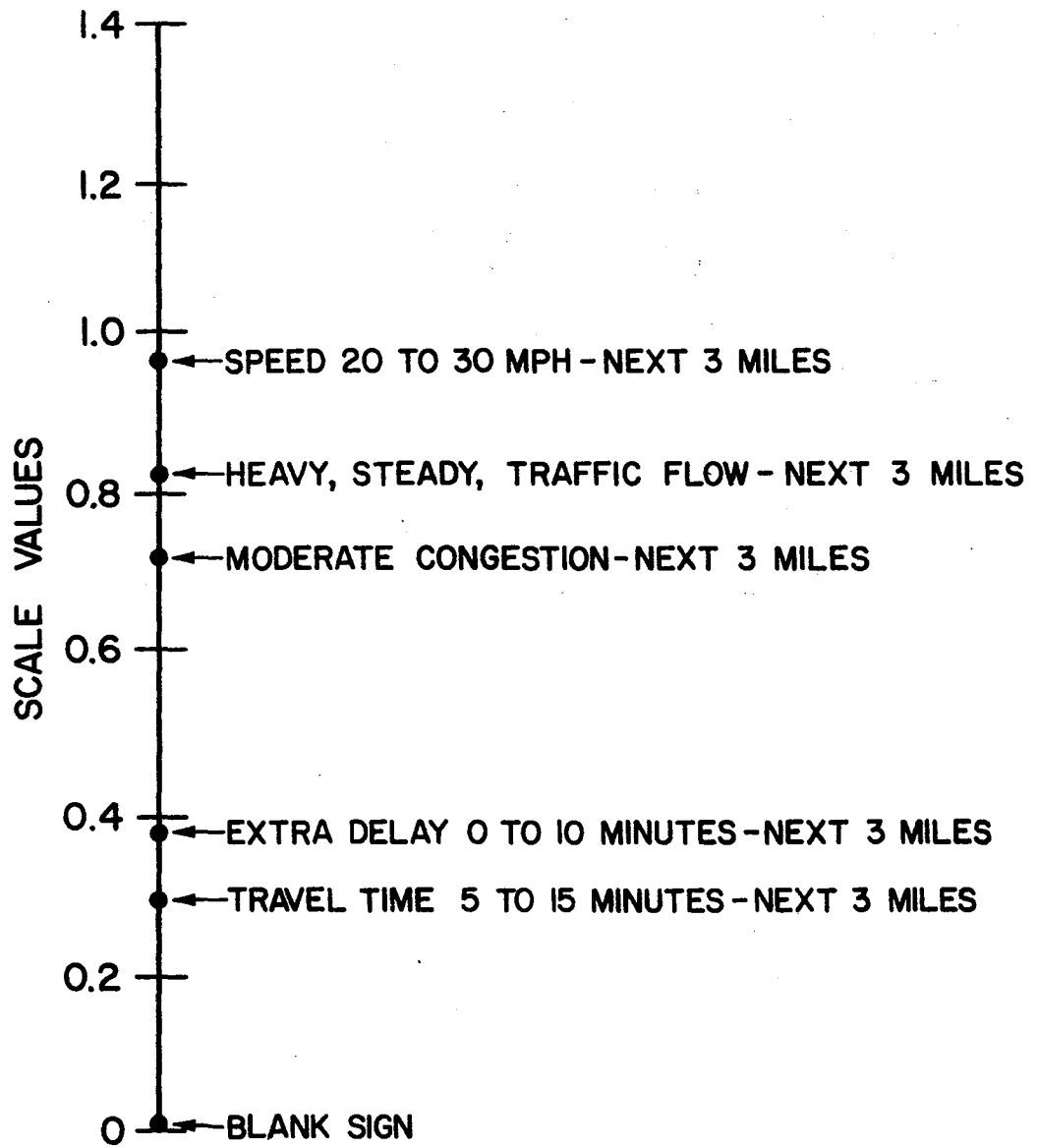


FIGURE 11 - SCALING OF DESCRIPTORS FOR MODERATE CONGESTION (18)

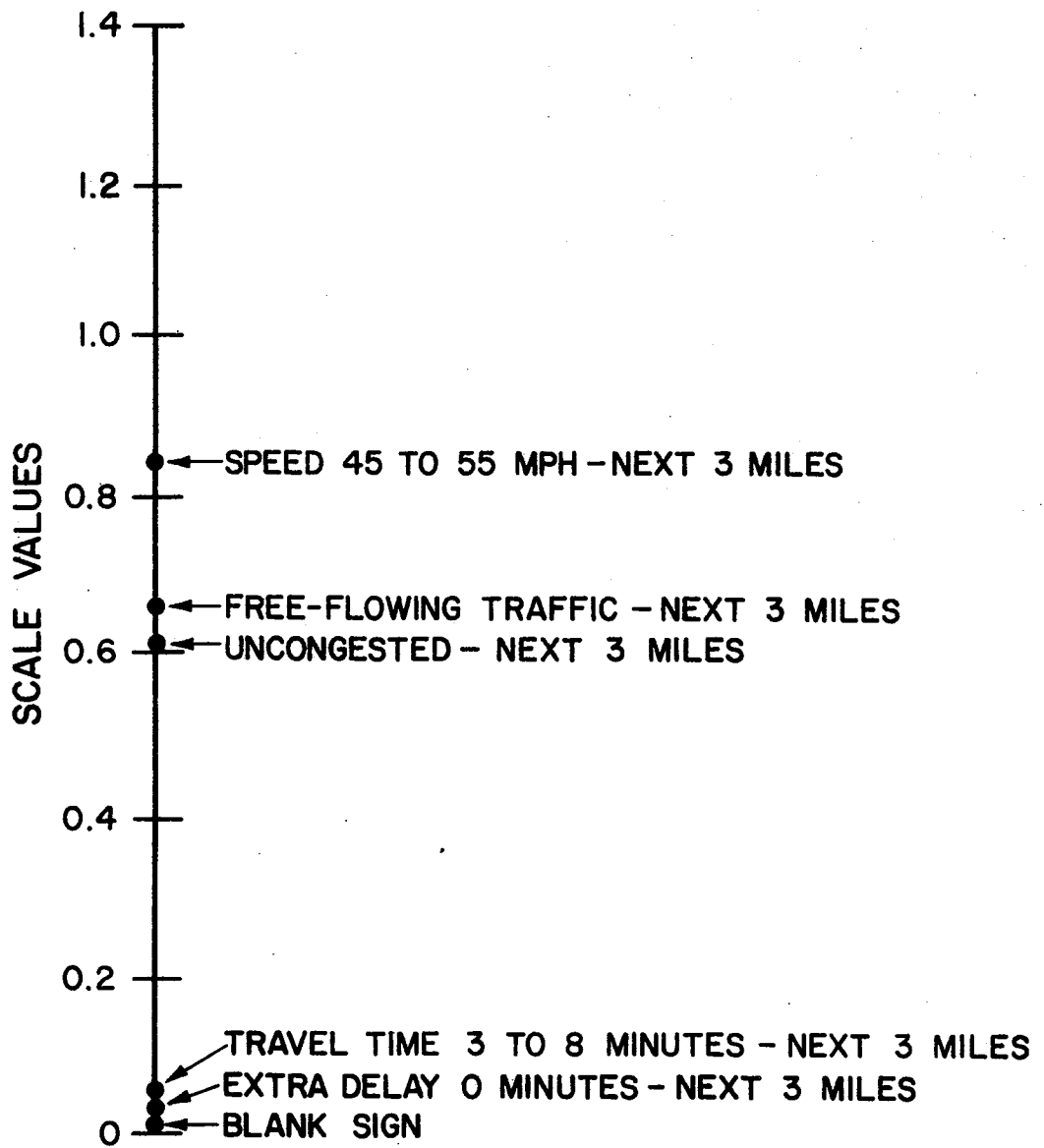


FIGURE 12 - SCALING OF DESCRIPTORS FOR NO CONGESTION (18)

of the first attempts to define some of the driver preferences for real-time freeway information through a public opinion poll. The study was conducted in one city; it would be worthwhile to evaluate driver preferences in other metropolitan areas.

Changeable Message Sign Summary - The results of earlier research, as reported herein, suggest that changeable message signs offer promise as one effective method of communicating with the urban freeway driver in real-time. However, additional research is necessary to better define the informational and the visual display requirements for effective system design.

Holosigns (19)

Holography is a technique for storing information about the phase and amplitude of light waves so that the original light waves coming from the object holographed can be reconstructed. This process allows a three-dimensional picture to be projected into space without the requirement of a surface such as a projection screen. The image is generated solely by the shaping of light wavefronts which are viewed directly. The viewer sees an image as though he were looking at the real object.

The projection of a highway sign into space using this technique has been referred to as "holosigns." Some laboratory experimentation has been done with holosigns; however, the experience to date has resulted in operational problems which would render this technique premature for immediate application to real-time freeway communications.

EXTERNAL AUDIO SYSTEMS

External audio systems constitute devices whereby voice messages or alarms external to the vehicle would be presented to the motorists. California (20) experimented with a horn device, in conjunction with an automatic sign and light, in an attempt to prevent wrong-way entrance to a freeway via an exit ramp. Audio warning was accomplished by two electric horns, one continuous and the other pulsating. The total warning device seemed to be effective. However, the horns were abandoned in later installations.

Voice messages of this type appear inappropriate for real-time freeway information because they must compete with other external noises or sounds, as well as those within the vehicle such as the car radio. If such a system is to be effective, the messages must be loud enough to be heard by the motorist in a competing environment. The required audio volume level would certainly be considered a nuisance in an urban area.

ON-BOARD VISUAL SYSTEMS

Experimental Route Guidance System (ERGS) (21)

ERGS is an experimental system being developed for the Federal Highway Administration as a method of automatically providing drivers with routing instructions at decision points in the roadway network (22). In theory these instructions successfully guide the driver along the "best route" to his destination. Proponents of the system argue

that current methods of signing are deficient, and that variable message visual and audio systems are only intermediate aids to the driver, since they do not take into account his ultimate destination. The concept of ERGS, it is argued, would overcome the inherent limitations of highway signs and would communicate information with the individual driver.

ERGS is destination-oriented and makes use of a coded system which was designed to uniquely identify all intersections in the country as a destination. An assigned code word for a specific destination would be entered into equipment located in the vehicle. Then, as the vehicle approaches each instrumented intersection, the code word would be communicated to roadside equipment which would 1) determine how the driver should leave the intersection to best reach his destination, 2) encode the appropriate routing instruction and 3) communicate it back to the vehicle. The appropriate maneuver is visually displayed to the driver on a display console located in the vehicle. The system design, therefore, requires the installation of electronic equipment in each vehicle.

The driver display, designed by General Motors (23) as part of this system, is a trans-illuminated unit which presents routing instructions in the form of sixteen graphic and verbal symbols (Figure 13). The graphic symbols are presented when a simple maneuver with no ambiguity is required. For more complex instructions, the verbal symbols and combinations of graphic and verbal symbols may be used. The display is capable of generating approximately 100 different

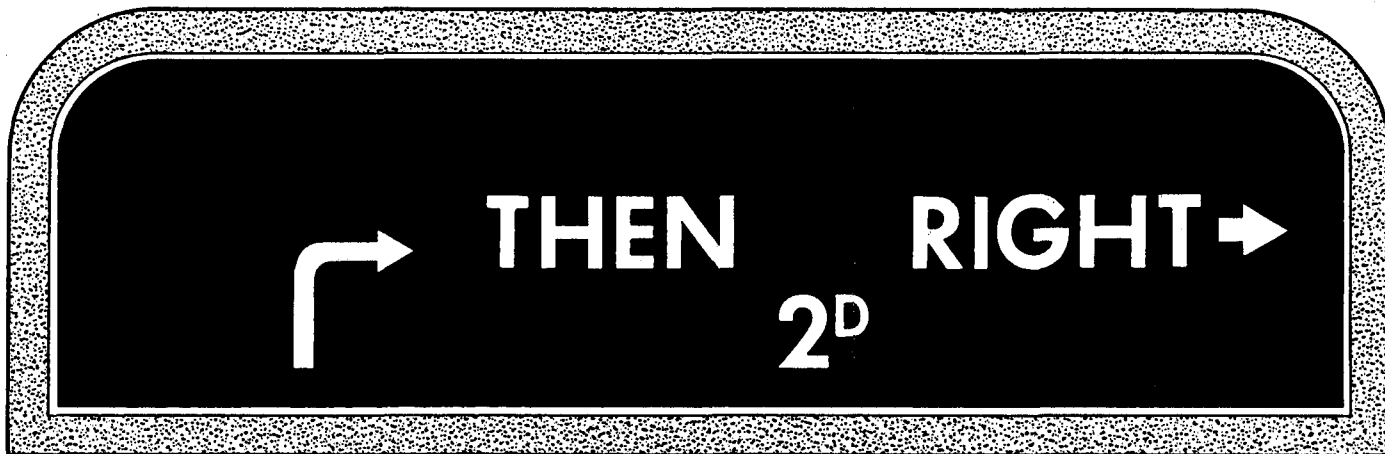
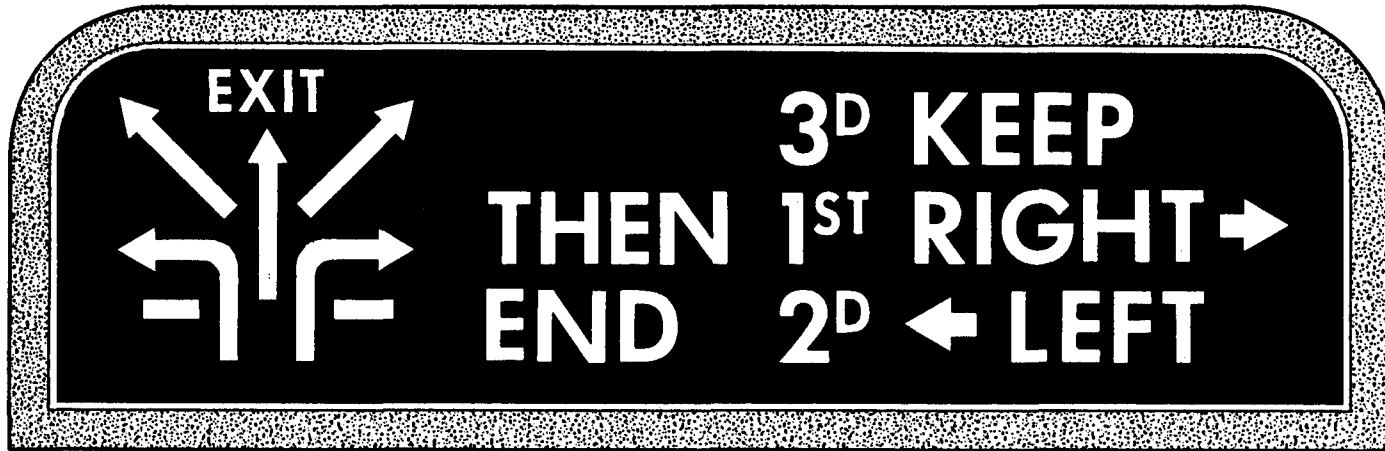


FIGURE 13 - DRIVER DISPLAY FOR ERGS
a) ALL MESSAGES; b) SINGLE MESSAGE (23)

maneuvering instructions.

Further research conducted by Kollsman Instrument Corporation (24) led to the adoption of the head-up concept as the most effective display technique. The term "head-up display" was coined by the aerospace industry to describe a new avionics technique to project a virtual-image symbolic representation of the visual scene on the aircraft windshield or other partially reflective surface, superimposed on the real world. The hardware for displaying the routing information is a self-contained unit that can be mounted on top of the dashboard in the automobile.

Serendipity Associates (25) conducted a user acceptance study to determine the general acceptance of this type of guidance system, to identify the types of roads where it would be most useful, and to verify some of the information requirements and display concepts that had been generated. A film-questionnaire was structured to measure driver response to the concepts of routing information and to specific types of displays. The questionnaire was administered to 561 drivers. Some of the results of the study were as follows:

1. The majority of the respondents felt that lane-change information was necessary (87 percent). Only six percent felt that lane-change information was not necessary, and six percent were undecided.
2. The respondents were asked to indicate their preference for two symbols that provided turning information at an intersection. One symbol showed the correct path in green and the incorrect paths in red. The other showed only the correct path in green. Seventy-five percent of the respondents preferred the symbol showing both correct and incorrect paths.

3. The respondents were asked whether they preferred to have exit information from an expressway presented solely in the car or preferred a combination of in-car information keyed to external signing. An overwhelming majority (92%) of the respondents preferred the combination of in-car information and external signing.
4. A majority of the respondents preferred display of ERGS routing information by means of a head-up display (78 percent) rather than a dashboard display (22 percent).
5. When asked to indicate their choice among four possibilities for presentation of lane change information - namely by sound alone, sight alone, sound and sight, or a warning tone and sight - almost no one preferred sound alone (only 1 percent of the sample). Thirty-seven percent preferred sight alone, 34 percent preferred a warning tone and sight, and 28 percent indicated that they preferred sound and sight.
6. The respondents were asked whether they preferred lane-change messages composed of arrows alone, words alone, or a combination of arrows and words. The majority (81 percent) indicated a preference for the latter choice, while 15 percent preferred arrows, and only 4 percent preferred words alone.
7. When asked if ERGS was preferred over conventional signing, 84 percent answered yes, 15 percent did not know, and only 1 percent indicated that ERGS was not better.
8. Only 43 percent of the respondents indicated that they would purchase this type of equipment, 39 percent were undecided and 18 percent indicated that they would not.

Driver Aid, Information and Routing System (DAIR)

This system has been developed by the General Motors Corporation to assist the motorist with his driving tasks (26). It utilizes a combination of visual and audio communication modes. Four features of the system are as follows: 1) coded emergency messages that can be transmitted from the car to automatic recorders in a service center, with voice acknowledgment and voice radio communication between the

car and service center, 2) a roadside-to-vehicle system, using FCC Citizens Band radio channels, which provides audio messages about emergency traffic conditions ahead, motel accommodations, and service facilities, 3) an on-board visual display which repeats highway sign information when the vehicle drives over roadway magnetic detectors, and 4) an on-board visual route guidance display which informs the motorist of the direction to travel when he approaches a major intersection.

Roadside transmitters are used to communicate with the motorist and provide information on emergency traffic conditions on the roadway ahead, motel accommodations, and service facilities. The transmitters contain pre-recorded messages, but can be activated to transmit current emergency messages from the service center.

Passing Aid System (PAS-II)

PAS is an electronic system being designed to aid drivers in the judgmental portion of their driving task (27). The system consists of four major subsystems: sensor, display, communication and control. The sensor subsystem consists of groups of four induction loops placed at 200-foot intervals on the roadway for the purpose of 1) detecting the presence of vehicles, 2) determining the direction of vehicle travel, 3) providing a means through which passing information can be transmitted to the driver.

Information is displayed visually on a panel mounted in the vehicle. Presently, transmittable information is limited to a two-

message display, such as PASS and DON'T PASS. Research and development is in progress, however, to expand the display capability up to eight messages.

The third subsystem is a communication link between the sensors and the fourth subsystem - the control center. The control center receives data from the sensors, processes and displays data, and transmits appropriate signals (information) back to the sensors. A prototype system is currently being planned for installation in Maine.

On-Board Visual Systems Summary

Each of the on-board systems described above requires that special equipment be installed both on the highway and within the vehicle. Therefore, both private and governmental ownership and cost are involved. The cost of on-board visual displays, which must be purchased and maintained by each individual motorist, is not known, but it is reasonable to expect that the initial investment for each driver might exceed \$100.

Based on the available facts, it appears that research directed toward the development of on-board visual systems should continue for use in the future. However, the problem exists now, and the system being developed as part of this research must be capable of immediate implementation. Implementation of an urban freeway traffic information system using external visual displays would seem to be more practical at this time.

RADIO ROAD ALERT

Road Radio Alert - The Ford Motor Company proposes a system called Radio Road Alert (RRA), using existing hardware, in which coded messages from roadside transmitters trigger a memory storage in the vehicle and cause recorded announcements through the car radio whether it is on or off (28). A logic circuit overrides the message being received if one of a more critical nature is encountered. The developers suggest that the system can be used to control vehicle speeds automatically, and that it is compatible with emergency call systems, driver guidance systems and automation of traffic flow. One of the major advantages of this type of system is that messages are transmitted via the regular A.M. car radio. This means that no direct cash outlay would be required on the part of the individual motorist.

Hy-Com - A method of driver-roadside communication was tested on the Atlanta Freeway System during daytime and nighttime driving activities in 1964 and 1965 (29). The two related studies attempted to evaluate the effectiveness of roadside radio communication on driver behavior in relation to his execution of a diverging maneuver from a freeway traffic system. The radio system, called Hy-Com, provided radio communications from the roadside to the driver, and consisted of a car-mounted receiver and a roadside transmitter.

Volunteer participants were randomly assigned to one of various test conditions employed in the experiments. Each test condition provided guidance information on varying degrees of advance and exit

information using highway signing, radio communication, or a combination of both of these modes of communication. While information was being given to participants in each test condition, data on traffic characteristics of the driver were collected at various positions along the freeway and the deceleration lane prior to an exit ramp selected for the study. Time-lapse photography, the Federal Highway Administration traffic analyzer, and manual recording were used in the collection of the data.

Data analysis indicated that audio messages were as effective as visual messages, and when given together, the performance of test drivers was generally better than the performance of test drivers with only visual or audio messages. Indications of this investigation were that a radio-signing system which will provide the necessary information where needed can be effective and, at the same time, avoid extensive over-signing. The investigators indicated that additional research would be required to determine the use of radio as a communication device on a system basis. One disadvantage of this type system is the requirement for special on-board receivers. However, the cost of this type of system may not be prohibitive.

Driver Aid, Information and Routing (DAIR) - The DAIR system also provides an audio communication link between a service center and the vehicle. The principles of this system were described earlier.

Commercial Radio - Radio stations in many cities broadcast traffic conditions on major routes daily during the peak periods. The radio stations receive information from either the local police or from

radio station personnel reporting from helicopters circling the city, or from automobiles positioned at strategic locations along freeways and major arterials. The effectiveness of radio reports is not completely known, due to the lack of quantified data for its evaluation.

An attempt was made by Weinberg, et al. (30) to evaluate traffic reporting from a helicopter. A questionnaire was sent to motorists affected by one specific incident. Using these data, the traffic situation was reconstructed to estimate the following:

- 1) The amount of delay incurred by drivers who became involved in the traffic tie-up.
- 2) The amount of delay that could have been incurred by drivers who would have been involved in the tie-up without helicopter traffic reporting.
- 3) The additional travel time incurred by drivers using an alternate route as a result of heeding the helicopter traffic reports.

The results of the study indicated a net savings of 361 vehicle hours of travel due to the helicopter reports.

Heathington, et al., (31) used a home questionnaire survey to evaluate driver attitudes toward priorities associated with expenditures for transportation improvements on expressways for the Chicago area. Each respondent was furnished ten envelopes, nine of which had pre-determined descriptors listed on them, and one structured so that the respondent could write in an additional descriptor not listed on the other nine. One of the descriptors was to "provide additional radio traffic reports." Each respondent was given the envelopes in random order and was asked to budget \$100.00 in play money in any manner he wished on any or all of the descriptors. Heathington concluded that

the priorities of the sample for the Chicago area were in the order listed below:

- 1) Better repair of pavement damages such as holes, bumps, etc. (Descriptor A)
- 2) Increased enforcement of regulations concerning shoulder riding, lane changing, driving speed (minimum and maximum), etc. (Descriptor B)
- 3) Provision of signs that can be electronically changed to furnish information about traffic conditions on the expressway ahead. (Descriptor C)
- 4) Other (Descriptor D)
- 5) Complete removal of stalled vehicles and vehicles involved in accidents from the expressway. (Descriptor E)
- 6) Provision of free telephones which are only connected to the Highway Department or Police Department and which can be used by the motorists to call for assistance. (Descriptor F)
- 7) Better maintenance of painted lines on pavement that separate lanes. (Descriptor G)
- 8) Construction of more entrance ramps. (Descriptor H)
- 9) Provision of additional radio traffic reports. (Descriptor I)
- 10) Reduction in the number of entrance ramps. (Descriptor J)

The results of the study are shown in Table 5.

Heathington further analyzed the "dominant" descriptors by the number of respondents who chose to allocate all of their play money to one, two, three, etc., respectively, descriptors. The results of total allocation to one, two, and three descriptors is presented in Table 6. Based on this analysis, he concluded that descriptors A, B, and C dominated. He further noted that, based on total allocation to one descriptor, the provision of freeway assistance telephones (Descriptor F)

ranked sixth, while the provision of additional radio traffic reports (Descriptor I) ranked tenth. Heathington concludes "In general, the respondents interviewed had a preference for information items."

Similar analyses were made of several descriptors for city streets.

Heathington arrived at the following conclusions:

1. Information on traffic conditions seemed to be relatively important while driving on the expressway but unimportant while driving on a city street.
2. The provision of real-time expressway traffic information and of motorist aid telephones were given the lowest priority when placed in relation to selected improvements in city streets.
3. The provision of additional traffic reports was of very low priority.

Without an intimate knowledge of the conditions in the Chicago area, which may have led to the selection of priorities by the local motorists, it is difficult to extrapolate the results to other major cities. For example, there seems to be some inconsistency in the response toward the need for real-time freeway traffic information. The need for changeable message signs was rated relatively high, while the need for additional radio reports on traffic conditions was of low priority. This perhaps could mean that the information provided by the local radio stations in Chicago is adequate to meet the motorists' needs. A correlation between the motorist response and the frequency of freeway usage during the peak periods would have been helpful in interpreting the results.

Heathington rank-ordered the descriptors that were used for the expressway and the city streets according to the mean expenditure.

Table 5 reveals that the standard deviation of each descriptor was larger than the mean, indicating that there may have been more variance within the subjects' preferences than there was between preferences. Consequently, some caution should be employed in the interpretation of the rank order of descriptors which are listed in Table 5.

Additional research is needed to fully define the application of commercial radio to real-time freeway information for urban areas. The fact that a large majority of the automobiles contain radios suggests that this may be a candidate for real-time communications. It would be desirable to evaluate driver attitudes toward this mode of communication in relation to other feasible alternatives.

Citizens Band Radio - The City of Detroit, Department of Streets and Traffic, has been operating a General Motors-sponsored CB Radio Driver Aid Network since July of 1966 (32). Although this system was designed specifically to report traffic-related information such as accidents, traffic flow interruptions, etc., it has been included in this report because CB radio represents a possible candidate for providing the driver with information regarding freeway traffic.

Fundamentally, the system in Detroit consists of CB radio-equipped vehicles, the drivers of which report observed incidents to a base station. The base station operator then transmits action needs via telephone to the appropriate authority or agency which, in turn, dispatches the type of assistance required.

Initially, approximately 20 city of Detroit employees and about 80 employees of the General Motors Corporation had their cars equipped

TABLE 5

EXPENDITURES FOR TRANSPORTATION IMPROVEMENTS ON EXPRESSWAYS
FOR CHICAGO DRIVERS (31)

Descriptor	Mean	Order of Mean Expenditure	Standard Deviation	Percent Spending Money on Item	Percent Allocating A Maximum Expenditure to Item
A. Better repair of pavement damages such as holes, bumps, etc.	\$20.84	1	22.53	65.98	37.04
B. Increased enforcement of regulations concerning shoulder riding, lane changing, driving speed (minimum and maximum), etc.	16.22	2	20.51	61.04	26.20
C. Provision of signs that can be electronically changed to furnish information about traffic conditions on the expressway ahead.	15.47	3	18.35	63.92	21.54
D. Other, please specify	11.49	4	24.77	26.06	17.15
E. Complete removal of stalled vehicles and vehicles involved in accidents from the expressway.	10.49	5	14.99	52.67	14.68

Descriptor	Mean	Order of Mean Expenditure	Standard Deviation	Percent Spending Money on Item	Percent Allocating A Maximum Expenditure to Item
F. Provision of free telephones which are only connected to the Highway Department or Police Department and which can be used by the motorist to call for assistance.	8.54	6	12.43	50.62	10.56
G. Better maintenance of painted lines on pavement that separate lanes.	8.06	7	12.51	44.44	10.56
H. Construction of more entrance ramps.	3.79	8	11.76	17.97	5.49
I. Provision of additional radio traffic reports.	2.82	9	6.61	22.63	2.61
J. Reduction in the number of entrance ramps.	2.28	10	7.27	12.62	2.74

TABLE 6

CROSS TABULATIONS OF PERCENT OF RESPONDENTS ALLOCATING
 TOTAL EXPENDITURES FOR A GIVEN NUMBER OF DESCRIPTORS
 FOR CHICAGO EXPRESSWAYS (31)

Number of Items Chosen For Total Expenditure	Descriptors Chosen For Expenditures									
	A	B	C	D	E	F	G	H	I	J
1	1.92	2.06	1.23	3.43	.69	.14	.27	.69	0	0
2	5.90	3.16	4.80	2.06	1.92	2.88	2.33	.27	.14	.14
3	10.01	10.01	9.05	4.66	6.17	4.94	4.80	1.51	1.78	2.19

with mobile CB transceivers. The base station was manned from 6:00 A.M. until 8:00 P.M., five days a week. By coincidence, rather than by specifically organized publicity, the CB radio community, in general, spontaneously became an unofficial part of the network.

Results of a questionnaire study to the "official" participants in the program suggested the following:

1. The monitoring hours be increased.
2. Weekends be included in the monitoring schedule.
3. The geographic area covered by the system be increased.

The encouraging results obtained from initial experimentation led to the installation of a system which covered the entire city. Preliminary results of the expanded system indicated that approximately 75 percent of all the calls were made by the general CB community. In addition, most of the calls received involved incidents on the freeways, and requests for information were primarily related to traffic conditions on the freeways. The number of such requests varied considerably in a given month, depending primarily upon the severity of weather conditions.

It was very interesting to note the response for the desirability of freeway information on the part of the general CB community, especially during inclement weather conditions. This trend further supports the need for real-time freeway information. Whether CB radio can play a role as part of a total communication system would require further evaluation. This type of system requires additional on-board equipment, the cost of which must be borne by the motorists. Since CB

channels are normally "crowded" during the peak-period, special frequencies may have to be assigned for this purpose.

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