CONRAD L. DUDEK

HUMAN FACTORS REQUIREMENTS FOR REAL-TIME MOTORIST INFORMATION DISPLAYS

VOL. 2 STATE OF THE ART: MESSAGES AND DISPLAYS IN FREEWAY CORRIDORS

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a report from the Texas A&M RESEARCH FOUNDATION

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16. Abstract

This report is a state-of-the-art of real-time motorist information displays for freeway corridors covering a period through February 1975. Emphasis is on messages and displays.

Since the emphasis in previous years has been in the visual display mode of communication by the use of changeable message signs, the bulk of the report addresses this area. The last section of the report deals with audio modes.

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PREFACE

This document is part of a seventeen-volume report entitled, Human Factors Requirements For Real-Time Motorist Information Displays. Titles of all volumes are shown below.

Volume	FHWA-RD Number	Title
1	78-5	Design Guide
2	78-6	State of the Art: Messages and Displays in Freeway Corridors
3	78-7	Summary of Systems in the United States
4	78-8	Bibliography and Selected Annotations: Visual Systems
5	78-9	Bibliography and Selected Annotations: Audio Systems
6	78-10	Questionnaire Survey of Motorist Route Selection Criteria
7	78-11	Analysis of Driver Requirements for Intercity Trips
8	78-12	Analysis of Driver Requirements for Intracity Trips
9	78-13	A Study of Physical Design Requirements for Motorist Information Matrix Signs
10	78-14	Human Factors Evaluation of Traffic State Descriptor Variables
11	78-15	Human Factors Evaluation of Route Diversion and Guidance Variables
12	78-16	Supplement to Traffic State Descriptors and Route Diversion and Guidance Studies
13	78-17	Human Factors Evaluation of Audio and Mixed Modal Variables
14	78-18	Point Diversion for Special Events Field Studies
15	78-19	Freeway Incident Management Field Studies
16	78-20	Feasibility of Audio Signing Techniques
17	78-21	Driver Response to Diversionary Information

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This report is a state-of-the-art of real-time information displays for freeway corridors covering a period through February 1975. Emphasis is on messages and displays. The reader is referred to a previous report (1) prepared by the author in 1970, and reports by Knapp, Peters, and Gordon (2), and by the Committee on Traffic Control Devices of the Transportation Research Board (3) for supplemental information.

Several individuals and agencies throughout the United States having operational or planned real-time motorist information systems were contacted to make this report as current as possible. A summary of these contacts is presented in Table A-1 of the Appendix. Descriptions of the operating systems are presented in a companion report (4).

Since the emphasis in previous years has been in the visual mode of communication by the use of changeable message signs, the bulk of this report addresses this area. The visual systems portion of this report is conveniently structured according to the location of the signs (i.e., on the freeway, frontage road and arterial, or major generator). The chapter on freeway information is further divided according to signing objectives to help the reader evaluate the types of displays and messages used for specific objectives such as warning of slow traffic, lane use control, diverting traffic off the freeway to the frontage road or an arterial street, etc.

The last section of this report deals with audio modes. The use of audio modes of communication for freeway corridors is much more in its infancy than visual modes. As such, very limited research has been conducted in this area.

INFORMATION ON THE FREEWAY

Information Preferences

Four studies have been reported which deal specifically with driver preferences for certain types of traffic descriptor messages. Heathington, et al. (5) investigated driver preferences for descriptors under three levels of traffic congestion (heavy, moderate, and no congestion). Descriptors were presented as overhead sign messages followed by the common message NEXT 3 MILES. They found for heavy congestion the most preferred descriptor was ACCIDENT-HEAVY CONGESTION/NEXT 3 MILES; second best was SPEED-5 TO 15 MPH/ NEXT 3 MILES; third and fourth best were HEAVY CONGESTION/NEXT 3 MILES and STOP AND GO TRAFFIC/NEXT 3 MILES. Least preferred were EXTRA DELAY-10 TO 20 MINUTES/NEXT 3 MILES, TRAVEL TIME 15-25 MINUTES/NEXT 3 MILES, and a blank sign. Similar results were found for moderate congestion except that the ACCIDENT and STOP AND GO TRAFFIC descriptors were not given to the respondents as alternatives.

Dudek, et al. (6) conducted a questionnaire survey of 505 drivers in Houston and Dallas. When asked to select the types of information most helpful to a motorist in telling about freeway traffic conditions, 70 percent preferred knowing either the location and length of a congested area or the degree of congestion (heavy, moderate, light). Forty percent selected the reason for the congestion, whereas travel time and speed were least preferred.

Case, et al. (7) conducted an extensive study of changeable messages for freeway signing in the Los Angeles area. They found a different priority of message types with first preference for knowing which lanes were blocked when lane blockage had occurred. Location of the problem, expressed in terms of distance, ranked second.

Results of later studies by Beers (8) before and after operation of the changeable message sign system began on the Santa Monica Freeway in Los Angeles, were somewhat consistent with those of Case. The major exception was Beers found that the location of the problem was preferred above delay and travel time information.

Table 1 presents a comparison of the rank ordering of various descriptors in the four studies. Heathington did not investigate preferences for location or length of a congested area since this was present in all messages in NEXT 3 MILES. Dudek did not investigate delay or stop and go descriptors. Case and Beers investigated preferences for lane blockage but did not investigate preferences for speed information.

The first two studies suggest that motorists have a strong preference for qualitative information on level of congestion while quantitative information on travel time was less preferred. The results disagree on the importance of speed information and are not comparable in several other areas. The disagreements in part are due to the fact that different alternative descriptors were used in each of the above studies.

Table 1

RANK ORDERING OF TRAFFIC DESCRIPTORS
BY THREE SURVEYS OF MOTORIST PREFERENCE

HEATHINGTON, et. al. (5)	DUDEK, et. al. (6)	CASE, et. al. (7)	BEERS (8)	
			BEFORE SIGN OPERATION	AFTER SIGN OPERATION
1. Cause, Congestion Level, & Freeway Length Affected	1. Location and Length of Congestion	1. Lane Blockage (if any)	1. Distance to Blockage	1. Distance to Blockage
2. Speed & Freeway Length Affected	2. Congestion Level	2. Distance to Problem	2. Location (by ramp name)	2. Lane Blockage
3. Congestion Level & Freeway Length Affected	3. Cause of Congestion	3. Delay Time	3. Lane Blockage (which lanes)	3. Location
4. Stop and Go & Freeway Lenght Affected	4. Speed	4. Reason for Delay	4. Delay Time	4. Delay Time
5. Delay Time and Freeway Length Affected	5. Travel Time	5. Location (by ramp or interchange name)	5. Reason for Delay	5. Reason for Delay
6. Travel Time & Freeway Length Affected			6. Travel Time	6. Travel Time
7. Blank Sign				

Speed Control and Warning

Experience with variable speed message signs indicate that motorists are not very willing to reduce their speeds to coincide with the posted speed unless there is an apparent reason to do so. Displayed speeds less than 40 mph seem to have little, if any, additional effect on lowering speeds. No research to date, however, has shown whether the lower posted speeds reduce the frequency of rear-end collisions or near misses by alerting motorists to slow traffic downstream.

One of the first large-scale experimental systems in the United States made use of a series of overhead variable speed control signs (Figure 1) installed on 3.2 miles of the John C. Lodge Freeway in Detroit as part of the National proving Ground traffic control system (9). Freeway conditions were monitored by observers via closed circuit television. The speed signs were illuminated based on the observers' evaluations of freeway conditions and freeway traffic data presented on a Cathod Ray Tube display.

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.

Results of studies by Wattleworth, et al. (10) 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.

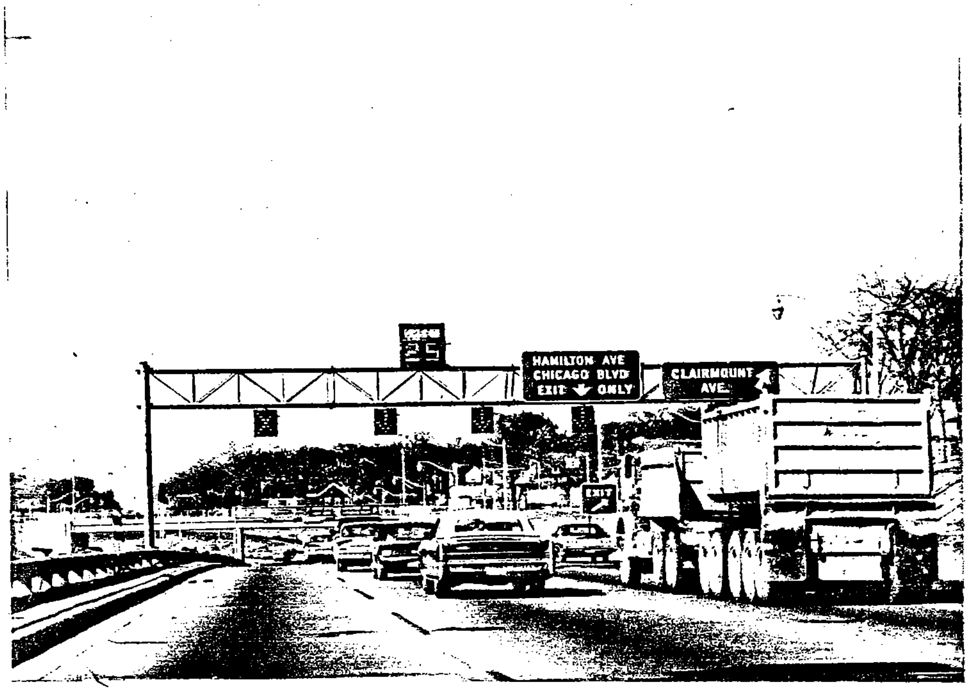


Figure 1 - Variable Speed Control and Lane Control Signs - Detroit (9)

Although the studies by Wattleworth were of limited scope, research conducted by the California Department of Transportation (11) 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 Department of Transportation 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 (12). 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.

Erected along the New Jersey Turnpike are 103 speed limit signs spaced at intervals between two and five miles (13). As the speed is reduced, the lamp matrix speed limits are also lowered (50, 45, 40, 35, or 30). The speed limit signs are either adjacent to or approximately 300' downstream of a warning sign. These are described in the next section entitled *Warning of Slow Traffic*. The effectiveness of these speed limit signs has not been evaluated as of this writing.

Warning of Slow Traffic

Research has shown that specific signs with attention-getting characteristics have been successful in alerting motorists of freeway stoppages in locations where visibility is restricted. Static signs with flashing beacons have been shown to significantly reduce rear-end accidents (14). Other approaches such as the multiple use of variable message signs (e.g., matrix, rotating drum, etc., for warning, advisories, diversion) are being used but no data are available relative to the effectiveness of the warning messages. It has not been clearly demonstrated whether a special sign used exclusively for warning is more effective than a variable message sign serving multiple functions. However, there is indication that the word

CAUTION

followed by either

SLOW TRAFFIC AHEAD

or

SLOWING AHEAD

seems to imply to the driver that the danger is in the near vicinity and drivers will tend to slow down (8, 14). Beers (8) found that nearly two-thirds of the drivers interviewed after the Santa Monica system became operational responded that they slow automatically when they see a message

CAUTION/SLOWING AHEAD

The researcher concluded that drivers are accepting this message as a command to slow rather than a suggestion to be alert to slow. She speculated that drivers over-react to the word CAUTION, particularly if that is the only word they catch of the message. The researcher concluded that placement of this message is critical. If the message is too far back from the blockage or congestion, drivers will automatically slow down when there is no immediate need, which may be an unsafe driving behavior. She recommended that agencies should utilize messages that would eliminate the word CAUTION except in the immediate vicinity of a blockage or congestion.

Dudek and Biggs (15) reported on the design development of a prototype safety warning system that was later installed on the Gulf Freeway in Houston for evaluation. The objective of the system was to increase freeway efficiency by alerting approaching motorists to stoppages or slow traffic on the far side of crest type vertical curves. Four alternate designs were considered and analyzed:

1. Flashing beacons
2. Static sign with flashing beacons
3. Blank-out type sign
4. Blank-out type sign with flashing beacons

The static sign with flashing beacons was selected for the prototype design.

Approximately 20 alternate messages were initially considered by the researchers. A screening process led to the selection of 5 candidate messages that were then evaluated by a team of 18 experts in traffic operations and driver communications from the Texas Highway Department, Federal Highway Administration, and Texas Transportation Institute. Although no one message received unanimous first place rankings, the message BE ALERT was consistently considered to be least preferred. A statistical analysis revealed that there was not a discernible pattern regarding the rankings of the remaining four messages. However, the decision was made to use the message: CAUTION/SLOW TRAFFIC/WHEN FLASHING. The order of selection based on average rank values was as follows:

1. CAUTION/SLOW TRAFFIC/WHEN FLASHING
2. SLOW TRAFFIC/AHEAD/WHEN FLASHING
3. PREPARE/TO BRAKE/WHEN FLASHING
4. REDUCE/SPEED/WHEN FLASHING
5. BE ALERT

Signs with black lettering on a yellow background were selected for the prototype system. The signs (Figure 2) were installed upstream of three overpasses on the Gulf Freeway for evaluation. In addition, flashing beacons were mounted on the bridge rail on the top of each crest (Figure 3). Detectors located upstream and downstream of the overpasses provided the capability for a traffic responsive system.

Evaluation studies of the system (14) revealed that the system is cost-effective. Both primary and secondary accidents were significantly reduced. Questionnaire studies indicated that the motorists believe the system to be useful, the warning sign readily noticed, and the message is generally understood. Eighty-nine percent of the respondents expected the slowdown to occur from a block to 1/2 mile away.

A similar system is also operational in Kentucky (16). A single sign on I-65 southbound out of Louisville was originally a blank-out sign; however, the message was too small to be easily read so that it has now been replaced

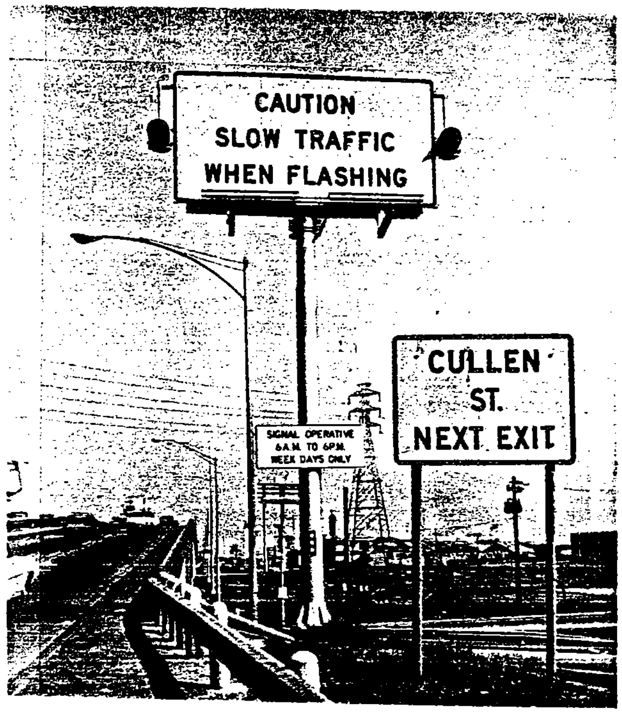


Figure 2 - Warning Sign with Flashers on the Gulf Freeway (14)

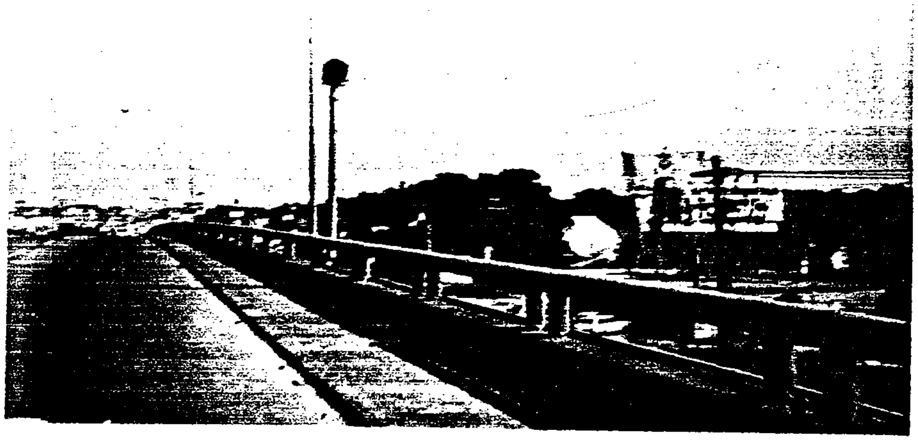


Figure 3 - Flasher Unit at Crest of Overpass (14)

with flashers on a larger static sign that reads: CONGESTION/AHEAD/WHEN FLASHING. The sign is located upstream of a vertical curve and is controlled by a time clock to correspond with routine backup of traffic from an exit ramp located downstream of the grade. The system has not been evaluated as of this writing.

Five variable matrix signs were also installed in Kentucky on I-75 northbound approaching the Cincinnati-Covington area (16). The signs were primarily intended to provide advance warning or alternate routing instructions on the high volume, hilly and curvy section of I-75. Warning messages were as follows:

ACCIDENT AHEAD/PREPARE TO STOP

CONGESTION AHEAD/PREPARE TO STOP

CURVES-HILL/REDUCE SPEED

Several systems have used variable message signs for multiple purpose messages including advance warning. Matrix signs on the Gulf Freeway in Houston (17) display the following warning message capabilities:

Upper Line	Middle Line	Lower Line
FWY CONDITION	SLOW TRAFFIC	1 MI AHEAD
	LANE BLOCKED	2 MI AHEAD
		3 MI AHEAD

Matrix signs on I-70, I-25, and US 36 in Denver (18) have a greater variety of messages including the following warning message combinations:

Upper Line	Lower Line
HEAVY CONGESTION	NEXT MILE
STOP AND GO TRAFFIC	NEXT 2 MILES

Upper Line (Cont.)	Lower Line (Cont.)
LEFT LANE BLOCKED	NEXT 3 MILES
RIGHT LANE BLOCKED	NEXT 4 MILES
CENTER LANE BLOCKED	1 MILE AHEAD
ROAD WORK	2 MILES AHEAD
ICY ROAD	3 MILES AHEAD
	5 MILES AHEAD
	BE PREPARED TO STOP

Matrix changeable message signs in Minneapolis (19) on I-94 designed to warn motorists approaching the Lowry Hill Tunnel of problems in the area have the capabilities for displaying the following warning messages:

Upper Line	Lower Line
CONGESTION AHEAD	REDUCE SPEED
MAINTENANCE WORK	PREPARE TO STOP
STALLED VEHICLE	
TUNNEL CLOSED	
ACCIDENT AHEAD	

A system in Cincinnati (20) on southbound I-75 composed of matrix signs and inserts can display the following warning messages:

ACCIDENT AHEAD/REDUCE SPEED

RIGHT LANES/BLOCKED

LEFT LANES/BLOCKED

I-75/BLOCKED AHEAD

RIGHT LANES/BLOCKED AHEAD

LEFT LANES/BLOCKED AHEAD

The system of matrix signs on the Santa Monica Freeway in Los Angeles (Figure 4) is one of the most elaborate systems in the United States and has probably the greatest flexibiilty in message selection (21). The following warning messages are most commonly used in order of frequency:

SLOWING AHEAD

SLOWING AHEAD/X MILES AHEAD

USE CAUTION AHEAD

STALLED VEHICLE/RIGHT LANE

ACCIDENT AHEAD

ROAD WORK AHEAD

LEFT LANES/SLOW AHEAD

ACCIDENT/X MILES AHEAD

HARBOR FWY SOUTH/EXIT CONGESTED

CLOVERFIELD OFF/EXIT CONGESTED

STALLED VEHICLE/RIGHT LANE AHEAD

ACCIDENT AHEAD/RIGHT LANES

LINCOLN EXIT/HEAVY TRAFFIC

SPILLED LOAD/AHEAD

The New Jersey Turnpike Authority is using blank-out type signs for speed warning (13). Newer signs have the following traffic messages:

REDUCE SPEED/ACCIDENT/AHEAD

REDUCE SPEED/CONGESTION/AHEAD

REDUCE SPEED/CONSTRUCTION/AHEAD

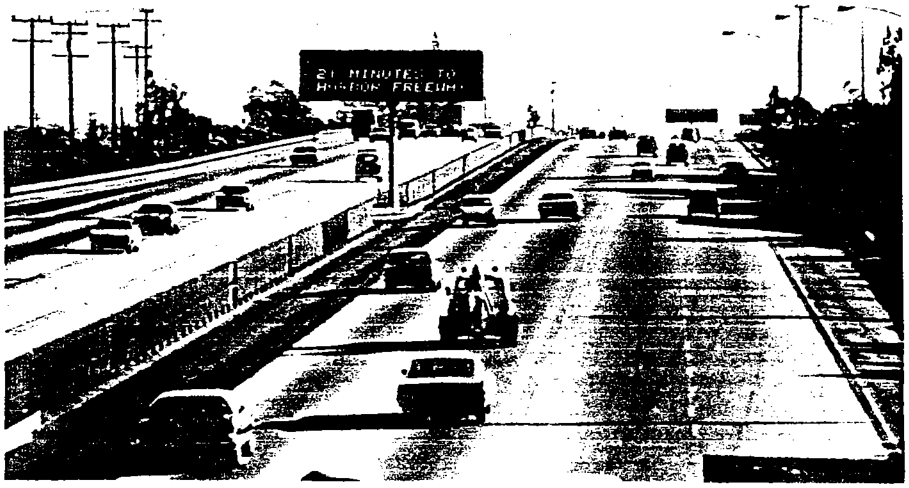


Figure 4 - Matrix Sign on Santa Monica
Freeway in Los Angeles

Older signs read

DRIVE SLOW AHEAD/ACCIDENT

Preliminary design plans for the Jones Falls Expressway system in Baltimore (22) suggest the use of speed advisory messages to indicate reduction in speeds as shown in Figure 5. In addition, the word WORK is recommended to alternate with the word "AHEAD."

Although the Pennsylvania Department of Transportation proposes to install a system on the Penn-Lincoln Parkway with unlimited message capabilities, specific candidate messages have been identified as possible displays (23). Some of the combinations of messages proposed for the three line signs are as follows:

Upper Line	Middle Line	Lower Line
RIGHT LANE BLOCKED	X MILE	BE PREPARED TO STOP
LEFT LANE BLOCKED	AHEAD	REDUCE SPEED
CENTER LANE BLOCKED	X FEET	
ROAD BLOCKED	NEXT X MILE	
TUNNEL BLOCKED	NEXT X FEET	
RIGHT LANE CLOSED		
LEFT LANE CLOSED		
CENTER LANE CLOSED		
TUNNEL CLOSED		
WORK AREA		
HEAVY CONGESTION		
LIGHT CONGESTION		

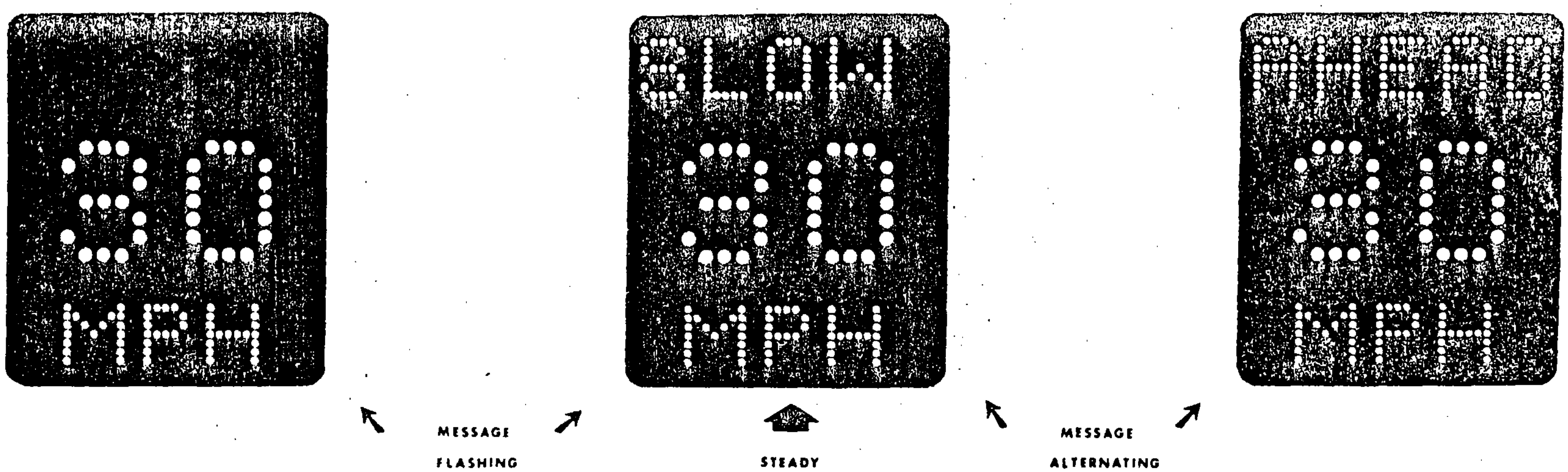


Figure 5 - Suggested Advisory Messages to Indicate Reduction in Speed - Baltimore (22)

Environmental Warnings

The flexibility of changeable message signs has led some organizations to utilize the added capabilities to sign for hazardous driving conditions due to environmental conditions. The effectiveness of these messages has not been totally demonstrated in the literature.

Kentucky Department of Transportation experimented with matrix signs on both approaches to the Kentucky River crossing on I-64 to warn of icing and/or fog conditions in the area (16). The signs were programmed to flash any combination of the messages:

ICE ON BRIDGE FOG AHEAD REDUCE SPEED

The Cincinnati system (20) on southbound I-75 utilizes the following messages:

FOG AHEAD/REDUCE SPEED

ICE AHEAD/REDUCE SPEED

Environmental hazard warning messages used in the Denver system include (18):

ICY ROAD/NEXT X MILES

ICY ROAD/X MILES AHEAD

The system on the New Jersey Turnpike (13) has the following messages:

REDUCE SPEED/ICE/AHEAD

REDUCE SPEED/FOG/AHEAD

REDUCE SPEED/SNOW/AHEAD

The recommendations for the Baltimore system (22) include the following descriptors that would alternate above the speed sign shown in Figure 5.

WET/AHEAD

FOG/AHEAD

ICE/AHEAD

Incident Information

The types of incident descriptors that drivers actually need to take appropriate actions is not known and has not been fully addressed in the literature. Operational and experimental driver information systems are using different descriptors to advise motorists of accidents or other incidents on the freeway. The overhead red X was used in early work on the John C. Lodge Freeway in Detroit (9) to indicate that a lane was physically blocked by an incident. More recent systems use word descriptors such as ACCIDENT AHEAD, LANE BLOCKED, STALLED VEHICLE AHEAD, CONSTRUCTION AHEAD, MAINTENANCE AHEAD, etc. The reported effectiveness of the red X in Detroit (9, 24) seems to indicate that a freeway driver assumes that the red X indicates that an accident, stalled vehicle, load spill, etc., has occurred or construction or maintenance activities are downstream. However, it has not been demonstrated whether the red X is sufficient in itself or whether specific information about the nature of each incident must be displayed to accomplish certain operational objectives.

Although research has supported the need for incident information (5,8) it has not proved or disproved the effectiveness of the types of incident information descriptors currently being used. It should be emphasized that some form of visual surveillance is necessary if it is determined that drivers require specific information about incidents. Visual surveillance would be needed to ascertain the nature and characteristics of the incident in order to maintain information credibility.

Many of the messages now used to inform motorists of incidents have been previously discussed in the section entitled *Warning of Slow Traffic*. The reason why they were included in this earlier section is because of the possible "warning" effect of these messages. For example, telling a motorist that an accident has occurred implies that there is stopped or slow traffic ahead. For the sake of trying to be as complete as possible in this report, incident messages currently used are again listed in the following paragraphs.

The following descriptors are used on I-75 in Kentucky (16):

ACCIDENT AHEAD

CONGESTION AHEAD

In Denver the following descriptors are used (18):

HEAVY CONGESTION	RIGHT LANE BLOCKED
STOP AND GO TRAFFIC	CENTER LANE BLOCKED
LEFT LANE BLOCKED	ROAD WORK

On I-95 in Minneapolis the following incident information is displayed (19):

CONGESTION AHEAD

MAINTENANCE WORK

STALLED VEHICLE

TUNNEL CLOSED

ACCIDENT AHEAD

Selected signs in Cincinnati (20) display the following messages:

ACCIDENT AHEAD

RIGHT LANES/BLOCKED

LEFT LANES/BLOCKED

I-75/BLOCKED/AHEAD

RIGHT LANES/BLOCKED AHEAD

LEFT LANES/BLOCKED AHEAD

The incident descriptor messages on the New Jersey Turnpike (13) are:

ACCIDENT

ACCIDENT/AHEAD

CONGESTION/AHEAD

CONSTRUCTION/AHEAD

The most commonly used incident descriptors in the Los Angeles system (21) are:

SLOWING AHEAD	ROAD WORK AHEAD
HEAVY TRAFFIC	ACCIDENT
EXIT CONGESTED	ACCIDENT AHEAD
MEN WORKING AHEAD	SPILLED LOAD

Pennsylvania proposes to use the following messages on the Penn-Lincoln Parkway (23):

RIGHT LANE BLOCKED	ROAD BLOCKED
LEFT LANE BLOCKED	TUNNEL BLOCKED
CENTER LANE BLOCKED	TUNNEL CLOSED
RIGHT LANE BLOCKED	WORK AREA
LEFT LANE CLOSED	HEAVY CONGESTION
CENTER LANE CLOSED	LIGHT CONGESTION

Researchers in Houston have decided upon a single message incident descriptor (17), namely:

LANE BLOCKED/KEEP RIGHT (LEFT)

Location of Incident and Congestion

Results of questionnaire studies conducted in Dallas and Houston by Dudek, et al. (6) and in Los Angeles by Case, et al. (7) and Beers (8), have indicated that motorists desire to know where an incident has occurred although there is some disagreement as to the priority of this information in comparison to other types of information. The rank ordering of traffic descriptors from the three studies was shown in Table 1.

Probably the most inportant issue that still needs to be resolved is whether the incident location descriptors should be in terms of distance, location with respect to an arterial street intersection, or location with respect to a freeway interchange. With the exception of the Los Angeles system, most installations are describing the location of incident exclusively in terms of miles from the sign. The most common descriptor is

X MILES AHEAD

or

X MI AHEAD

Some operating agencies have elected to delete the word AHEAD with the assumption that it is implied by the message X MILES and thus understood by the motorists.

Generally, distance descriptors are used on the Santa Monica Freeway System in Los Angeles. At times, however, the freeway problem is referenced to an intersecting arterial or freeway. The Minneapolis, Cincinnati, and New Jersey Turnpike systems do not use incident location descriptors.

There is evidence that drivers are also interested in knowing the length of congestion or the length of freeway affected (5, 6). Since the message X MILES AHEAD probably is inappropriate to describe the length of congestion, most systems have adopted a message similar to the following:

NEXT X MILES

Denver (18) has the following options for incident location and length of congestion:

1 MILE AHEAD	NEXT MILE
2 MILES AHEAD	NEXT 2 MILES
3 MILES AHEAD	NEXT 3 MILES
5 MILES AHEAD	NEXT 4 MILES

Tentative plans for the Penn-Lincoln Parkway system in Pennsylvania (23) call for the following descriptors:

X MILES/AHEAD	NEXT X MILES
X FEET/AHEAD	NEXT X FEET

The Houston system (17) utilizes the

X MI AHEAD

incident location descriptor and attempts to display the length of congestion by sequencing messages such as:

LANE BLOCKED/3 MI AHEAD

SLOW TRAFFIC/1 MI AHEAD.

The flexibility in the California system (21) enables them to use a variety of incident and congestion length descriptors. Typical messages include:

ACCIDENT/X MILES AHEAD

HEAVY TRAFFIC/NEXT X MILES

HEAVY TRAFFIC/TO (STREET)

X MINUTES TO/HARBOR FREEWAY

Lane-Use Control

Early studies concerning overhead X and arrow lane control signals have shown the signals to be very effective in warning motorists of freeway lane blockages. Studies have shown that they were extremely effective in getting freeway motorists to move into the open lanes far in advance of the Obstruction during light-to-moderate volumes. However, because of the overloaded condition during peak periods, few people have the opportunity to merge into the open lanes and the signals are less effective in lane traffic redistribution. Little is known about the possible effects lane use signals have in alerting drivers of traffic hazards ahead.

Lane-use control signals have been adopted by the Federal Highway Administration as a national standard to permit or prohibit the use of specific lanes of a street or highway or to indicate the impending prohibitions of use (25). According to the MUTCD, lane-use control signals are now *most commonly used for reversible-lane control.* (They may) *also be used where there is no intent or need to reverse lanes. Some applications of this type are:*

1. *On a freeway, where it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway.*
2. *On a freeway, near its terminus, to indicate a lane that ends.*
3. *On a freeway or long bridge, to indicate a lane which may be temporarily blocked by an accident, breakdown, etc.*

Several operating agencies with sign installations use word descriptors for lane-use control. The following variations are commonly used:

KEEP RIGHT	RIGHT LANE CLOSED (BLOCKED)
KEEP LEFT	LEFT LANE CLOSED (BLOCKED)
	CENTER LANE CLOSED (BLOCKED)

As the above word messages imply, they can be used for a two or three lane section of freeway. When the number of lanes is four or more, then word descriptors such as the above cannot be used when one or more of the middle lanes are blocked. Some attempts have been made in Los Angeles to utilize the following symbols on two lines of existing matrix sings to inform the motorists which lanes are blocked:

(Line 1):	1	2	3	4
(Line 2):			X	

(The lane next to the shoulder lane is blocked). The effectiveness of this approach has not been determined as of this writing.

The development of lane-use signals perhaps emanated from the early work of Forbes, et al (26) who evaluated approaches to indicating to the motorist that specific lanes should not be used, but that he should proceed in other lanes. The researchers discussed the advantages of symbols over word messages. Seven different symbols and colors were selected as being most likely on the basis of known engineering psychology principles to show the natural association desired. The symbols were: a red X, two kinds of red arrows, a red arrow with a slash mark across the stem (which is similar to symbols used in other countries indicating that one should not go in this direction), and a yellow X and a yellow bull's-eye. For comparison purposes, the standard red bull's-eye stop signal was also used in the experiment. The results of the study revealed that the red X was definitely most effective.

In addition to the variable speed control signs, a series of overhead red X and green arrow lane control signals (Figure 1) were installed on the John C. Lodge Freeway in Detroit during the early 1960's following Forbe's experiments. The purpose of the lane control signals 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.

Clinton (27) conducted before and after studies to evaluate the effect of lane control signals on the lane change rate. He observed that they had no appreciable effect on the average lane change rate. Initial observations made by Dudek (28) of the effectiveness of the signals indicated that they were effective during the off-peak period in clearing the lane in which an incident occurred.

In a more comprehensive study, Gervais (29) evaluated the operational benefits of these signals. The results revealed that a definite and considerable improvement in freeway operation was realized utilizing the lane control signals. 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 percent of vehicles trapped behind the obstruction was reduced.

Further evaluations by Wattleworth, et al. (10) revealed that the effectiveness of the overhead lane control signals appeared to be a function of the freeway demand. The effectiveness of getting motorists to merge into the open lanes was reduced considerably when the freeway demand exceeded the capacity of the obstructed section.

In general, overhead lane control signals appeared 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.

The arrows on the early lane-use signals on the John C. Lodge Freeway were pointed up. These signals were later changed with the arrows pointing downward.

As previously mentioned, MUTCD has adopted the concept of the X and arrow indications for the objectives mentioned above. The meanings of the current standards are listed below (25).

1. *A steady DOWNWARD GREEN ARROW means that a driver is permitted to drive in the lane over which the arrow signal is located.*
2. *A steady YELLOW X means that a driver should prepare to vacate, in a safe manner, the lane over which the signal is located because*

a lane control change is being made, and to avoid occupying that lane when a steady RED X is displayed.

3. *A flashing YELLOW X means that a driver is permitted to use a lane over which the signal is located for a left turn, using proper caution.*

4. *A steady RED X means that a driver shall not drive in the lane over which the signal is located, and that this indication shall modify accordingly the meaning of all other traffic controls present. The driver shall obey all other traffic controls and follow normal safe driving practices.*

Lane-use signals on streets and highways are now in use at several locations for reversible lane operations in the United States. The author is aware of only two freeway installations. One location is in Minneapolis (19) where lane signals are being used to indicate which lanes are blocked on the I-94 system.

A second installation is an experimental system of lane-use signals (Figure 6) on westbound I-10 at the I-610 interchange in Houston (30). The objective of this latter system is to shift the I-10 traffic demand for short periods of time to the inner two lanes so that the ramp traffic from I-610 would have greater merging opportunities. Preliminary studies have indicated that initial compliance to the signals has been in the order of 80-90 percent. Periodic enforcement is now necessary to sustain a high degree of compliance. In contrast to the systems in Detroit and Minneapolis the operation of the lane control signals in Houston on I-10 does not presume to impart a message of a physical blockage, but that a lane is closed to traffic. It is not known whether using the red X for different objectives tends to confuse the motorists.

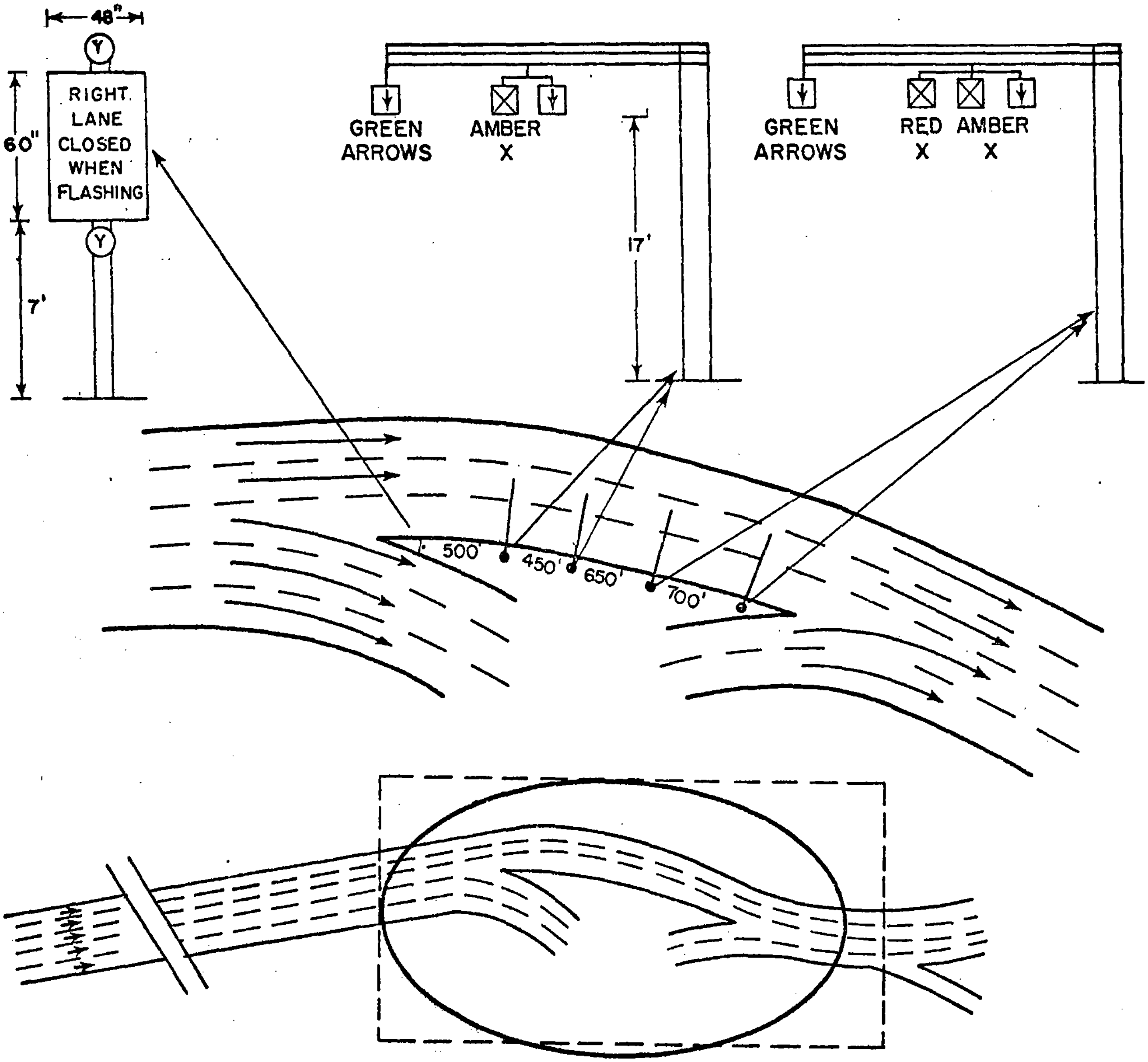


Figure 6 - Design and Location of Mainline Control Devices on I-10 in Houston (30)

Generally, agencies operating changeable message signs have elected to utilize word descriptors or symbols on the signs to indicate which lanes are blocked or open. The system in Denver on sections of freeway with three lanes in a direction uses (18):

RIGHT LANE BLOCKED

LEFT LANE BLOCKED

CENTER LANE BLOCKED

The following descriptors are used in Cincinnati on I-75 (20):

RIGHT LANE BLOCKED

RIGHT LANES BLOCKED

LEFT LANE BLOCKED

LEFT LANES BLOCKED

On the three-lane section of the Gulf Freeway, the lane use descriptors used are (17):

KEEP RIGHT

KEEP LEFT

In addition to the lane number and the lane closure designations used on matrix signs as shown on page 15, in Los Angeles, the following descriptors are most frequently used (21):

STALLED VEHICLE/RIGHT LANE AHEAD

LEFT LANES/SLOW AHEAD

ACCIDENT AHEAD/RIGHT LANES

The preliminary plans for the Jones Falls Expressway in Baltimore (22) do not include any messages for lane use control.

The messages proposed for the Penn-Lincoln Parkway system (23) include:

RIGHT LANE BLOCKED/(distance)/MERGE LEFT

LEFT LANE BLOCKED/(distance)/MERGE RIGHT

CENTER LANE BLOCKED/(distance)/MERGE LEFT

CENTER LANE BLOCKED/(distance)/MERGE RIGHT

RIGHT LANE CLOSED/(distance)/MERGE LEFT

LEFT LANE CLOSED/(distance)/MERGE RIGHT

CENTER LANE CLOSED/(distance)/MERGE LEFT

CENTER LANE CLOSED/(distance)/MERGE RIGHT

Travel Time, Delay Time, and Average Speed Information

The results of questionnaire studies discussed earlier indicate that motorists prefer qualitative rather than quantitative information. Travel time, delay time, and average speed information were generally rated below qualitative information such as knowledge that a lane is blocked, distance to the problem or location of the problem, and level of congestion. Although consistently rated low in comparison to qualitative descriptors, it is not known whether travel time, delay, or average speed is essential information necessary for drivers to evaluate a traffic problem and to decide whether to divert. On the other hand, there is still an unresolved question whether drivers, particularly unfamiliar or non-local drivers, can relate to travel time and delay descriptors. It would appear that drivers would need some common base for comparing the degree to which travel times and delays are above what would normally be expected.

Displaying travel time, delay time, and average speed information requires a relatively high degree of electronic surveillance sophistication. For example, travel time and delay time prediction computer models must be available. The dynamics of the changing traffic conditions may result in the motorist experiencing a higher or lower travel time, delay time, or average speed than that displayed on the signs thus adversely affecting credibility.

Currently, only California is displaying travel time information. Travel time is referenced to major freeway interchanges and is displayed continuously on selected signs during the morning and afternoon peak periods. Typical messages are (21):

X MINUTES TO/HARBOR FWY

and

X MINUTES TO/SAN DIEGO FWY

where X is in 2 minute increments. The effectiveness of these messages has not yet been determined.

The suggested system for the Jones Falls Expressway in Balitmore includes delay information. The recommended signs are essentially the same as shown in Figure 5 with the following types of alternating messages (22):

DELAY/15/MIN

AHEAD/15/MIN

or

DELAY/15/MIN

AHEAD/2/MI.

Pennsylvania proposes to give qualitative delay information rather than specific numerical delay values on the Penn-Lincoln Parkway (23). Typical descriptors include:

MAJOR DELAY

MINOR DELAY

Typical messages might be as follows:

ROAD BLOCKED/2 MILE/USE NEXT EXIT

ROAD BLOCKED/2 MILE/MAJOR DELAY

The descriptors USE NEXT EXIT and MAJOR DELAY would flash alternately.

Sperry Rand (31) also suggests displaying travel time and/or delay time for both the primary freeway route that passes through the city, and for the freeway that loops around the city and can be used as an alternate route for drivers traveling through the city. The information would be displayed upstream of the intersection of the two freeways. Details of the Sperry Rand study are discussed later in the section entitled *Diverting Traffic Off the Freeway to an Alternate Freeway or Freeway Section.*

Levels of Congestion and Congestion Coding

Although research has indicated the need to display congestion or traffic state levels (5, 6) there have been only limited laboratory or field evaluations to define the maximum and minimum number of descriptors and the most effective approach for display. Both the type and number of congestion or traffic level descriptors vary in existing operational systems. There is no evident trend.

It is still not known whether incident descriptors alone are translated by the driver into relative levels of congestion. For example, one might see the following different messages and visualize different severities of problems that might be expected depending on the time of day:

GRASS CUTTING

MAINTENANCE

CONSTRUCTION

ACCIDENT

2 OF 4 LANES BLOCKED

3 OF 4 LANES BLOCKED

TRUCK OVERTURN

MINOR ACCIDENT

MAJOR ACCIDENT

The Colorado Department of Transportation has selected word descriptors to display three levels of traffic operations in Denver (18):

FREE FLOWING TRAFFIC

MODERATE CONGESTION

HEAVY CONGESTION

Two levels of delay time are used as descriptors in Minneapolis (19):

5-10 MIN DELAY

10-20 MIN DELAY

Plans for the Baltimore system (22) suggest the use of eleven levels of delay descriptors ranging from:

1 MIN

to

50 MIN

The Los Angeles system (21) has the capability to display an infinite number of traffic level descriptors in terms of delay time. A typical message is:

14 MINUTES TO/HARBOR FWY

The system on the Penn-Lincoln Parkway (23) will use two levels

LIGHT CONGESTION/MINOR DELAY

MAJOR CONGESTION/MAJOR DELAY

on the three-line variable message signs. In addition, one of the three proposed signs will be a variable message-static sign used exclusively to give traffic conditions on three downstream segments of the Parkway. The message proposed for this sign is as follows:

PARKWAY TRAFFIC CONDITIONS	
Carnegie to Green Tree	NORMAL
Green Tree to West End	HEAVY
West End to Downtown	JAMMED

The letters and background on the rotating drums would be color coded.

A similar system is proposed for the Schuylkill Expressway in Philadelphia (23) as shown below:

EXPRESSWAY TRAFFIC CONDITIONS	
Roosevelt Expy	JAMMED
City Ave - Vine St.	NORMAL
South of Vine St.	HEAVY

"JAMMED" - white on red

"NORMAL" - white on green

"HEAVY" - white on yellow

One sign is proposed for the expressway and ten signs will be installed on arterial streets leading to the expressway.

The Texas Transportation Institute and the Texas Highway Department have developed, implemented, and are currently evaluating a new approach to describe levels of operations by using letter codes (17). Letter grades of A, B, C, D, F, and X are used to display six levels of traffic conditions, A, B, C for light to moderate flow, D for moderate congestion, F for heavy congestion, and X when a major incident occurs on the freeway. The letter grades are displayed on the last module of the top matrix insert on the sign used to indicate that the system is operational. Thus, the top line of the three-line sign would read:

FWY CONDITION A

A letter grade is always displayed in combination with one of the following traffic descriptors:

OK

SLOW TRAFFIC

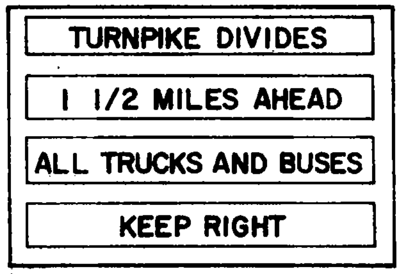
LANE BLOCKED

Diverting Traffic Off the Freeway to an Alternate Freeway or Freeway Section

The only known system of changeable message signs that is used in part to divert traffic off one freeway to another freeway section is located on the New Jersey Turnpike (13). This portion of the Turnpike is a divided dual-dual freeway, three inner lanes and three outer lanes in each direction for 24 miles of the 118 mile toll road. The inner lanes are restricted for cars only, whereas the outer lanes are open to all traffic. In case of accidents or other emergencies, all traffic is diverted to the uneffected side of the dual freeway at the roadway fork. Since the distance traveled by a driver would be the same regardless of whether he is on the inner or outer freeway and since the route is the same, this perhaps constitutes the simplest (relative to other freeway alternates) form of diversion from freeway to freeway.

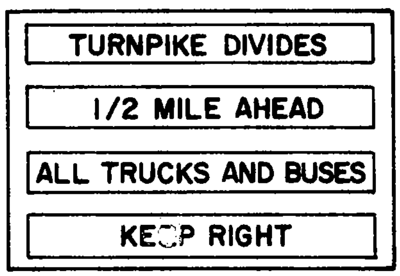
A series of rotating drum signs mounted at three locations preceding the fork are used to divert the traffic. In addition, the New Jersey Turnpike Authority physically closes the effected roadway at the fork using barricades and maintenance trucks. New Jersey Turnpike authorities report that there is approximately 90 percent compliance to the diversion messages before the maintenance crews physically block the entrance to the roadway.

During normal conditions the messages are displayed at three successive sign locations on rotating drum signs having a green background color, as can be seen on the following pages.

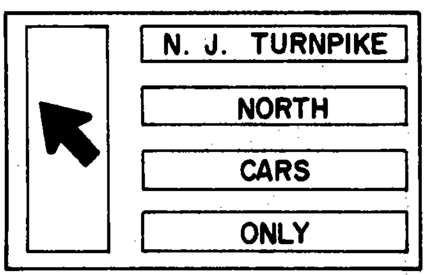


Letters

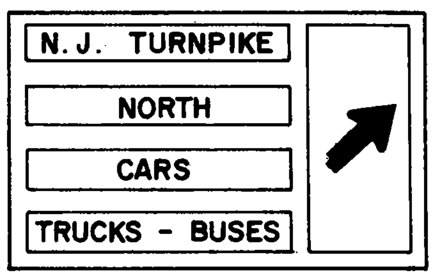
(White on Green)



(White on Green)

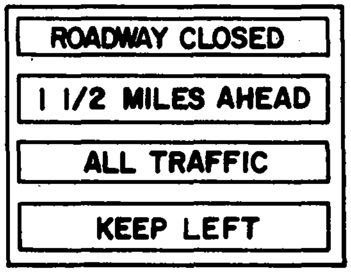


(White on Green)

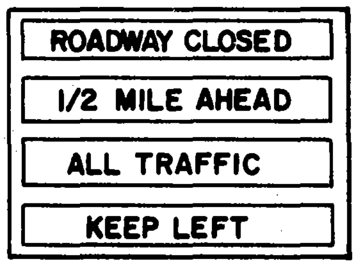


(White on Green)

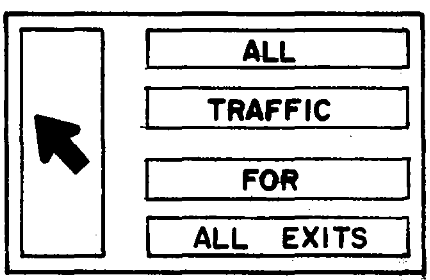
Under incident conditions the messages on the three signs are as follows:



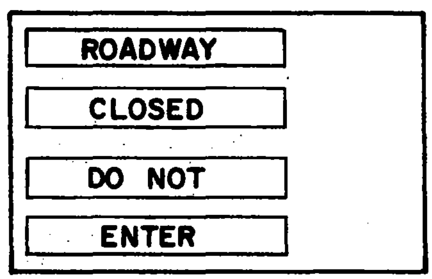
(White on Red)



(White on Red)



(White on Green)



(White on Red)

It is interesting to note that during diversion the sign at the fork gives drivers the assurance that they can reach all exits if they divert.

The factors that influence the high percentage of diversion in the absence of physical closure are not known and are worth studying. Presently, one can only speculate. Possible reasons might include:

1. The message ROADWAY CLOSED implies complete closure of all lanes. This, coupled with the fact that the dual roadway is 24 miles long, may concern the driver about possibly getting trapped on the road for a prolonged period of time.
2. The assurances given on the open roadway by the message ALL EXITS may add to the motorists' willingness to divert.
3. Unfamiliar motorists perhaps would be more inclined to adhere to the positive messages so as not to get trapped or diverted to arterial roads.

Sperry Systems Management (31) conducted driver surveys to determine the suitability of candidate messages and message arrangements for initial operation and testing of a single point diversion (freeway-to-freeway) system. The single point diversion system, which will direct I-95 southbound through motorists to the better route along I-695 around the Baltimore area, will provide information by means of variable message signs at the bifurcation of I-95 and I-695 just north of Baltimore.

Several specific aspects of the signing system were investigated. These include the following:

1. Motorist decisions on route selection when presented with the signing sequence approaching the diversion point.

2. Motorist route selection decisions and reaction time for the messages presented on the main variable matrix sign.

3. Motorist preference for the message content of the fixed sign which alerts the motorist to the upcoming information.

The survey focused on two signs within the overall signing sequence: the overhead variable message sign and the advance warning sign. Response to the overall signing sequence was also obtained. Five advance warning signs, twenty-four variable message signs, and three message arrangements as shown in Table 2 comprised the survey in which 274 subjects took part. The sign candidates chosen for use in the initial operation and testing were selected on the basis of frequency of selection by the subjects, effectiveness in inducing motorists to divert, and comparative subject response time to the message.

The testing was divided into four short portions, each corresponding to one of the objectives noted above. The first part consisted of showing a slide sequence of the signing system, using one message set. For the second part of the test, the subject was shown individual slides of the main matrix sign, each containing a different message. Here, he selected which route he would take. His choice and reaction time were recorded. In the third part of the test, different message formats with similar messages were shown, in pairs, for the main matrix sign. The paired comparisons represented all combinations of three formats. The subject indicated his preference in each case. The final part was similar to the third part, except that here, the preference was related to the fixed advance warning sign.

Table 3 shown the effectiveness of the simulated signing configuration in inducing the motorists to divert. In Phases I and II the full matrix sign

TABLE 2

POINT DIVERSION SIGN STUDY ALTERNATIVES (31)

	Sign Station	Phase I	Phase II	Phase III	Phase IV
PART I Slide Sequence	Advance Warning	Signs Ahead For Best Route To Washington And Points South	(Use Preferred Sign From Results of Phase I, Part IV)	(Use Preferred Sign From Results of Phase II, Part IV)	(Use Preferred Sign From Results of Phase III, Part IV)
	Full Matrix	I-95 South-Congested Use I-695 West For Washington	I-95 South-Accident I-695 West-Moderate Use I-695 West For Washington	Routes To Washington Via I-95 South-Light Via I-695 West-Heavy	Routes To Washington Via I-95--15 Min Delay Via I-695--5 Min Delay
	Exit & One Mile Advance Guide Signs	(Center Panel) (Right Panel) Congested Washington	(Center Panel) (Right Panel) Accident Washington	(Center Panel) (Right Panel) Washington --	(Center Panel) (Right Panel) Washington Alt. To Wash.
PART II Response For Full Matrix Sign	Full Matrix Sign	Routes To Washington Via I-95 South-Moderate Via I-695 West-Light	Routes To Washington Via I-95 South-Heavy Via I-695 West-Moderate	Routes To Washington Via I-95 South-Heavy Via I-695 West-Light	Routes To Washington Via I-95 South-Accident Via I-695 West-Moderate
		I-95 South-Congested Use I-695 West For Washington	I-95 South-Accident Use I-695 West For Washington	I-95 South Delays Use I-695 West For Washington	I-695 West-Congested Use I-95 South For Washington
		I-95 South-Heavy I-695 West-Moderate Use I-695 West For Wash.	I-695 West-Congested I-95 South-Light Use I-95 For Washington	I-95 South-Moderate I-695 West-Light Use I-695 West For Wash.	I-95 South-Heavy I-695 West-Light Use I-695 West For Wash.
		Routes To Washington Via I-95 South-10 Min. Delay Via I-695 West-5 Min. Delay	Routes To Washington Via I-95 South-20 Min Delay Via I-695 West-5 Min Delay	Routes To Washington Via I-95 South-25 Min Delay Via I-695 West-5 Min Delay	Routes To Washington Via I-95 South-15 Min Delay Via I-695 West-5 Min Delay
		Delays On I-95 South Washington Traffic Use I-695 West	Congestion I-95 South Washington Traffic Use I-695 West	Congestion On I-695 West Washington Traffic Use I-95 South	Accident On I-95 South Washington Traffic Use I-695 West
		I-695 West-Accident I-95 South Moderate Use I-95 South For Wash.	I-95 South-Accident I-695 West-Moderate Use I-695 West For Wash.	I-95 South-Construction I-695 West - Moderate Use I-695 West For Wash.	I-95 South-Construction I-695 West- Light Use I-695 West For Wash.
PART III Format Preference Full Matrix Sign	Full Matrix Sign	Routes To Washington Via I-95 South-Congested Via I-695 West-Light	Routes To Washington Via I-95 South-Accident Via I-695 West-Moderate	Routes To Washington Via I-95 South-Light Via I-695 West-Heavy	Routes To Washington Via I-95 South-15 Min Delay Via I-695 West-5 Min Delay
		I-95 South-Congested I-695 West-Light Use I-695 West For Wash.	I-95 South-Accident I-695 West-Moderate Use I-695 West For Wash.	I-695 West-Heavy I-95 South-Light Use I-95 South For Wash.	I-95 South-15 Min Delay I-695 West-5 Min Delay Use I-695 West For Wash.
		I-95 South-Congested Use I-695 West For Washington	Accident On I-95 South Use I-695 West For Washington	I-695 West-Heavy Washington Traffic Use I-95 South	I-95 South-15 Min Delay Washington Traffic Use I-695 West
PART IV Message Preference For Advance Sign	Advance Warning Fixed Sign	Signs Ahead For Best Route To Washington And Points South 95 or 695 To Washington Signs Ahead For Best Route	(Retain Best 2 Messages From Phase I, Part IV)	(Retain Best 2 Messages From Phase II, Part IV)	Test 5 Best Messages
		Traffic Advisory Signs Ahead For Washington And South	Washington and Points South Traffic Information ½ Mile Ahead	Traffic Conditions Ahead For Routes To Washington	

Table 3

SIGNING CONFIGURATION
EFFECTIVENESS FOR INDUCING DIVERSION (31)

PHASE	ROUTE SELECTED I-95/HTT	ROUTE SELECTED I-695	PERCENT	
I	3	72	96.0	Advisory
II	8	60	88.2	
III	59	7	89.3	No Advisory
IV	32	33	50.7	

included an advisory to use I-695, and the insert panels on the overhead guide signs contained the "Washington" destination in the I-695 panels (Table 2). In Phase III, there was no advisory on the full matrix sign, but the inserts indicated "Washington" on the I-95 panels, consistent with the descriptor content on the full matrix sign (via I-95-Light, via I-695 Heavy).

In Phase IV, there was also no advisory and the variable message inserts indicated "Washington" (I-95 panel) and "Alt. to Wash." (I-695 panel) in conjunction with a delay message on the full matrix favoring I-695 by 10 minutes. The researchers concluded that the presence of "Washington" on either panel, with a descriptor or blank on the other panel, was in fact associated with the high diversion cases. This conclusion was further supported in Part IV of the study. The researchers noted that the simultaneous use of the "Washington" and "Alt. to Wash." legends was specifically included in the survey to preserve the element of driver choice in conjunction with the full matrix sign. They felt, however, that had a "blank" been used in place of the "Alt. to Wash." legend, a significantly higher diversion to I-95 would have resulted from the Part I sign sequence.

Table 4 presents the results of the sign effectiveness studies for the full matrix sign performed in Part II. The results showed that the total range in effectiveness extended from 54.5 to 100 percent. The researchers concluded that, for automatic diversion purposes, the message should include a congested descriptor since it produced the highest diversion percentages in conjunction with minimum response time. This message would be as follows:

I-95 SOUTH CONGESTED
USE I-695 WEST
FOR WASHINGTON

Since the I-95 South-Harbor Tunnel Thruway route represents the normal route, the survey concentrated on messages to divert traffic from this route

Table 4

SIGN EFFECTIVENESS IN INDUCING DIVERSION (31)

	%		%		%		%
Routes to Washington Via I-95 South-Moderate Via I-695 West-Light	61.4	Routes to Washington Via I-95 South-Heavy Via I-695 West-Moderate	91.2	Routes To Washington Via I-95 South-Heavy Via I-695 West-Light	77.3	Routes To Washington Via I-95 South-Accident Via I-695 West-Moderate	81.4
I-95 South-Congested Use I-695 West For Washington	93.3	I-95 South-Accident Use I-695 West For Washington	91.2	I-95 South-Delays Use I-695 West For Washington	83.3	*I-695 West-Congested Use I-95 South For Washington	92.0
I-95 South-Heavy I-695 West-Moderate Use I-695 West For Washington	89.3	*I-695 West-Congested I-95 South-Light Use I-95 South For Washington	88.2	I-95 South-Moderate I-695 West-Light Use I-695 West For Washington	54.4	I-95 South-Heavy I-695 West-Light Use I-695 West For Washington	81.1
Routes to Washington Via I-95 South-10 Min Delay Via I-695 West - 5 Min Delay	72.0	Routes To Washington Via I-95 South-20 Min Delay Via I-695 West-5 Min Delay	86.8	Routes To Washington Via I-95 South-25 Min Delay Via I-695 West-5 Min Delay	86.3	Routes To Washington Via I-95 South-15 Min Delay Via I-695 West-5 Min Delay	80.5
Delays On I-95 South Washington Traffic Use I-695 West	90.5	Congestion on I-95 South Washington Traffic Use I-695 West	89.8	*Congestion On I-695 West Washington Traffic Use I-95 South	95.5	Accident On I-95 South Washington Traffic Use I-695 West	92.5
*I-695 West-Accident I-95 South-Moderate Use I-95 South For Washington	95.3	I-95 South-Accident I-695 West-Moderate Use I-695 West For Washington	94.1	I-95 South-Congestion I-695 West-Moderate Use I-695 West For Washington	77.3	I-95 South-Construction I-695 West-Light Use I-695 West For Washington	87.7

* Directed To Use I-95

to the I-695 (Beltway) route. Twenty of the twenty-four variable messages tested were for this case. Although less emphasis was placed on the nondiversionary messages, there was an indication that another format might be preferred for these cases. This format was as follows:

ROUTES TO WASHINGTON
VIA I-95 SOUTH - (DESCRIPTOR)
VIA I-695 WEST - (DESCRIPTOR)

This indication was obtained from format preference results.

Table 5 presents the diversion potential resulting from traffic conditions conveyed to the motorists by word descriptors. Word descriptors inducing different diversion percentages are indicated on the table by brackets. The descriptors used in the survey included: ACCIDENT, CONSTRUCTION, CONGESTION (or CONGESTED), HEAVY, MODERATE, LIGHT, DELAYS, and quantitative delay (XX MINUTES). The results for descriptors were generally as the researchers expected, i.e., the use of ACCIDENT, CONGESTION, and HEAVY produced the highest diversion percentages (although there was one exception where a heavy-light combination yielded lower percentages). CONSTRUCTION and DELAYS were somewhat less effective, and combinations such as MODERATE and LIGHT, respectively, for the two routes yielded the lowest diversion percentages. Quantitative delay showed the expected trend of increasing diversion percentage with increasing delay difference between the two routes.

Table 6 presents the results of Part IV of the survey. The researchers concluded that Sign 1, having the interstate shields for each route and no complex or obvious information, was the overwhelming winner for the advance warning sign. This candidate is shown on page 53.

Table 5

DIVERSION POTENTIAL (31)

I95/HTT	I-695	% Diversion	Format
Moderate	Light	54.5	2
Moderate	Light	61.4	1
10 Min Delay	5 Min Delay	72.0	1
15 Min Delay	5 Min Delay	77.0	1
Construction	Moderate	77.3	2
Heavy	Light	77.3	1
Delays	- -	83.3	3A
Construction	Light	86.1	2
25 Min Delay	5 Min Delay	86.3	1
20 Min Delay	5 Min Delay	86.8	1
Light	Congested	88.2 - To I95/HTT	2
Heavy	Moderate	89.3	2
Congestion	- -	89.8	3B
Delays	- -	90.5	3B
Heavy	Moderate	91.2	1
Accident	- -	91.2	3A
Heavy	Light	92.4	2
Congested	- -	93.3	3A
Moderate	Accident	93.3	2
Accident	- -	94.0	3B
Accident	Moderate	94.1	2
Accident	Moderate	95.5	1
	Congestion	95.5 - To I95/HTT	3B
	Congested	100.0 - To I95/HTT	3A

_________Uncertainty

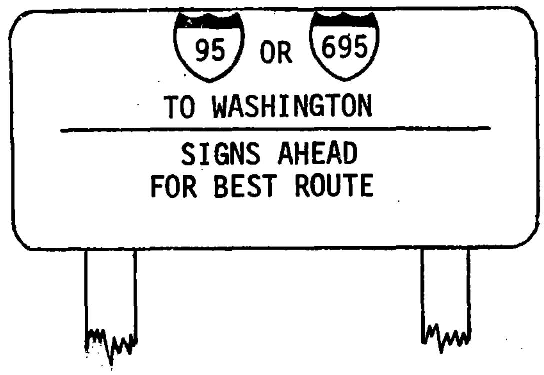
---------Reversal

Table 6

RESULTS - ADVANCE SIGN
FOR SINGLE POINT DIVERSION (31)

SIGN NUMBER		FREQ. SELECTED	MAX. POSSIBLE	%	RANK
1	95 OR 695 TO WASHINGTON SIGNS AHEAD FOR BEST ROUTE	339	418	81.0	1
2	TRAFFIC ADVISORY SIGNS AHEAD FOR WASHINGTON AND SOUTH	110	279	38.4	4
3	SIGNS AHEAD FOR BEST ROUTE TO WASHINGTON AND POINTS SOUTH	130	351	37.0	5
4	WASHINGTON AND POINTS SOUTH TRAFFIC INFORMATION 1/2 MILE AHEAD	140	276	50.6	2
5	TRAFFIC CONDITIONS AHEAD FOR ROUTES TO WASHINGTON	102	262	38.9	3

(Significance <0.1% level)



Since the researchers changed more than one variable between each sign, it is not clear what factors about Sign 1 were appealing to the drivers. For example, in addition to adding new information, the line placement of the information was also varied between signs. It is not clear as to whether the interstate decal route designation or the ordering of the information shown on Sign 1 were both preferred, or whether only one of these two factors influenced motorists' choices.

Gordon (32) studied diversion signs showing time, speed, traffic state, and time-and-traffic information. The studies were conducted in a trailer laboratory located north of Baltimore. One-hundred and ninety-six volunteer drivers were asked to choose between the tunnel and the beltway interstate routes, and were asked which type of sign they preferred. The tunnel route is 17 miles long and the beltway route is 27 miles long.

The volunteer drivers were shown examples of experimental signs. The time signs were shown first, followed by speed, traffic state, and time-and-traffic signs. The beltway condition was held constant in each sign series. For example, tunnel times were compared to the constant beltway time of 40 minutes. The tunnel route conditions were varied serially from most to least favorable.

The results (Figure 7 and Table 7) revealed that the tunnel alternatives were equally attractive when tunnel time was about 39 minutes, (beltway time 40 minutes) i.e., when both times were approximately equal. Gordon concluded that time is the basic variable on the basis of which the driver makes his route choice.

The studies of speed information (Figure 8 and Table 7) revealed the route choices were equal when tunnel speed was 33 mph and beltway speed 40 mph. Eighty-seven percent of test drivers selected the beltway when the tunnel route speed was 20 mph. Gordon concludes that the data suggest that speed information can achieve an adequate diversion.

Traffic state results (Figure 9 and Table 7) indicated that simple traffic state information can also be used to divert traffic.

The combined time-and-traffic condition signs produced a rough diversion function and an inversion between the 20 and 25-minute tunnel time condition (Figure 10 and Table 7) even though the beltway time was 40 minutes. Gordon concluded that drivers were probably confused by the two types of information. He believed that this conclusion was supported by the long response times of time-and-traffic signs (Table 8). The 95th percentile times varied from 4.73 seconds (traffic) to 6.29 seconds (time-and-traffic). Gordon attributed the longer response time to added reading time and difficulty of making more complex choices.

Preference studies showed that 62 percent preferred time-and-traffic, 17 percent preferred time, 15 percent preferred traffic state, and 6 percent speed. Gordon attributed the inconsistency between preferences and reaction time for the time-and-traffic signs (most preferred, longest reaction time) to the general bias of drivers to ask for as much information as possible.

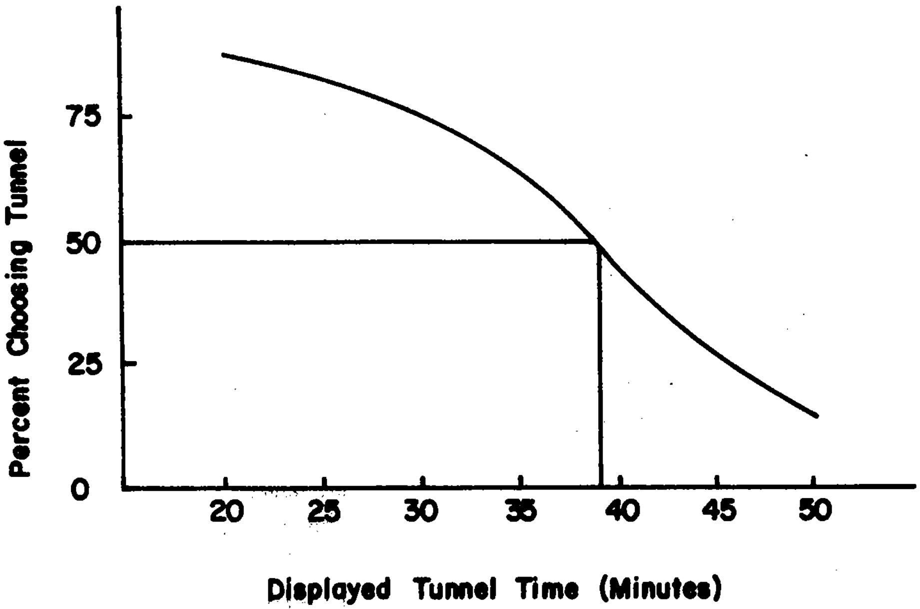


Figure 7 - Tunnel Choices Related to Displayed Tunnel Times (Beltway comparison time was always 40 minutes) (32)

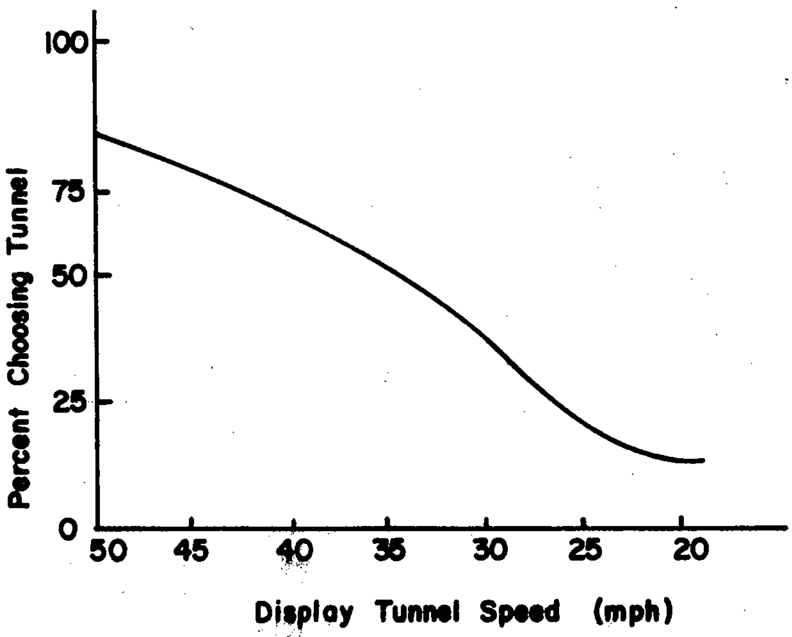


Figure 8 - Percent Choosing Tunnel Related to Displayed Tunnel Speed (Beltway comparison speed was always 40 miles per hour) (32)

Table 7

DRIVERS' ROUTE CHOICES (32)

Type of Sign	Information Beltway	Displayed Tunnel	Driver Choices Tunnel	Driver Choices Beltway	Total
Time	40 mins.	20 mins.	88%	12%	100%
	40 mins.	25	84	16	
	40 mins.	30	77	23	
	40 mins.	35	67	33	
	40 mins.	40	46	54	
	40 mins.	45	23	77	
	40 mins.	50	14	86	
Speed	40 M.P.H.	20 M.P.H.	13	87	100%
	40 M.P.H.	25	17	83	
	40 M.P.H.	30	38	62	
	40 M.P.H.	35	54	46	
	40 M.P.H.	40	63	37	
	40 M.P.H.	50	80	20	
Traffic State	Medium	Light	87	13	100%
	Medium	Medium	64	36	
	Medium	Heavy	8	92	
Time-Traffic	40 Mins. Med.	20 Mins. Light	80	20	100%
		25 Mins. Light	85	15	
		30 Mins. Med.	69	31	
		35 Mins. Med.	61	39	
		40 Mins. Med.	47	53	
		45 Mins.Heavy	11	89	
		50 Mins.Heavy	10	90	

Sample Size: 196 Subjects

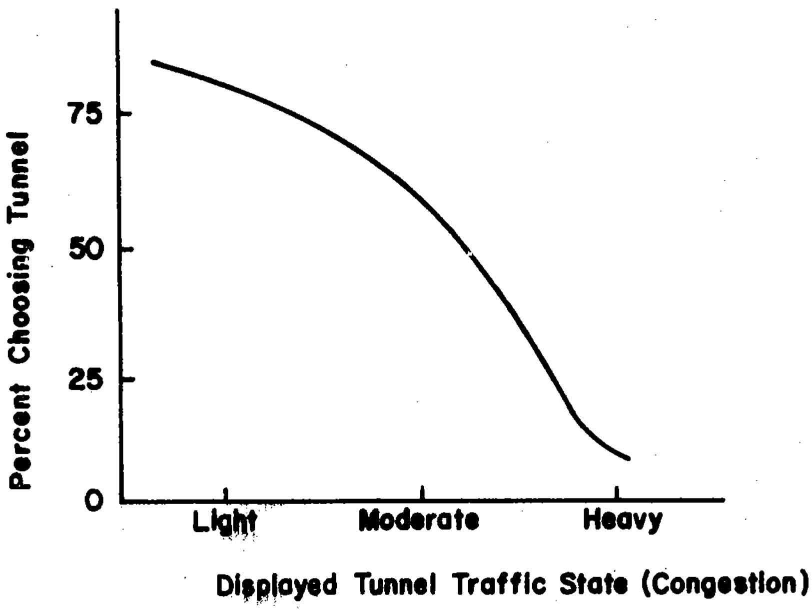


Figure 9 - Tunnel Choices Related to Displayed Tunnel Traffic State (Beltway comparison was always moderate congestion) (32)

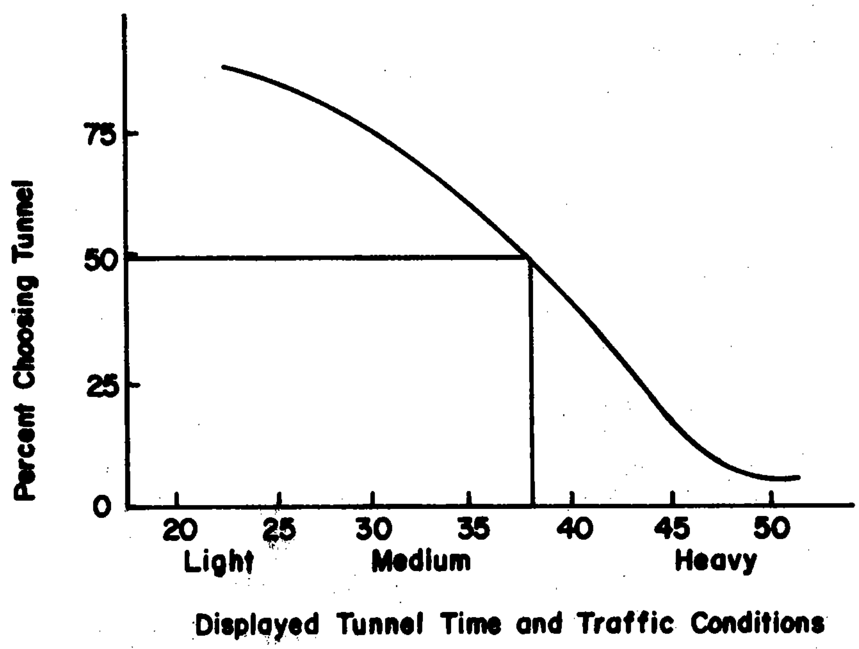


Figure 10 - Tunnel Choices Related to Displayed Tunnel Time-and-Traffic State (Beltway comparison was moderate traffic and 40 minute time) (32)

Table 8

RESPONSE TIMES TO SIGNS (32)

Type of Sign	Information Beltway	Displayed Tunnel	Response time (Sec.) Median	95th Centile
Time	40 Mins.	20 Mins.	2.4 secs.	5.9
	40 Mins.	25	2.4	4.6
	40 Mins.	30	2.3	4.8
	40 Mins.	35	2.2	5.3
	40 Mins.	40	2.1	5.0
	40 Mins.	45	2.4	4.8
	40 Mins.	50	2.4	5.7
		Mean	2.31	5.16
Speed	40 M.P. Hour	20 M.P.H.	2.3	6.1
	40 M.P. Hour	25	2.2	5.0
	40 M.P. Hour	30	2.3	5.2
	40 M.P. Hour	35	2.2	4.5
	40 M.P. Hour	40	2.0	4.1
	40 M.P. Hour	50	2.4	5.9
		Mean	2.23	5.13
Traffic State	Medium	Light	2.2	4.5
	Medium	Medium	2.0	4.1
	Medium	Heavy	2.1	5.6
		Mean	2.10	4.73
Time Traffic	40 Mins. Med.	20 Mins. Light	2.8	6.2
	40 Mins. Med.	25 Mins. Light	2.75	6.4
	40 Mins. Med.	30 Mins. Medium	3.0	6.0
	40 Mins. Med.	35 Mins. Medium	2.4	6.4
	40 Mins. Med.	40 Mins. Medium	2.2	6.2
	40 Mins. Med.	45 Mins. Heavy	2.8	6.3
	40 Mins. Med.	50 Mins. Heavy	2.9	6.5
		Mean	2.69	6.29

Sample Size: 196 Subjects

In spite of its popularity, Gordon did not recommend the use of the time-and-traffic diversion sign on the grounds that the signs confuse the driver. He recommended that diversion signs show either time or traffic state information because they were responded to quickly, they had a clear influence on drivers' route choices, and were relatively popular with drivers. He believed that the speed sign is objectionable because it will result in driver complaints when the posted speed does not agree with actual speed. He does not cite the same objection for time information.

A second study involved the use of color coding and advisory infomation on diversion signs. In all, 300 subjects participated. One hundred drivers viewed the control series of conventional colored guide signs, the second hundred viewed color coded signs (Series II), and the third hundred viewed color coded Series III.

Each series included 7 time information signs, 3 traffic state signs, and 2 advisory signs. In the control series, the signs showed conventional white letters on a green backgound. The Series II and III signs were the same as the control series except color cues were added. The circle series showed a large colored disc between the message and arrows. A green disc indicated the approved route, while red indicated the less preferred route. In the arrow series, the arrow of the signs was coded green or red, according to whether the route was, or was not, recommended.

The average times taken by drivers to make their choices are given in Table 9. On the average, drivers in Group II responded 0.74 second faster, and Group III responded 0.92 second faster than the control group. Contrary to Gordon's expectations, advisory information signs did not help drivers reach a quick decision. Advisory sign responses were longer than reactions to time or traffic state descriptors.

Table 9

MEAN RESPONSE TIMES TO DIVERSIONARY SIGNS GROUP II SIGNS BY COLOR CODED CIRCLES, GROUP III SIGNS HAD COLOR CODED ARROWS (32)

	Time Signs *								Traffic State Signs **				Advisory Signs ***		
	20 mins.	25	30	35	40	45	50	Mean (secs.)	Light	Medium	Heavy	Mean (sec.)	Tunnel	Beltway	Mean (sec.)
Control Group I	2.76	3.28	3.12	3.00	2.85	2.99	3.07	3.01	3.08	3.12	2.56	2.92	3.69	3.19	3.44
Group II	2.08	2.60	2.09	2.48	1.94	2.29	2.65	2.30	2.20	2.47	1.85	2.17	2.67	2.47	2.57
Group III	1.83	2.35	1.98	2.16	1.92	2.10	2.25	2.08	2.13	2.31	1.66	2.03	2.60	2.33	2.46

* The beltway time was kept at "40 minutes", associated tunnel times are shown.

** The beltway traffic state was kept at "moderate", tunnel traffic state was varied.

*** The advisory sign recommended the tunnel or the beltway.

The study results also revealed that color coded signs did not provide more effective diversion than the standard white on green control sign. The differences between the coded circles and the arrows in encouraging diversion was small. The results of preferences between arrows and circles are consistent with the findings of Dudek and Jones (33).

Gordon concluded that the colors on the signs did not function as on a traffic signal. The green color did not significantly induce drivers to follow the route shown, nor did the red prevent a route from being chosen. He suggested that if the use of green and red is objectionable, other colors may be more effective.

Hall and Dickinson (34) conducted two questionnaire studies on I-95 near Baltimore to determine what type of real-time information the road users desire and to determine how the driver wanted the information presented. Out of 6,593 questionnaires distributed, 2,896 or nearly 44 percent were returned.

Approximately 72 percent of the respondents indicated that the current signing on the highway system is adequate. The most frequent complaint involved the lack of sufficient advance warning to permit proper route choice at interchanges and intersections. The researchers concluded that this finding suggests that special attention is therefore warranted in the development of variable message signs for route diversion.

Questions on pre-trip planning for intercity trips resulted in the following:

(63 percent) - Obtained roadway map, studied map prior to beginning of trip, and followed signs.

(17 percent) - Followed highway signs only.

(11 percent) - Obtained planned trip package from automobile club or oil company.

(9 percent) - Followed highway signs, only.

The researchers concluded that the reported reliance on road maps suggests that an efficient real-time diversion scheme should be coordinated with the static information contained on such maps. Identification of routes by number, rather than by name, is one example of coordination. In addition, all routes to be used in the diversion system should be indicated on current, state-wide maps which are generally made available to the public.

The first questionnaire presented three signs (labeled Sign 1, 2, and 3 in Figure 11) and asked the drivers to select the "best," the "worst," and to indicate the reason for their selections. The sign most frequently chosen as the "best" was Sign #2. Approximately 46 percent of the time it was chosen the "best" sign, while 41 percent of the time Sign #1 was selected. The distinction is comparatively small, and does not suggest a real difference between a simple color coded sign containing minimal information and a word message sign giving more detailed messages.

The sign most frequently identified as "worst" was the pictorial color coded sign (74 percent). This result is consistent with the those of Dudek and Jones (33). About 15 percent of the time, Sign #2 was chosen as the "worst" sign.

The conciseness of Sign #1 was most frequently cited as its major advantage. The authoritative nature of Sign #2 (i.e., EXIT HERE) was appreciated by a large number of motorists who were concerned about what specific course of action to take. The major problem noted for Sign #3 was that it took too long to find the desired information on the sign.

SIGN 1

FREEWAY CONDITION
0 Normal
● Congested
Next________Miles

SIGN A

FREEWAY CONDITION
0 Normal
● Congested
Accident Ahead

SIGN B

FREEWAY CONDITION
0 Normal
● Congested
Delay Time 5 Min.

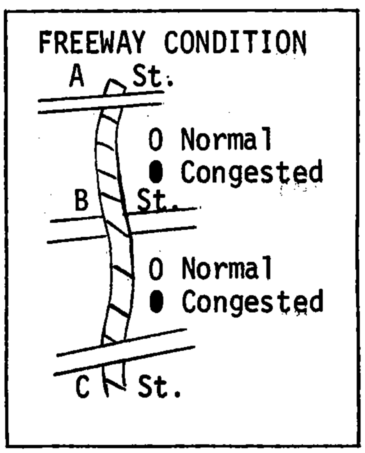
SIGN 2

FREEWAY CONDITION
Accident Ahead Keep Right
Congestion Ahead
Exit Here

SIGN C

FREEWAY CONDITION
0 Normal
● Congested
Next 2 Miles

SIGN 3



SIGN D

FREEWAY CONDITION
0 Normal
● Congested
SPEED 30 MPH

SIGN E

FREEWAY CONDITION
0 Normal
● Congested
Use Alternate Route
Spring Ave.

Figure 11 - Sign Design Study Alternatives (34)

Analysis of the responses to a question which solicited the driver's opinion on the most important characteristics of a sign message, produced the following hierarchy (shown in decreasing order of importance):

1. Brief and concise.
2. Indicate the nature of the situation.
3. Suggest appropriate driver response.
4. Provide supplementary information.

Several motorists noted that the terms NORMAL and CONGESTED are ambiguous. It was not clear to some drivers whether NORMAL meant free flow, or average flow, or typical conditions for the specific time of day when the message is displayed. Although the color code itself is comparatively straightforward, the interpretation of the message must be clarified if this method of presenting information is to be useful.

Five different signs (labeled Sign A, B, C, D, and E in Figure 11) were presented on the second questionnaire and the respondents were asked to indicate their preference when the signs were compared two at a time. Each sign included a color-coded indication for NORMAL or CONGESTED, along with one of the following types of variable messages:

Sign	Message
A	Cause of congestion
B	Expected delay time (min.)
C	Length of congestion (mi.)
D	Variable speed limit
E	Alternate route information

Sign C, which indicated the length of congestion in miles, was found to be most popular. It compared favorably with each of the other four signs. The runner-up was Sign E, which suggested an alternate route of travel to avoid the congestion. In response to a question which asked the motorists to compare these two signs, Sign C was selected 56 percent of the time. Sign B (expected delay time) ranked third, and was followed by Sign A (cause of congestion). In comparison with each of the other signs, D (variable speed limit) was always judged to be the worst.

On the basis of the analysis, the researchers concluded that there are three sign types which are worthy of consideration for real-time route diversion. These are:

	Questionnaire One	Questionnaire Two
CONGESTION LENGTH MESSAGE (MI.)	1	C
CONGESTION CAUSE/EXIT INSTRUCTION	2	-
ALTERNATE ROUTE INFORMATION	-	E

The researchers felt that the comparatively close ranking of these three signs precludes a judgment as to which is truly the "best." Based upon this sample of freeway drivers, it is not possible to give a favorable recommendation to signs employing schematic representations, or to those indicating speed or delay parameters. The former seem to require too much time to locate the intended message, while the latter apprently do not satisfy the drivers' needs with meaningful information.

The researchers cautioned that although the signs tested in this study are representative of the types which others have suggested (and even used in urban corridors), there is no assurance that the optimal sign message and design is actually included among the signs presented on the questionnaires. This, in fact, is an inherent problem in trying to select an optimal alternative. However, the judicious field testing and evaluation of the recommended signs may suggest ways in which they can be modified or supplemented to achieve the most suitable design.

The researchers concluded that the generally recognized need for uniformity and consistency would tend to support the concept that one type of route diversion sign should be used. It is easy to appreciate, however, that the sign should be suited to the circumstances, and that this may require the use of two or more types of signing along a specific route. The placement of signs advising the motorist to EXIT or to use a specified alternate route require that the diversion network include a proper route for diverting at least moderate volumes of traffic at that location. If the only available alternate at a particular interchange is a local road, the more subtle advice given by the congestion length message might be more appropriate. It would be more likely to prompt the early exit from the freeway of a few local motorists who had originally planned to exit within a mile or two. On the other hand, the diversion of through motorists at major diversion points is probably enhanced by signs advising of alternate routes.

Diverting Traffic off the Freeway to Frontage Roads or Arterials

Questionnaire surveys (33) have indicated that motorists would be less willing to divert once they are on the freeway than prior to entering. Thus, information presesented on the freeway must be very convincing to the motorists in order to encourage them to leave the freeway and reroute around an incident via the frontage roads or arterial streets. Perhaps, the farther away that the incident bypass route is from the freeway, the less apt motorists would be willing to divert. There is also evidence that unfamiliar motorists would be less likely to leave the freeway than familiar motorists.

Some operating agencies are using messages that recommend leaving the freeway and using an alternate route when incidents occur. The messages usually indicate a problem on the freeway as supporting reason for the motorist to reroute. The effectiveness of the various displays have not been fully evaluated. Other systems, due to one reason or another, do not recommend rerouting. This is due in part to: 1) absence of frontage roads, 2) no suitable alternate routes, 3) lack of surveillance on alternate routes, or 4) on-freeway changeable message system is primarily experimental and messages are still being developed.

The Denver system (18) uses the message

ALT ROUTE ADVISED

in conjunction with freeway condition descriptors. Several combinations of messages are available that can be sequenced with the alternate route advisement. Typical sequencing of messages might be as follows:

HEAVY CONGESTION/NEXT 4 MILES

HEAVY CONGESTION/ALT ROUTE ADVISED

The system in Minneapolis (19) uses the message

TAKE NEXT EXIT

along with incident descriptors. Typical messages might include one of the following:

CONGESTION AHEAD/TAKE NEXT EXIT

MAINTENANCE WORK/TAKE NEXT EXIT

STALLED VEHICLE/TAKE NEXT EXIT

TUNNEL CLOSED/TAKE NEXT EXIT

ACCIDENT AHEAD/TAKE NEXT EXIT

Also, over-head lane-use signals identify the lanes blocked by the incident.

Messages used in the Cincinnati system (20) are more specific. The following are examples of diversion messages:

I75/CONGESTED/ALT 75/USE EXITS 2A 1C

STADIUM &/DNTOWN/USE EXITS/SHOWN

RIGHT LANES/BLOCKED/ALT 75/USE EXITS 2A 1C

FREEWAY BLOCKED AHEAD/ALT 75/USE EXITS 2A 1C

The changeable message signing system in Cincinnati is integrated with static signs. In order to fully understand the message content, one must have perspective of the messages on the static signs. The following sequence of static/changeable message displays (Figure 12) illustrates the types of messages motorists would observe in sequence while driving on the freeway. The lamp matrix changeable message portion of the signs are illustrated in Figure 12 by the block around the message.

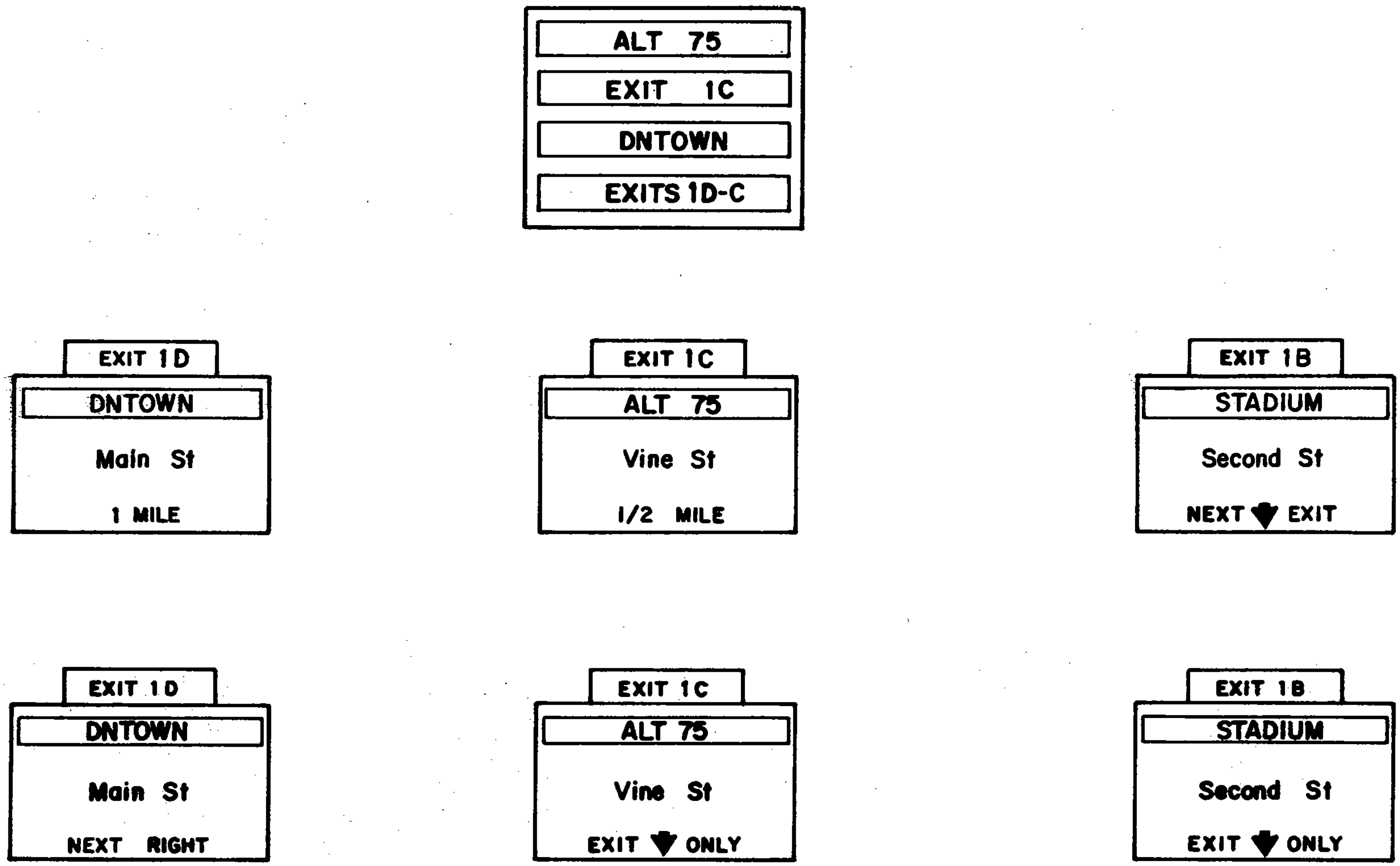


Figure 12 - Typical Messages on a Series of Changeable Message Signs in Cincinnati (20)

The California Department of Transportation has an operational unit in the Los Angeles area called the Major Incident Response Team (21, 35). Members of the team have assigned vehicles and are on call 24 hours per day, 7 days a week. The primary purpose of the team is to furnish, as rapidly as possible, equipment and manpower to aid the California Highway Patrol in management of freeway traffic at or near a major traffic incident. Early warning, alternate route signing, etc., are made available with this team.

The signing elements consist of cloth-type signs mounted on pickup trucks that are used on the freeway (Figure 13). Message inserts and typical messages used on the trucks are shown in Tables 10 and 11. The cloth signs consists of black letters on yellow background. In addition, traffic cones are placed on the freeway lanes to physically force traffic off the freeway to the alternate routes. Black on yellow guidance signs are also placed along the diversion route to guide the drivers around the incident and back to the freeway. These signs are either strapped to a pole or tree by one person or placed on tripod stands for the duration of the incident. An example of the guidance signs is shown in Figure 14. The arrows on the signs are movable to point to any direction that applies.

Figure 13 - Caltrans Major Incident Response Team Vehicle (21)

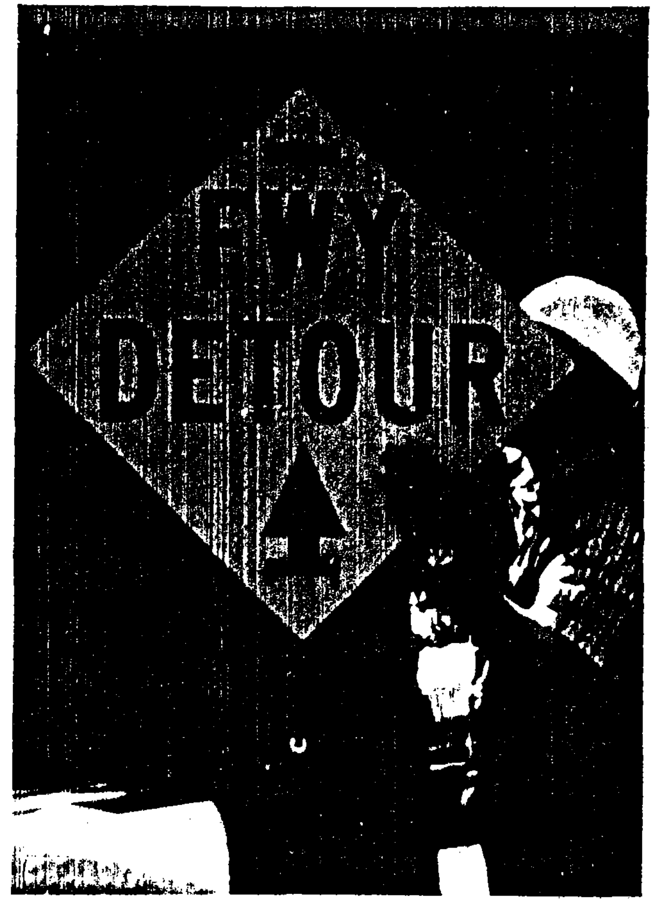


Figure 14 - Incident Management Guidance Sign - Caltrans Major Incident Response Team (21)

Table 10

TRUCK MOUNTED FABRIC CHANGEABLE MESSAGE SIGN LIBRARY FOR CALTRANS MAJOR INCIDENT RESPONSE TEAM (21)

FULL PANELS		PARTIAL PANELS
ACCIDENT	LEFT	1, 2, 3, 4, 5, 6, 7, 8, 9, 0
AHEAD	LEFT LANES	1/4, 1/2, 3/4
CAUTION	MERGE	AND
CLOSED	RAMP	EAST
CONGESTED	RIGHT	HR. DELAY
CONGESTION	ROAD WORK	MI. AHEAD
CONNECTOR	RT. LANE	NEXT
DETOUR	SLOW	NORTH
DETOUR AHD.	STOPPED	SOUTH
FWY CLOSED	TRAFFIC AHD.	USE
HEAVY		WEST

Table 11

TYPICAL MESSAGES FOR TRUCK MOUNTED SIGNS - CALTRANS MAJOR INCIDENT RESPONSE TEAM (21)

SLOW ACCIDENT AHEAD	SLOW CONGESTION AHEAD	SLOW STOPPED TRAFFIC AHD
SLOW RT LANE CLOSED	SLOW LEFT LANES CONGESTED	SLOW HEAVY TRAFFIC AHD
ACCIDENT FWY CLOSED DETOUR 3 MI AHEAD	ACCIDENT FWY CLOSED DETOUR AHD 1/2 HR DELAY	ACCIDENT NORTH 605 CONNECTOR CLOSED
ACCIDENT RT LANES CLOSED AHEAD	ACCIDENT LEFT LANES CLOSED 1/2 HR DELAY	ACCIDENT 2 MI AHEAD 1/2 HR DELAY
CAUTION RT LANES CONGESTED AHEAD	CAUTION ACCIDENT FWY CLOSED DETOUR AHD	CAUTION CONGESTION NEXT 5 MILES
CAUTION ACCIDENT MERGE RIGHT	NORTH 60 CONNECTOR CLOSED DETOUR AHD	5 AND 60 CONNECTOR CLOSED DETOUR AHD
SLOW FWY CLOSED DETOUR AHD		

Mimimum Information Requirements for Diverting Traffic Off a Freeway

Most of the studies reported in the literature polled drivers as to priorities of information. The results have shown rather consistent results in priorities. For example, distance or location, degree of incident, lanes blocked, etc., have generally been rated high. Travel time and delay have generally been rated low. These studies have indicated priorities but do not give any clue as to the minimum amount of information drivers need to make decisions concerning:

a. Diverting from a freeway to another freeway or freeway section.
b. Diverting from the freeway to the frontage road and/or arterial streets around the incident.
c. Diverting from the freeway to the frontage road and/or arterial streets to final destination.

Research is needed to identify the minimum information requirements of drivers to enable them to evaluate freeway traffic conditions and to decide upon an appropriate action.

Information During Non-Incident Conditions - To Display or Not to Display

There is a division of opinion whether an operating agency should display messages during non-incident conditions. One school of thought is to display a message at all times so that the motorists are aware the system is operating and that conditions are "normal." Questionnaire studies (5, 8) have shown that motorists desire to have some message displayed rather than seeing a blank sign. One issue that needs to be resolved through further study is whether this "desire" is really a "need." Another school of thought is that if there is a need to know that conditions are "normal", this can be accomplished with signs that are normally blank unless an incident occurs.

Displaying information during the off-peak periods in the absence of incidents is not a difficult task. Experience by the author, however, has shown that because of the rapidly changing conditions on the freeway, information signing during non-incident peak period conditions becomes very complex. The dynamics of the traffic stream require continuous surveillance and frequent message changes and is perhaps the most difficult part of operating changeable message signs. The problem is compounded when different sign operators are used since it is extremely difficult to achieve consistency in sign operation among operators in these cases. An operating agency, however, can develop more consistent sign operation guidelines when incidents occur. Inconsistency in operation may materially hamper the effectiveness of the signs. The problem can be somewhat reduced with fully automated sign operation. However, every system is currently operated manually even though operators rely on computer displayed data for message selection in some cases.

A human factors concept is: *Don't tell a motorist something he already knows*. Some experts are concerned that a peak period commuter who daily sees the same messages of conditions he is already in, or knows he will be in, will rapidly become disenchanted with the signing system. For example, a commuter may see the following message every day: SLOW TRAFFIC/1 MILE AHEAD. Some observers believe the message is unnecessary since the commuters are aware of the daily bottleneck during the peak period. However, the information would be extremely useful during an off-peak period since it would be associated with a bottleneck resulting from an incident and the motorist would not normally expect the slow-down.

Some individuals are very concerned about the operating costs of certain types of changeable message signs and question the need to display messages in the absence of incidents, particularly during the off-peak period. Others believe that messages should be displayed when the system is operational, especially during the peak periods because the public may negatively react to the expenditure for the system when they observe blank signs. The following paragraphs summarize research concerning messages and messages currently used in operating systems in the U.S. during non-incident conditions.

Heathington, et al (5) administered a questionnaire to 732 drivers residing in the Chicago area. Table 12 summarizes the studies of 6 descriptors for uncongested freeways. Each descriptor included the length of freeway to which the message applied (NEXT 3 MILES). The results indicate that the message

SPEED 45 TO 55 MPH/NEXT 3 MILES

was the most preferred descriptor followed closely by

FREE-FLOWING TRAFFIC/NEXT 3 MILES

and

UNCONGESTED/NEXT 3 MILES

Table 12

SCALING OF DESCRIPTORS FOR NO CONGESTION (5)

WORD DESCRIPTOR	APPROXIMATE SCALE VALUE*
SPEED 45 TO 55 MPH/NEXT 3 MILES	0.85
FREE-FLOWING TRAFFIC/NEXT 3 MILES	0.65
UNCONGESTED/NEXT 3 MILES	0.60
TRAVEL TIME 3 TO 8 MINUTES/NEXT 3 MILES	0.05
EXTRA DELAY 0 MINUTES/NEXT 3 MILES	0.05
(Blank Sign)	0.00

*Sample size: 732 subjects

Few people preferred travel time, delay information, and blank signs.

The results of studies by Dudek and Jones (36) of motorists' preferences for words that describe usual traffic conditions (in the absence of incidents) are shown in Table 13. The results show that, of the six descriptors presented to the respondents, the words

NORMAL

FREE FLOWING TRAFFIC

and NORMAL TRAFFIC

were most preferred for both the peak and off-peak periods.

Some caution must be exercised in interpreting the results. First of all, the preferences relate only to the specific and limited number of messages presented to the respondents. It is not clear what preferences would have been exhibited if descriptors such as

SLOW TRAFFIC

STOP AND GO TRAFFIC

HEAVY TRAFFIC

and CONGESTION

had been included in the alternatives for peak period signing. Secondly, the respondents were all commuters and were therefore familiar with traffic operations experienced daily on specific freeways. The effects that the preferred messages would have on unfamiliar motorists are not known. It would have been beneficial if the researchers had interviewed unfamiliar motorists.

Comparable results were obtained by Case, et. a. (7), as shown in Table 14 of the nine messages studied by Case to describe "no congestion" conditions

Table 13

PREFERENCES OF WORDS FOR DESCRIBING USUAL TRAFFIC CONDITIONS (36)

PEAK PERIODS		OFF-PEAK PERIODS	
WORD DESCRIPTOR	PERCENT SELECTED*	WORD DESCRIPTOR	PERCENT SELECTED*
NORMAL TRAFFIC	33	NORMAL TRAFFIC	26
FREE FLOWING TRAFFIC	27	FREE FLOWING TRAFFIC	25
NORMAL	24	NORMAL	25
CLEAR	6	CLEAR	13
UNCONGESTED	5	UNCONGESTED	6
NO DELAY	4	NO DELAY	5
	100		100

*Sample size: 305 subjects

Table 14

RESPONSES TO "NO CONGESTION" TYPE MESSAGES (7)

WORD DESCRIPTOR	PERCENT SELECTED**
NORMAL*	75.6
NORMAL TRAFFIC	45.9
TRAFFIC NORMAL	31.5
NORMAL FLOW	28.2
FREE FLOW	23.2
NO CONGESTION	20.6
- - - *	13.8
OK*	11.1
(Blank)*	3.8

* Generally shown with heading FREEWAY CONDITION

**Sample sizes ranged between 29 and 108 subjects (presumably off-peak) the following messages were most preferred:

NORMAL

NORMAL TRAFFIC

TRAFFIC NORMAL

The word OK (11.1%) and a blank sign (3.8%) were least preferred. In a follow-up study Case (7) found the order of preference of three descriptors to describe "no congestion" conditions was as follows:

NORMAL	(57%)
OK	(24%)
---	(11%)

A survey of existing sign installations indicates that only the signs in Houston and Denver have traffic descriptor messages that would generally be used during the off-peak periods in the absence of incidents. The signs in Houston (17) display the message

OK

whereas, the signs in Denver (18) have the capabilities to display

FREE FLOWING TRAFFIC

The signs in Houston are operated during off-peak periods when conditions are normal. (The author is not certain whether the Denver system displays messages during these times.)

The California Department of Transportation (21) initially displayed safety and other traffic related messages during the off-peak period on the

Santa Monica Freeway in Los Angeles but soon abandoned the concept after receiving numerous calls from citizens during the initial energy crisis criticizing the agency for wasting energy. California has since adopted a coding approach in an attempt to inform the motorist that the system is operational, but no unusual events have occurred on the freeway. The code is to illuminate three lamps in the matrix signs as follows:

●●●

Pennsylvania (23) proposes to always display a message on the Penn-Lincoln Parkway variable message signs even when traffic and roadway conditions are normal. The feeling is that if no message is displayed, drivers do not know whether the sign is inoperative, or if traffic and roadway conditions are such that no message need be displayed. The problem, the agency feels, is particularly true with bulb matrix signs. Preliminary studies by Stockton et al. (37) have shown that approximately 52 percent of Houston freeway motorists thought that the traffic condition was light and normal when no message was displayed. The remainder either felt the surveillance office was closed, the equipment had failed, or simply were not sure.

Pennsylvania (23) proposes to display the message

NORMAL TRAFFIC

during occasions when no other message applies.

Some researchers and operating agencies have elected not to use the word

NORMAL

It is not definite enough and it can beam different things to different people, particularly during various times of the day.

Dudek and Jones (33) evaluated nine word messages for describing "unusual" traffic conditions. The results, shown in Table 15, indicate that the message

HEAVY CONGESTION

was the preferred descriptor for peak periods; whereas the message

SLOW TRAFFIC

was preferred during the off-peak period. In both cases, however, the messages were selected by less than 30 percent of the respondents. The researchers believed that it was difficult to draw any definite conclusions from their analysis since no descriptor was selected by a majority. They also felt that the large number of alternatives offered too many selection possibilities and a more restricted list and a better classification of alternatives may have provided more meaningful results.

Case et al. (7) studied 14 messages that describe moderate congestion. The results from sample sizes ranging from 34 to 65 respondents is shown in Table 16. Three messages elicited more than 50 percent favorable responses

FREEWAY CONDITION/CONGESTION BEGINS/2 MILES AHEAD

REDUCE SPEED

MODERATE/CONGESTION/AHEAD

The message receiving the least favorable responses was the concept of travel time.

Case also studied the concept of heavy congestion using 16 alternate messages using sample sizes ranging from 34 to 74 (Table 17).

Table 15

PREFERENCES OF WORDS FOR DESCRIBING UNUSUAL TRAFFIC CONDITIONS (36)

PEAK PERIODS		OFF-PEAK PERIODS	
WORD DESCRIPTOR	PERCENT SELECTED*	WORD DESCRIPTOR	PERCENT SELECTED*
HEAVY CONGESTION	26	SLOW TRAFFIC	29
JAMMED TRAFFIC	16	CONGESTION	15
TRAFFIC JAM	11	STOP AND GO TRAFFIC	11
STOP AND GO TRAFFIC	11	HEAVY CONGESTION	10
CONGESTION	10	HEAVY TRAFFIC	10
HEAVY TRAFFIC	9	JAMMED FREEWAY	8
EXTRA DELAY	7	TRAFFIC JAM	7
SLOW TRAFFIC	6	EXTRA DELAY	5
FREEWAY BREAKDOWN	3	FREEWAY BREAKDOWN	3
	100		100

*Sample size: 505 subjects

Table 16

RESPONSES TO MODERATE CONGESTION TYPE MESSAGES (7)

WORD DESCRIPTOR	PERCENT SELECTED**
CONGESTION BEGINS/2 MILES AHEAD*	54.3
REDUCE SPEED	52.9
MODERATE/CONGESTION/AHEAD	52.2
REDUCE SPEED/NEXT 3 MILES/MODERATE CONGESTION	44.2
CAUTION	31.8
MODERATE/CONGESTION AHEAD*	28.3
DELAY AHEAD	26.4
DELAY AHEAD/REDUCE SPEED TO 30 MPH/NEXT 3 MILES	23.0
MODERATE CONGESTION/15-30 MPH/NEXT 3 MILES	20.0
MODERATE/DELAY AHEAD*	19.6
15-30 MPH/NEXT 3 MILES/MODERATE CONGESTION	18.0
CAUTION/15-30 MPH TRAFFIC/NEXT 3 MILES	15.0
USE CAUTION	8.8
MODERATE CONGESTION/TRAVEL TIME 5 MIN/NEXT 3 MILES	7.6

*Shown with heading FREEWAY CONDITION

**Sample sizes range between 34 and 65 subjects

Table 17

RESPONSES TO HEAVY CONGESTION TYPE MESSAGES (7)

WORD DESCRIPTOR	PERCENT SELECTED**
HEAVY/CONGESTION/AHEAD	63.6
HEAVY/CONGESTION/AHEAD*	55.6
REDUCE SPEED/NEXT 3 MILES/ACCIDENT AHEAD	41.0
ACCIDENT AHEAD/USE CAUTION/NEXT 3 MILES	30.7
5 MIN DELAY/NEXT 2 MILES*	28.8
USE/EXTREME/CAUTION	26.4
DELAY AHEAD	26.4
CAUTION/LEFT LANE CLOSED/3 MILES AHEAD	25.0
EXTREME CAUTION	24.3
REDUCE SPEED	23.5
EXTREME CAUTION/5-15 MPH/NEXT 3 MILES	18.1
CONGESTION BEGINS/2 MILES AHEAD*	17.7
DELAY AHEAD/REDUCE SPEED TO 15 MPH/NEXT 3 MILES	15.9
5-15 MPH/NEXT 3 MILES/HEAVY CONGESTION	11.6
CAUTION/NO. 1 LANE CLOSED/3 MILES AHEAD	10.0
HEAVY CONGESTION/TRAVEL TIME 10 MIN/NEXT 3 MILES	5.1

*Shown with heading FREEWAY CONDITION

**Sample sizes ranged between 34 and 74 subjects

The descriptor

HEAVY CONGESTION AHEAD

which was shown in both a three-line message and a two-line message with the heading FREEWAY CONDITION, showed 63.5 and 55.6 percent respectively, for a combined 58.9 favorable response. The least liked message again was the concept of travel time.

In contrast with Case, Heathington, et al. (5) found that speed information was the perferred descriptor for moderate congestion (Table 18). The messages

SPEED 20 to 30 MPH/NEXT 3 MILES

HEAVY, STEADY, TRAFFIC FLOW/NEXT 3 MILES

MODERATE CONGESTION/NEXT 3 MILES

were preferred (in the above order) well above delay, travel time, and blank signs.

Heathington also found that the descriptor

ACCIDENT

apparently is of significant interest to motorists for heavy congestion conditions (Table 19). The message

ACCIDENT/HEAVY CONGESTION/NEXT 3 MILES

was preferred over

SPEED 5 to 15 MPH/NEXT 3 MILES

HEAVY CONGESTION/NEXT 3 MILES

and STOP AND GO TRAFFIC/NEXT 3 MILES

Table 18

SCALING OF DESCRIPTORS FOR MODERATE FLOW (5)

WORD DESCRIPTOR	APPROXIMATE SCALE VALUES*
SPEED 20 TO 30 MPH/NEXT 3 MILES	0.95
HEAVY, STEADY, TRAFFIC FLOW/NEXT 3 MILES	0.80
MODERATE CONGESTION/NEXT 3 MILES	0.70
EXTRA DELAY 0 TO 10 MINUTES/NEXT 3 MILES	0.40
TRAVEL TIME 5 TO 15 MINUTES/NEXT 3 MILES	0.30
(Blank Sign)	0.00

*Sample size: 732 subjects

Table 19

SCALING OF DESCRIPTORS FOR EHAVY CONGESTION (5)

WORD DESCRIPTOR	APPROXIMATE SCALE VALUES*
ACCIDENT/HEAVY CONGESTION/NEXT 3 MILES	1.40
SPEED 5 TO 15 MPH/NEXT 3 MILES	1.00
HEAVY CONGESTION/NEXT 3 MILES	0.95
STOP AND GO TRAFFIC/NEXT 3 MILES	0.95
EXTRA DELAY 10 TO 20 MINUTES/NEXT 3 MILES	0.70
TRAVEL TIME 15 TO 25 MINUTES/NEXT 3 MILES	0.55
(Blank Sign)	0.00

*Sample size: 732 subjects

Delay, travel time, and a blank sign, again, were <u>least</u> preferred.

Many of the messages commonly used during the peak period in the absence of incidents have been partly addressed in previous sections entitled *Warning of Slow Traffic*, and *Travel Time, Delay Time, and Average Speed Information*. Specific messages currently or previously used in operating systems are as follows:

Houston:	SLOW TRAFFIC/X MI AHEAD
	OK/X MILES AHEAD
Kentucky:	CONGESTION AHEAD/PREPARE TO STOP
Denver:	HEAVY CONGESTION/NEXT X MILES
	HEAVY CONGESTION/X MILES AHEAD
	HEAVY CONGESTION/BE PREPARED TO STOP
	STOP AND GO TRAFFIC/NEXT X MILES
	STOP AND GO TRAFFIC/X MILES AHEAD
	STOP AND GO TRAFFIC/BE PREPARED TO STOP
Minneapolis:	CONGESTION AHEAD/REDUCE SPEED
	CONGESTION AHEAD/PREPARE TO STOP
	CONGESTION AHEAD/5-10 MIN DELAY
	CONGESTION AHEAD/10-20 MIN DELAY
New Jersey:	REDUCE SPEED/CONGESTION AREA
	(Variable Speed Limit Signs)
Baltimore:	SLOW/X/MIN - AHEAD/X/MIN

Detroit:	(Variable Speed Signs)
Los Angeles:	SLOWING AHEAD
	SLOWING AHEAD/X MILES AHEAD
	HEAVY TRAFFIC/NEXT X MILES
	HEAVY TRAFFIC/TO (street)
	X MINUTES TO/HARBOR FWY
	X MINUTES TO/SAN DIEGO FWY
	HARBOR FWY NORTH/EXIT CONGESTED
	405 FWY SOUTH/HEAVY TRAFFIC
	405 FWY SOUTH/EXIT CONGESTED
	USE CAUTION AHEAD
Cincinnati:	I-75 CONGESTED
	I-75 SOUTH/CONGESTED
	I-71 EXIT 1D/CONGESTED
	RIGHT LANES/CONGESTED AHEAD
	LEFT LANES/CONGESTED AHEAD
	FREEWAY/CONGESTED AHEAD
Pennsylvania:	HEAVY CONGESTION
	LIGHT CONGESTION

INFORMATION ON THE FRONTAGE ROAD AND ARTERIALS

Ramp Control

Some of the first studies with ramp control signs were conducted in Detroit in the spring of 1960 as preliminary tests to measure the effectiveness of the signs prior to a larger installation on the John C. Lodge Freeway. An experimental ramp control sign was installed at the Trumbull Avenue entrance ramp to the westbound lanes of the Edsel Ford Freeway. Trumbull Avenue is an arterial that crosses the freeway in a section without a frontage road. Thus, the entrance ramp connects directly from Trumbull Avenue. The installation consisted of two back-to-back blank-out type signs bearing the legend DON'T ENTER mounted on a mast arm so they were visible to both directions of on-coming Trumbull Avenue traffic. The results of this experiment were documented in a report by Belprez and Dudek (38).

In general, the experiment proved that motorists read the sign when placed in a visible location. But while the motorists read the sign, they did not always obey it. Several drivers were observed looking intently at the sign and then looking around to determine if the ramp was still usable. If the ramp was clear of obstructions, the drivers entered the freeway ramp.

The "sheep" effect was also noted during this experiment. When one motorist entered the ramp against the sign message, others would follow. But if the lead motorist in a platoon obeyed the sign, the remainder of the motorists did likewise.

Similar signs (Figure 15) were later installed at nine ramps on the John C. Lodge Freeway (39). In addition, trailblazer signs were used to mark alternate routes. These signs advised motorists how to proceed along the alternate route to reach the next entrance point on the freeway. The signs

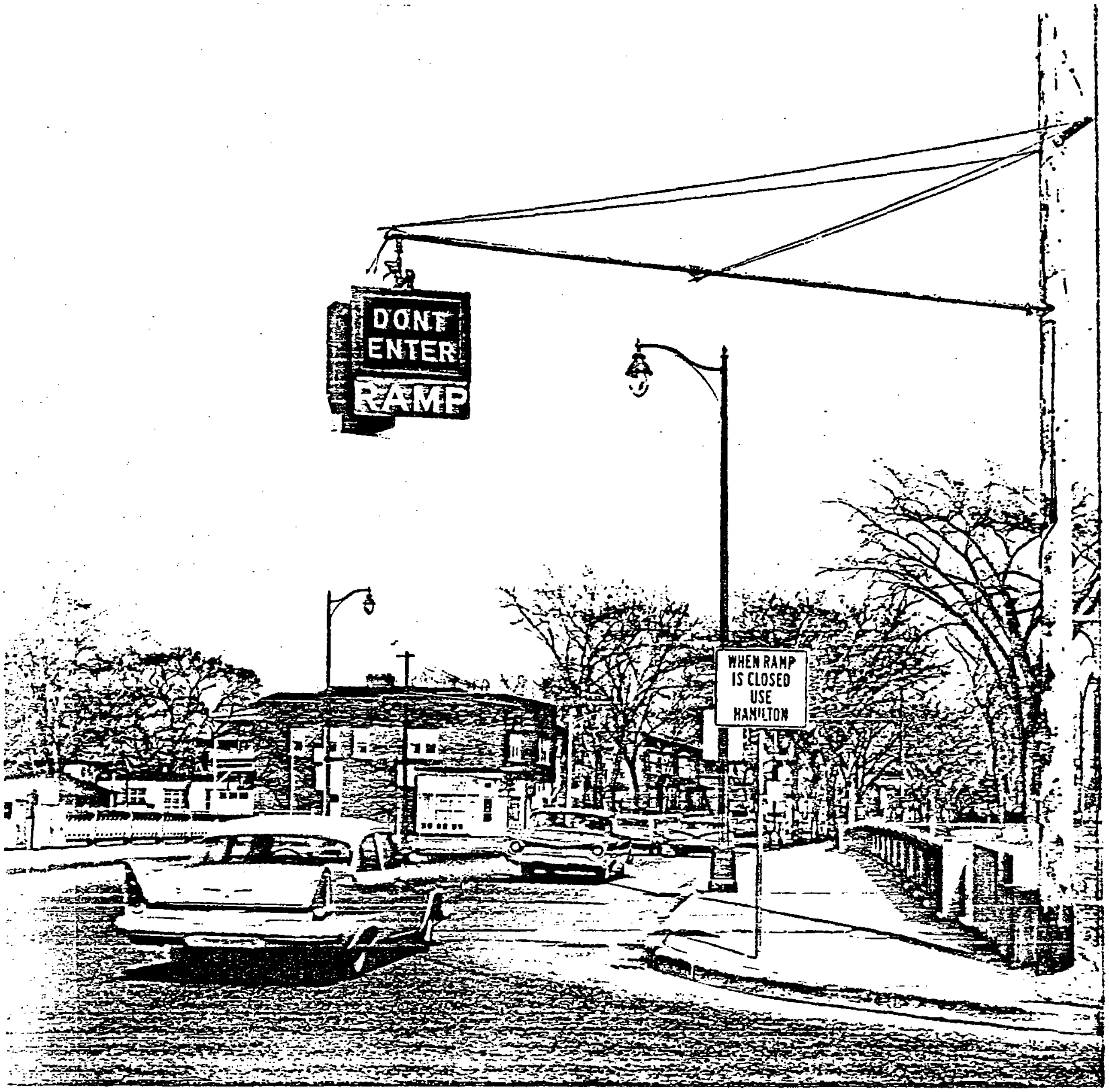


Figure 15 - Ramp Control Sign - Detroit (39)

were designed so the direction of the arrow could be manually changed.

The ramp control signs were used to divert ramp traffic on the frontage roads and arterials intersecting the freeway during the peak periods to balance freeway demands in attempts to alleviate recurrent congestion. They were also used during both the peak and off-peak periods when incidents occurred.

The use of the ramp control signs to balance demands to alleviate recurrent congestion was not effective. Initially there was a high compliance. However, as soon as motorists learned the signs were advisory and not enforceable, the effectiveness of the signs quickly deteriorated. The effectiveness of the ramp control signs during off-peak incidents was also questionable. There was a tendency for drivers to look at the traffic flow on the freeway (freeway was below street elevation), if conditions seemed satisfactory to them, they entered the freeway (40).

These signs were later modified by Courage (41) as part of research conducted by the Texas Transportation Institute and sponsored by NCHRP. The blank-out message on the new sign read:

FREEWAY

STOPPED AHEAD

Since these signs were only one part of a new and larger signing system, the contribution of this sign and message to the overall effectiveness of the system is not known.

Courage (41) also reported on the effectiveness of newer types of ramp control signs. 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 (an extension of the frontage road) where drivers must make a decision whether to turn to use the freeway.

Figure 16 shows one of 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 other words, the control strategy was to balance delay on the ramps. The following mode of operation was employed:

1. When there was no delay at the ramp adjacent to the sign location, the "OK" indication, the adjacent ramp name, and the ramp arrow, were illuminated in green. Other ramp legends and arrow symbols were not illuminated.
2. When there was delay at the adjacent ramp, the "delay" message was illuminated in red and the names of all the remaining downstream ramps were illuminated in either green or red depending upon the congestion at the ramp.
3. When the downstream ramp names were illuminated, the vertical alternate route arrows were also illuminated in green as far as the last green ramp and red beyond that point.

As a continuing phase of the NCHRP research study, the University of Michigan expanded the motorist information research activity in 1969 (42, 43, 44, 45). When the University of Michigan (U of M) first considered the extension of the alternate route system, the researchers concluded that there were design deficiencies in the existing ramp signs and that they should be replaced.

Although no information was available on public response to the existing signs, the U of M researchers believed that presenting information on one sign

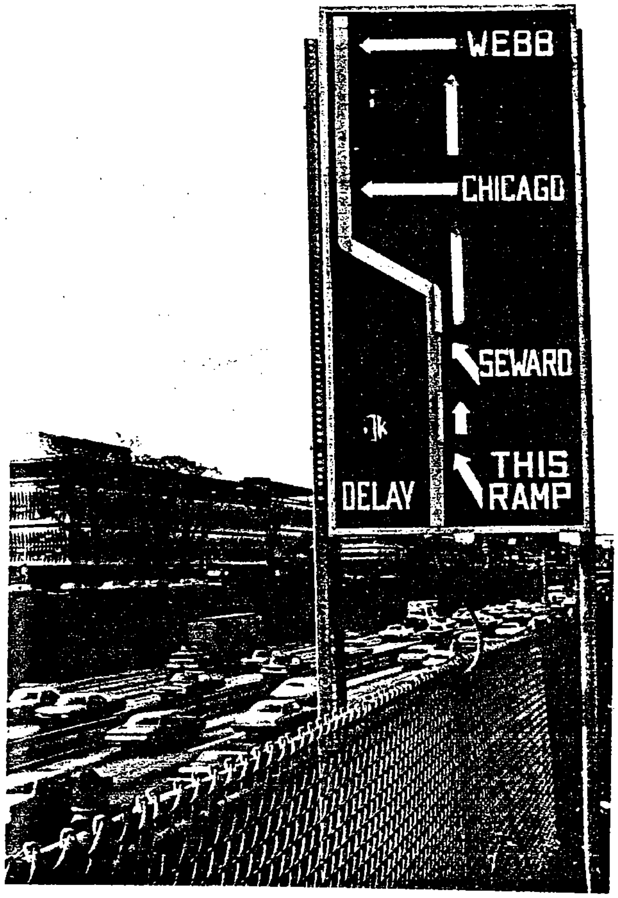


Figure 16 - Freeway Ramp Information Sign - Detroit (41)

of four ramps was not necessary and was potentially detrimental to sign effectiveness. Thus, they decided to reduce the maximum number of ramp condition indications to three. Additional modifications were made to increase legibility and to provide "positive" guidance.

The signs were evaluated in terms of the following measures of effectiveness:

1. Sign visibility
2. Sign legibility
3. Driver comprehension of the presented message
4. Driver obedience and persistence in following an alternate surface street routing
5. Changes in traffic routing patterns induced by the signs.

Ten subject drivers were directed to drive along a route which passed three of the ramp condition information signs in order to study sign visibility and legibility. The distances at which they first perceived each sign and then were able to read the sign messages were recorded by an observer in the vehicle. The tests were conducted for the TTI signs. These signs were then removed and replaced with the U of M signs. Studies were then conducted with the new signs using the same subjects.

The study results indicated an increase in visibility and legibility distances with the newer signs. The U of M researchers, however, point out that the increases for the signs may be biased by the subjects being more familiar with the test and types of signs by the time the newer signs were evaluated.

Results of a questionnaire evaluation and a test subject comprehension study indicated that the signs were less effective than anticipated. Less than half the ramp users recalled receiving information on the signs. A study using twelve test subjects also revealed that only 13 percent responded correctly to the first sign. Response improved, however, with learning experience. Field studies also revealed that the newer sign was ineffective in diverting sufficient vehicles away from a high volume entrance ramp. Ramp signs at lower volume ramps were somewhat more effective.

In their report, the U of M researchers made several observations on the reasons for less than anticipated level of correct sign usage. Their studies indicated that frequent ramp users were less likely to use the signs than less frequent users. They speculated that the familiar drivers in general preferred the freeway. It may be, however, that commuter drivers will not respond to manipulation of ramp traffic to balance ramp delay especially when they know what the traffic conditions will be when they enter the freeway. It would appear, and the U of M researchers also indicated, that drivers would be more apt to respond to freeway congestion information.

The U of M researchers also cited misinterpretation of the ramp signs as another of many reasons why drivers did not respond to the signs as expected.

Three issues seem to result from the U of M studies. First of all, the signs, although presenting a large amount of information and detailed information about ramp conditions, were very difficult for the average driver to understand. Secondly, motorists are not necessarily naive drivers and will not as a rule respond to diversion solely to encounter less delay on another ramp, particularly when they must travel through one or more signalized intersections. Thirdly, it appears that drivers will respond to information of unusual congestion due to freeway incidents but will not divert when freeway conditions are congested due to regular peak period demand-capacity problems. In the latter case, they know what to expect and they accept it willingly on a daily basis.

Although the signs designed by Courage (TTI) and Pretty and Cleveland (U of M) had good intentions, that is to give as much information as possible by using diagrammatic type signs, their designs were less than successful. Other researchers (33, 34) have observed that drivers require simpler type designs. The current trend with operational changeable message sign systems is toward the use of word messages as brought out so vividly in the previous chapter.

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 in the late 1960's with a prototype sign to inform the motorists traveling on the arterial streets of freeway and entrance ramp conditions. These experiments have been documented by Hoff (46). 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 delays 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 17). 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

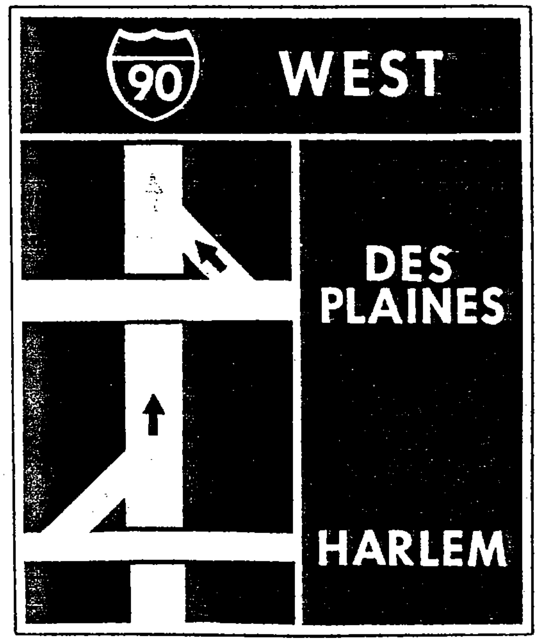


Figure 17 - Schematic of Freeway Information Sign - Chicago (46)

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 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.

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 were located 300 feet in advance of the intersections. Each sign was externally illuminated during darkness by flourescent 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 (46) 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 driving.

In addition to ramp control signs discussed earlier, University of Michigan also studied route diversion variable message signs in the John C. Lodge freeway corridor. One variable message sign was placed overhead on a major arterial (West Grand Blvd.) that intersects with the John C. Lodge Freeway and carries high volumes of traffic from a major generator to the freeway. The sign was placed upstream of a one-way street (Second Avenue) that runs parallel to the freeway and is a good alternate route for drivers heading north. Seven message states were possible.

State

1. NO MESSAGE (arrows only)
2. USE SERVICE DRIVE AND SEWARD RAMP
3. USE SERVICE DRIVE AND CHICAGO RAMP
4. USE SERVICE DRIVE AND HAMILTON
5. DELAY AHEAD USE SECOND AND SEWARD
6. DELAY AHEAD USE SECOND AND CHICAGO
7. DELAY AHEAD USE SECOND AND WEBB

The message appeared in a panel below the fixed message NORTHBOUND LODGE FREEWAY.

In the uncongested message state (State 1), a straight ahead directional arrow was illuminated on both sides of the message panel. For all other messages, however, the arrow display appeared only on the right side of the sign.

The messages were designed to support and augment the messages displayed on the West Grand Boulevard ramp condition information sign. Of the seven possible message states, four correspond exactly to the information sign by directing motorists up West Grand Boulevard to the Lodge Service Drive and then along the Service Drive to the recommended ramp of entry, either West Grand Boulevard, Seward or Chicago, or farther along the alternate route if the degree of congestion was severe (States 1, 2, 3, and 4). Two of the remaining three messages recommended usage of the Seward or Chicago ramps, but advised use of Second Avenue rather than the Service Drive (States 5 and 6). State 7, DELAY AHEAD /USE SECOND AND WEBB, led the driver to Webb and another dynamic sign at Hamilton. Arrows on the right of the sign indicated the directional equivalents of the street name directions except when entrance at West Grand Boulevard was advised. In this instance an arrow which points straight ahead appeared on both the left and right sides of the sign.

In addition, trailblazer signs were designed, supplied and erected (Figure 18). The trailblazer signs were designed to guide freeway drivers to ramps other than the West Grand Boulevard ramp. The signs consisted of the fixed legend NORTHBOUND LODGE FREEWAY framed by two arrows, only one of which was illuminated at any time. Four different signs were developed to suit right turns (Design A), left turns from a one-way street (Design B), left turns from a two-way street (Design C), and left turns from a one-way street with two-way traffic ahead (Design D). Only the Design C sign was mounted over the roadway. The other signs were erected at the side of the road corresponding with the turning direction and at the lowest height permitted by City of Detroit requirements. In addition to the variable guide signs, more than 100 static guide signs were installed along the alternate routes.

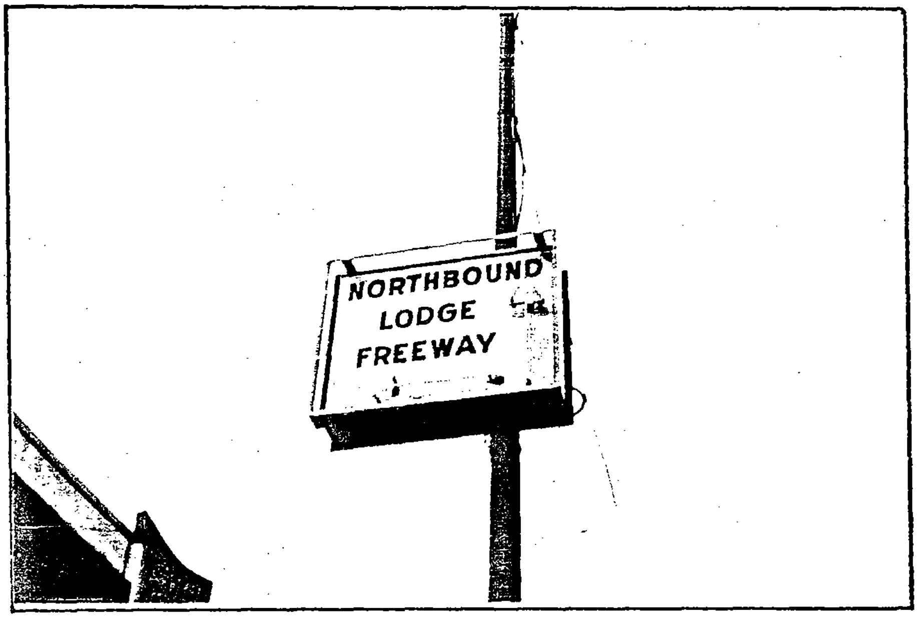


Figure 18 - Changeable Trailblazer Guide Sign - Detroit (45)

The signs according to specifications were to have a standard highway green or black background. The messages could be in red, green, or white. If any messages or arrows were green, sufficient contrast had to be provided by means of a black background. This last provision, however, was modified by the lowest bidder whose design included a white background. Thus, the signs were in highway green and white, appropriate colors for freeway guide signs. Also, all dynamic directional arrows were in green. It was believed that the green display by way of its positive nature implies an affirmative action and was best for a guide sign of this type.

Four separate tests were carried out to evaluate the effectiveness of the information system. First, the visibility of the signs was checked for various air temperatures and weather conditions. Second, a human factors study was carried out to measure observance and ability to follow the sign.

The third and fourth evaluation studies were concerned with the response of corridor traffic to the combined information and control system. These two types of studies focused on microscopic behavior of variable display decision points and a macroscopic study of overall performance.

The lowest bidder for the variable signs proposed green neon arrows on a white background for all arrow displays on the 17 signs utilizing arrows. It was known to the project staff that green neon, unlike red neon, fades badly in cold weather. The proposal of the lowest bidder was accepted, however, because of the limited funds available.

The variable message sign at West Grand Boulevard and a sample of trailblazer signs throughout the freeway corridor were evaluated in terms of their frequency of being seen, understood, and obeyed by paid subjects. Twenty-eight subjects, all college students, were used in this study.

The study results revealed that on the coldest day in conditions of sunlight, the mean visibility distance for the trailblazer signs (green neon arrows on white background) was only 30 feet. Although 87 percent of the test subjects responded correctly to the trailblazer sings, only 55 percent (7 or 13) made the correct choice when observing the route diversion signs on West Grand Boulevard, even though a large percentage (93 percent) sighted the diversion signs.

Field evaluation studies of traffic patterns indicated that, although there was an increase of drivers (average of 3 percent) choosing to take the recommended route displayed on the route diversion sign and trailblazer signs, there is no reason to believe that it was due to the signs. The difference may have been due to normal daily fluctuations in traffic. The studies also indicated that drivers that did respond were more apt to do so during the peak period in comparison to off-peak.

The U of M researchers suggested that the evaluation findings pointed to weaknesses in both the design and placement of the signs. They believed that the 17-foot height at which most of the trailblazer signs were placed above the sidewalk of roadway was too high and increased the problem of viewing the dynamic display. At that height, the signs were intermingled among the advertising signs placed on buildings abutting the road or blended with other types of background (trees, etc.). The researchers felt that this helped account for the fact that many of the trailblazers were not sighted by cooperative subject drivers.

Even for the motorist familiar with the Lodge Freeway Corridor, there was a fundamental difficulty in the sign as the green neon arrows tend to "fade" and become almost invisible in cold weather and bright sunlight. A slight tendency for green to fade could be tolerated, especially when the advantages of a familiar, positive command are weighed against the use of any other color. The extreme fading found in this study, however, confirms the inadequacy of this type of display in the cold environment.

In contrast, the variable message route diversion sign used standard white lettering on a green background and red neon messages. The red neon showed no tendency to fade. This sign also used a green arrow to complement the red message and thus minimized the negative connotation of red. Studies also cast doubt on whether or not all seven messages displayed on the variable message sign were necessary. The researchers concluded that a properly-designed trailblazer could have been equally satisfactory.

The U of M researchers speculated that, in addition to the design and placement problems, disobedience could have been caused by other problems. These included failure on the part of the driver to see the signs, inability to react in time to the message, unfamiliarity with the corridor, doubt about travel time savings, disbelief in the sign messages and the environment of the surface streets. In their study of overall effectiveness, it was found that, due generally to communication problems with leased lines, detector operations were erratic. This resulted in the signs sometimes showing incorrect messages based on a lack of accurate flow information. Under these circumstances, a driver diverting to a congested link may have lost confidence in the ability of the signs to show the correct paths.

The U of M researchers felt that it was difficult to make a definite statement from the results of their study on whether or not diversion before or after reaching a freeway service drive is desirable. This is because of the complexity of the Lodge freeway corridor. It appeared to them, however, that if a freeway had a fairly straight alignment, the designation of only one alternate route would be preferable thus reducing the number of signs and the costs. This would necessitate that cross-street traffic from one side of a freeway be diverted to the other side. Signs to do this might have to be larger than simple trailblazers. Also, an alternate route of sufficient capacity would have to be available to handle diversion from both sides of a freeway.

Based on sign laboratory studies involving driver evaluations of real-time displays, TTI researchers concluded that drivers prefer a simpler type display than the diagrammatic signs used on the John C. Lodge freeway by Courage and the U of M researchers (5). The research also identified basic information requirements that drivers have in a corridor.

Three rotating drum signs were installed in the North Central Expressway Corridor in Dallas along Skillman Avenue, a major route which roughly parallels the expressway (47). The signs were located upstream of where drivers may make a decision to either go to the expressway or stay on the arterial to reach downtown.

The purpose of the signs is to provide drivers with information on travel conditions to be expected on the North Central Expressway. In some cases, an alternate route which would avoid the congestion will be suggested. In general, drivers are not directed to an alternate route unless there is a significant time savings.

Each sign has four rotating drums and each drum has four sides for messages. At least one side of each drum is blank, so that the sign may be "blanked out" when not in use. The possible messages for each are shown in Table 20. Typical messages are shown in Figure 19.

Figure 19a shows the message displayed when the freeway is operating normally for that time of day. The overall sign is green with OK displayed in white letters on a green background. The message displayed when speeds drop below normal levels can be seen in Figure 19b. The SLOW panel is yellow with black letters while the mileage panel, which indicates the distance congestion extends on the freeway, is green.

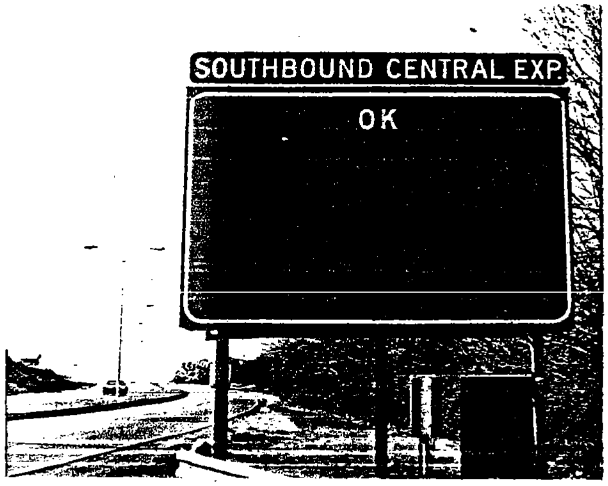
Figure 19c shows the message displayed when a freeway lane is physically blocked and an alternate route is suggested. In this case, the lane blockage is north of Lovers Lane and south of Loop 12 and drivers may avoid it by continuing on Skillman to Lovers Lane and then to the freeway. The lane blocked message is in white letters on a red background. The remainder of the sign is green with white letters.

Figure 19d shows the sign being updated (bottom drum) to reflect a worsening condition as drivers will be directed farther south to Mockingbird. In this case, the incident is located south of Lovers Lane. The message displayed when the freeway incident is south of Mockingbird and the driver is directed to use the arterial to downtown appears in Figure 19e.

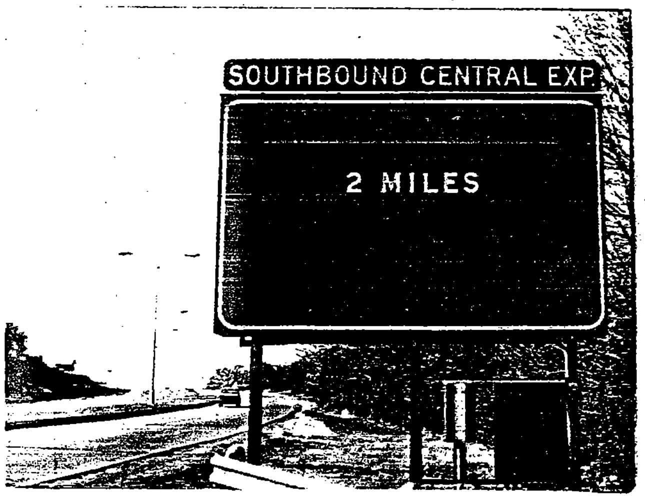
Table 20

MESSAGES AVAILABLE ON VARIABLE MESSAGE SIGNS - DALLAS (47)

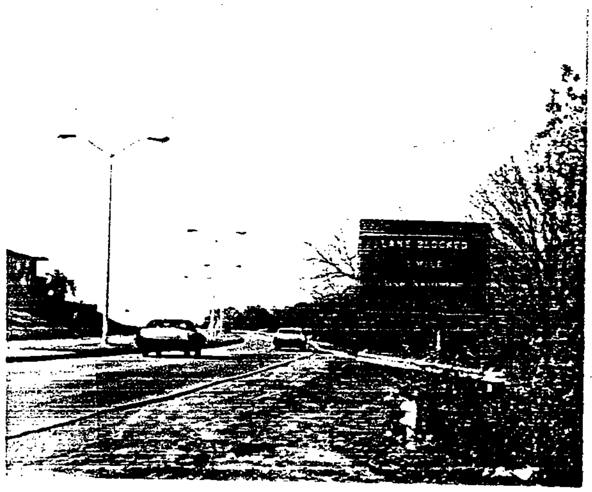
	FOREST LANE SIGN	LOOP 12 SIGN	LOVERS LANE SIGN
DRUM 1 (TOP)	OK SLOW LANE BLOCKED BLANK	OK SLOW LANE BLOCKED BLANK	OK SLOW LANE BLOCKED BLANK
DRUM 2	1 MILE 3 MILES 5 MILES BLANK	1 MILE 2 MILES 3 MILES BLANK	1 MILE 2 MILES 3 MILES BLANK
DRUM 3	USE SKILLMAN BLANK BLANK BLANK	USE SKILLMAN BLANK BLANK BLANK	USE SKILLMAN BLANK BLANK BLANK
DRUM 4	TO LOOP 12 TO LOVERS LANE TO DOWNTOWN BLANK	TO LOVERS LANE TO MOCKINGBIRD TO DOWNTOWN BLANK	TO MOCKINGBIRD TO DOWNTOWN BLANK BLANK



(a)



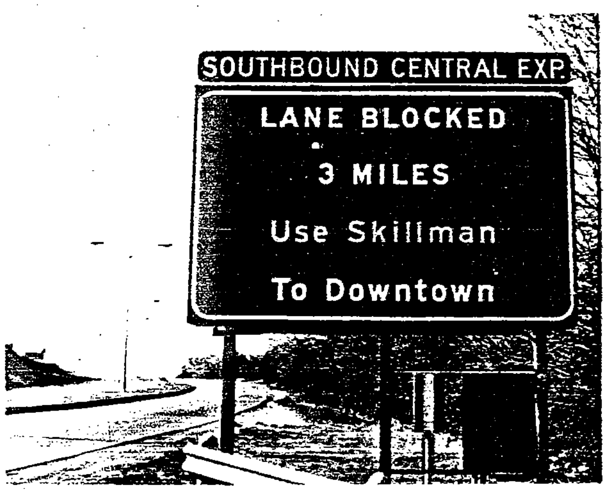
(b)



(c)

Figure 19 - Typical Messages on Rotating Drum Signs on Skillman Ave. in Dallas (47)

(d)



(e)

Figure 19 (Cont.) - Typical Messages on Rotating Drum Signs on Skillman Ave. in Dallas (47)

INFORMATION AT MAJOR GENERATORS

Limited research has been devoted to developing systems for communicating with drivers at major generators. The signing system in Cincinnati is designed to guide motorists to parking facilities near a stadium, but in general, few systems are designed to give drivers freeway traffic information as they leave a major generator. The Los Angeles and Chicago Freeway Surveillance and Control Systems (21, 48) have experimented with direct information links to local radio stations. The effectiveness of this approach has not been documented. The City of Dallas (49) is currently testing a telephone call-in system by which drivers can obtain up-to-date freeway traffic information prior to leaving work or their homes. This system is discussed further in the next chapter.

AUDIO SYSTEMS

There has been accelerated interest recently in the development of auditory modes for real-time driver information displays for use in freeway corridors. Only limited experimentation and application of audio other than commercial radio broadcasts have been implemented and tested in the United States. As such, the impact and effectiveness are not completely known, although some experts believe that the audio mode can be an effective part of an integrated motorist information system (50, 51, 52, 53, 54).

Dudek and Carvell (52) conducted a feasibility study of audio modes and suggest specific applications, advantages, and disadvantages of commercial radio, limited range radio, and telephone call-in systems. Limited-range radio radio systems have the capability of broadcasting traffic information over the car radio on a pre-selected station. In contrast to a commercial radio station, however, it operates at a low power output and thus can only be received within a limited range of the antenna (usually up to 1/4 mile). Telephone call-in systems are systems whereby drivers can dial a given telephone number from their homes or offices and receive traffic information about the freeways they intend to take. Each form of these audio information concepts can serve specific functions, and in combination with changeable message signs could result in an effective freeway corridor driver information system. The following sections on *Commercial Radio*, *Telephone Dial-In System*, and *Limited Range Radio* were abstracted in part from the feasibility study by Dudek and Carvell (52).

Commercial Radio

Results of research suggest that commercial radio could play an important role as part of an effective real-time information system for urban freeway motorists. However, to be effective, improvements in the reliability and timeliness of information provided would be necessary. For example, a study of three radio stations in Houston revealed the following (55):

1. Of the 110 observed accidents, 52 percent were not reported by any of the stations. Only 7 percent were reported by all three stations.
2. Only 3 of 114 stalled vehicles were reported by the radio stations.
3. The average time to report an accident after it was observed was more than 20 minutes with a range between 1 and 98 minutes.
4. No radio reports monitored indicated whether an accident, previously reported, had been cleared.
5. Little information was broadcast that indicated the length of freeway affected by an incident.

Conceptual Design (52) - A wide range of information sources and dissemination methods may be used by commercial radio stations in providing the public service of driver information. However, the information is usually by necessity area wide and fairly macroscopic. Certain sources may be microscopic in nature but the sources are not sufficient in number to provide information in all sections of a major metropolitan area.

Providing information by area, or by corridor, would be desirable since it could then be more specific and the time allotted for traffic reports could be used more effectively. Using commercial radio stations for this purpose obviously has drawbacks. Commercial radio stations would probably be reluctant to restrict their broadcasts to only one segment of listeners.

It would seem that a system design for commercial radio information service should include elements of both types of information. This implies that some type of information management agency should receive, analyze, verify, and disseminate traffic information, since each individual commercial radio station would not have the means or possibly the inclination to provide such a comprehensive service.

It is apparent that some trade-offs will be necessary in order to satisfy the need of drivers for accurate, timely and appropriate information and to satisfy the commercial and audience requirements of commercial radio stations.

The design of the commercial radio subsystem can take on several forms. The variations in form would depend upon specific requirements of the operating agency and the radio stations. Conceptually, the operating agency staff located in an urban traffic management center could tape traffic advisories and continuously play back the information using magnetic tape recorder/playback equipment. Information would be updated as freeway conditions changed. The diverse origins of trips by the motoring public would probably require that the information cover all the freeways in the metropolitan area thus be macroscopic in nature. Therefore, one recorder and one playback unit would be required. All radio stations would have direct communications to the playback unit and could obtain information at any point in time. When an incident occurs, personnel in the management center could send a signal alert to the radio stations advising them of an emergency condition and encouraging them to update their traffic broadcasts. This approach should be acceptable to the radio station management and enhance working relationships with the operating agency. The freeway surveillance and control systems in Los Angeles and Chicago have provisions for notifying local radio stations of unusual freeway traffic conditions(21, 48).

If the above approach is not effective due to the reluctance of radio station personnel to utilize the subsystem to its fullest capabilities, it may become necessary for the operating agency to implement and operate its own radio station. This approach will receive considerable opposition by the commercial radio station management. The operating agency must therefore be in a position to justify the approach and have the support of the public, city council, and possibly the state legislative body.

Considerations for Implementation and Operation (52) - *(1) Relatively low cost to implement.* The major component of the cost, obviously, has already been borne by the radio stations. The basic requirement for additional hardware involves transmission facilities and communications link between the urban traffic management center and the radio stations. Since the equipment necessary in the center will be utilized for a combination of information subsystems such as low-power radio and telephone call-in subsystems discussed later in this report, the cost is therefore distributed. In addition, it is speculated that radio station management will share the cost for the necessary communications link between the urban management center and the radio stations.

(2) Adaptable for area wide coverage. Commercial radio has the distinct advantage of transmission to a large segment of the population scattered throughout the metropolitan area. The traffic advisories will therefore generally be macroscopic in nature.

(3) Requires cooperation of radio stations. Implementation and operation requires full cooperation of the radio station management and disc jockies. Radio station management fully understand the importance their listeners place on traffic advisories. It appears that they would be receptive to having current traffic information available for their audience.

(4) Broadcasts are controlled by an organization other than operating agency. Broadcasts of traffic advisories are controlled by the radio stations and therefore the time of reports may not always be compatible with the desires of the operating agency. Radio stations respond to commercial sponsors that place a degree of restriction on their own flexibility. One would therefore expect some delay in reporting incidents; however, it is expected that the delay of approximately 20-25 minutes as found in Houston, would be significantly reduced.

(5) Requires no additional purchases by the motorist. Since radios are in common usage by the motoring public, no additional expenditures would be required on their part.

(6) Limitations on the frequency of broadcasts. Because of demands and restrictions placed on commercial broadcasting, the frequency of traffic advisories may not be sufficient on all radio stations. It is expected that radio stations would generally provide traffic advisories more frequently during the peak periods in comparison to off-peak.

(7) Motorist receives no message if radio is off. The operating agency has no guarantee that a motorist will be listening to his radio. If motorists elect to leave the power off, a portion of the motoring public fails to receive the traffic advisory reports. One possible approach to compensate for this is to design and equip all automobiles with special adaptors for the automobile radio which would provide automatic priority reception of audio messages.

(8) Not all vehicles are equipped with A.M. radios. Buses and a small segment of the automobile population are not equipped with A.M. radios and therefore would not currently be in a position to receive audio messages.

Effectiveness (52) - The effectiveness of the commercial radio subsystem will largely depend on the cooperation of radio stations and the utilization of information provided by the urban traffic management center. The popularity and use of radio by the motoring public is evident. The potential exists!

Summary (52) - Effectiveness of driver information provided by commercial radio is widely variable. In Dallas, the primary source of information is a police information service which provides data on accidents and incidents being investigated or to be investigated by police. Individual stations augment this service with aerial observers, mobile units, and traffic reporters.

The primary shortcoming of existing commercial radio is that it cannot consistently provide sufficiently detailed information for planning prior to the trip and updating during the trip. Response time and the lack of positive follow-up on clearance of incidents and accidents further limit its effectiveness. Also, less severe accidents and incidents may not be reported due to lack of news excitement value, although such an occurrence may have an extreme effect on traffic operations.

Commercial radio stations would obviously desire to provide a unique service to listeners so that the listeners would prefer that station over others. By having a sound base of information through centrally managed center, commercial stations would still have the option of providing additional services as they see fit. The key is to have a reliable, comprehensive data base to work from.

The success of commercial radio for motorist information in an urban freeway corridor is largely dependent upon the cooperation of local radio stations. The operating agency does not have full control of the type and

and frequency of traffic advisories reported via commercial radio.

Commercial radio cannot satisfy all of the information needs of urban freeway motorists but should be very effective for pre-trip planning and en route traffic advisories. It is a feasible approach for communicating with the driver and can be very effective when integrated into an overall traffic management and information program.

Telephone Dial-In System

The Need (52) - The results of motorist attitudes and preferences indicated the need for traffic advisories for pre-trip planning. Although radio was ranked rather high for pre-trip planning, it is conceivable that other modes might also serve as effective complements to a radio subsystem. The results of the survey must be interpreted in view of the participants' familiarity or concept of a particular subsystem. The popularity and the current utilization of radio for traffic advisories support its feasibility for satisfying many of the requirements for pre-trip planning. However, there are limitations to this mode that create voids for total motorist coverage necessary for pre-trip planning.

Generally, when the term "pre-trip planning" is mentioned the immediate thought relates to the home-to-work trip. Because of its availability and utilization, commercial radio can be very effective for this trip purpose. Since a motorist has considerable time while at home in the morning to listen to the radio for traffic advisories, the effectiveness of commercial radio is enhanced. However, there are other trip components that will render commercial radio less effective.

One component is the work-to-home trip. In this situation, commercial radio is not as accessible and would therefore be less effective. Personal telephones, on the other hand, are accessible in both large and small office buildings and could therefore fill the void for pre-trip planning information. Of significance is that an individual could conceivably call a specified telephone number at the urban traffic management center that would provide him with traffic advisories concerning specific freeways on his route. Granted, radios are available in the automobiles, but an individual leaving the office normally must make decisions concerning his route selection in a short period of time. Traffic advisories on commercial radio may not be frequent enough or the broadcast time may not be compatible with the trip time to be of value to the motorist. However, after traffic advisories are obtained by telephone, information received via the car radio and/or changeable message signs would confirm and support the motorist's decision of routing while in transit.

Another important trip component is the off-peak trip. The limitations of the frequency of radio traffic broadcasts during the off-peak might render this mode ineffective for pre-trip planning for an off-peak trip. In most cases, it would be convenient to utilize the telephone subsystem to obtain traffic advisory information on specific freeways.

Conceptual Design (52) - The integration of a telephone subsystem into a total motorist information system for urban freeway corridors obviously must be directed at the origin of trip where telephones are accessible. Thus, traffic advisories for pre-trip planning could conceivably be transmitted using a telephone dial-in subsystem. The telephone subsystem must be coordinated with the activities of the urban management control center. The utilization of the subsystem as part of an integrated motorist information system assumes that the urban management control center has the surveillance and incident detection capabilities on the freeway, surveillance capabilities on the alternate arterials and can reliably predict the relative travel times on these routes.

There are at least two approaches for design. One approach would be location specific and would advise of conditions on the freeway(s) directly on the path to particular destinations. It is envisioned that taped broadcasts would be made for each specific freeway leading into the CBD or other major generators of significant magnitude. Separate telephone numbers would be available to the motoring public and would be dependent upon the zone of origin and final destination. This approach requires separate tape recorders, located in the urban management center, for each zone of interest. The exact arrangement of the zones would be selected based on the frequency of usage and the capabilities of the management office. This approach, although it covers a wide area, would provide only information that would be of prime interest to motorists within a specified zone.

Another approach is to utilize one telephone number and one recorder device which would provide information of all freeways in the urban area. This approach, of course, reduces the cost and the requirements within the management center, but the information is not necessarily location specific. In other words, it would be more comparable broadcasts made via the commercial radio subsystem.

Effectiveness (52) - The effectiveness of a telephone subsystem is not known at this time. Experimentation planned by TTI as part of the Dallas Freeway Corridor study (49) should provide data necessary for cost-effectiveness evaluations. The utilization of a telephone subsystem will require effective planning and public education and relations. The public must certainly be knowledgeable of the existence of the system and the personal benefits to be derived.

Considerations in Implementation and Operation (52) - *(1) Relatively low cost.* The subsystem does not require the installation of any hardware in the form of receivers or transmission. Tape recorders/playback units in addition to a telephone answering service would constitute the major hardware expenditure.

(2) Can reach a large audience for pre-trip planning. The accessibility of telephones in the homes and in office buildings suggests that a large portion of the population can utilize the telephone call-in subsystem for pre-trip planning.

(3) Effective during off-peak as well as peak periods. Since the operating agency can transmit continuous messages throughout the day, a telephone call-in subsystem, unlike commercial radio, can be very effective during any part of the day for pre-trip planning.

(4) Flexibility in application for other public service information. A telephone call-in subsystem is very flexible in that various public service announcements can be related to the motoring public. For example, maintenance or construction operations, weather, pavement conditions, etc., along heavily traveled arterials can be made available during weekends.

(5) Conditions on the freeway can materially change after the motorist receives traffic advisory via the telephone. Freeway incidents are unpredictable and, therefore, conditions can materially change after a motorist is advised via the telephone of freeway conditions. Motorists must rely on other modes of communications for up-to-date information while en route.

Experimental System and Information Requirements - The City of Dallas plans to implement an experimental telephone dial-in system in early 1975 to provide motorists real-time information regarding traffic conditions on the North Central Expressway. As a prelude to operating the system, Huchingson and Dudek (49) conducted a survey of 303 motorists in the Dallas CBD to determine the types of information that should be transmitted and other stated or implied requirments for the design of the system. The following are some of the recommendations of the researchers based on this study:

1. The format of the telephone messages should include the six major types of traffic descriptors preferred by the urban motorists as applicable to the traffic situation. In order of preference, these were location and degree of congestion, recommended alternate routes, lane blockage, reason for congestion, and expected delay.
2. When there is no incident, construction, or maintenance, the first information should be a qualitative statement of the level of congestion (heavy, moderate, light) and the location of the heaviest congestion expressed in terms of two cross-street names or one cross-street and "downtown."
3. Both inbound and outbound conditions should be given, but the information of greater demand should be given first, i.e., inbound in the mornings and outbound in the afternoons. The busy listener thereby has an option as to whether to continue listening after satisfying his informational need. A concluding statement that there are no incidents on the freeway may also be reassuring.
4. When an incident has occurred, this information takes priority. It should be identified as to its general nature (stalled car,

accident, unidentified blockage, etc.). The exact location should be defined in terms of inbound/outbound, its location, and the lanes blocked. The words, "inbound" or "outbound" should be emphasized since they are most important. Locations are again referenced to the nearest cross-streets and/or expressed as a range (between X and Y). Lanes blocked should be expressed as "right, middle, and left." Never use "inside" or "outside" since these terms are ambiguous.

5. The message should also give how far the traffic is backed up, and the estimated duration of the blockage in minutes. The latter information should be updated whenever there is any change in status, as for example, a wrecker appearing on the scene. Both information on the onset of the stoppage wave and the delay information should be updated as often as possible.
6. When an incident occurs, the message should also indicate recommended alternate routes and entrance ramps to avoid the greatest congestion. If the expressway is still quicker than other alternatives, this advisory should be given instead. As applicable, motorists should be told where they should leave the freeway and take the frontage road to avoid an incident.
7. As soon as the incident has been removed and traffic congestion begins to subside, the traffic advisory should indicate this and also state again how far traffic is backed up and level of congestion. It is still desirable to repeat which lane was blocked since the backup may still be greater in this lane.

8. Messages for morning and afternoon advisories during peak periods are analogous in format, but the probability of an incident inbound or outbound will vary, of course, with the prevailing traffic loads.
9. The message for off-peak periods will be analogous to peak periods with no incidents except that when the traffic inbound and outbound are both light and approximately equal; one statement should suffice, i.e., "Traffic inbound and outbound is light."
10. Although the greatest demand from commuters will be between 6 and 9 a.m. and between 4 and 7 p.m., Monday through Friday, the system should be operational during off-peak periods throughout the day. Whenever the system is not in operation, a taped message should provide this information.
11. The success of the operation depends upon brevity in the messages since the demand on the telephone system will come primarily during two short periods each day. The messages should never exceed 60 seconds and normally should be held to 15 to 20 seconds. There should be sufficient extensions so that a caller will not receive a busy signal during peak periods.
12. The messages should be delivered by trained speakers with easily understood voice qualities and diction. They should emphasize the key words in the messages.

The above recommendations will be incorporated into the system and will be modified as new knowledge is gained from the operational dial-in system.

Summary (52) - There is a need to fill the information voids for pre-trip planning because of the limitations of commercial radio. The telephone call-in subsystem is a feasible approach to fill some of the void for pre-trip planning information. This subsystem is capable of communication over a wide area of the city and thus reach a large segment of the public. As the cost should be relatively low, it is an appealing alternative for pre-trip planning. Since conditions on the freeway can change after a motorist has received traffic advisories via the telephone, it would be necessary for him to supplement the information while en route with information provided by a commercial radio subsystem, limited range radio subsystem, and/or changeable message signs.

Limited Range Radio

Results of motorist attitude and preference studies suggest that the radio would have high utility as an integral part of a total motorist information system for urban freeway corridors. Although the reported studies were concerned with commercial radio broadcasts, the results also suggest that traffic bulletins provided via radio per se would have high utility. In effect, the car radio provides a suitable and acceptable means for communicating with the motorist while en route. This suggests that limited range radio would be an effective means of communication.

The previous discussions have suggested the limitations of both commercial radio and telephone call-in subsystems for en route information. Information for pre-trip planning can be made available for a majority of the motorists utilizing a combination of the above two subsystems. However, the obvious lack of availability of telephones and the area wide coverage of commercial radio limit their use for en route information that is location specific. The motorist needs confirmation of freeway advisories while en route and needs specific instructions along alternate routes. These needs can be satisfied with a combination of limited range radio and changeable message signs. In essence, all of the informational requirements, discussed earlier for rerouting motorists to alternate or along diversion routes can effectively be transmitted by these latter two subsystems.

Limited range radio can also complement commercial radio and telephone call-in subsystems for pre-trip planning information that the latter two subsystems cannot completely satisfy. For example, there are several traffic generators within urban areas, such as factories, where telephones are not readily accessible and where commercial radio broadcasts will not be timely for effective pre-trip planning. The use of limited range radio at the parking lots of these major generators could effectively fill this void.

In addition to the above macroperformance information needs, limited range radio may also be effectively used for situational needs such as information concerning accidents ahead, slippery pavement conditions, etc. The information can be transmitted within a local area thus enabling the motorist to directly relate conditions to the freeway he is travelling.

Conceptual Design (52) - The integration of a limited range radio subsystem into a total motorist information system for urban freeway corridors should involve development to satisfy macroperformance needs, both pre-trip planning and routing while in transit, and also situational information along the primary route. As with the other subsystems discussed, the limited range radio subsystem must be coordinated with an urban management control center.

Limited range radio transmitters can be installed at major generators where both telephone and commercial radio cannot adequately satisfy the information needs for pre-trip planning. The operation and specific information broadcasted from the urban management center using tape recorders would be dependent on the relative location of the generator to the freeway system. For example, a generator in the CBD would probably require area-wide information concerning several freeways in the city because of the wide distribution of destinations. Broadcasts at generators near a freeway would conceivably be oriented to the adjacent and connecting freeways. Since the radio transmitters are capable of only a short area of transmission, it is conceivable that only one or two A.M. frequencies would be necessary throughout the metropolitan area even though different messages are broadcast at the various locations. The concept would minimize the requirements for space on an already crowded radio band in most large metropolitan areas.

Several transmitters can be wired in series to provide local coverage along extended sections of the primary freeway route to inform motorists of unusual traffic, pavement, or environmental conditions downstream. When an emergency condition exists, a changeable message sign could instruct the motorists to tune to the emergency frequency where specific information and guidance would be provided. It is envisioned that a majority of the commuter motorists would have one of their automatic tuning buttons set on the emergency station. The only action that would be required to obtain the emergency message would be to press the pre-selected station button. If diversion is recommended, the motorist would be guided along diversion routes via information received on the radio and complemented with changeable message signs.

The above concepts can also be applied along primary arterials feeding into the freeway and along alternate routes paralleling the freeway.

Effectiveness (52) - The effectiveness of a limited range radio subsystem, as for the other subsystems, can only be speculated at this time because of the lack of very limited experience with pilot installations to evaluate the concept in real-world situations.

Considerations in Implementation and Operation (52) - *(1) Relatively low cost in comparison to changeable message signs.* Limited range radio is cost competitive with changeable message signs; in particular, it is estimated that limited range radio should be less expensive for application at major generators.

(2) Can be applied to sections of highway where localized motorist information is desirable. Specific information concerning freeway conditions downstream or routing instructions along alternate routes can be broadcast within a localized area without affecting motorists in other parts of the urban area. Of significance, is that the information becomes more personal thus enhancing the utilization of the subsystem.

(3) Capable of providing on-the-spot information. Since the information transmitted over a limited range radio subsystem will originate directly from an urban traffic management center, there will be little delay in reporting traffic events to the motorists.

(4) Possesses great flexibility. Limited range radio is beneficial due to its flexibility in usage and message transmission. The hardware is portable and can be moved to meet pressing demands. It also allows the operating agency to broadcast an unlimited number of messages that can be easily and

quickly changed, offering advisories or instructions of an extremely versatile and dynamic nature. One or several available frequencies can be selected for specific applications.

(5) Requires no additional purchases by the motorist. Since radios are in common usage by the motoring public, no additional expenditures would be required on their part.

(6) Operating agency controls messages. The operating agency has complete control over the frequency and types of messages broadcasted.

(7) Possible adverse reaction from radio station management and/or broadcasters associations. Adverse reaction may stem from the above groups since the limited range radio subsystem will take a portion of their listening audience during prime broadcast times (peak periods).

(8) Limitation of available space on RF range for AM broadcasts in large metropolitan areas. The AM band in large metropolitan areas may be so crowded with licensed radio stations such that a frequency may not be available for low power transmission.

(9) No guarantee of available broadcast frequency. Since some forms of limited range radio subsystem are not licensed by FCC, there is no guarantee that a selected frequency will be available for an extended period of time. New radio stations may be licensed in the area with the possible effect of overriding transmission via limited range radio on the selected frequency. It may become necessary to change broadcast frequencies.

(10) Motorist receives no message if radio is off. The operating agency has no guarantee that a motorist will tune to the emergency station when requested. If motorists elect to listen to another station or to leave the power off, a portion of the motoring public fails to receive the emergency

message, routing instructions, etc. Priority reception of audio messages could possibly be approached with special automobile radio adaptors.

(11) Not all vehicles are equipped with A.M. radios. Buses and a small segment of the automobile population are not equipped with A.M. radios and therefore would not currently be in a position to receive audio messages.

Experimental Systems and Information Requirements - The only known experimental limited range radio systems for highway traffic use were tested in California. A pilot system was tested in California in the early 1970's along a heavily travelled highway near Los Angeles following destruction of portions of the highway due to an earthquake. Favorable public response prompted the California Department of Transportation to incorporate limited range radio as part of an integrated Los Angeles driver information system. Opposition by the local broadcaster's association resulted in a necessity for plan revisions that all but killed the limited range radio system for the Los Angeles area (21).

The second limited range radio system is presently installed at Los Angeles International Airport (LAX) and is operative, transmitting over 530 Khz. This system has been licensed by the FCC for experimental operation to determine its utility and public acceptance. The objective of the system is to transmit information to drivers approaching and entering the airport in order to assist the driver in minimizing delays for obtaining appropriate parking, return of lease cars, and reaching a pickup or delivery point at a specified terminal.

Over 1 mile of cable is buried on the approach road (Century Blvd.), and approximately 6,000 feet of cable is buried on the terminal loop road.

This provides capabilities for two separate radio systems that operate on the same frequency. A CCTV camera mounted on the airport tower provides visual surveillance of terminal and approach roads. In addition, parking lot attendants radio parking information to operators.

Evaluation studies by Lampert, et al. (56) indicated a favorable response to the system. They also found that the more frequent user of the airport, and thus a knowledgeable driver, would have little occasion to listen unless traffic was heavy or there was some marked departure from normal conditions involving his route and/or his usual parking area. During periods of light to moderate traffic, the needs of the motorist for general information was low and the radio utility limited. The researchers emphasized that this does not preclude its usefulness when traffic is heavy--and congestion imminent. It is during such periods that the information to be provided by the radio is critical and it is important that a significant percentage of motorists is aware of the system and can tune it in. The researchers believe that broadcasts of proper and timely messages can serve to ease anxieties, reduce the potential for accidents and speed up the flow--hence has high utility.

Over 100 pre-recorded messages are available ranging in length between 20 to 90 seconds. Although specific messages were not made available to the author, the following represents a subjective evaluation by the L.A. airport radio system operating staff (57):

1. Daily motorists experienced boredom with hearing the same messages every day.
2. An attempt to use different voices to reduce motorist boredom did not appear to be successful. Using a sexy female voice

generally lead motorists to concentrate on the voice and not the message.

3. There were motorist acceptance problems when recordings were made by the staff. The staff recommended having a professional announcer record the tapes. (When incidents occur that are different from the library of tapes, it is necessary to use staff broadcasts).
4. Try to keep from using disc jockey commercial type messages.

Summary (52) - Results of motorist interviews suggest that radio provides a suitable and acceptable means for communicating with the motorist. Limited range radio appears to have considerable merit to fill the motorist needs for pre-trip planning at certain major generators. In addition, limited range radio is a feasible alternative for providing motorists with information on a primary freeway and might fulfill information needs along alternate or diversion routes. The information can be location specific. The many advantages of limited range radio more than offset the disadvantages previously listed. The negative consequences do not appear to be insurmountable and can be overcome with effective planning and a close working relationship with commercial broadcasters. Limited range radio should be used in conjunction with other forms of communication such as changeable message signs, commercial radio, and telephone call-in techniques to form an integrated information system. It can only satisfy portions of the total requirements for real-time traffic information in an urban freeway corridor.

Citizens Band (CB) Radio

Although CB radio was not evaluated by Dudek and Carvell (52) in their feasibility study of audio modes, the ever increasing popularity of CB suggest possible utility as part of an integrated motorist information system.

The operation of a CB radio subsystem would be much like commercial radio with the exception that the operating agency would have some control over when information is broadcast. Unless the operating agency had a dedicated CB station, however, it would have to compete with other users of the station. The information broadcast would be generally macroscopic, similar to commercial radio with the added advantage that drivers in mobile units would contact the operating agency whenever they encounter unusual traffic conditions. Thus, they can provide additional surveillance without any expenditure of public money. However, there is no guarantee that surveillance would always be available when it is needed. The CB radio system would also have features provided by a telephone call-in service whereby users can call to obtain latest traffic information concerning freeways of interest to them.

The motivation for purchasing a CB radio system by a motorist, to a great extent, is the ability to communicate for personal and business users and not specifically for highway information use. The success of the system would be dependent upon convincing the motorist that an investment for purely highway information and emergency purposes is warranted.

Proponents of CB radio for highway communications (54, 58, 59) admit that there are still problems that need to be resolved including that of unpredictable coverage. Stephany (60), in his response to an article on the use of CB radio for highway emergencies, emphasizes that the CB radio service was used because it was available and that CB was never intended to fully meet highway communication requirements. He observed that a lack of effective control is a major problem that needs to be overcome.

Experimental Systems - The City of Detroit, Department of Streets and Traffic, operated a General Motors-sponsored CB Radio Driver Aid Network beginning July of 1966 (61). Fundamentally, the system consisted of CB radio-equipped vehicles, the drivers of which report observed incidents to a base station. The base station operator then transmitted action needs via telephone to the appropriate authority or agency which, in turn dispatched 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 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. This CB radio system concept has since been taken over by a local radio station in Detroit.

An experimental state-wide emergency communications network utilizing CB radio was conducted in Ohio. This project, known as the Ohio REACT Emergency Network, was a joint effort of REACT National Headquarters and the Ohio State Highway Patrol. The 2-year project was established as an experiment to test the effectiveness of volunteer citizens monitoring emergency communications and providing assistance to motorists in accordance with the Federal Communications Commission's establishment of Channel 9 as the official emergency channel. Chiaramonte and Kreer (58) reported on the results of the first year of operation; Trabold and Reese (59) describe how CB radio was used for aid and information purposes during the 2-year program.

Table 21 shows that about 82.8 percent of the calls were road related. The categories of accidents and stalled vehicles accounted for 47.8 percent of the reports by the CB users and 17.7 percent were requests for road information. Table 22 illustrates that 76.1 percent of all calls originated from a passerby (48.9 %), mobile REACTer (25.4 %), or trucker (1.8 %).

Trabold and Reese (59) estimate that there were approximately 13,768 active licensees using CB radio for emergency communications in Ohio at the time of the study. They concluded that the use of CB radio for emergency communications is a substantial existing and constantly growing resource that makes no demand on public money.

Table 21

OHIO REACT EMERGENCY NETWORK -
CALL REPORTS BY TYPE OF ROAD-RELATED INCIDENT (59)

INCIDENT	TOTAL CALLS	PERCENT
Accident count	3,476	23.57
Vehicle count	6.618	
With injuries	579	
With fatalities	56	
Stalled vehicle, occupied	2,497	16.93
Stalled vehicle, unoccupied	817	5.54
Abondoned vehicle, no plates	94	0.64
Road obstruction or traffic hazard	1,216	8.24
Major traffic jam	310	2.10
Traffic control equipment malfunction	707	4.79
Reckless or drunk driver	351	2.38
Request for road information	2,611	17.70
Vehicle fire	134	0.91
Total		82.82

Table 22

OHIO REACT EMERGENCY NETWORK-
SOURCES OF CALL REPORTS (59)

SOURCE	TOTAL CALLS	PERCENT
Caller involved in incident	1,354	9.18
Passerby	7,212	48.89
REACTer	3,751	25.43
Police	259	1.76
Base station	273	1.85
Trucker or commercial vehicle	269	1.82
Total		88.93

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APPENDIX

TABLE A-1

ACTIVITIES INVOLVING USE OF DYNAMIC INFORMATION DISPLAYS IN THE UNITED STATES*

LOCATION	CONTACT	ORGANIZATION	FACILITY LOCATION	STATUS			COMMENTS
				Planned	Being Installed	Operational	
1. Baltimore	Hugo Liem	City of Baltimore	Jones Falls Expressway	X			Preliminary engineering report prepared. System will include warning beacons, lamp matrix freeway advisory signs, and blank-out corridor routing signs.
2. Baltimore	Robert L. Gordon	Sperry Rand Corp.	I95/HTT/I695	X			Diversion of traffic at a single point. Signing system recommendations made in Final Report.
3. Boston	Jeremiah Murphy	City of Boston	I-93	X			Plans & specifications should be ready in early 1975.
4. Chicago	Joseph M.McDermott	Chicago Area Expressway Surveillance Project		X			Plans to purchase one matrix sign for experiments on the freeway.
5. Cincinnati	E. Nels Burns T. E. Young	Ohio Dept. of Transportation City of Cincinnati	I-75			X	Traffic control system for events at Riverfront Stadium & for peak periods in southbound direction. Nineteen lamp matrix signs & inserts.
6. Cincinnati-Covington	B. R. Flener	Kentucky D.O.T.	I-75			X	Five lamp matrix signs to provide advance warning of congestion, incidents, slippery conditions. Maintenance problems reduced the use and effectiveness of system.

TABLE A-1 (Cont.)

ACTIVITIES INVOLVING USE OF DYNAMIC INFORMATION DISPLAYS IN THE UNITED STATES*

LOCATION	CONTACT	ORGANIZATION	FACILITY LOCATION	STATUS			COMMENTS
				Planned	Being Installed	Operational	
7. Dallas	Conrad L. Dudek	Texas Transportation Institute	Skillman Ave.			X	Three rotating drum signs on inbound Skillman an arterial parallel to North Central Exp.
			North Central Expressway		X		Telephone call-in system should be operational in early 1975.
			North Central Expressway	X			Two miles of linear radio system.
8. Denver	Doug Shaffer	Colorado D.O.T.	I-25, I-70, US-36			X	Four matrix signs operational since May 1974.
9. Detroit	Herb Crane	Michigan Dept. of State Highways					No immediate plans.
10. Houston	Conrad L. Dudek	Texas Transportation Institute	Gulf Freeway			X	Three matrix signs adjacent to Gulf Freeway.
			Gulf Freeway			X	Three safety warning signs consisting of static message sign and flashing beacons automatically operated by digital computer.
11. Louisville	B. R. Flener	Kentucky D.O.T.	I-65			X	Warning sign consisting of static message and flashing beacons to warn of slow traffic ahead controlled by time clock corresponding with routine back-up of exit ramp traffic.

TABLE A-1 (Cont.)

ACTIVITIES INVOLVING USE OF DYNAMIC INFORMATION DISPLAYS IN THE UNITED STATES*

LOCATION	CONTACT	ORGANIZATION	FACILITY LOCATION	STATUS Planned	Being Installed	Operational	COMMENTS
12. Los Angeles	Richard Green Al Grover	California D.O.T.	Santa Monica Freeway			X	Thirty-five lamp matrix signs on Santa Monica Freeway.
13. Los Angeles	John Dinan	R.T.V. Systems	L.A. International Airport			X	Induction cable radio system.
14. Miami	Tom Heinly	Florida D.O.T.	7th Ave.		X		Changeable message signs will be used in a demonstration program for bus and carpool lanes. Signs should be operational in early 1975.
15. Minneapolis	Glenn Carlson	Minnesota Dept. of Highways	I-94, I-35W	X		X	Red X and green arrow lane-control signs. Three lamp matrix signs on freeway. Lamp matrix signs on two ramps.
16. Mobile	C. Alexander	Alabama Highway Department	Mobile Bay Tunnel	X			Contract on computerized changeable message sign system to be let in early 1975.
17. New Jersey	R.L. Hollinger	New Jersey D.O.T.	Network near Newark Airport	X			Installation approximately two years away.
18. New Jersey	Jerry Kraft Robert Dale	New Jersey Turnpike Authority	New Jersey Turnpike			X	103 speed limit signs; 100 speed warning signs; 68 rotating drum signs used to divert traffic around congestion.

TABLE A-1 (Cont.)

ACTIVITIES INVOLVING USE OF DYNAMIC INFORMATION DISPLAYS IN THE UNITED STATES*

LOCATION	CONTACT	ORGANIZATION	FACILITY LOCATION	STATUS			COMMENTS
				Planned	Being Installed	Operational	
19. New York City	Vinson Hoddinott	N.Y. City Dept. of Transportation	Long Island Expressway	X			Will use changeable message signs and arrows and X's for bus contra-flow lanes on Long Island Exp.
			Van Wyck Expressway	X			Implementation about two years away.
20. New York	Robert Foote	Port Authority of New York & New Jersey	Holland & Lincoln Tunnels			X	Signs at portal to tunnels. Currently using 2 Varicom and 10 lamp matrix. Will replace lamp matrix with Varicom in near future.
21. Philadelphia	Tom Bryer	Pennsylvania D.O.T.	Schuylkill Expressway	X			Four rotating drum signs.
			Penn-Lincoln Parkway	X			Implementation expected in one year.
22. Seattle	Don Hoffman	Washington State Dept. of Highways	I-5			X	"OPEN" "CLOSED" messages for reversible-lane operation.
			I-5	X			Surveillance, control, and information system planned on 17 miles of I-5. Motorist aid changeable message signs expected in 1976-77.

TABLE A-1 (Cont.)

ACTIVITIES INVOLVING USE OF DYNAMIC INFORMATION DISPLAYS IN THE UNITED STATES*

LOCATION	CONTACT	ORGANIZATION	FACILITY LOCATION	STATUS			COMMENTS
				Planned	Being Installed	Operational	
23. Washington, D.C.	George Schoene	D.C. Dept. of Highways and Traffic	Shirley Highway Busway			X	Lane assignment signs for busway. Messages: LANE CLOSED, BUSES ONLY.
			9th Street	X			Blank-out signs at ramps and intersections. Messages: DO NOT ENTER, NO RIGHT TURN, NO LEFT TURN, etc.
			I-95 Tunnel between 2nd and 3rd Streets	X			Plans to have 32 variable message signs with full message capability. Plans and specifications should be ready in early 1975.

* This table includes the listing of activities based on personal contacts throughout the country. It is possible that some systems may have been inadvertently omitted from the table.