

**Project No. 20-7 (155)**

**SIGNING FOR TWO-LANE EXITS WITH AN OPTION LANE**

**FINAL REPORT**

Prepared for  
National Cooperative Highway Research Program  
Transportation Research Board  
National Research Council

Jonathan Upchurch, Donald Fisher, and Bhupinder Waraich  
University of Massachusetts

February, 2004

### **ACKNOWLEDGMENT OF SPONSORSHIP**

This work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Research Council.

### **DISCLAIMER**

This is an uncorrected draft as submitted by the research agency. The opinions and conclusions expressed or implied in the report are those of the research agency. They are not necessarily those of the Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, or the individual states participating in the National Cooperative Highway Research Program.

This report is the fourth of four project deliverables for this project. The first deliverable was a Summary of Current Practice, which was provided to the project panel in January, 2003. The Experimental Design, also provided to the project panel in January, 2003, was the second deliverable. The third deliverable was the sign configurations to be evaluated, which were concurred with by the project panel in March.

This report documents the data results, evaluation, analysis, findings, and recommendations from the running of 96 test subjects in a driving simulator and a subsequent debriefing survey.

## **SUMMARY OF THE PROBLEM**

The Manual on Uniform Traffic Control Devices, Millennium Edition (MUTCD) is the national standard for traffic control devices on all public roads. Section 2E.20, Signing for Interchange Lane Drops, does not address the situation of a two-lane freeway exit where the left-hand exit lane also continues as a through lane (commonly known as an option lane). Section 2E.19, Diagrammatic Signs, includes as guidance that diagrammatic signs should be used “where a two-lane exit has an optional lane that carries the through route (see Figures 2E-6 and 2E-7). These interchanges create serious expectancy problems for drivers unfamiliar with the interchange.” Diagrammatic signs are sometimes not practical to install and the layouts of the lane drop and diagrammatic signing approach similar geometries in inconsistent ways. Because of these shortcomings, several states have adopted alternative approaches to signing two-lane exits with an option lane based on limited analyses.

## **OBJECTIVE**

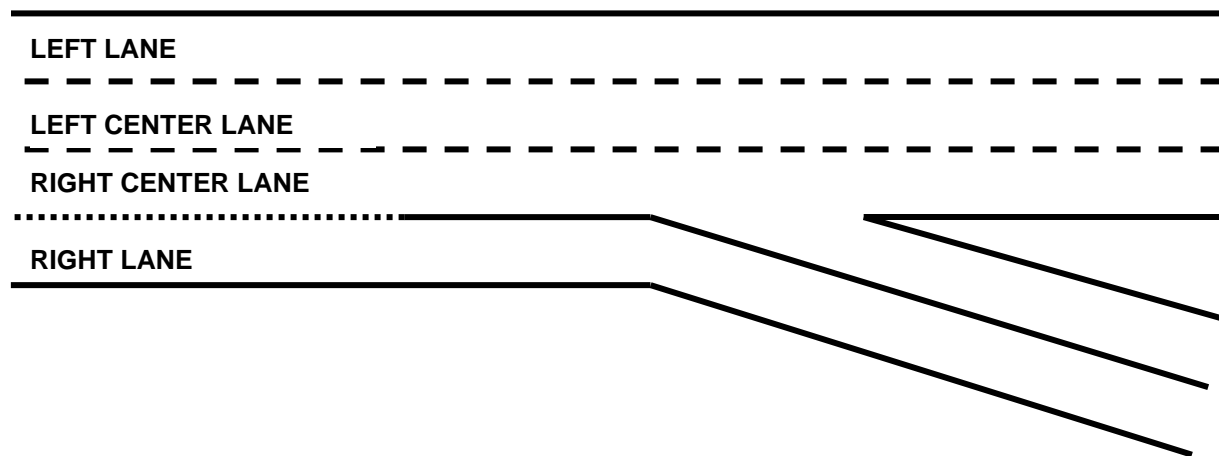
The objective of this research is to assess alternative sign designs for two-lane freeway exits where the left-hand exit lane also continues as a through lane. It is expected that the results will be considered in the next revision of the *Manual on Uniform Traffic Control Devices*.

## **CHALLENGES IN CREATING A SIGN DESIGN**

A two-lane exit with an option lane (see Figure 1, next page) presents a challenge in communicating information to the motorist. Information should be presented in a simple sign design that will be easily understood by drivers and allow them to understand the following.

- The only destination that can be reached by the right lane is the exit
- Both the exit destination and the mainline destination can be reached by the right-center lane
- The only destination that can be reached by any other lane is the mainline
- Provide identifying information about each destination (mainline and exit), such as street name, route number, or destination name

**FIGURE 1 - TWO-LANE EXIT WITH AN OPTION LANE**



### **THE FOUR SIGN DESIGNS THAT WERE TESTED**

Four different sign configurations were tested in this study. The signing configurations were identified in cooperation with the project panel and with input from the Guide and Motorist Information Signs Technical Committee of the National Committee on Uniform Traffic Control Devices. The four sign configurations are shown in Figures 2A through 2D (pages 4 – 7) and are briefly described in the following paragraphs.

The term “Advance Guide Sign” is used to describe the signs displayed at the locations 1 mile and 1/2 mile before the gore. The term “Lane Designation Sign” is used to describe the signs displayed at, or near, the gore.

The Existing MUTCD Sign Configuration (Figure 2A, next page) is based upon the design for Diagrammatic Signs for Two-Lane Exit with Optional Lane, as shown in Figure 2E-7 (page 2E-26) of the MUTCD. A refinement for the design tested in this study was to improve the diagrammatic symbol. The stem of the two-headed arrow was adjusted to more clearly show the number of lanes on the approach roadway and to more clearly show that the right-center lane may be used to reach both the exit and the mainline.

Some traffic engineers have commented that this diagrammatic type of sign has traditionally been used only for major splits and for locations at which the exiting roadway carries a major route and / or a relatively large volume. In this regard, past use of this diagrammatic type of sign has been for a different situation than that which this study was designed to address. This study is oriented toward two-lane exits (with an option lane) to arterial cross streets – a situation in which the exiting volume is smaller, relative to the mainline volume.

## FIGURE 2A - EXISTING MUTCD SIGN CONFIGURATION

These Signs are very similar to those given in MUTCD (page 2E-26) for a two lane exit with an option lane. The design of the diagrammatic figure has been modified to clearly indicate four lanes on the approach.

Lane Designation Signs (Longitudinally located at the theoretical gore, i.e., at a point where the right edgeline for the mainline and the left edgeline for the ramp begin at a common point and then diverge. Laterally located so that arrows are centered above the lanes to which each applies.)



34.0 x 15.0 ft



22.0 x 15.0 ft

Advance Guide Sign (Located approximately ½ mile in advance of exit and centered over the four approach lanes)



32.5 x 8 ft

Advance Guide Sign (1 mile in advance of exit and centered over the the four approach lanes)



32.5 x 8 ft

## FIGURE 2B – TYPE IB SIGN CONFIGURATION

Lane Designation Sign (Longitudinally located slightly upstream of the theoretical gore; located before the point where the option lane begins to diverge. Laterally located so that arrows are centered above the lanes to which they apply)



22.5 x 10.5 ft

Advance Guide Sign (Located approximately ½ mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)



22.5 x 10.5 ft

Advance Guide Sign (Located 1 mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)



22.5 x 10.5 ft

**FIGURE 2C – TYPE II SIGN CONFIGURATION**

Lane Designation Signs (Longitudinally located at the theoretical gore, i.e., at a point where the right edgeline for the mainline and the left edgeline for the ramp begin at a common point and then diverge. Laterally located so that arrows are centered above the lanes to which each applies.)



34.0 x 15.0 ft



22.0 x 15.0 ft

Advance Guide Sign (Located 1/2 mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)



20.0 x 10.5 ft

Advance Guide Sign (Located 1 mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)



20.0 x 12.5 ft

## **FIGURE 2D – TYPE III SIGN CONFIGURATION**

**Lane Designation Sign (Longitudinally located slightly upstream of the theoretical gore; located before the point where the option lane begins to diverge. Laterally located so that arrows are centered above the lanes to which they apply.)**



**20.0 x 11.0 ft**

**Advance Guide Sign (Located 1/2 mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)**



**20.0 x 10.5 ft**

**Advance Guide Sign (Located 1 mile in advance of exit. Laterally located so that arrows are centered above the lanes to which they apply)**



**20.0 x 12.5 ft**



Even though this study is oriented toward a different situation, the MUTCD sign configuration was included to serve as a basis of comparison for the other three sign types.

The Type IB configuration (Figure 2B, page 5) was conceived by the Guide and Motorist Information Signs Technical Committee. Two slightly different variations of the Type I sign were prepared by that Committee. The Type IA configuration (not shown) utilized a sign panel about 6 feet wider which allowed the cardinal direction (such as NORTH) and the route number (such as I-475) to be positioned side by side, rather than one above the other. The design of the remainder of the Type IA sign is virtually the same as the Type IB sign.

For Type IB, the Lane Designation Sign is identical in design to the Advance Guide Signs.

The Type II configuration (Figure 2C, page 6) was also conceived by the Guide and Motorist Information Signs Technical Committee. The advance guide sign in this configuration is similar to signs used in several states. The only design modification is the inclusion of a white horizontal line above the down arrows and the EXIT ONLY panel.

The two sign panels for the Lane Designation Signs are intended to provide positive guidance to both the drivers destined for the through roadway and for the exit. The design of the Lane Designation Signs is similar to the Lane Designation Signs for the Existing MUTCD Sign Configuration. The sign panel for the exit, however, includes a black on yellow EXIT ONLY panel and uses arrows that point upward to the right.

The Type III configuration (Figure 2D, page 7) is similar in design to Type II. The design of the Advance Guide Signs is identical to the Type II signs except that the white horizontal line is not included. The Lane Designation Sign is similar in design to the Advance Guide Signs except that the arrows point upward to the right, rather than straight downward. The Type III design is the only design for which the Lane Designation Sign does not provide information for the mainline destination.

The sign dimensions shown in Figures 2A – 2D (pages 4 – 7) are representative dimensions. These are the sign dimensions that were used on signs shown to test subjects in the driving simulator in this study. In real-world application, sign dimensions could vary slightly, for example, to obtain full foot increments in panel sizes, to allow larger letter sizes, or to accommodate longer destination names.

Sign location, both laterally and longitudinally, is very important for all of the sign configurations. Figures 2A – 2D (pages 4 – 7) provide a text description of proper sign placement and Figures 3A – 3D (pages 9 – 12) illustrate proper sign placement.

FIGURE 3A - LOCATIONS OF EXISTING MUTCD SIGN CONFIGURATION

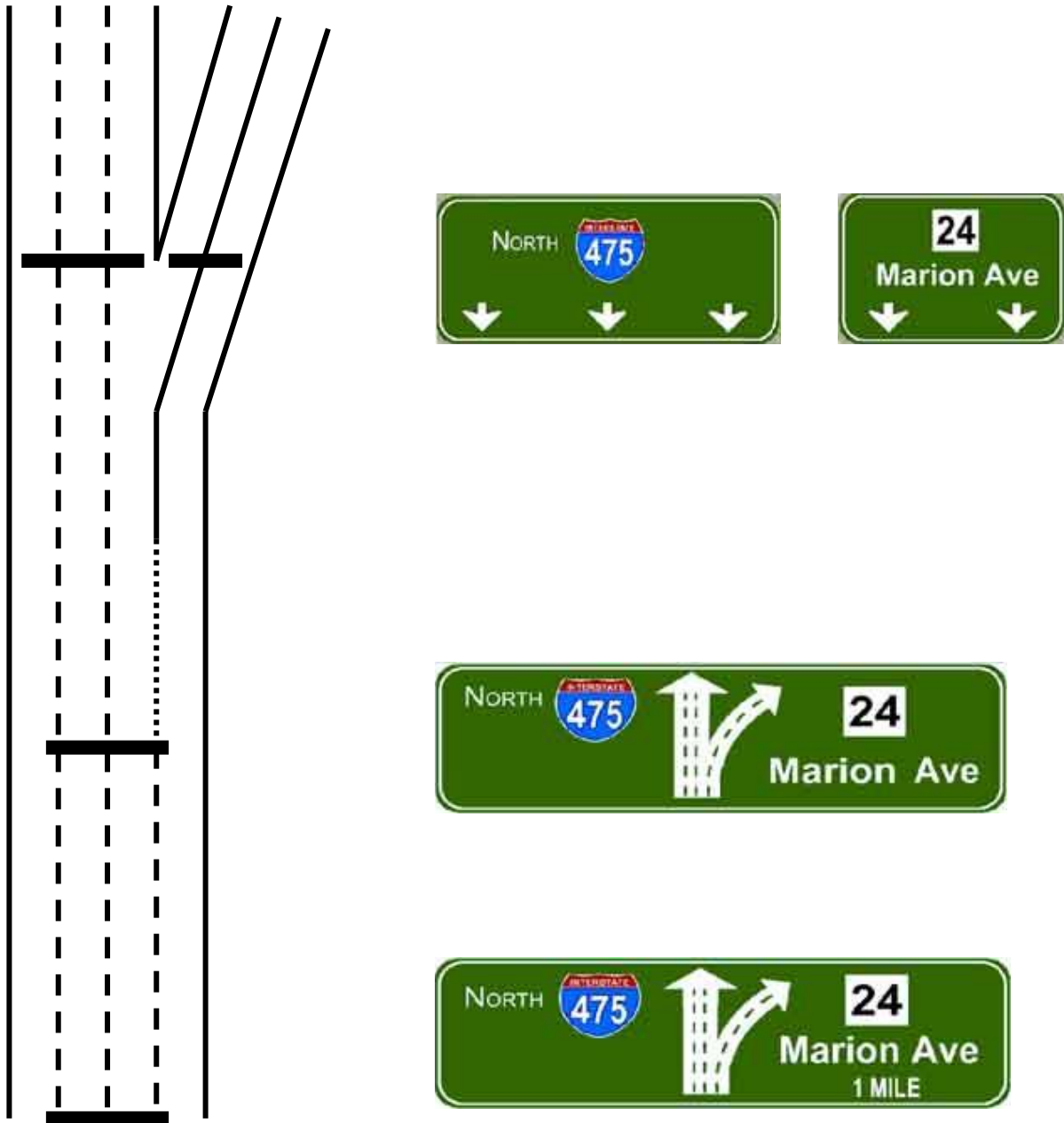


FIGURE 3B - LOCATIONS OF TYPE IB SIGNS

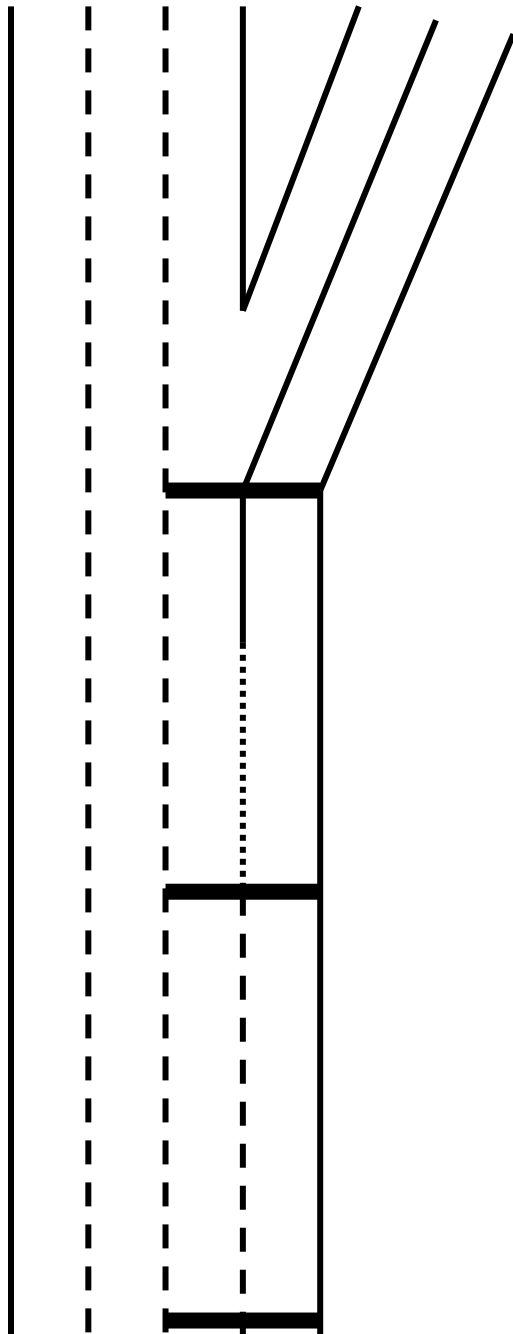


FIGURE 3C - LOCATIONS OF TYPE II SIGNS

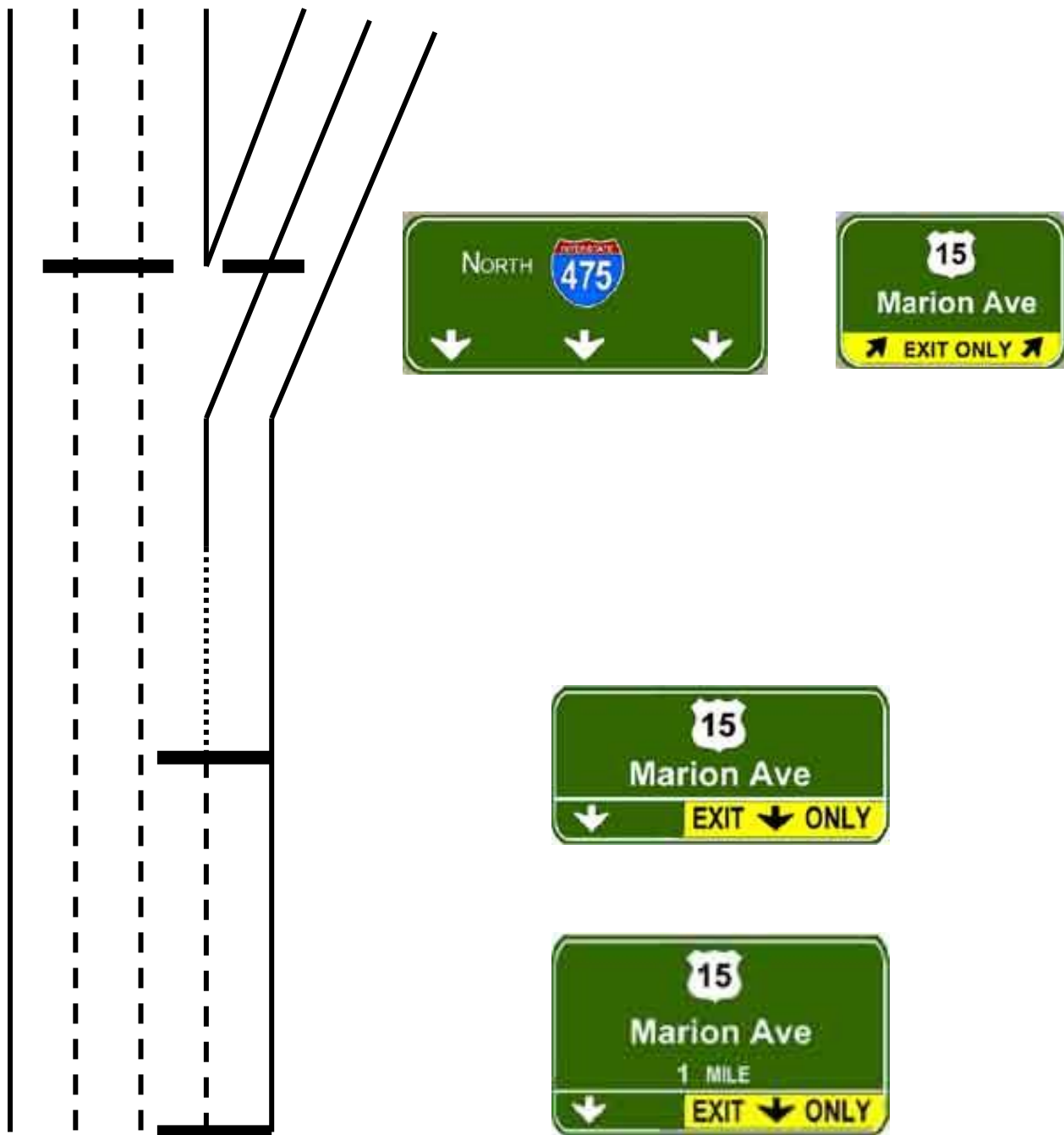
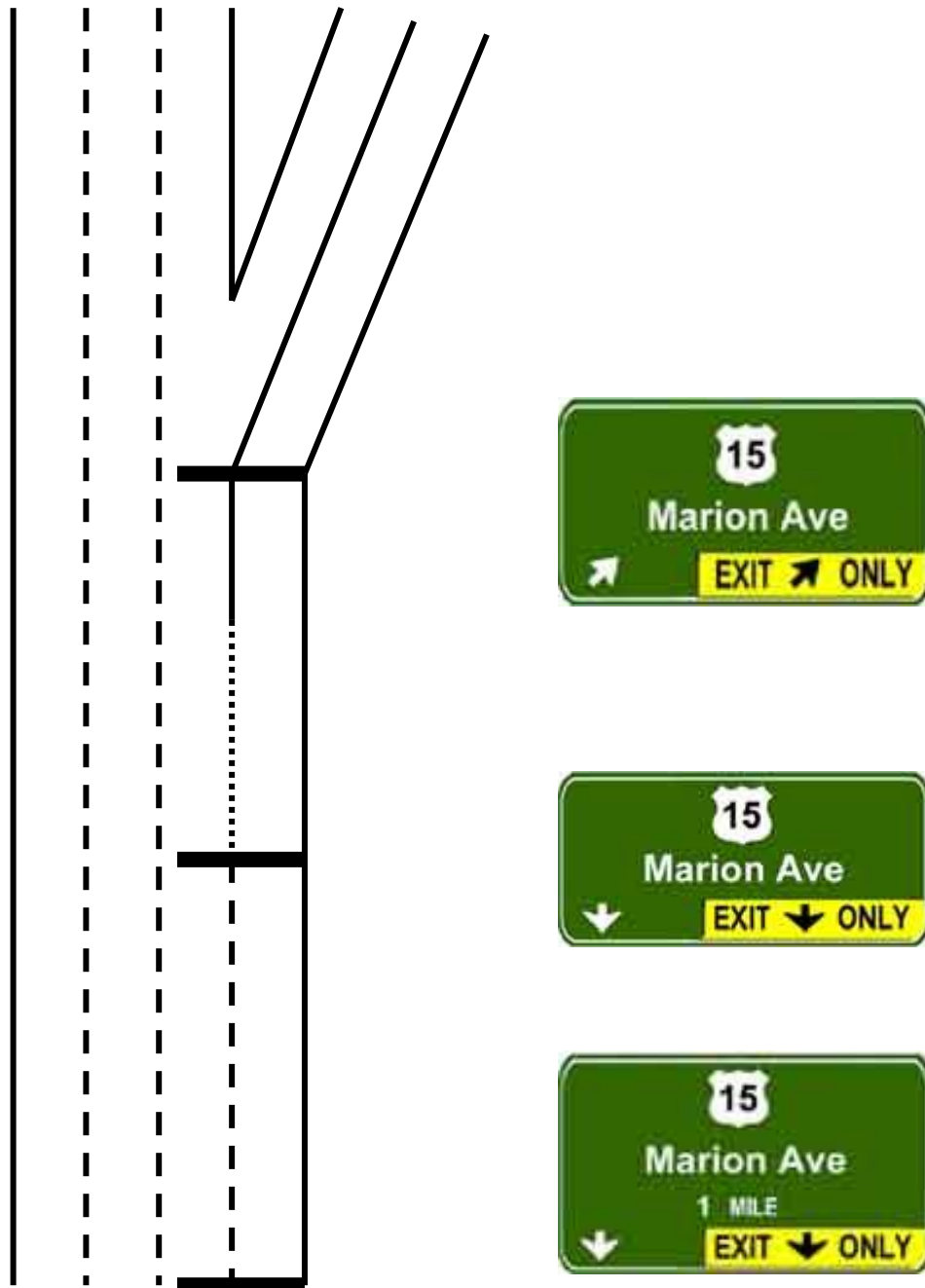


FIGURE 3D - LOCATIONS OF TYPE III SIGNS



## EXPERIMENTAL DESIGN

A comprehensive description of the experimental design was provided to the project panel in January, 2003 and updated in March, 2003. A brief summary is provided here.

Ninety-six (96) test subjects were hired to participate in an experiment in a driving simulator. The 96 subjects were divided into four groups of 24 individuals. Each group participated in an experiment in which they were exposed to one of the four sign configurations. In other words, 24 subjects participated in an experiment evaluating the MUTCD sign, 24 subjects evaluated the Type IB sign, etc. Each group of 24 subjects included 18 younger subjects and 6 older subjects (age 65 and older). All subjects were required to hold a valid drivers license.

Each subject drove in a driving simulator for about one hour. During this time each subject drove on 23 segments of freeway. Each segment included about 1 1/4 to 2 1/4 miles of freeway approaching an exit. Each segment included Advance Guide Signs for an exit and Lane Designation signs at the exit. One segment was a practice segment, ten segments included exits that were not two-lane exits, and 12 segments included two-lane exits with an option lane.

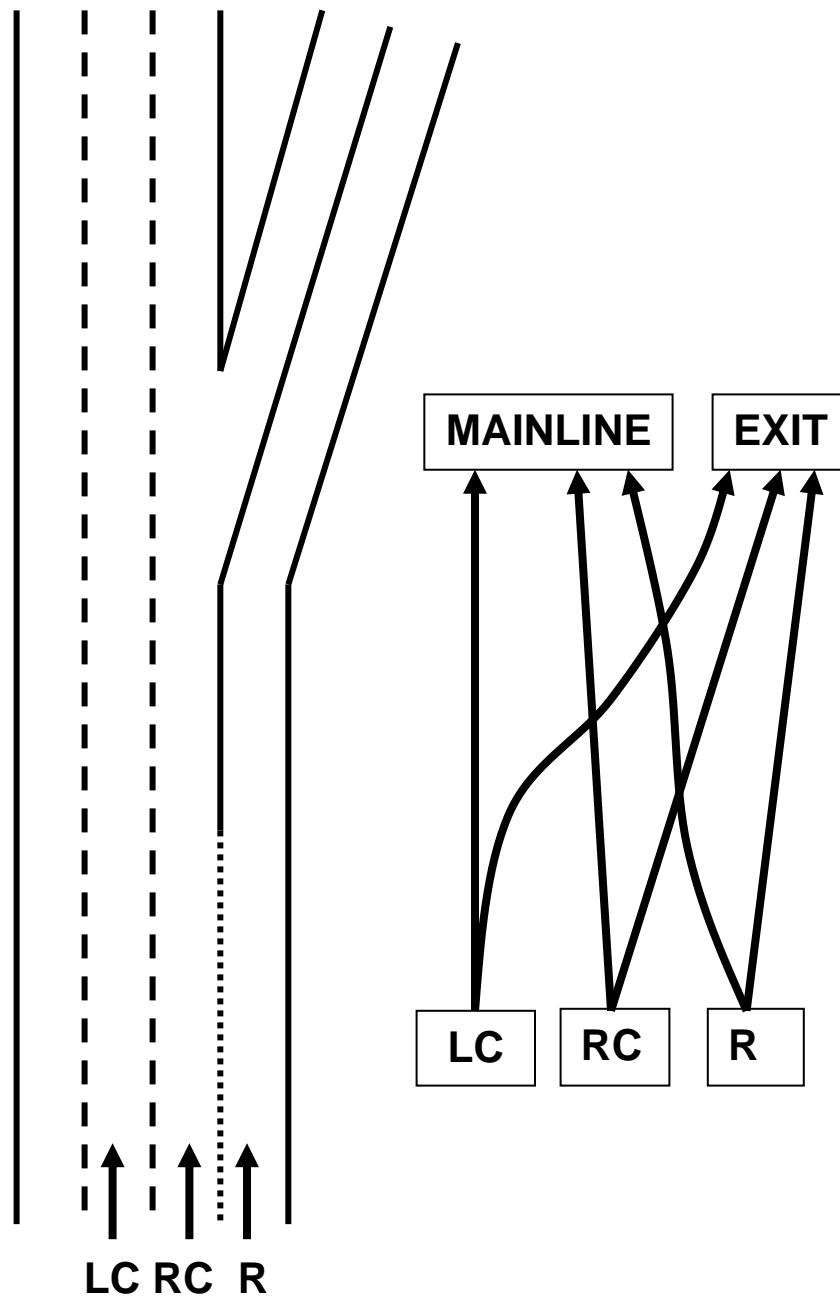
Each freeway segment had four lanes in the direction of travel – the left lane, the left-center lane, the right-center lane, and the right lane. For those segments that had two-lane exits with an option lane, the right lane was required to exit and the right-center lane was the option lane (as shown in Figure 1, page 3).

At the beginning of each segment, the subject was assigned a lane in which to begin -- the left-center lane, the right-center lane, or the right lane. This lane is referred to as the origin. Each subject was also given a destination in the form of either a street name or a route number. The subject did not know whether the destination would be reached via the mainline or via an exit. The subject was directed to begin driving, to maintain a speed of 60 mph, and given the following instruction. “Stay in the lane in which you begin until you see information indicating that you need to do otherwise to reach your destination.”

The experiment was counterbalanced in terms of the origin lane and destination. Street name destinations were equally likely to be associated with the mainline or with the exit. Similarly, route number destinations were equally like to be associated with the mainline or with the exit. The experiment was also counterbalanced for the order in which the origin-lane combinations were presented.

With three possible origins (left-center lane, right-center lane, and right lane) and two possible destinations (corresponding to either the mainline or an exit), there were six origin-destination pairs, as shown in Figure 4 (page 14). Each subject encountered each of the six origin-destination pairs two different times.

FIGURE 4 - ORIGINS AND DESTINATIONS



Data on driver behavior was automatically collected by the driving simulator. Measures of interest derived from the recorded data included locations of lane changes, whether unnecessary lane changes were made, and whether a driver missed an assigned destination.

Upon completion of the drive in the simulator, subjects completed a debriefing survey. A sample of this survey is shown in Appendix 1. The sample shown in Appendix 1 is the survey that was given to those subjects who were exposed to the Existing MUTCD Sign Configuration. The second and third rows of signs on the first page are the Advance Guide Sign and the Lane Designation Sign for the two-lane exit with an option lane. Surveys shown to other subjects were identical except that the second and third rows of signs on the first page were for the sign configurations that they saw on their drives. The first sign on the first page and all of the signs on the second page are signs that the subjects encountered on the freeway segments that did not have two-lane exits with an option lane.

## **MEASURES OF EFFECTIVENESS**

The Experimental Design described several measures of effectiveness to be used in evaluation of the candidate sign configurations. Those measures of effectiveness, plus additional measures of effectiveness identified during the course of the experiment and subsequent analysis, are described here.

A sign can be considered effective if drivers follow the ideal path for a given origin lane and destination. Figure 5 (next page) illustrates the desirable travel paths for each origin-destination pair. These are the travel paths that have no unnecessary lane changes and no missed destinations.

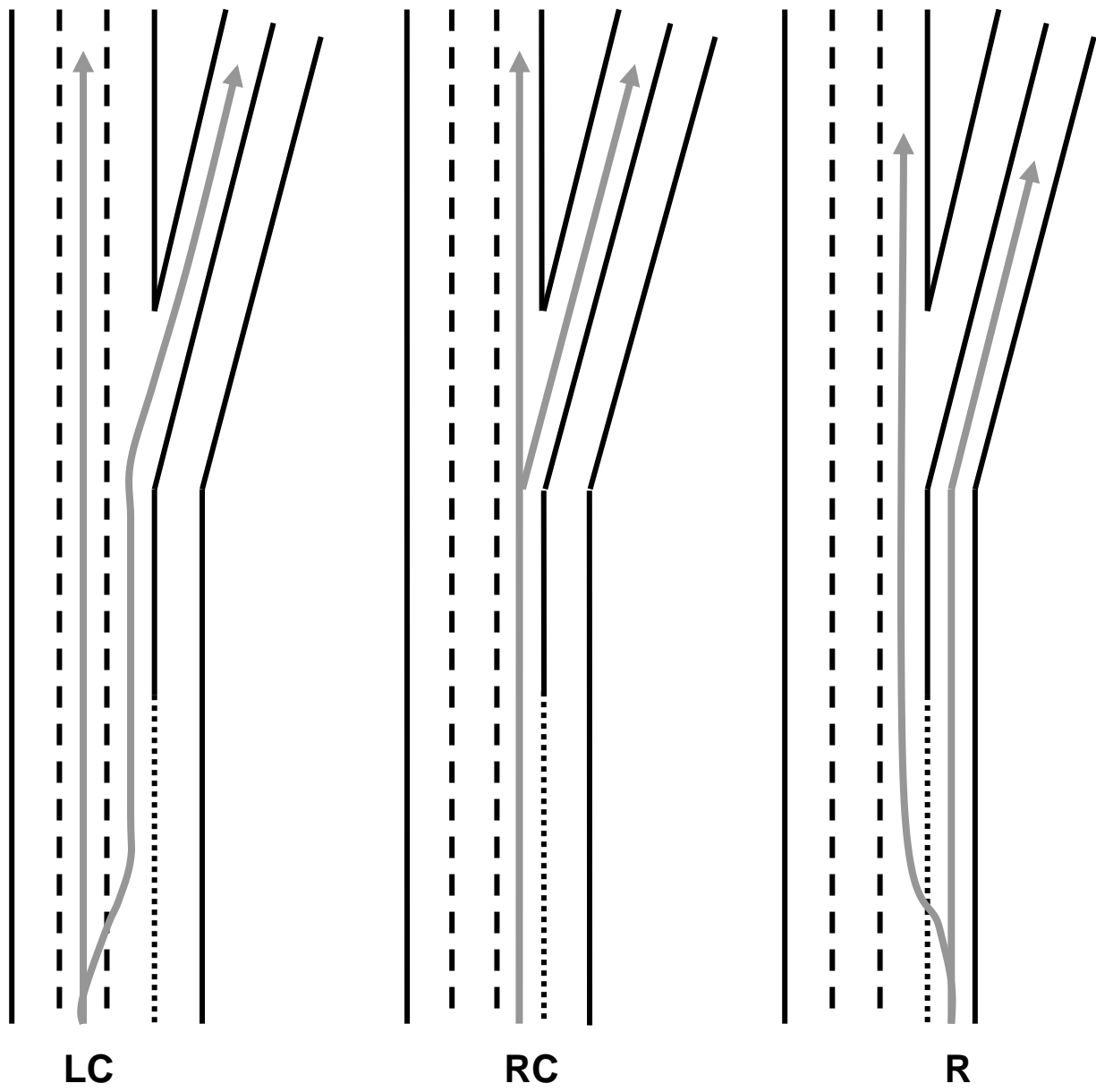
There are several measures of effectiveness that can be used to determine how well each guide signing configuration communicates information to each group of drivers.

Obviously, the fraction of drivers that follow the ideal path is an important consideration. The sign is fully effective if all drivers follow the ideal path for each origin-destination pair. However, not all drivers may do such. In this case, measures of effectiveness are needed that capture the departures of drivers from the ideal paths pictured in Figure 5 (next page). Various possible departures are pictured in Figure 6 (page 17).

**1.** One measure of effectiveness for ideal travel paths is the frequency with which test subjects fail to reach their assigned destination. In other words, how many drivers “miss” their destination vs. how many are able to reach their destination? For example, do some drivers mistakenly stay on the mainline when they should have exited to reach their destination? Note that a sign that is judged to be effective will have very few drivers missing the exit and one which is judged to be ineffective will have a great many drivers missing the exit. Thus, a high score on this measure of effectiveness is associated with a sign that is not effective.



**FIGURE 5 - DESIRABLE TRAVEL PATHS**



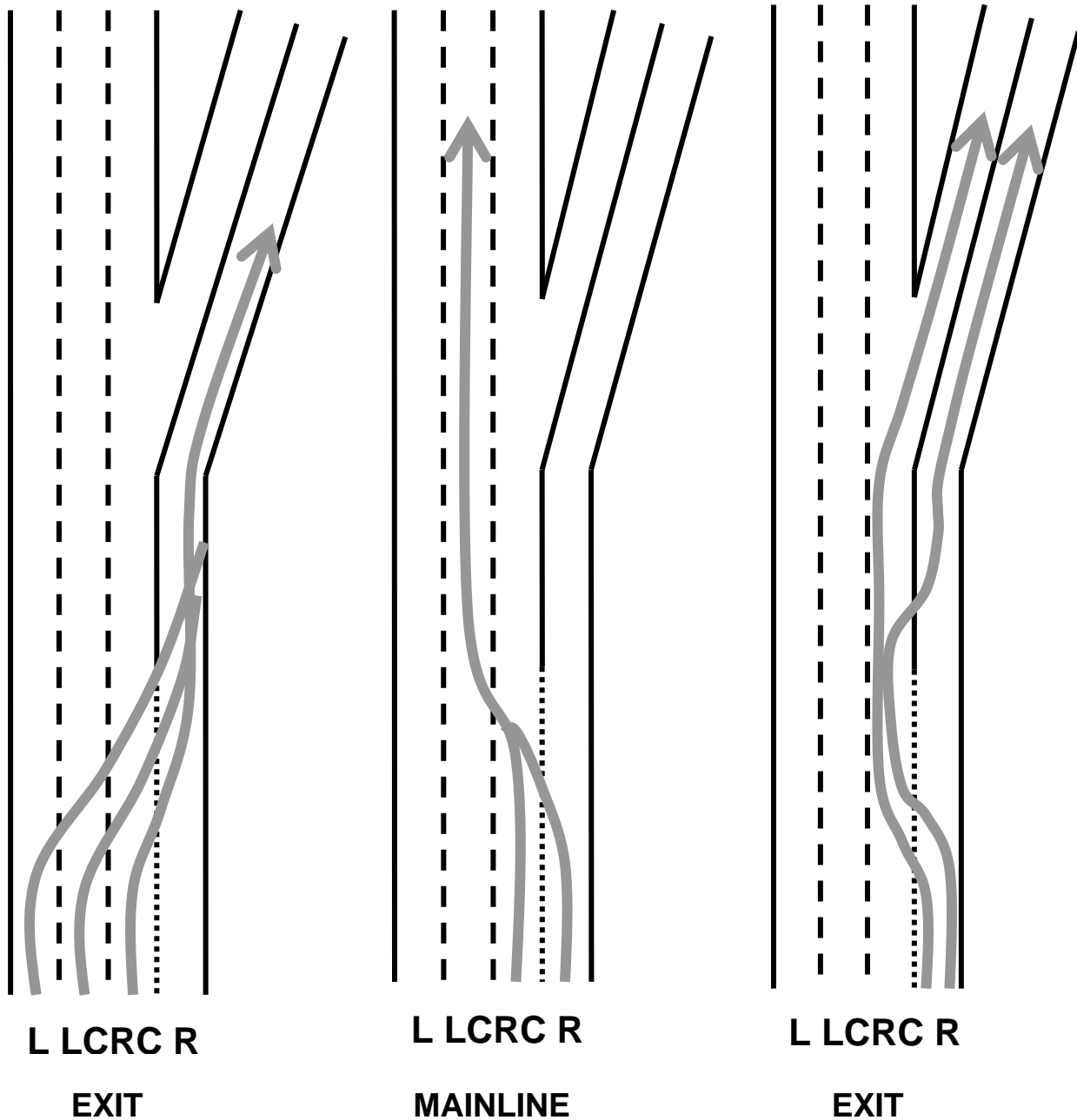
**DESIRABLE TRAVEL  
PATHS FROM AN ORIGIN  
IN THE LEFT-CENTER  
LANE**

**DESIRABLE TRAVEL  
PATHS FROM AN  
ORIGIN IN THE RIGHT-  
CENTER LANE**

**DESIRABLE TRAVEL  
PATHS FROM AN  
ORIGIN IN THE RIGHT  
LANE**

**FIGURE 6 - EXAMPLES OF UNNECESSARY LANE CHANGES**

( Note that originating lane of each path is labeled immediately below the lane schematic and the destination is shown below the origin)



2. A second measure of effectiveness for ideal travel paths is, how many unnecessary lane changes do subjects make to reach their destination (for example, move out of an option lane when they do not have to do so)? There are several examples of this, as described by the following questions.

- Will drivers starting in a Left-Center Lane and wanting to exit realize that they need only change lanes into the Right-Center Lane or will they change lanes unnecessarily into the Right Lane? (See left hand lane schematic in Figure 6, previous page.)
- Will drivers starting in the Right-Center Lane and continuing on the mainline realize that they can stay in the Right-Center Lane or will they change lanes unnecessarily to the left? (See middle lane schematic in Figure 6.)
- Will drivers starting in the Right-Center Lane and wanting to exit stay in the Right-Center Lane or change lanes unnecessarily to the Right Lane? (See left hand lane schematic in Figure 6.)
- Will drivers starting in the Right Lane and wanting to continue on the mainline move into the Right-Center Lane or unnecessarily change two lanes to the left? (See middle lane schematic in Figure 6.)
- And will drivers starting in the Right Lane and wanting to exit stay in the Right Lane or will they change unnecessarily into Right-Center Lane and then leave on the left-hand exit lane? (See right hand lane schematic of Figure 6.)

For this study, unnecessary lane changes were counted as follows. First, the optimum (or desirable) number of lane changes for each origin-destination pair was determined. Those values are shown.

ORIGIN	DESTINATION	OPTIMUM NUMBER OF LANE CHANGES
Left-center lane	Mainline	0
Left-center lane	Exit	1
Right-center lane	Mainline	0
Right-center lane	Exit	0
Right lane	Mainline	1
Right lane	Exit	0

Next the actual number of lane changes made by the subject was observed. Finally, the number of unnecessary lane changes was calculated as the actual number of lane changes minus the optimum number of lane changes. Thus, it is possible in some cases that one subject made more than one unnecessary lane change. . Note that for this measure of effectiveness, the smaller is the measure the fewer the number of unnecessary lane changes and therefore the more effective is the sign.

3, 4, 5. Another measure of effectiveness is the number of lane changes are made within a short distance of the gore. Lane changes near, at, or beyond the painted gore are presumably more hazardous, especially when it is a needed lane change. A needed lane change is a lane change that is necessary for a subject to successfully reach his/her destination. There are two origin-destination pairs that require a needed lane change. An origin in the Left Center lane

requires a lane change to reach an Exit destination (left-hand lane schematic in Figure 5, page 16), and a Right Lane origin requires a lane change to reach a Mainline destination (right-hand lane schematic in Figure 5, page 16).

In a previous study of guide signing for the Central Artery Tunnel in Boston, the researchers observed a number of lane changes at two-lane exits with an option through lane that were made very close to the gore or even beyond the painted gore. Generally speaking, the closer to the gore that the lane change is made, and the more abruptly the lane change is made, the more hazardous is the maneuver.

A distance of 88 feet (1 second of travel time at 60 mph) was tentatively selected for this study as the criterion. Any lane changes after this criterion distance were judged as too close. Because no lane changes were observed this close to the gore, a second criterion distance of 450 feet (about five seconds of travel time at 60 mph) was added. For the 450 feet distance, data were collected for both any lane changes made within 450 feet and needed lane changes made within 450 feet.

A measure of effectiveness for abrupt lane changes was proposed, but then discarded. Specifically, originally, it was proposed to measure the duration of a lane change (from initiation of the maneuver to completion of the maneuver) on the theory that an abrupt lane change suggests a higher probability of conflict with other vehicles. Again, on a previous study of guide signing for the Central Artery Tunnel, the researchers did observe some very abrupt lane changes. In the current study, on Two-Lane Exits with an Option Lane, almost no abrupt lane changes were observed when riding with the test subjects. It also became obvious that measuring the duration of the lane change was not practical because of the uncertainty in determining exactly when a lane change begins and when it ends. For these reasons, this measure of effectiveness was judged not to be useful.

6. The distribution of lane changes is an indication of how well subjects understand the message conveyed by a sign or signs. A lane change that is made when the subject views the 1 MILE sign implies a rapid understanding of the message and is preferable to a lane change made at the 1/2 mile point. Similarly, a change made at the 1/2 mile point is preferable to a lane change made near the gore. Distribution of lane changes was utilized as a measure of effectiveness.

In addition to data collected in the driving simulator, a post-drive debriefing survey was also conducted. Results from this survey are also helpful in assessing driver understanding of alternative sign configurations.

7, 8. One debriefing survey question was: “For this sign, how certain were you about the lane you should be in to reach your assigned destination?” The more certain a driver was, the greater was the index of effectiveness. This question was asked for both advance guide signs and lane designation signs.

**9, 10.** A second debriefing survey question was: “Rate each sign on how difficult it was to understand.” The less difficult a sign was, the greater was the index of effectiveness. This question was asked for both advance guide signs and lane designation signs.

The ten measures of effectiveness described above were used to compare the four different types of static signs for two-lane exits with an option lane. By comparing each of the above measures for different signing configurations, any meaningful and statistically significant differences between configurations can be determined.

## **STUDY FINDINGS**

### **1. Number of Failures to Reach Assigned Destination**

Table 1 (next page) presents information on the number of failures to reach assigned destination. The 24 subjects who were exposed to a given sign type were exposed to that sign type 12 times each. Thus, each sign type received 288 exposures.

The number of failures was very small, either 2 failures out of 288 exposures (in the case of the MUTCD sign type) or 3 failures out of 288 exposures for each of the other three sign types. None of the differences in the proportion of failures in each of the six different possible pairwise comparisons of sign types were statistically significant. It should be noted that there is more than enough power to pick up practically significant differences. So, for example, if the number of failures in one sign type had been 2 out of 288 and the other had been 9 out of 288, the difference would have been significant at the .05 level.

Also shown is information on how the failures are related to origin-destination pair and to younger and older subjects. The difference in the proportion of failures among older and younger subjects was not statistically significant, even though older subjects failed almost four times more frequently than younger adults. There tend to be more failures when the destination is an exit than when it is the mainline (7 out of 11 failures involve an exit destination). However, the difference in proportions is not statistically significant.

**TABLE 1 - NUMBER OF FAILURES TO REACH ASSIGNED DESTINATION**

Notes: This table represents all origin-destination combinations

Each cell shows the number of failures compared to the number of exposures

SIGN CONFIGURATION	YOUNGER SUBJECTS	OLDER SUBJECTS	ALL SUBJECTS
MUTCD	1 / 216	1 / 72	2 / 288
TYPE IB	2 / 216	1 / 72	3 / 288
TYPE II	1 / 216	2 / 72	3 / 288
TYPE III	1 / 216	2 / 72	3 / 288

Notes: This table is broken down by origin-destination pair

SIGN CONFIGURATION	ORIGIN - DESTINATION PAIR																		Total	
	LC-M			RC-M			R-M			LC-Exit			RC-Exit			R-Exit				
	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS		
MUTCD																			2	
TYPE IB										1		1					1	1	2	3
TYPE II								1	1	1	1	2								3
TYPE III	1		1					2	2											3

Notes: The key for origin-destination pairs is -

LC-M Left Center to Mainline  
 RC-M Right Center to Mainline  
 R-M Right to Mainline  
 LC-Exit Left Center to Exit  
 RC-Exit Right Center to Exit  
 R-Exit Right to Exit

The key for subject group is -

YS Younger Subjects  
 OS Older Subjects  
 AS All Subjects

## **2. Unnecessary Lane Changes**

Table 2 (page 23) presents information on unnecessary lane changes. Again, the number of exposures for each sign type (288) is given. There is very little variation among the four sign types, ranging from 92 unnecessary lane changes for the Type III sign to 105 unnecessary lane changes for the MUTCD sign. None of the differences in the proportion of failures in each of the six different possible pairwise comparisons of sign types were statistically significant. About one-third of all exposures resulted in an unnecessary lane change and about two-thirds did not involve an unnecessary lane change. Virtually the same proportion of older subjects makes

unnecessary lane changes as do younger subjects. The differences were not statistically significant.

Also shown is information on how the unnecessary lane changes are related to origin-destination pair, to younger and older subjects, and, collapsed across origin, to just the destination. For each sign type, the proportion of unnecessary lane changes when the subject's destination is the mainline is significantly less than the proportion of unnecessary a lane changes when the subjects destination is an exit (MUTCD,  $z = -2.05$ ,  $p < .02$ ; Type 1B,  $z = -7.97$ ,  $p < .001$ ; Type II,  $z = -8.92$ ,  $p < .001$ ; and Type III,  $z = -9.55$ ,  $p < .001$ ).

Moreover, as can be seen from Table 2 (next page), the distribution of the unnecessary lane changes across trips with both mainline and exit destinations is very different for the MUTCD type sign than it is for the other three types of signs. For the Types IB, II, and III signs, most of the unnecessary lane changes occur when the subject's destination is the exit. Eighty-four percent or more of the unnecessary lane changes involve the exit destination for each of these sign types. For the MUTCD sign type, only about 59 percent involve the exit destination and an unnecessary lane change is relatively much more common when the destination is the mainline.

Consistent with these qualitative observations, the proportion of unnecessary lane changes when the destination is the mainline for the MUTCD sign type is significantly greater than this proportion for any one of the other three sign types ( $p < .05$  for each of the three comparisons). And the proportion of unnecessary lane changes when the destination is the mainline for the Type IB signs is significantly greater than this proportion for the Type III signs. These differences in behavior must be related, some way, to the sign design, but it is not obvious what aspect of the sign design accounts for this difference.

**TABLE 2 - NUMBER OF UNNECESSARY LANE CHANGES TO REACH ASSIGNED DESTINATION**

Notes: This table represents all origin-destination combinations  
 Each cell shows the number of unnecessary lane changes  
 compared to the number of exposures

SIGN CONFIGURATION	YOUNGER SUBJECTS	OLDER SUBJECTS	ALL SUBJECTS
MUTCD	77 / 216	28 / 72	105 / 288
TYPE IB	75 / 216	26 / 72	101 / 288
TYPE II	73 / 216	27 / 72	100 / 288
TYPE III	69 / 216	23 / 72	92 / 288

Notes: This table is broken down by origin-destination pair

SIGN CONFIGURATION	ORIGIN - DESTINATION PAIR																		Total	Mainline	Exit
	LC-M			RC-M			R-M			LC-Exit			RC-Exit			R-Exit					
	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS			
MUTCD	1	0	1	18	3	21	17	4	21	19	10	29	22	11	33	0	0	0	105	43	62
TYPE IB	0	1	1	3	1	4	8	3	11	32	10	42	32	11	43	0	0	0	101	16	85
TYPE II	1	0	1	2	1	3	7	1	8	34	11	45	29	12	41	0	2	2	100	12	88
TYPE III	2	0	2	1	0	1	4	0	4	30	9	39	30	12	42	2	2	4	92	7	85

Notes: The key for origin-destination pairs is -

LC-M Left Center to Mainline  
 RC-M Right Center to Mainline  
 R-M Right to Mainline  
 LC-Exit Left Center to Exit  
 RC-Exit Right Center to Exit  
 R-Exit Right to Exit

The key for subject group is -

YS Younger Subjects  
 OS Older Subjects  
 AS All Subjects

### **3, 4, 5. Lane Changes Made Close to the Gore**

Table 3 (next page) shows that no needed lane changes were made within 88 feet of the painted gore. All four sign types are performing equally well in terms of not creating needed lane changes very close to the gore.



**TABLE 3 - NUMBER OF LAST NEEDED LANE CHANGES MADE LESS THAN 88 FEET FROM PAINTED GORE**

Notes: Only two origin-destination pairs require lane changes  
This table is broken down by origin-destination pair

SIGN CONFIGURATION	Right-Mainline			Left-Center - Exit			Total
	YS	OS	AS	YS	OS	AS	
MUTCD	0	0	0	0	0	0	0
TYPE IB	0	0	0	0	0	0	0
TYPE II	0	0	0	0	0	0	0
TYPE III	0	0	0	0	0	0	0

Notes: The key for subject group is -

YS Younger Subjects  
OS Older Subjects  
AS All Subjects

Table 4 shows the number of needed lane changes made within 450 feet of the painted gore. This represents about five seconds of travel time at 60 mph. Because there are only two origin-destination pairs that require lane changes, the total number of exposures for each sign type is 96. The number of lane changes made within 450 feet of the painted gore ranges from 3 (for the MUTCD and Type II signs) to 8 (for the Type III sign). The proportion of such lane changes for the MUTCD and Type IB signs was significantly less than this proportion for the Type III signs ( $z = -2.71, p < .003$ ). Most of the lane changes made close to the gore involve an origin in the Right lane and a Mainline destination (16 out of 19 lane changes). Lane changes made close to the gore are more frequent for Type III signs than for other sign types.

**TABLE 4 - NUMBER OF LAST NEEDED LANE CHANGES MADE LESS THAN 450 FEET FROM PAINTED GORE**

Notes: Only two origin-destination pairs require lane changes  
This table is broken down by origin-destination pair  
Each cell shows the number of exposures and the number of lane changes less than 450 feet from gore

SIGN CONFIGURATION	Right-Mainline			Left-Center - Exit			Combined		
	YS	OS	AS	YS	OS	AS	YS	OS	AS
MUTCD	3 / 36	0 / 12	3 / 48	0 / 36	0 / 12	0 / 48	3 / 72	0 / 24	3 / 96
TYPE IB	2 / 36	1 / 12	3 / 48	0 / 36	0 / 12	0 / 48	2 / 72	1 / 24	3 / 96
TYPE II	3 / 36	0 / 12	3 / 48	2 / 36	0 / 12	2 / 48	5 / 72	0 / 24	5 / 96
TYPE III	6 / 36	1 / 12	7 / 48	0 / 36	1 / 12	1 / 48	6 / 72	2 / 24	8 / 96

Notes: The key for subject group is -

YS Younger Subjects  
OS Older Subjects  
AS All Subjects

Needed lane changes that are made close to the gore (described above) are of particular interest because these subjects must make a lane change to successfully reach their assigned destination. Thus, these subjects may be more likely to engage in risky lane changing to avoid missing their destination.

It is also of interest to note how many lane changes are made close to the gore, regardless of whether the lane change is needed to reach an assigned destination. Some subjects will make lane changes close to the gore even when it is not required to reach their assigned destination.

Table 5 presents the number of last lane changes made within 450 feet of the painted gore. Type IB has the fewest lane changes while the MUTCD type has the most changes. The proportion of such lane changes was significantly smaller for the Type 1B signs than it was for either the MUTCD signs ( $z = 2.23, p < .013$ ) or the Type III signs ( $z = 1.84, p = < .032$ ).

**TABLE 5 - NUMBER OF LAST LANE CHANGES MADE LESS THAN 450 FEET FROM PAINTED GORE**

Notes: This table represents all origin-destination combinations

Each cell shows the number of lane changes less than 450 feet from gore compared to the number of exposures

SIGN CONFIGURATION	YOUNGER SUBJECTS	OLDER SUBJECTS	ALL SUBJECTS
MUTCD	12 / 216	1 / 72	13 / 288
TYPE IB	3 / 216	1 / 72	4 / 288
TYPE II	8 / 216	1 / 72	9 / 288
TYPE III	9 / 216	2 / 72	11 / 288

Notes: This table is broken down by origin-destination pair

SIGN CONFIGURATION	ORIGIN - DESTINATION PAIR																		Total		
	LC-M			RC-M			R-M			LC-Exit			RC-Exit			R-Exit					
	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS	YS	OS	AS
MUTCD	0	0	0	1	1	2	3	0	3	0	0	0	7	1	8	0	0	0	12	1	13
TYPE IB	0	0	0	1	0	1	2	1	3	0	0	0	0	0	0	0	0	0	3	1	4
TYPE II	0	0	0	1	1	2	3	0	3	2	0	2	2	0	2	0	0	0	8	1	9
TYPE III	1	0	0	1	0	1	6	1	7	0	1	1	1	0	1	0	0	0	9	2	11

Notes: The key for origin-destination pairs is -

LC-M Left Center to Mainline  
RC-M Right Center to Mainline  
R-M Right to Mainline  
LC-Exit Left Center to Exit  
RC-Exit Right Center to Exit  
R-Exit Right to Exit

The key for subject group is -

YS Younger Subjects  
OS Older Subjects  
AS All Subjects

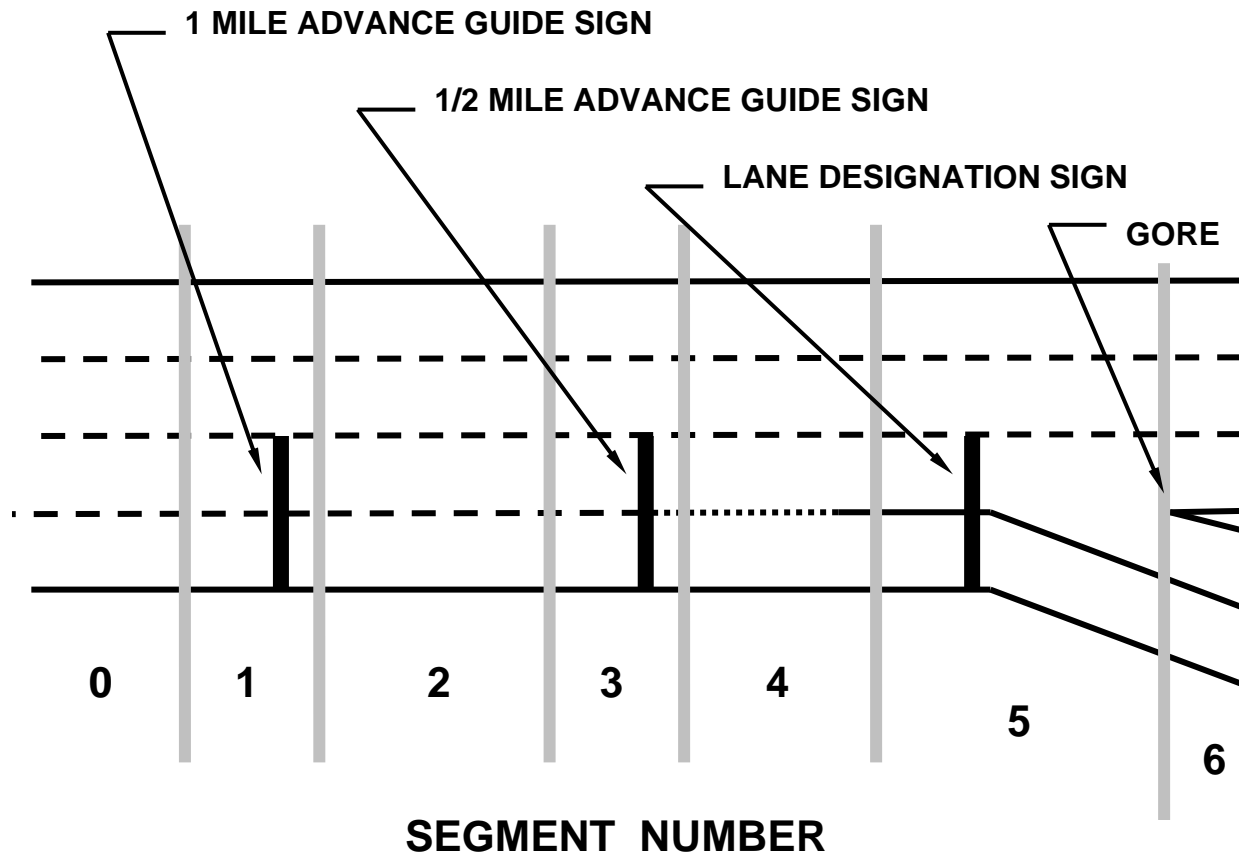
In the breakdown by origin-destination pair, there are two situations that have a lot of lane changing. The MUTCD sign type has a lot of lane changing for a Right Center Lane origin and an Exit destination. This is an origin-destination pair that does not require any lane changing. The Type III sign has a lot of lane changing for a Right Lane origin and a Mainline destination. This is an origin-destination pair that does require lane changing and in this case many lane changes are being made within a short distance of the gore.

## **6. Location of Last Needed Lane Change**

Table 6 (page 28) presents additional information on the location of the last needed lane change. As a reminder, only two origin-destination pairs require lane changes, and this table reflects information for only those two pairs. For purposes of this table, the freeway was divided into seven segments, as follows, and also shown in Figure 7 (next page).

0. Prior to 1 mile sign becoming legible – any lane change that was made so far upstream that the 1 mile sign would not have been legible to the subject
1. In response to 1 mile sign – any lane change that was made upstream of the 1 mile sign and within the distance in which the sign is legible, or within 5 seconds travel time downstream of the sign
2. Delayed response to 1 mile sign – any lane change made more than 5 seconds travel time downstream of the 1 mile sign, but before the 1/2 mile sign is legible
3. In response to 1/2 mile sign – any lane change that was made upstream of the 1/2 mile sign and within the distance in which the sign is legible, or within 5 seconds travel time downstream of the sign
4. Delayed response to 1/2 mile sign – any lane change made more than 5 seconds travel time downstream of the 1/2 mile sign, but before the Lane Designation sign is legible
5. In response to lane designation sign – any lane change that was made upstream of the Lane Designation sign and within the distance in which the sign is legible and before the gore
6. Beyond the gore – This segment applies to those subjects who did not make the last needed lane change and thus failed to reach the assigned destination

**FIGURE 7 - FREEWAY SEGMENTS FOR LOCATION OF  
LAST NEEDED LANE CHANGE**



Each needed lane change was assigned to one of the segments. Table 6 shows the distribution of the locations of these lane changes for each sign type.

Table 7 presents the distribution of locations in a different form. In this table the number of lane changes that had not yet been made at the end of each segment is given.

**TABLE 6 - LOCATION OF LAST NEEDED LANE CHANGE**

Notes: The origin-destination pair of Right Lane origin and Mainline destination, and the O-D pair of Left Center origin and Exit destination both require that a lane change be made. This table shows how frequently the required lane change was made in various longitudinal segments of the freeway.

SIGN CONFIGURATION	SEGMENT 0 PRIOR TO 1 MILE SIGN BECOMING LEGIBLE	SEGMENT 1 IN RESPONSE TO 1 MILE SIGN	SEGMENT 2 DELAYED RESPONSE TO 1 MILE SIGN	SEGMENT 3 IN RESPONSE TO 1/2 MILE SIGN	SEGMENT 4 DELAYED RESPONSE TO 1/2 MILE SIGN	SEGMENT 5 IN RESPONSE TO LANE DESIGNATION SIGN	SEGMENT 6 BEYOND THE GORE - MISSED DESTINATION
MUTCD	4	77	4	7	4	0	0
TYPE IB	0	77	4	10	1	3	1
TYPE II	0	80	2	5	0	6	3
TYPE III	0	68	5	13	0	8	2

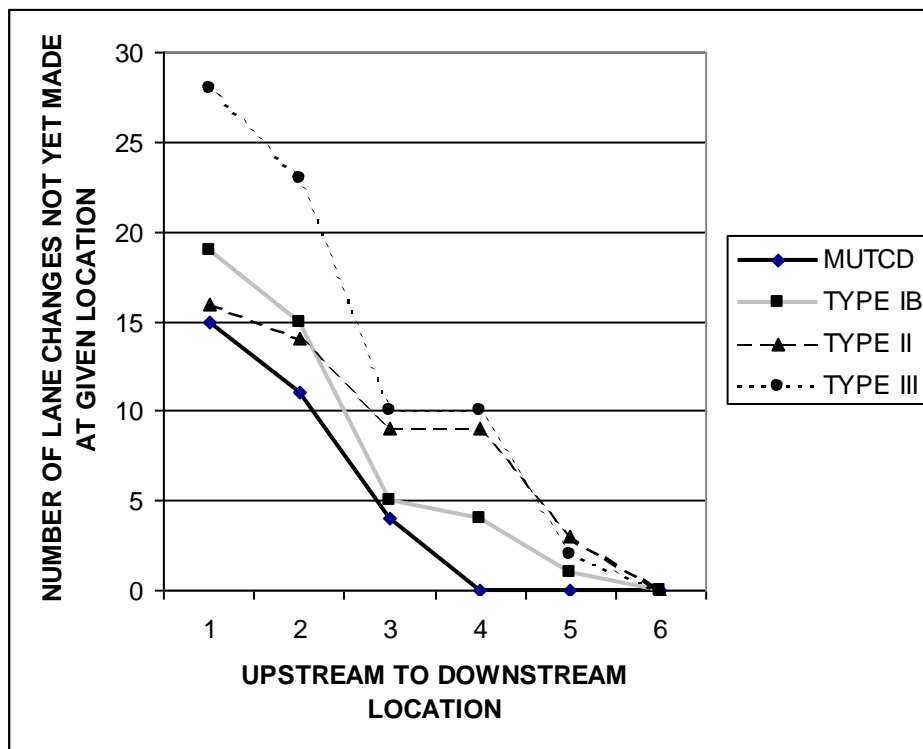
**TABLE 7 - NUMBER OF LANE CHANGES NOT YET MADE AT END OF SEGMENT**

SIGN CONFIGURATION	SEGMENT 0 PRIOR TO 1 MILE SIGN BECOMING LEGIBLE	SEGMENT 1 IN RESPONSE TO 1 MILE SIGN	SEGMENT 2 DELAYED RESPONSE TO 1 MILE SIGN	SEGMENT 3 IN RESPONSE TO 1/2 MILE SIGN	SEGMENT 4 DELAYED RESPONSE TO 1/2 MILE SIGN	SEGMENT 5 IN RESPONSE TO LANE DESIGNATION SIGN	SEGMENT 6 BEYOND THE GORE - MISSED DESTINATION
MUTCD	92	15	11	4	0	0	NA
TYPE IB	96	19	15	5	4	1	NA
TYPE II	96	16	14	9	9	3	NA
TYPE III	96	28	23	10	10	2	NA

The Table 7 data are also shown in Figure 8 (next page) and the differences between sign types are more obvious. The MUTCD sign type elicits lane changes that are made further upstream than the other three sign types. This is an indication of how well subjects understand the messages conveyed by the MUTCD sign. A simple sign test (a statistical test) can be used to evaluate the likelihood that the number of lane changes not yet made at each of the five upstream to downstream locations (1 – 5) would be less for the MUTCD sign type than it would for any of the other sign types. This probability is small (.032) and therefore it is very unlikely that the performance differences seen with the MUTCD sign type are due to chance alone.

In general, Type IB elicits lane changes further upstream than Types II or III, and Type II elicits changes further upstream than Type III. However, using the same simple sign test, one cannot reject the hypothesis that the differences are due to chance alone.

**FIGURE 8 -- LOCATION OF LAST NEEDED LANE CHANGE**



This study presented advance guide signs to the test subjects at both 1 mile and 1/2 mile before the gore. Thus, subjects had two exposures to each advance guide sign. In real-world applications there will be many instances in which it will not be possible to present two advance guide signs to motorists. In urban areas, interchanges are often closely spaced and there is not enough distance between an upstream interchange and the two-lane exit to present two advance guide signs. A second factor, which is especially pertinent for the Types IB, II and III signs is that the two freeway lanes from which one may exit may not exist a full mile upstream of the gore. If the two lanes do not exist, it is not possible to use the advance guide signs because the two arrows on such a sign must be laterally placed over the lanes to which they apply.

In view of the fact that in many instances it will not be possible to present two advance guide signs, it is important to note the number of lane changes not yet made at the ends of segments 1 and 2. These numbers represent the subjects' behavior after they have been exposed to only one advance guide sign – a situation that may occur often in field application. The MUTCD sign has the fewest lane changes not yet made, while the Type III sign has the most lane changes not yet made.

## **DEBRIEFING SURVEY QUESTIONS**

In addition to data collected in the driving simulator, a post-drive debriefing survey was also conducted. Results from this survey are also helpful in assessing driver understanding of alternative sign configurations.

In the debriefing survey, a subject rated only one sign type for a two-lane exit with an option lane – the sign type that the subject had seen in the driving simulator.

### **7, 8. Debriefing Survey Questions 3A and 3B**

Table 8 (next page) presents results for the question: “For this sign, how certain were you about the lane you should be in to reach your assigned destination?”

Subjects had the choice of four subjective answers – very certain, certain, uncertain, and very uncertain. As described in the table, a point value was given to each of these possible answers and an overall score computed. The MUTCD sign scored best for the Advance Guide sign and the Type II sign scored the worst. The scores on the MUTCD signs were significantly better than only the scores on the Type II signs ( $t(37) = 1.96, p < .031$ ) and Type III signs ( $t(40) = 1.84, p < .037$ ).

The Type II sign scored best for the Lane Designation sign. In fact, the scores on the Type II sign were significantly larger than the scores on all other signs (MUTCD signs,  $t(35) = -2.07, p < .023$ ; Type IB,  $t(31) = -2.85, p < .003$ ; Type III,  $t(37) = 2.87, p < .003$ ). None of the other differences were statistically significant.

The Type III sign received a low score for the Lane Designation sign. It should be noted that this is the only sign type that does not provide information on the mainline destination. This fact likely contributes to the sign’s low score.

## TABLE 8 - DEBRIEFING SURVEY, QUESTION 3

Question 3 asked: For this sign, how certain were you about the lane you should be in to reach your assigned destination?

The possible responses were: very certain, certain, uncertain, and very uncertain  
Scores were assigned to these responses as follows:

- 4 = very certain
- 3 = certain
- 2 = uncertain
- 1 = very uncertain

ADVANCE GUIDE SIGN		
SIGN CONFIGURATION	AVERAGE SCORE	RANKING OF SCORE
MUTCD	3.45	1
TYPE IB	3.27	2
TYPE II	3.00	4
TYPE III	3.04	3

LANE DESIGNATION SIGN		
SIGN CONFIGURATION	AVERAGE SCORE	RANKING OF SCORE
MUTCD	3.36	2
TYPE IB	3.14	4
TYPE II	3.74	1
TYPE III	3.21	3

Note: These are the average scores for 91 subjects who completed the debriefing survey

### 9, 10. Debriefing Survey Questions 4A and 4B

Table 9 (next page) presents results for the question: “Rate each sign on how difficult it was to understand.”

Subjects had the choice of five subjective answers – very easy, easy, average, difficult, very difficult. As described in the table, a point value was given to each of these possible answers and an overall score computed. The MUTCD sign scored best for the Advance Guide sign and the Type III sign scored the worst. The scores on the MUTCD sign were significantly better than the scores on both the Type II signs ( $t(40) = 2.46, p < .009$ ) and Type III signs ( $t(42) = 3.37, p < .000$ ). The scores on the Type IB signs were only significantly better than the scores on the Type III signs ( $t(44) = 1.97, p < .027$ ). Finally, the Type II sign scored best for the Lane Designation sign. The scores on this sign differed significantly from the scores on the Type III signs ( $t(36) = 2.38, p < .011$ ). No other differences were statistically significant.



## TABLE 9 - DEBRIEFING SURVEY, QUESTION 4

Question 4 asked: Rate each sign on how difficult it was to understand  
The possible responses were: very easy, easy, average, difficult, very difficult  
Scores were assigned to these responses as follows:

5 = very easy  
4 = easy  
3 = average  
2 = difficult  
1 = very difficult

ADVANCE GUIDE SIGN		
SIGN CONFIGURATION	AVERAGE SCORE	RANKING OF SCORE
MUTCD	4.45	1
TYPE IB	4.13	2
TYPE II	3.77	3
TYPE III	3.50	4

LANE DESIGNATION SIGN		
SIGN CONFIGURATION	AVERAGE SCORE	RANKING OF SCORE
MUTCD	4.18	2
TYPE IB	3.86	3
TYPE II	4.39	1
TYPE III	3.75	4

Note: These are the average scores for 91 subjects who completed the debriefing survey

## ADDITIONAL DEBRIEFING SURVEY RESULTS

The debriefing survey also asked three open-ended questions, as follows.

- What aspect of the sign design (if any) made it difficult to understand?
- Describe the confusion (if any) this sign created for you.
- Write down any other comments you have about this sign.

A compilation of responses to these three questions is given in Appendix 2. The subjective responses tend to reinforce the results of debriefing questions 3 and 4 (Tables 8 and 9). This is true in both the number and nature of responses.

For the Advance Guide sign, the MUTCD type drew the fewest responses, Type IB more responses, and Types II and III the most responses. This is the same pattern shown by questions 3 and 4.

For the Lane Designation sign, Type II drew the fewest responses.

## **COST CONSIDERATIONS**

In addition to driver response, the relative cost of installing each of the four sign configurations is an additional factor to be considered. Two of the four sign types require that overhead sign panels extend across all freeway lanes, thus requiring a sign bridge rather than a cantilever support.

Two state Departments of Transportation – Florida and Minnesota -- provided cost information for sign bridges, cantilever supports, and sign panels. The two agencies were asked to provide the following information.

1. The cost for a 90 foot long sign bridge (sufficient to span five 12 foot lanes), including foundations, the structure itself, and all costs of installation.
2. The total cost, installed, of two sign panels (like the MUTCD Lane Designation signs), including fabrication of the sign panels, reflective sheeting, installation of the panels on the sign bridge, luminaires, and electrical conduit and wiring on the sign structure.
3. The cost for a 40 foot long cantilever sign support (such as would be used for the Advance Guide signs for the Types IB, II, and III signs). Costs include foundation, the structure, and all costs of installation.
4. The total cost, installed, of one sign panel (such as would be used for the Advance Guide signs for the Types IB, II, and III signs) including fabrication of the sign panel, reflective sheeting, installation of the panel on the cantilever support, luminaires, and electrical conduit and wiring on the structure.

The cost information provided by the two states showed no major disparities from one state to the other. An average cost for the two states was used to estimate the costs of each of the four sign configurations.

### **11A. Cost for Three Newly Installed Sign Structures**

Estimated costs, assuming that all three sign structures must be newly installed, are as follows.

MUTCD	\$251,000
Type IB	\$151,000
Type II	\$191,000
Type III	\$151,000

It is important to note that sign location is of critical importance in signing for two-lane exits with an option lane.

### **Situations That May or May Not Require Three New Sign Structures**

In previous discussions within the AASHTO Traffic Engineering Subcommittee and within the Guide and Motorist Information Signs Technical Committee, some individuals have argued that some of the proposed sign types may be less expensive than others because an existing sign structure could be used. For example, let's say that an existing single-lane exit is converted to a two-lane exit with an option lane. The argument is that existing cantilever sign structures for a single lane exit can possibly be used for the Type IB, Type II, or Type III signs. This would, indeed, be less expensive if the cantilever structures allow for satisfactory lateral placement of the sign.

However, the lateral location of the Advance Guide signs for Types IB, II, and III must place the arrows above the centers of the lanes to which the arrows apply, and both the lateral and longitudinal location is important for the Lane Designation signs for all sign types (as described in Figures 2A – 2D on pages 4 – 7 and as shown in Figures 3A – 3D on pages 9 – 12). For these reasons, there will be many instances in which existing cantilever sign structures can not be used.

Another reason that an existing cantilever support could not be used is because an auxiliary lane will be added to the right side of the freeway in conjunction with the addition of a lane on the exit ramp. In this situation, the existing cantilever would be moved to provide space for the added lane.

### **11B. Cost for Two Newly Installed Sign Structures**

The costs for three newly installed sign structures were given above. Those costs represent situations in which it is possible to install Advance Guide Signs at both 1 mile and 1/2 mile before the gore. As noted earlier, there may be many instances in which only one Advance Guide Sign can be installed. The costs for installing two sign structures – a structure for one Advance Guide Sign and a structure for Lane Designation Sign(s) – are as follows.

MUTCD	\$171,000
Type IB	\$101,000
Type II	\$140,000
Type III	\$100,000

## **SELECTION OF “BEST” SIGN CONFIGURATION**

Table 10 (next page) summarizes the performance for each of the 10 measures of effectiveness and for the cost of installation (the columns labeled as “RAW DATA”).

A review of the raw data shows that there is no decisive “winner” that performs best in all categories. One sign type performs best in some categories, another sign performs best in other categories, etc. Each sign type performs best, or is tied for best, for at least two different measures (see summary near the bottom of table). For these reasons it is not clear that any of the

**TABLE 10 - SUMMARY OF PERFORMANCE**

MEASURE NUMBER	MEASURE DESCRIPTION	RAW DATA				WEIGHT
		MUTCD	TYPE IB	TYPE II	TYPE III	
<b>1</b>	Number of failures to reach assigned destination	2	3	3	3	4.31
<b>2</b>	Number of unnecessary lane changes to reach assigned destination	105	101	100	92	5.76
<b>3</b>	Number of last needed lane changes made less than 88 feet from painted gore	0	0	0	0	3.55
<b>4</b>	Number of last needed lane changes made less than 450 feet from painted gore	3	3	5	8	6.14
<b>5</b>	Number of last lane changes made less than 450 feet from painted gore	13	4	9	11	6.48
<b>6</b>	Location of last needed lane change	<b>SEE FIGURE 8</b>				7.79
<b>7</b>	Certainty of lane to reach destination - advance guide sign	3.45	3.27	3	3.04	6.66
<b>8</b>	Certainty of lane to reach destination - lane designation sign	3.36	3.14	3.74	3.21	7.03
<b>9</b>	Difficulty in understanding - advance guide sign	4.45	4.13	3.77	3.5	6.52
<b>10</b>	Difficulty in understanding - lane designation sign	4.18	3.86	4.39	3.75	6.52
<b>11</b>	Cost of installation	\$251,000	\$151,000	\$191,000	\$151,000	4.14
		\$171,000	\$101,000	\$140,000	\$100,000	

Number of measures for which the sign type performs best *	4 plus 1 tie	2 plus 1 tie	2	1 plus 1 tie
Weights associated with the measures for which the sign type performs best **	4.31 7.79 6.66 6.52 6.14	6.48   4.14 6.14	7.03 6.52	5.76   4.14

\* For example, the Type II sign has the best performance for Measure 8 and Measure 10

\*\* For example, for the Type II sign, the weight for Measure 8 is 7.03 and the weight for Measure 10 is 6.52.

sign types is best overall. A judgement on which sign type is best is highly dependent upon one's opinion of which measures of effectiveness are more important than others.

### **Relative Importance of Measures of Effectiveness**

To determine the relative importance of the 10 measures of effectiveness, plus cost of installation, a questionnaire survey was sent to about 40 transportation professionals. These were all individuals who have professional experience in traffic control devices. Responses were received from 29 individuals, comprised of:

- 7 members of the NCHRP panel for this project
- 18 members of the Guide and Motorist Information Signs Technical Committee of the National Committee on Uniform Traffic Control Devices
- 4 State Traffic Engineers

The questionnaire survey is reproduced in Appendix 3. The respondents were given background information on the study, including descriptions of the measures of effectiveness. They were also given information on the raw data, although the survey did not reveal the performance of each sign type (see Appendix 3). Thus, a respondent's judgment on a particular measure of effectiveness was not influenced by their advocacy for one of the four sign types.

Respondents were asked to assign a weight to each of the 11 items. They were instructed to select the measure that they thought was most important and assign a weight of 10 to that item. They were to then assign weights to the other items based upon their relative importance to the most important item.

For each measure, the mathematical average of the weights assigned by the 29 respondents was calculated. This is the value shown in the "WEIGHT" column in Table 10 (previous page). These values represent the consensus judgement of 29 transportation professionals on the relative importance of the 10 measures of effectiveness, plus installation cost.

Respondents placed greatest importance on Measure 6 – Location of Last Needed Lane Change. Least importance was placed on Measure 3 – lane changes less than 88 feet from the gore, presumably because no such lane changes were observed for any sign type. A low weight was also placed on Cost of Installation.

A summary at the bottom of Table 10 shows the number of measures for which each sign type performs best. For example, the Type II sign has the best performance for two measures – for Measures 8 and 10. A second summary at the very bottom of Table 10 shows the *weights* for the measures for which each sign type performs best. For example, for the Type II Sign, the weight for Measure 8 is 7.03 and the weight for Measure 10 is 6.52. These two summaries are indicators of which sign types perform better than others. These are simple indicators and, as such, they do not capture the effect of measures for which a sign performs second best or third best and how those measures contribute to the sign's overall performance. In addition, this simple summary does not distinguish between a situation in which the first place sign type did only slightly better than the second place sign type on a particular measure versus a situation in which the first place sign type greatly exceeded the performance of the second place sign type.

### **Relative Score for Each Sign Type**

To further distinguish overall performance between sign types and gain a better understanding of which is “best”, a scalar is needed to represent how well each sign type performed on a given measure of effectiveness. This is referred to here as the Relative Score for each sign type.

Table 11 shows relative scores that were assigned to each of the four sign types. A column for a fifth sign type (MUTCD / II) also appears in Table 11 and will be discussed later. Rationales for the relative scores are presented below.

**TABLE 11 - RELATIVE SCORE FOR EACH SIGN TYPE**

MEASURE NUMBER	MEASURE DESCRIPTION	RAW DATA				RELATIVE SCORE				
		MUTCD	TYPE IB	TYPE II	TYPE III	MUTCD	TYPE IB	TYPE II	TYPE III	MUTCD/II
<b>1</b>	Number of failures to reach assigned destination	2	3	3	3	1	1	1	1	1
<b>2</b>	Number of unnecessary lane changes to reach assigned destination	105	101	100	92	4	5	5	6	4.5
<b>3</b>	Number of last needed lane changes made less than 88 feet from painted gore	0	0	0	0	1	1	1	1	1
<b>4</b>	Number of last needed lane changes made less than 450 feet from painted gore	3	3	5	8	10	10	6	1	10
<b>5</b>	Number of last lane changes made less than 450 feet from painted gore	13	4	9	11	1	10	7	8	7
<b>6</b>	Location of last needed lane change					10	6	3	1	10
<b>7</b>	Certainty of lane to reach destination - advance guide sign	3.45	3.27	3	3.04	10	6	1	1	10
<b>8</b>	Certainty of lane to reach destination - lane designation sign	3.36	3.14	3.74	3.21	4	1	10	2	10
<b>9</b>	Difficulty in understanding - advance guide sign	4.45	4.13	3.77	3.5	10	7	3	1	10
<b>10</b>	Difficulty in understanding - lane designation sign	4.18	3.86	4.39	3.75	7	2	10	1	10
<b>11</b>	Cost of installation	\$251,000	\$151,000	\$191,000	\$151,000	1	10	5	10	1
		\$171,000	\$101,000	\$140,000	\$100,000					

Relative Scores span a range from 1 to 10, with 10 representing the best score and 1 representing the worst score. For most of the measures, a Relative Score of 10 was assigned to the sign type with the best raw data, and a Relative Score of 1 was assigned to the sign type with the worst raw data. For example, Measure 9 had a best raw data value of 4.45 (for the MUTCD sign type) and

a worst raw data value of 3.50 (for the Type III sign). These sign types were given relative scores of 10 and 1 respectively.

Raw data values between the best and worst values were assigned Relative Scores that were proportionate to the raw data values. For example, the raw data values of 4.13 and 3.77 for Measure 9 were assigned Relative Scores of 7 and 3 respectively.

Measures 1, 2, and 3 are exceptions to the general rules described above. For Measure 3, all four sign types had identical raw data (0 lane changes within 88 feet of the painted gore). All four sign types were assigned relative scores of 1.

Similarly, Measure 1 had no statistically significant difference between the raw data for the four sign types (either 2 missed destinations or 3 missed destinations). A further consideration is that the 29 professionals tended to assign either a very low weight or a very high weight to Measure 1. The low weights (14 professionals assigned a 0, 1, or 2) were likely assigned because there was no statistically significant difference in the raw data. The high weights (10 professionals assigned an 8, 9, or 10) were likely assigned because the number of failures to reach the assigned destination was felt to be very important (although almost no distinction between signs was detected in the experiment). For these reasons, all four sign types were assigned a Relative Score of 1.

Measure 2 yielded some differences between sign types in the raw data, but these differences were not statistically significant. Relative Scores were assigned over a narrow range between 4 and 6.

### **Hybrid Sign Type**

Referring to Figure 9, the reader will note that there are minor differences in the design of the lane designation signs for the MUTCD sign configuration and the Type II sign configuration. The left hand panel for these two sign types is the same. The right hand panel includes two downward pointing white arrows for the MUTCD sign type, and includes a black on yellow EXIT ONLY panel with two diagonally upward pointing arrows for the Type II sign.

**FIGURE 9 – LANE DESIGNATION SIGNS**



From the simulator data (Measures 1 – 6), it is not possible to conclude that one of these lane designation signs results in better performance than the other. Debriefing questions 3B and 4B (Measures 8 and 10), however, show that the Type II lane designation sign received the highest rating of any of the lane designation signs. For question 3B there was a statistically significant

difference between the Type II lane designation sign and the MUTCD type lane designation sign (the Type II sign being better).

Responses to the open-ended questions on the debriefing survey tend to reinforce the results of debriefing questions 3B and 4B and also indicate a preference for the Type II lane designation sign.

These findings suggested that the performance of the MUTCD sign configuration would be better if the Type II lane designation sign were substituted for the MUTCD lane designation sign. This, in essence, is a hybrid sign configuration. In Table 11 it is described as “MUTCD / II”.

The Relative Scores for the MUTCD / II sign type in Table 11 (p. 37) are based on judgements of how well this sign type would likely have performed if it had been tested in the experiment.

- Measures 1 and 3 were assigned relative scores of 1 because all four of the other sign types had been assigned scores of 1.
- Measure 2 was assigned a relative score of 4.5 (the midpoint between the relative scores for the MUTCD and Type II signs) because there was no conclusive reason to support a value of either 4 or 5.
- If last needed lane changes are made less than 450 feet from the painted gore, it is primarily due to the failure of the advance guide signs to elicit a lane change. Therefore, the relative score for the hybrid sign should be the same as for the sign type that uses the same advance guide sign. Because the hybrid sign uses the same advance guide signs as the MUTCD sign type, the hybrid sign was assigned a relative score of 10 for Measure 4.
- A similar rationale based on the advance guide sign supports the relative scores assigned for Measures 6.
- Measure 5 is primarily related to lane changes elicited by the lane designation signs. Because the hybrid sign has the same lane designation signs as Type II, the hybrid sign was assigned a relative score of 7.
- The relative scores for Measures 7 through 10 are directly associated with specific signs that were evaluated in the debriefing survey.
- The relative score for Measure 11 is based on the estimated cost of installation, which is the same as for the MUTCD sign type.

### **Point Total for Each Sign Type**

Table 12 (page 41) presents the raw data, Relative Scores, Weight for each Measure, and the calculations that yield a point total for each sign type. The point total is a representation of how well each sign type performed, based on a Relative Score for each Measure and a Weight for each Measure. This method helps to distinguish between the performance of different sign types in a way that is not obvious when one simply looks at the raw data.





**TABLE 12 - POINT TOTAL FOR EACH SIGN TYPE**

MEASURE NUMBER	MEASURE DESCRIPTION	RAW DATA				RELATIVE SCORE					WEIGHT	RELATIVE SCORE X WEIGHT				
		MUTCD	TYPE IB	TYPE II	TYPE III	MUTCD	TYPE IB	TYPE II	TYPE III	MUTCD/II		MUTCD	TYPE IB	TYPE II	TYPE III	MUTCD/II
1	Number of failures to reach assigned destination	2	3	3	3	1	1	1	1	1	4.31	4.31	4.31	4.31	4.31	4.31
2	Number of unnecessary lane changes to reach assigned destination	105	101	100	92	4	5	5	6	4.5	5.76	23.04	28.80	28.80	34.56	25.92
3	Number of last needed lane changes made less than 88 feet from painted gore	0	0	0	0	1	1	1	1	1	3.55	3.55	3.55	3.55	3.55	3.55
4	Number of last needed lane changes made less than 450 feet from painted gore	3	3	5	8	10	10	6	1	10	6.14	61.40	61.40	36.84	6.14	61.40
5	Number of last lane changes made less than 450 feet from painted gore	13	4	9	11	1	10	7	8	7	6.48	6.48	64.80	45.36	51.84	45.36
6	Location of last needed lane change					10	6	3	1	10	7.79	77.90	46.74	23.37	7.79	77.90
7	Certainty of lane to reach destination - advance guide sign	3.45	3.27	3	3.04	10	6	1	1	10	6.66	66.60	39.96	6.66	6.66	66.60
8	Certainty of lane to reach destination - lane designation sign	3.36	3.14	3.74	3.21	4	1	10	2	10	7.03	28.12	7.03	70.30	14.06	70.30
9	Difficulty in understanding - advance guide sign	4.45	4.13	3.77	3.5	10	7	3	1	10	6.52	65.20	45.64	19.56	6.52	65.20
10	Difficulty in understanding - lane designation sign	4.18	3.86	4.39	3.75	7	2	10	1	10	6.52	45.64	13.04	65.20	6.52	65.20
11	Cost of installation	\$251,000	\$151,000	\$191,000	\$151,000	1	10	5	10	1	4.14	4.14	41.40	20.70	41.40	4.14
		\$171,000	\$101,000	\$140,000	\$100,000											
POINT TOTAL											386.38	356.67	324.65	183.35	489.88	
Number of measures for which the sign type performs best		4	3	2	2	POINT TOTAL WHEN NOT INCLUDING COST OF INSTALLATION					382.24	315.27	303.95	141.95	485.74	



The Type III sign yields the lowest point total (183.35) and is clearly surpassed in performance by other sign types.

The Type II sign has a point total (324.65) that is much higher than the Type III sign and this is attributed to the points earned for Measures 4, 5, 6, 8, 9, and 10.

The Type II sign does not perform as well as the Type IB sign (a point total of 356.67). The principal reason that the Type II sign is only 32 points below the Type IB sign is that the Type II sign has high points earned for Measures 8 and 10. In fact, these are the only Measures for which the Type II sign has higher points earned than the Type IB sign.

The MUTCD sign has a point total of 386.38, a point total that is 30 points higher than the Type IB sign. The Type IB sign performs slightly better than the MUTCD sign for Measure 2. The Type IB sign performs substantially better – 58 points earned better – for Measure 5 and the costs of installation is less for the Type IB sign. For all other measures, the MUTCD sign performs better. It could be argued that the Type IB sign is competitive with the MUTCD sign.

The hybrid sign – the combination of the MUTCD and Type II sign configurations – takes advantage of the strengths of both sign configurations. The MUTCD / II point total of 489.88 exceeds the MUTCD sign type by over 100 points. This is due almost exclusively to the points earned for Measures 5, 8 and 10.

It is also clear that the hybrid sign outperforms the Type IB sign. The Type IB sign has slightly better points earned for Measure 2. The Type IB has higher points earned for Measure 5 and has a lower cost of installation. Overall, however, the hybrid sign has a point total 130 points better than the Type IB sign.

It is also of interest to observe the point totals of the five sign types if the cost of installation is not included in the point total. As shown at the bottom of Table 12 (page 41), if installation cost is removed, the result is to further emphasize the better performance of the MUTCD and hybrid signs.

The weights used in Table 12 (page 41) represent the average of the weights assigned by the 29 professionals. It is of interest to ask how the five sign types compare if each professional's weights are individually applied in Table 12 (page 41), rather than using the average weight.

For the four sign types, 25 out of 29 professionals would have “selected” the MUTCD sign. When the hybrid sign type is included, 27 out of 29 professionals would have “selected” the hybrid sign. This indicates that these signs score best for a variety of relative weights that may be assigned to the measures. Or, stated another way, the selection of the best performing sign is insensitive to relative weight, at least within the range of weights that were assigned by the 29 professionals.

There is one additional factor, not included in the above analysis, that give the MUTCD sign type and the hybrid sign type an advantage over the Type IB sign.

For the Type IB sign, the exiting lane and the option lane must physically exist at the upstream locations where the advance guide signs are located. Those lanes must physically exist because the sign is intended to be located laterally so that the two arrows are centered above each of the lanes to which they apply. The advance guide signs for the MUTCD and hybrid sign types have more flexibility. Their lateral location is less important and they could be used at upstream locations where the exiting lane (and the option lane) do not exist. The diagrammatic symbol simply indicates that at the location of the gore it is possible to exit from the two rightmost lanes. Thus, the MUTCD and hybrid sign types have more flexibility in application.

## **RECOMMENDED SIGN CONFIGURATION**

Numerous groups will have a role in the ultimate decision on which sign design to include in the MUTCD. These groups will include the NCHRP panel, the Guide and Motorist Information Signs Technical Committee of the National Committee, the National Committee as a whole, commentators to federal rulemaking, and finally, the Federal Highway Administration. Each of these groups may consider other factors in evaluating different sign designs that were not included in this study. These groups may also assess and evaluate the data from this study and place different emphasis on various sign characteristics than did this report. Nonetheless, this study should make a recommendation.

Based upon the experimental results and the analysis of the measures of effectiveness, a hybrid sign configuration is recommended. It consists of the Advance Guide signs in the MUTCD sign configuration and the Lane Designation Signs in the Type II sign configuration. The recommended sign configuration is illustrated in Figure 10 (next page).

The sign dimensions shown in Figure 10 are representative dimensions. These are the sign dimensions that were used on signs shown to test subjects in the driving simulator in this study. In real-world application, sign dimensions could vary slightly, for example, to obtain full foot increments in panel sizes, to allow larger letter sizes, or to accommodate longer destination names.

## FIGURE 10 - RECOMMENDED SIGN CONFIGURATION

These Signs are similar to those given in MUTCD (page 2E-26) for a two lane exit with an option lane. The design of the diagrammatic figure on the Advance Guide Signs has been modified to clearly indicate four lanes on the approach. The right hand sign panel of the Lane Designation Signs is a different design from that given on page 2E-26 of the MUTCD.

Lane Designation Signs (Longitudinally located at the theoretical gore, i.e., at a point where the right edgeline for the mainline and the left edgeline for the ramp begin at a common point and then diverge. Laterally located so that arrows are centered above the lanes to which each applies.)



34.0 x 15.0 ft



22.0 x 15.0 ft

Advance Guide Sign (Located approximately ½ mile in advance of exit and centered over the four approach lanes)



32.5 x 8 ft

Advance Guide Sign (1 mile in advance of exit and centered over the the four approach lanes)



32.5 x 8 ft

## **APPENDIX 1**

### **DEBRIEFING SURVEY**

Upon completion of the drive in the simulator, subjects completed a debriefing survey. There were four different versions of debriefing survey, corresponding to the four different types of signs for two-lane exits with an option lane. A subject received the version of survey that showed the sign type seen by the subject during the simulator drive.

The sample debriefing survey shown here is the survey that was given to those subjects who were exposed to the Existing MUTCD Sign Configuration. The second and third rows of signs on the first page are the Advance Guide Sign and the Lane Designation Sign for the two-lane exit with an option lane. Surveys shown to other subjects were identical except that the second and third rows of signs on the first page were for the sign configurations that they saw on their drives. The first sign on the first page and all of the signs on the second page are signs that the subjects encountered on the freeway segments that did not have two-lane exits with an option lane.




# DEBRIEFING SURVEY

Subject Code \_\_\_\_\_







PLEASE ANSWER THE FOLLOWING QUESTIONS (**BOTH FRONT AND BACK**) AND RETURN TO THE EXPERIMENTER.

Did pavement markings help you to determine the proper lane to reach your destination? Answer “yes” if this was true for one or more of your target destinations.      Yes    No

Did pavement markings ever help you to understand that, if you stayed in a lane, you would be forced to exit?      Yes    No

SIGN	Do you remember seeing a sign of this style (or one very similar) in the driving simulator?	In your “real world” driving experience, how frequently have you seen signs with a design like this?	For this sign, how <u>certain</u> were you about the lane you should be in to reach your assigned destination?  1 = very certain 4 = very uncertain	Rate each sign on how difficult it was to understand.  1 = very easy 5 = very difficult	What aspect of the sign design (if any) made it difficult to understand? If none, write “none”. You may mark up the sign illustrated in the left column	Describe the confusion (if any) this sign created for you If none, write “none”..	Write down any other comments you have about this sign.
	Yes    No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes    No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes    No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			



SIGN	Do you remember seeing a sign of this style (or one very similar) in the driving simulator?	In your “real world” driving experience, how frequently have you seen signs with a design like this?	For this sign, how <u>certain</u> were you about the lane you should be in to reach your assigned destination?  1 = very certain 4 = very uncertain	Rate each sign on how difficult it was to understand.  1 = very easy 5 = very difficult	What aspect of the sign design (if any) made it difficult to understand? If none, write “none”. You may mark up the sign illustrated in the left column	Describe the confusion (if any) this sign created for you If none, write “none”..	Write down any other comments you have about this sign.
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			
	Yes No	Never Rarely Sometimes Often	1 very certain 2 certain 3 uncertain 4 very uncertain	1 very easy 2 easy 3 average 4 difficult 5 very difficult			

THANK YOU FOR YOUR PARTICIPATION.

**APPENDIX 2**

**COMPILATION OF RESPONSES  
TO QUESTIONS ON DEBRIEFING SURVEY**

## **EXISTING MUTCD SIGN CONFIGURATION**

### **ADVANCE GUIDE SIGN (AT 1/2 MILE)**

What aspect of the sign design (if any) made it difficult to understand?

If staying on 475, 'right center' is probably okay, but I'd get in 'left center' to be sure

Center right lane [subject drew an arrow to the right center lane on the sign]

3<sup>rd</sup> lane being forced to turn or not [subject drew arrow on the right center lane showing that it has the option of either mainline or exit]

Distance to the exit

Describe the confusion (if any) this sign created for you.

Is 'right center' for 24 only?

It was slightly annoying

Write down any other comments you have about this sign.

I like it when they specify 1 or 2 lanes for exit

Right lane exit only

This sign was clear in showing that the right 2 lanes could exit, but all the dotted lines made the sign too busy

### **LANE DESIGNATION SIGN (AT GORE)**

What aspect of the sign design (if any) made it difficult to understand?

Could be indicated more clearly with lane dividers [subject sketched lane dividers on the sign]

Are the right two [lanes] exit only?

None, except if it is unclear which lane the arrow is pointing to

It's confusing because it makes me think there should be 4 lanes, when one is an exit and one isn't

There are more arrows than lanes

Lane group for exit 24

I knew that I was on a 4-lane highway, so the sign with 5 arrows was confusing

Too much to see at one time (O)

If it was a 5 lane road, (none) [no difficulty in understanding]. But if not I always go to far right lane for 24 or second to left for 475 (O)

Describe the confusion (if any) this sign created for you.

If I'm in the right lane can I still go 475 north?

It was slightly annoying

If I was in the Right-Center lane, I was uncertain if I would be forced to exit because there were 2 arrows for different destinations for that lane

5/6 lanes of traffic. One must decide what lane to stay in. 6 lanes or 5 lanes? (O) \*

Too many lanes (O)

None if a 5 lane road, if less I would assume 24 will lead to a two ... (O)

Write down any other comments you have about this sign.

I like it when they specify 1 or 2 lanes for exit

Completely clear

Too many lanes. I would not travel on a highway this busy at my age (O)

\* (O) indicates the response was from an Older subject

## **TYPE 1B**

### **ADVANCE GUIDE SIGN (AT 1 MILE)**

#### What aspect of the sign design (if any) made it difficult to understand?

Too much information on the sign  
[subject drew in dashed lane lines on the double-headed arrow]  
Right hand side has too much info  
“1 MILE” was confusing  
Not sure if one or two exit lanes  
The “1 MILE” on the bottom doesn’t specify “1 MILE” to where  
Name of the Avenue [the street name for the exit destination] and “EXIT ONLY” together  
“24” too vague. Too much info. “1 MILE” too small (O)  
Confusing what happens in 1 mile (O)  
Confusion on what “1 MILE” refers (O)

#### Describe the confusion (if any) this sign created for you.

Too much information on the sign  
Not used to this sign layout  
“1 MILE” – confused about what was after a mile  
EXIT ONLY part  
Panic ! with too much info (O)  
Right arrow should be smaller (O)  
Confusion on what “1 MILE” refers (O)

#### Write down any other comments you have about this sign.

Seems cluttered on right hand side  
Intuitive, assuming driving experience

### **LANE DESIGNATION SIGN (NEAR GORE)**

#### What aspect of the sign design (if any) made it difficult to understand?

Could specify lanes; could give mileage to exit [subject wrote in “1 MILE” on the sign and wrote in “”RIGHT LANE” above the EXIT ONLY panel]  
Not sure if both right lanes were exit lanes [subject drew in dashed lane lines on the double-headed arrow]  
Right hand side has too much info  
Not sure if one or two exit lanes [subject circled the two arrows to the right]  
The sign is for 2 different directions and “EXIT ONLY” grabs attention  
Name of the Avenue [the street name for the exit destination] and “EXIT ONLY” together  
“24” vague (O)  
Makes sense (O)  
Not clear a single exit (O)

#### Describe the confusion (if any) this sign created for you.

Not sure if car should change lanes immediately  
Not used to this sign layout  
EXIT ONLY part  
Had to slow down [implied lots of information on sign] (O)  
Number of lanes involved (O)

#### Write down any other comments you have about this sign.

Seems cluttered on right hand side  
Intuitive, assuming driving experience

## TYPE II

### ADVANCE GUIDE SIGN (AT 1/2 MILE)

What aspect of the sign design (if any) made it difficult to understand?

It is unclear whether 15 is the exit or the primary road [ subject circled the EXIT ONLY panel]

[subject circled the bottom portion of the sign (white line and below)]

[subject circled the two down arrows]

This sign does not explain the choices very well

Was difficult to understand [subject circled “Marion Ave” and white down arrow]

We may not know [where] “Marion Ave” is going – through or exit

The two arrows were confusing

Arrow with no destination indicated. [referring to the left arrow, the subject wrote: “Where does this arrow go?”]

Exits aren’t usually straight ahead (O)

Is Marion Ave thru or “exit only” or both? (O)

Describe the confusion (if any) this sign created for you.

Which lane arrow correspond with where to go

I waited until last minute to see where it will take me and missed my exit

We may not know [where] “Marion Ave” is going – through or exit

The exit could have been for both arrow lanes

Can you get to Marion Ave. from either arrow?

2 arrows. Get one sign / arrow suggest an exit

Write down any other comments you have about this sign.

Exit only arrows encouraged lane change, to the marked lane if it was my exit or out of it if it was not

Which one? [in reference to the two arrows]

Did not like this design

I got the hang of what it meant after making a mistake

We may not know [where] “Marion Ave” is going – through or exit

### LANE DESIGNATION SIGN (AT GORE)

What aspect of the sign design (if any) made it difficult to understand?

[subject circled the rightmost down arrow on the left sign panel and the leftmost up arrow on the right sign panel] Subject 14

You only need one sign, not two

This was very easy to understand. I like it better than [the 1/2 mile advance guide sign]

It’s harder to choose among 3 directions (O)

Describe the confusion (if any) this sign created for you.

Write down any other comments you have about this sign.

[subject commented on the rightmost down arrow on the left sign panel and the leftmost up arrow on the right sign panel] Subject 13

OK design

This one is nice and clear

### **TYPE III**

#### **ADVANCE GUIDE SIGN (AT 1/2 MILE)**

What aspect of the sign design (if any) made it difficult to understand?

That the sign it's pointing to two different lanes [subject circled the left arrow and put a question mark beside it]

2 arrows

If I take exit, will I be on 15 or not???

Not sure if "white" arrow [the left arrow] lane will lead to exit

Which lane to be in? Right or left?

After seeing it the first few times, I understood the difference between the must exit lane and the can exit lane

[subject circled the left arrow] (O)

Extra arrow (O)

Extra arrow makes it difficult to interpret (O)

Describe the confusion (if any) this sign created for you.

You can't decide which lane is the Avenue

Which lane should I be in?

Arrow on the left [subject circled left arrow]

Having street name with exit only with two down arrows to stay on [subject circled left arrow and EXIT ONLY panel]

If in "white" arrow lane will I still need to shift over one lane

Pavement markings help with these type of signs

Can't tell if there are 1 or 2 lanes

The white arrow [subject circled the left arrow]

15 and Marion Ave same? (O)

Extra arrow is confusing (O)

Write down any other comments you have about this sign.

#### **LANE DESIGNATION SIGN (NEAR GORE)**

What aspect of the sign design (if any) made it difficult to understand?

That the sign it's pointing to two different lanes [subject circled the left arrow and put a question mark beside it]

2 arrows

Does 15 go strait or it turns right

Not sure if "white" arrow [the left arrow] lane will lead to exit

Subject circled the left arrow (O)

Extra arrow where to? (O)

Not too easy to read because of small size [referring to EXIT ONLY panel and arrow] (O)

Describe the confusion (if any) this sign created for you.

You can't decide which lane is the Avenue

Do 2 lanes go that way?

Arrow on the left [subject circled left arrow]

The arrow pointing right [subject circled left arrow]

The arrows would normally be pointing down

Pavement markings help with these type of signs

15 and Marion Ave same? (O)

Difficult to see from a distance (O)

Write down any other comments you have about this sign.

The diagonal arrows made it easy to see where to go

Prefer [up] arrows to straight [down] arrows (O)

**APPENDIX 3**

**SURVEY**

**TO DETERMINE RELATIVE IMPORTANCE**

**OF 11 MEASURES OF EFFECTIVENESS**



**Dear member of the Guide and Motorist Information Signs Technical Committee:**

A laboratory study evaluating four different designs for signing Two-Lane Exit Ramps with an Option Lane has been completed. The research team is now in the process of selecting the sign type that provides the best performance.

Your help is essential in this selection process.

You are invited to read the attached background information and to then respond to a questionnaire with 11 questions. Your responses will be especially helpful.

I expect to make a presentation to the Guide and Motorist Information Signs Technical Committee at its January meeting.

**Please respond to the attached questionnaire by no later than Monday, November 24.** You may fill in the questionnaire and send it to me electronically at: [upchurch@ecs.umass.edu](mailto:upchurch@ecs.umass.edu)

If you have any questions, please telephone me at 202/226-5456.

Thank you. I look forward to seeing you in January.

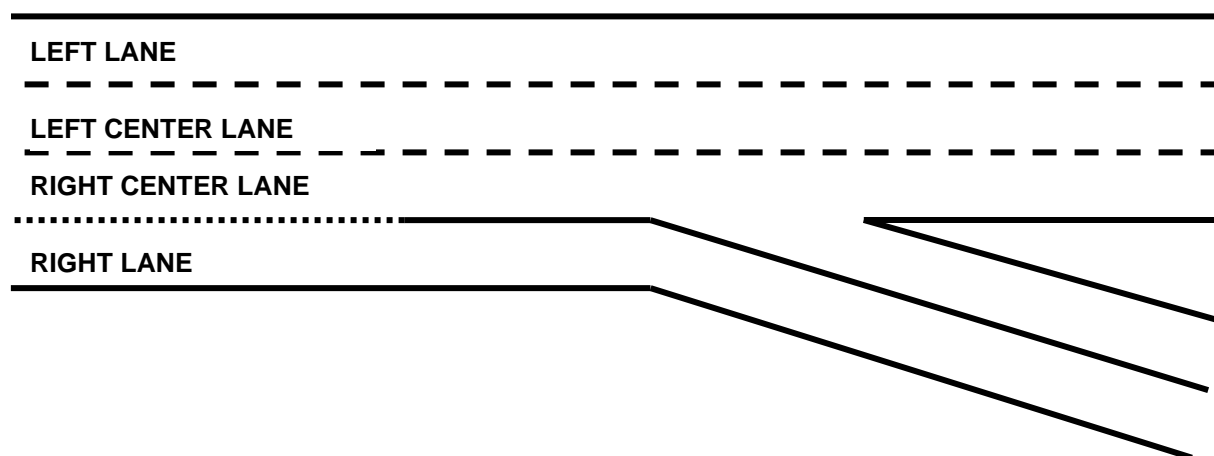
# BACKGROUND INFORMATION

## CHALLENGES IN CREATING A SIGN DESIGN

A two-lane exit with an option lane (see Figure 1) presents a challenge in communicating information to the motorist. Information should be presented in a simple sign design that will be easily understood by drivers and allow them to understand the following:

- The only destination that can be reached by the right lane is the exit,
- Both the exit destination and the mainline destination can be reached by the right-center lane,
- The only destination that can be reached by any other lane is the mainline, and
- The identifying information about each destination (mainline and exit), such as street name, route number, or destination name, that lets them determine whether to remain on the mainline or to exit.

**FIGURE 1 - TWO-LANE EXIT WITH AN OPTION LANE**



## FOUR SIGN DESIGNS

Four different sign configurations were tested in this study. The term “Advance Guide Sign” is used to describe the signs displayed at the locations 1 mile and 1/2 mile before the gore. The term “Lane Designation Sign” is used to describe the signs displayed at, or near, the painted gore.

## EXPERIMENTAL DESIGN

Ninety-six (96) test subjects were hired to participate in an experiment in a driving simulator. The 96 subjects were divided into four groups of 24 individuals. Each group was exposed to one of the four sign configurations.

Each subject drove in a driving simulator for about one hour. During this time each subject drove on 23 segments of freeway. Each segment included about 1 1/4 to 2 1/4 miles of freeway approaching an exit. Each segment included Advance Guide Signs for an exit and Lane Designation signs at the exit.

Each freeway segment had four lanes in the direction of travel – the left lane, the left-center lane, the right-center lane, and the right lane. For those segments that had two-lane exits with an option lane, the right lane was required to exit and the right-center lane was the option lane (as shown in Figure 1).

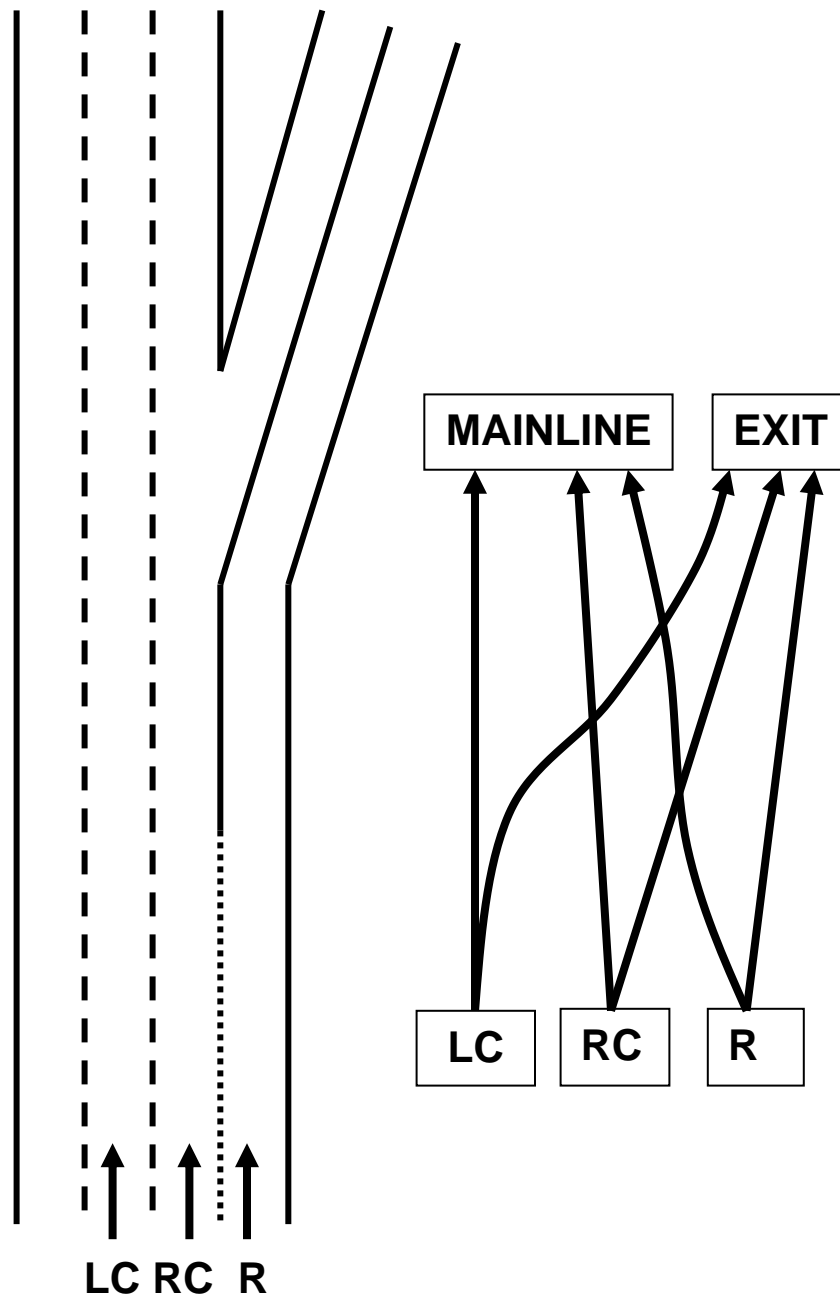
At the beginning of each segment, the subject was assigned a lane in which to begin -- the left-center lane, the right-center lane, or the right lane. This lane is referred to as the origin. Each subject was also given a destination in the form of either a street name or a route number. The subject did not know whether the destination would be reached via the mainline or via an exit. since both street names and route numbers were each used about equally often as mainline and exit destinations. The subject was directed to begin driving, asked to maintain a speed of 60 mph, and given the following instruction. “Stay in the lane in which you begin until you see information indicating that you need to do otherwise to reach your destination.”

With three possible origins (left-center lane, right-center lane, and right lane) and two possible destinations (corresponding to either the mainline or an exit), there were six origin-destination pairs, as shown in Figure 2. Each subject encountered each of the six origin-destination pairs two different times.

Data on driver behavior was automatically collected by the driving simulator. Measures of interest derived from the recorded data included locations of lane changes, whether unnecessary lane changes were made, and whether a driver missed an assigned destination.

Upon completion of the drive in the simulator, each subject completed a debriefing survey.

FIGURE 2 - ORIGINS AND DESTINATIONS



## MEASURES OF EFFECTIVENESS

A sign can be considered effective if drivers follow the ideal path for a given origin lane and destination. Figure 3 illustrates the desirable travel paths for each origin-destination pair. These are the travel paths that have no unnecessary lane changes and no missed destinations.

There are several measures of effectiveness that can be used to determine how well each guide signing configuration communicates information to each group of drivers.

1. A very basic measure of effectiveness is the frequency with which test subjects fail to reach their assigned destination. In other words, how many drivers “miss” their destination vs. how many are able to reach their destination? For example, do some drivers mistakenly stay on the mainline when they should have exited to reach their destination?

2. Another measure of effectiveness is how many unnecessary lane changes subjects make to reach their destination (for example, move out of an option lane when they do not have to do so). There are several examples of unnecessary lane changes, as shown in Figure 4.

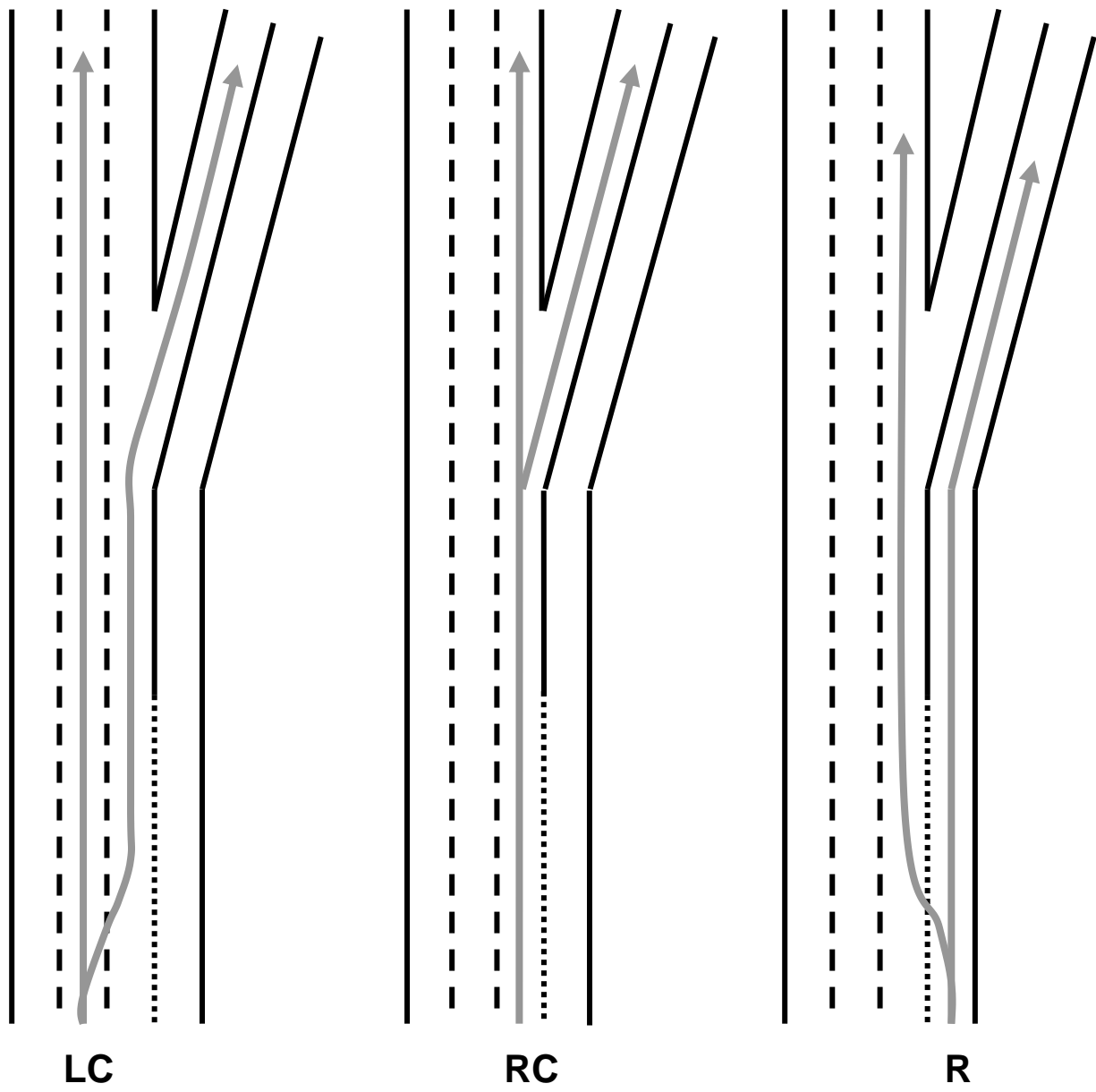
For this study, unnecessary lane changes were counted as follows. First, the optimum (or desirable) number of lane changes for each origin-destination pair was determined. Those values are shown.

ORIGIN	DESTINATION	OPTIMUM NUMBER OF LANE CHANGES
Left-center lane	Mainline	0
Left-center lane	Exit	1
Right-center lane	Mainline	0
Right-center lane	Exit	0
Right lane	Mainline	1
Right lane	Exit	0

Next the actual number of lane changes made by the subject was observed. Finally, the number of unnecessary lane changes was calculated as the actual number of lane changes minus the optimum number of lane changes. Thus, it is possible in some cases that one subject made more than one unnecessary lane change. . Note that for this measure of effectiveness, the smaller is the measure, the fewer the number of unnecessary lane changes and therefore the more effective is the sign.

3, 4. One can measure how many lane changes are made within a short distance of the gore. Lane changes near, at, or beyond the painted gore are presumably more hazardous, especially when it is a needed lane change. A needed lane change is a lane change that is necessary for a subject to successfully reach his/her destination. There are two origin-destination pairs that require a needed lane change. An origin in the Left Center lane requires a lane change to reach an Exit destination (left-hand lane schematic in Figure 3), and a Right Lane origin requires a lane change to reach a Mainline destination (right-hand lane schematic in Figure 3).

**FIGURE 3 - DESIRABLE TRAVEL PATHS**



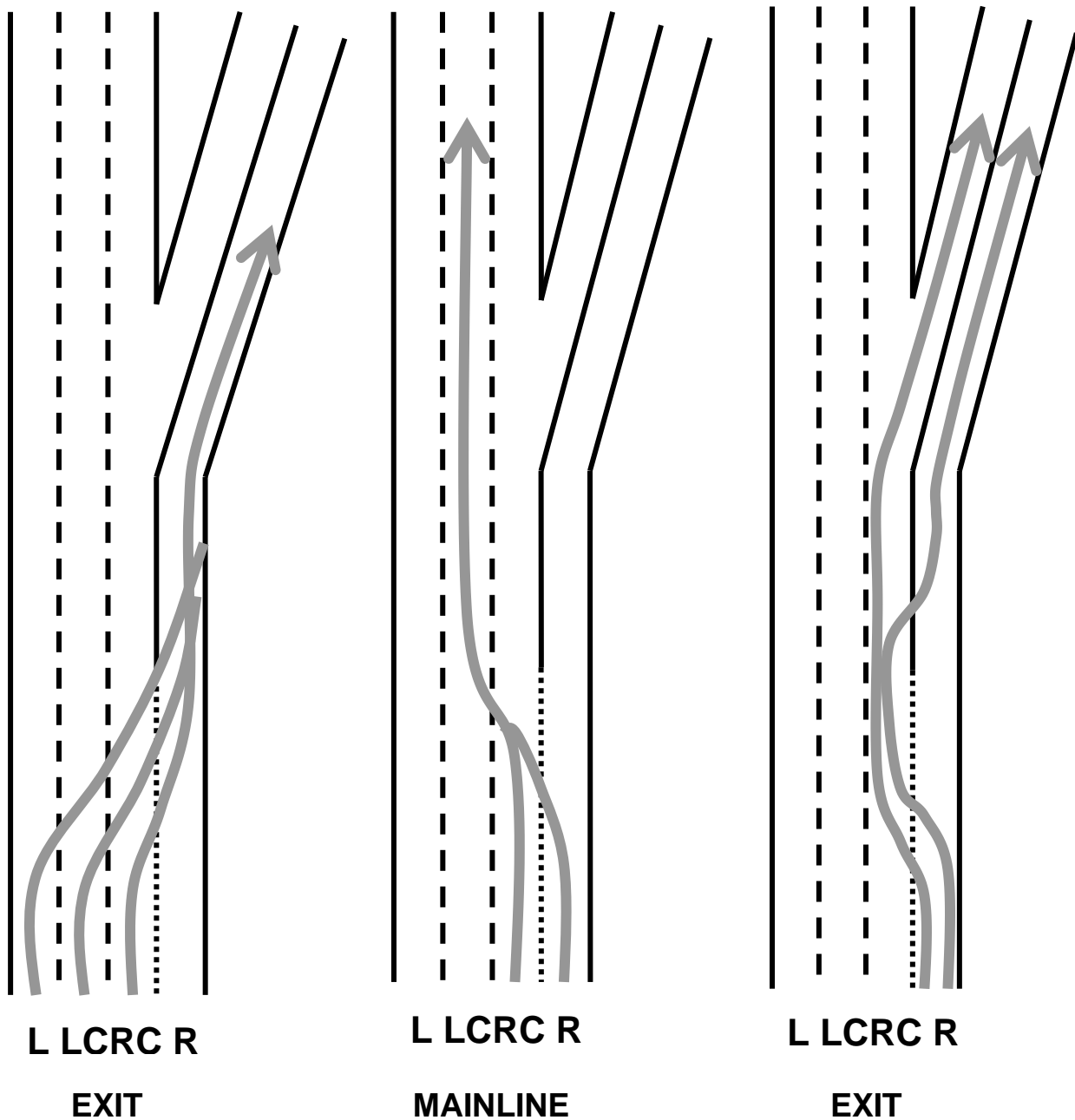
DESIRABLE TRAVEL  
PATHS FROM AN ORIGIN  
IN THE LEFT-CENTER  
LANE

DESIRABLE TRAVEL  
PATHS FROM AN  
ORIGIN IN THE RIGHT-  
CENTER LANE

DESIRABLE TRAVEL  
PATHS FROM AN  
ORIGIN IN THE RIGHT  
LANE

**FIGURE 4 - EXAMPLES OF UNNECESSARY LANE CHANGES**

( Note that originating lane of each path is labeled immediately below the lane schematic and the destination is shown below the origin)



Distances of 88 feet (1 second of travel time at 60 mph) and 450 feet (about five seconds of travel time at 60 mph) were selected for this study as the criterion.

5. Measure 5 is the number of lane changes made within 450 feet of the gore. This includes both needed lane changes and any other lane changes.

6. While measures 3, 4 and 5 consider lane changes that are made close to the gore, it is also important to consider the locational distribution of lane changes, beginning upstream as far as the first advance guide sign. Distribution of lane changes by location is an indication of how well subjects understand the message conveyed by a sign or signs. A lane change that is made when the subject views the 1 MILE sign implies a rapid understanding of the message and is preferable to a lane change made at the 1/2 mile point. Similarly, a change made at the 1/2 mile point is preferable to a lane change made near the gore.

Figure 5 helps to understand the distribution of lane changes from upstream to downstream. In Figure 5 the freeway was divided into seven segments, as described below.

0. Prior to 1 mile sign becoming legible – any lane change that was made so far upstream that the 1 mile sign would not have been legible to the subject
7. In response to 1 mile sign – any lane change that was made upstream of the 1 mile sign and within the distance in which the sign is legible, or within 5 seconds travel time downstream of the sign
8. Delayed response to 1 mile sign – any lane change made more than 5 seconds travel time downstream of the 1 mile sign, but before the 1/2 mile sign is legible
9. In response to 1/2 mile sign – any lane change that was made upstream of the 1/2 mile sign and within the distance in which the sign is legible, or within 5 seconds travel time downstream of the sign
10. Delayed response to 1/2 mile sign – any lane change made more than 5 seconds travel time downstream of the 1/2 mile sign, but before the Lane Designation sign is legible
11. In response to lane designation sign – any lane change that was made upstream of the Lane Designation sign and within the distance in which the sign is legible and before the gore
12. Beyond the gore – This segment applies to those subjects who did not make the last needed lane change and thus failed to reach the assigned destination



**FIGURE 5 - FREEWAY SEGMENTS FOR LOCATION OF  
LAST NEEDED LANE CHANGE**

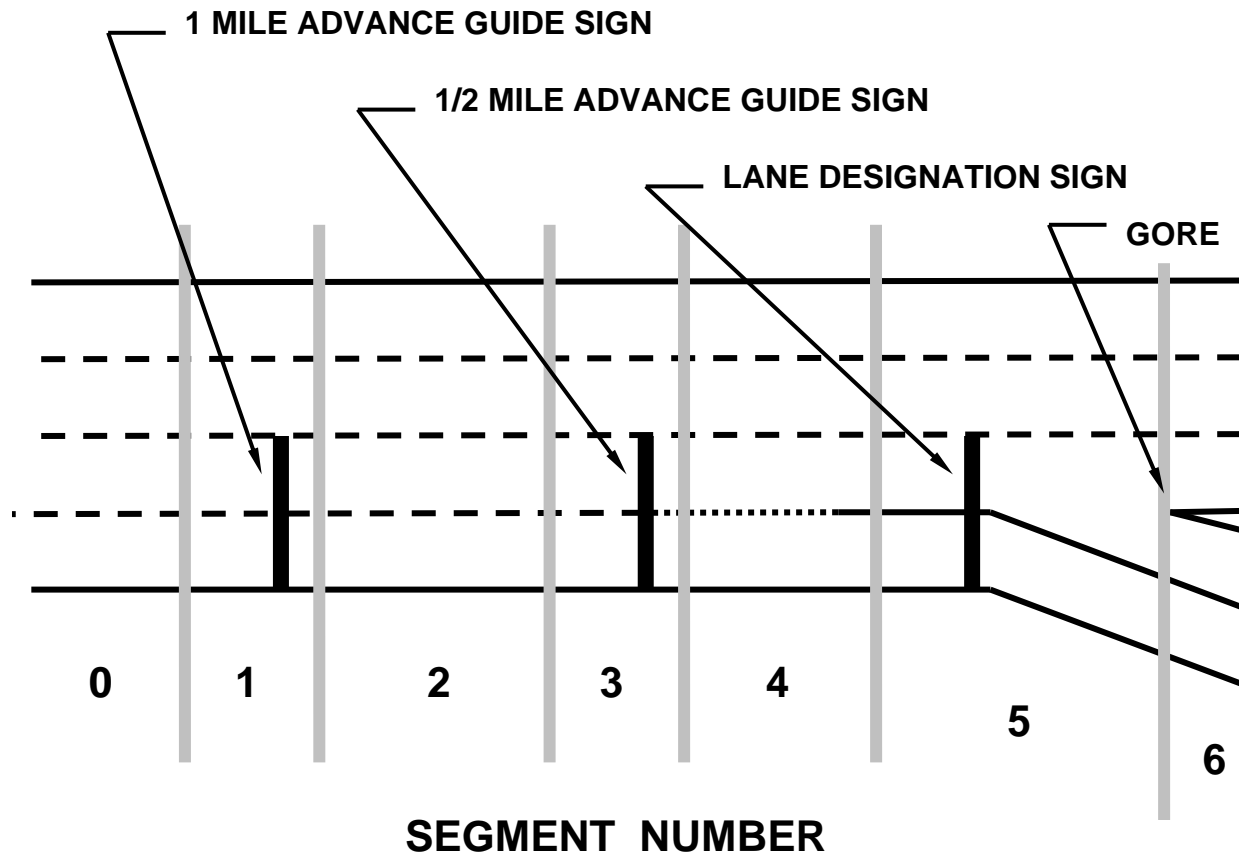
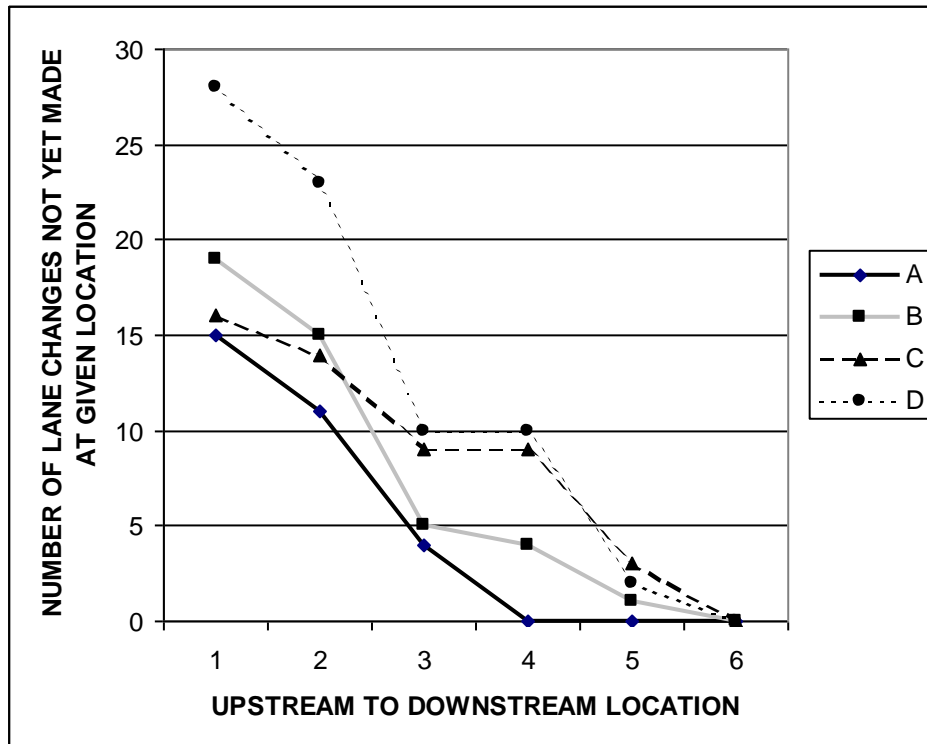


Figure 6 portrays the distribution of last needed lane changes among the last six of the seven freeway segments. The number of lane changes that had not yet been made at the end of each segment is given. As a reminder, only two origin-destination pairs require lane changes, and Figure 6 reflects information for only those two pairs.

**FIGURE 6 -- LOCATION OF LAST NEEDED LANE CHANGE**



This study presented advance guide signs to the test subjects at both 1 mile and 1/2 mile before the gore. Thus, subjects had two exposures to each advance guide sign. In real-world applications there will be many instances in which it will not be possible to present two advance guide signs to motorists. In urban areas, interchanges are often closely spaced and there is not enough distance between an upstream interchange and the two-lane exit to present two advance guide signs. A second factor is that one or both of the two freeway lanes from which one may exit may not exist a full mile upstream of the gore. If the two lanes do not exist, some designs of advance guide signs cannot be used because the two arrows on those signs must be laterally placed over the lanes to which they apply.

In view of the fact that in many instances it will not be possible to present two advance guide signs, it is important to note the number of lane changes not yet made at the ends of segments 1 and 2. These numbers represent the subjects' behavior after they have been exposed to only one advance guide sign – a situation that may occur often in field application.

In addition to data collected in the driving simulator, a post-drive debriefing survey was also conducted. Results from this survey are also helpful in assessing driver understanding of alternative sign configurations.

7,8. One debriefing survey question was: “For this sign, how certain were you about the lane you should be in to reach your assigned destination?” The more certain a driver was, the greater was the index of effectiveness. This question was asked for the advance guide sign, and again for the lane designation sign.

9,10. A second debriefing survey question was: “Rate this sign on how difficult it was to understand.” The less difficult a sign was, the greater was the index of effectiveness. This question was asked for the advance guide sign, and again for the lane designation sign.

# QUESTIONNAIRE

This questionnaire provides you with the results from the study on 11 measures of effectiveness for each of four sign types. Please familiarize yourself with each of the measures of effectiveness, which are described in the preceding section. Then, indicate the relative importance that should be placed on each of the 11 measures of effectiveness when selecting which sign type has the “best” design.

It is recommended that you use the following process to determine the weight that you would assign to each measure:

- a) First, determine which one of the 11 measures you believe should receive the most weight and give that measure a weight of 10
- b) Next, do the following for each of the other measures.  
Compare the importance of that measure to the measure that you gave a weight of 10. Based on its relative importance, assign a weight (0 to 10) to that measure.

In assigning a weight to a measure, you may want to consider the degree to which that measure distinguishes between different sign types. For example, if the results from the study for all four sign types are the same on a given measure of effectiveness, you may want to assign a weight of zero to that measure.

The four results given for the four sign types are simply listed in order from the best value to the worst value for each measure of effectiveness. The sign type that has the “best” performance varies from measure to measure. The sign type that has the “worst” performance also varies from measure to measure.

## MEASURE 1 – NUMBER OF FAILURES TO REACH ASSIGNED DESTINATION

Out of 288 possible opportunities to “miss” a destination, the number of “misses” were:

Best		Worst	
2	3	3	3

There is no statistically significant difference among the values.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

## MEASURE 2 – NUMBER OF UNNECESSARY LANE CHANGES TO REACH ASSIGNED DESTINATION

Out of 288 drives past each sign type, the number of unnecessary lane changes were:

Best			Worst
92	100	101	105

There is no statistically significant difference among the values.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 3 – NUMBER OF LAST NEEDED LANE CHANGES MADE LESS THAN 88 FEET FROM PAINTED GORE

Out of 288 drives past each sign type, the number of last needed lane changes made less than 88 feet from the painted gore were:

Best			Worst
0	0	0	0

There is no statistically significant difference among the values.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 4 – NUMBER OF LAST NEEDED LANE CHANGES MADE LESS THAN 450 FEET FROM PAINTED GORE

Out of 288 drives past each sign type, the number of last needed lane changes made less than 450 feet from the painted gore were:

Best			Worst
3	3	5	8

There is no statistically significant difference among the values.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 5 – NUMBER OF LAST LANE CHANGES MADE LESS THAN 450 FEET FROM PAINTED GORE

Out of 288 drives past each sign type, the number of last lane changes made less than 450 feet from the painted gore were:

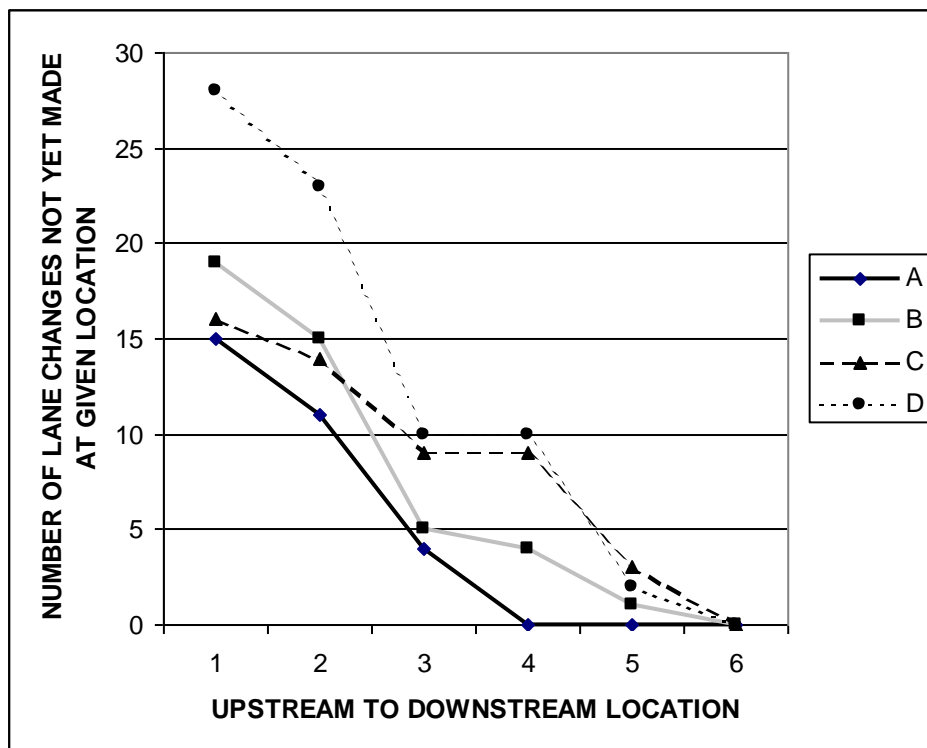
Best                      Worst  
4        9        11        13

The value of 4 is statistically different from the value of 13. There are no other statistically significant differences.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

## MEASURE 6 – LOCATION OF LAST NEEDED LANE CHANGE

The figure illustrates where lane changes were made for each of the types of sign. See the preceding Background section for a description of the six upstream to downstream locations.



The sign type labeled A elicits lane changes that are made farther upstream than the sign types labeled B, C and D. Using a statistical test, it can be shown that the better performance of sign type A is very unlikely due to chance alone.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 7 – DEBRIEFING SURVEY, QUESTION 3A, ADVANCE GUIDE SIGN

Subjects were asked this question for the advance guide sign: “For this sign, how certain were you about the lane you should be in to reach your assigned destination?”

The possible responses were: very certain, certain, uncertain, and very uncertain.

The scores assigned to these responses were as follows:

4 = very certain

3 = certain

2 = uncertain

1 = very uncertain

The average scores for the signs were:

Best			Worst
------	--	--	-------

3.45	3.27	3.04	3.00
------	------	------	------

The value of 3.45 is statistically different from 3.00

The value of 3.45 is statistically different from 3.04

There are no other statistically significant differences.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 8 – DEBRIEFING SURVEY, QUESTION 3B, LANE DESIGNATION SIGN

Subjects were asked this question for the lane designation sign: “For this sign, how certain were you about the lane you should be in to reach your assigned destination?”

The possible responses were: very certain, certain, uncertain, and very uncertain.

The scores assigned to these responses were as follows:

4 = very certain

3 = certain

2 = uncertain

1 = very uncertain

The average scores for the signs were:

Best			Worst
------	--	--	-------

3.74	3.36	3.21	3.14
------	------	------	------

The value of 3.74 is statistically different from 3.36

The value of 3.74 is statistically different from 3.21

The value of 3.74 is statistically different from 3.14

There are no other statistically significant differences.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 9 – DEBRIEFING SURVEY, QUESTION 4A, ADVANCE GUIDE SIGN

For the advance guide sign, subjects were asked to “Rate the sign on how difficult it was to understand.”

The possible responses were: very easy, easy, average, difficult, and very difficult.

The scores assigned to these responses were as follows:

- 5= very easy
- 4 = easy
- 3 = average
- 2 = difficult
- 1 = very difficult

The average scores for the signs were:

Best			Worst
4.45	4.13	3.77	3.50

The value of 4.45 is statistically different from 3.77

The value of 4.45 is statistically different from 3.50

The value of 4.13 is statistically different from 3.50

There are no other statistically significant differences.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_

---

## MEASURE 10 – DEBRIEFING SURVEY, QUESTION 4B, LANE DESIGNATION SIGN

For the lane designation sign, subjects were asked to “Rate the sign on how difficult it was to understand.”

The possible responses were: very easy, easy, average, difficult, and very difficult.

The scores assigned to these responses were as follows:

- 5= very easy
- 4 = easy
- 3 = average
- 2 = difficult
- 1 = very difficult

The average scores for the signs were:

Best			Worst
4.39	4.18	3.86	3.75

The value of 4.39 is statistically different from 3.75

There are no other statistically significant differences.

*On a scale of 0 to 10, what weight would you assign to this measure?* \_\_\_\_\_



---

## FACTOR 11 – COST OF INSTALLATION

Four estimates of the cost of installing each sign type was determined. These costs include: sign structure, foundations, sign structure installation, sign panel fabrication, reflective sheeting, installation of sign panels, luminaires, electrical conduit and wiring on the structure.

For the situation in which advance guide signs are placed at both 1 mile and 1/2 mile, and a lane designation sign is placed at the gore, the estimated costs were:

Lowest			Highest
\$151,000	\$151,000	\$191,000	\$251,000

For the situation in which advance guide signs are placed only at 1/2 mile,, and a lane designation sign is placed at the gore, the estimated costs were:

Lowest			Highest
\$100,000	\$101,000	\$140,000	\$171,000

*On a scale of 0 to 10, what weight would you assign to this factor?* \_\_\_\_\_

---

**NAME OF SURVEY RESPONDENT** \_\_\_\_\_

Please send your completed questionnaire, **by Monday, November 27**, to:

Upchurch@ecs.umass.edu

Thank you for your response.