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16. Abstract

This research study investigated guide signing practices used around the state and the rest of the nation for multilane exits. In particular, the research focused on signing for multilane exits with optional lanes. Photographs were taken of guide signing at multilane interchanges in the cities of San Antonio, Houston, Dallas, and Fort Worth, Texas. In addition, a questionnaire was sent to the state traffic engineers of each state, asking that they indicate their method of signing for a multilane exit with an optional lane and a secondary ramp split. The results of both studies indicated that a variety of signing practices for multilane exits are used in Texas and across the nation.

A review of previous research showed that most drivers understand the EXIT ONLY panel, commonly used to communicate a lane drop; however, as many as one half of all drivers are confused by the current method of signing used in Texas for an optional lane at a multilane exit. Guide signing alternatives were developed to improve driver comprehension of the optional lane situation at a multilane exit. The developed alternatives were tested against the recommended method of signing in two evaluations: an initial driver survey and a laboratory study. The phrase "MAY EXIT" was found to be the best understood alternative in the initial survey. In the laboratory study, however, the differences between the various alternatives were small. The research findings indicate that the current method of signing for multilane exits should continue to be used. Additional evaluations should continue in this subject area.

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AN EVALUATION OF GUIDE SIGNING AT RIGHT MULTILANE FREEWAY EXITS WITH OPTIONAL LANES

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IMPLEMENTATION STATEMENT

This study reveals that many different guide signing treatments are used around Texas and the nation to communicate multilane freeway exits. Consistent, uniform guide signing applications should be maintained. Uniform signing treatments can help reinforce driver expectancy, helping to guide the unfamiliar driver.

This study indicates that drivers have a good understanding of black on yellow EXIT ONLY panels used to communicate a lane drop. However, motorists sometimes misinterpret the white arrow often used with EXIT ONLY panels to communicate an optional lane. The initial research evaluations found that the phrase "MAY EXIT" exhibited potential for improving driver understanding of the optional lane at multilane freeway exits. Further analysis revealed that the potential improvement that can be realized from this alternative is minimal over the current method. The research findings indicate that current signing practices for optional lanes at multilane freeway exits should continue.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or a regulation; nor is it intended for construction, bidding, or permit purposes. This report was prepared by Richard A. Somers, H. Gene Hawkins, Jr., P.E. #61509, and Thomas Urbanik II, P.E. #42384.

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The TxDOT 1467 technical advisory panel chair, Gary Trietsch, is recognized for his time in providing direction and comments for this research. Lewis Rhodes and Mark Thorp, also of TxDOT, are recognized for their assistance in preparing the driver survey.

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SUMMARY

In urban areas, complex geometric situations make the guide signing task difficult. Since only a limited amount of space can be devoted to guide signing information, careful consideration must be given to the content of each sign. Guide signs should contain enough information to clearly convey upcoming interchange geometry, but not so much as to overload the driver's ability to process information. Previous studies have identified improving communication of the optional lane situation at a multilane exit as an area for further research.

The lack of explicit instruction in the Manual on Uniform Traffic Control Devices (MUTCD) on how to sign multilane interchanges has led to diverse, non-uniform guide signing applications around the nation. A review of nationwide practices as part of this research found that guide signing treatments are different between and within many states. A portion of the study involved a questionnaire sent to the state traffic engineer of each state, asking each to indicate the method of guide signing used in his/her state for a multilane exit with an optional lane and a secondary ramp split. In addition, guide signing treatments were inventoried and analyzed in the Texas cities of Dallas, Fort Worth, Houston, and San Antonio. This study concludes that consistent application should be adhered to, as drivers are likely to understand guide signing with which they are familiar.

The Texas MUTCD explicitly recommends signs for multilane exits, beyond those which are contained in the National MUTCD. Previous research indicates that many drivers do not understand the Texas MUTCD means of communicating an optional lane at a multilane exit. This research developed guide signing alternatives to better communicate the optional lane situation. The alternatives included use of the phrases "MAY EXIT" and "EXIT OK" over the optional lane, similar to the phrase "EXIT ONLY" used for lane drops, to help communicate the optional lane. In addition, alternatives using a divergent arrow over the optional lane were also tested. In this case, the divergent arrow took the place of the single arrow in exit directional signing. The divergent arrow was centered above the optional lane. Finally, forms of pull-thru signing were tested to see if they were of benefit in helping communicate the optional lane.

The alternatives were tested against the current method of signing to determine if increased driver comprehension could be realized through the use of the alternative signs. The initial test was conducted at the Houston Auto Show. The results of this initial survey showed that the use of the phrases "MAY EXIT" and "EXIT OK" significantly improved driver comprehension of the optional lane situation, with "MAY EXIT" being more effective than "EXIT OK." The divergent arrow tended to confuse many drivers, in that many felt that they could reach the destination shown on the sign by staying on the freeway. However, divergent arrow alternatives were successful in communicating the optional lane situation.

A detailed study was then conducted under laboratory conditions to evaluate three alternatives: the current Texas signing method, the "MAY EXIT" alternative, and a modification

of the Ohio signing method. The results of the detailed study showed only marginal improvements in comprehension resulting from the use of the "MAY EXIT" or modified Ohio alternatives.

As a result of these evaluations, the researchers do not believe that there is sufficient justification for changing current signing practices for multilane exits with an optional lane. However, the research results do support the need for additional evaluation of the alternatives.

1.0 INTRODUCTION

The ease of travel along the nation's freeway network is influenced by the adequacy of information supplied to the motorist. Information should provide the driver with a clear picture of any situation that may require an action or series of actions from the driver. This is sometimes difficult to accomplish at interchanges with complex movements.

Motorists may receive information at interchanges from formal or informal sources. Motorists may obtain informal information through the actions of other drivers, such as the illumination of brake lights, a sudden change in direction, or other actions. Other sources of informal information may include billboards, the driver's psychological expectancy, visual interpretation of the roadway, and radio traffic reports.

Formal information must be presented to the driver in an unambiguous and quickly comprehensible manner. Formal information supplements the driver's visual interpretation of the roadway through the use of signs, pavement markings, guide posts, reflectors, and other sources. The combination of these formal sources of information and the driver's visual interpretation of the roadway and roadway conditions should give the driver a clear picture of the upcoming segment of roadway. With this mental picture established, the driver can make a quick, informed decision on what action or series of actions to take.

Signing is the primary way to formally communicate information to motorists (1). Guide signs provide drivers with information to decide which path or paths to take to reach their destinations. Guide signs are important on controlled-access facilities, as drivers may be presented with several decisions concerning vehicle navigation. In some cases, drivers are unfamiliar with the area in which they are driving and require positive guidance. The high volumes and high speeds on controlled access facilities magnify the need for effective guide signing.

Guide signing can provide a clear and quickly comprehensible picture of any upcoming decision point. This mental picture, combined with the driver's own experience and judgement, helps drivers properly orient their vehicle with respect to an upcoming interchange. In addition, any lane changes may be performed well upstream of the exit.

1.1 PROBLEM STATEMENT

Multilane freeway exits present complex situations to the driver, particularly when the interchange is in a location unfamiliar to the driver. Optional lanes at multilane exits are particularly complex, in that the driver has the choice of continuing on the freeway or exiting from that lane. Driver comprehension of current guide signing practices at multilane interchanges with optional lanes needs to be further examined. Any deficiencies in guide sign comprehension should then be remedied by improving signing practices. Driver comprehension of current guide signs

has not been specifically addressed in the National Manual on Uniform Traffic Control Devices (MUTCD) (2).

1.2 RESEARCH OBJECTIVES

This research examined driver comprehension of guide signs for multilane freeway exits with an optional lane. Specifically, this research did the following:

1. Determined the informational requirements that pertain to the design, placement, and use of freeway guide signs;
2. Determined what freeway guide signing principles are used in Texas and the rest of the nation, and the roadway geometry to which the principles apply;
3. Reviewed previous studies on freeway guide signs;
4. Analyzed the effectiveness of current and alternative freeway guide signs for multilane interchanges; and
5. Recommended changes in freeway guide signing practices, based on the study results.

1.3 SCOPE

The first phase of the research project was to determine what guide signing practices are used in Texas and the rest of the nation. This was accomplished by reviewing both the National MUTCD (2) and the Texas MUTCD (3). In addition, a questionnaire was sent to the state traffic engineer of each state. This questionnaire asked each engineer to identify his or her state's method of guide signing at a multilane interchange. Finally, photographs were taken of freeway guide signs at multilane interchanges in several cities around Texas. These photographs were then analyzed to determine the consistency of guide signing applications at multilane freeway exits around the state.

The second phase of the project involved a review of research relevant to the topic. The review established findings of previous studies and identified areas requiring additional examination. This phase, in combination with the first phase, established the state of the practice of freeway guide signing at multilane interchanges.

The third phase of the project involved the development and testing of alternatives against established guide signing practices. The alternatives were developed by making slight modifications to current signing practices. Both the proposed alternatives and the standard practices were then tested in a survey format to determine what, if any, benefit could be gained by using the alternative signing practices.

The fourth and final phase of the research involved compiling the research findings and developing a list of recommendations concerning the use of freeway guide signs at multilane exits.

1.4 ORGANIZATION

This report is divided into five chapters. Chapter 1 introduces the problems associated with guide signing at multilane freeway exits. Chapter 2 describes the technical background. This chapter includes both a literature review and an inventory of current freeway guide signing practices used in Texas and around the nation. Chapter 3 describes the development and initial evaluation of alternatives to current guide signs. Chapter 4 describes the development of a laboratory experiment to test the identified signing alternatives. Chapter 5 describes the results of the laboratory test developed and described in Chapter 4. Chapter 6 offers conclusions and recommendations of the research. In addition, Chapter 6 also identifies areas requiring further research.

2.0 TECHNICAL BACKGROUND

The topic of freeway guide signing at multilane freeway exits has been the focus of only a few research studies. Many areas use multilane exit ramps in situations where ramp volumes warrant. Even with the frequent use of multilane exits, the National MUTCD does not specifically address the problems associated with signing a multilane exit ramp.

This chapter opens with an introduction to the guide signing treatments recommended in the National MUTCD. It presents the informational requirements for effective guide signing, and some of the issues that should be considered in the development of a guide signing system. The chapter then overviews the guide signing treatments recommended by the Texas MUTCD and treatments used in other states. Many of the issues contained in the chapter have been the focus of previous research efforts, and where possible, those research findings have been presented with the discussion of the topic to which they pertain. Although previous research on signing of optional lanes at multilane exits is limited, the information in this chapter should provide the reader with an understanding of the issues associated with signing for an optional lane.

2.1 FREEWAY GUIDE SIGNING PRACTICES IN THE NATIONAL MUTCD

The National MUTCD sets forth recommended signing practices to be used around the nation. The signing practices were developed by establishing specific objectives and functions of signing, and then designing signing that achieves those objectives and purposes in the most efficient manner. These signing practices are improved through research and development, so that the MUTCD changes, and hopefully improves, with each edition. The National MUTCD is the basis for the Texas MUTCD, so that all issues described in the following paragraphs are also addressed in the Texas MUTCD.

2.1.1 Guide Sign Purposes

According to the MUTCD, "The development of a signing system for expressways and freeways must be approached on the premise that the signing is primarily for the benefit and direction of drivers who are not familiar with the route or area. The signing must furnish drivers with clear instructions for orderly progress to their destinations" (2). Signing must also communicate upcoming roadway geometry (2).

Guide signing presents information to aid the driver in performing both the guidance and navigational driving tasks. The guidance task, also referred to as situational performance, involves the driver's selection of speed and path to adequately position his or her vehicle in the desired lane on a road. The navigational task, also referred to as macroperformance, involves the driver's planning and enactment of a trip between two destinations (4).

To facilitate driver needs, the National MUTCD sets forth the following set of distinct functions that freeway and expressway guide signing should serve:

1. Give directions to destinations, or to streets or highway routes, at intersections or interchanges;
2. Furnish advance notice of the approach to intersections or interchanges;
3. Direct drivers into appropriate lanes in advance of diverging or merging movements;
4. Identify routes, and directions on those routes;
5. Show distances to destinations;
6. Indicate access to general motorist services, rest, scenic, and recreational areas; and
7. Provide other information of value to the driver.

Guide signing for interchanges specifically serves functions 1, 2, 3, and 4.

2.1.2 Guide Sign Design Principles

In order to achieve the functions of guide signing, several design principles have been established to provide necessary information to the driver in as efficient a manner as possible. Signs may only contain a few pieces of information, so careful consideration must be given to the specific content and design of each sign.

The National MUTCD states, "expressway signs should be designed so that they are legible to drivers approaching them, and readable in time to permit proper responses. ... this usually means (a) high visibility, (b) large lettering and symbols, and (c) short legends for quick comprehension. Standard shapes and colors are required so that traffic signs can be promptly recognized"(2).

In their study of freeway guide signing in Georgia, Edwards and Kelcey (5) identified six design factors that should be considered in sign design:

1. **Comprehension** – The sign message should be logical to minimize misinterpretation.
2. **Emphasis**– More important information should be emphasized by increased size, placement in a prominent location, or use of a different lettering type.
3. **Expectancy**– The sign legend and location should conform to driver expectancy.
4. **Uniformity** – Signing treatments for similar geometric conditions should not differ between sites.
5. **Consistency** – Similar types of information should be kept in the same location on guide sign panels.
6. **Maintenance** – Guide signs should be adequately maintained to insure proper legibility and working condition.

These six factors, in combination with the previously mentioned functions and principles, should govern the design of freeway guide signs and guide sign systems. Although these factors are for guide signs in general, they should be followed for guide signs at multilane exits as well.

The engineer should give special thought to the signing content to determine the most effective means of communicating the intended message to the driver. The message contained on the sign should be short enough so that drivers can read and comprehend the sign in a short amount of time, but long enough to provide necessary information to the driver. In other words, a sign should contain the minimum amount of information needed to convey the situation to which it applies. Too much information on a sign may be as bad or worse than a lack of information. McNees and Messer (6) identify a maximum level to be six "bits" of information per panel. A bit may be defined as one unit of information, such as an arrow, destination, or the phrase "EXIT ONLY." Edwards and Kelcey (5) restate the six bit per panel limit, and set an absolute limit of 20 bits of information for a sign structure. In addition, 16 bits was selected as a desirable limit. To avoid overloading the driver's capability to process information, the MUTCD states that no more than three sign panels should be used on any overhead guide signing bridge. Each sign should contain no more than two destinations or intersecting street names. Finally, abbreviations should to be kept to a minimum. According to the MUTCD (2), abbreviations should be "unmistakably recognized" by motorists.

In order for signing to be effective, consistent and uniform application is desirable. In other words, an exit in Idaho should be signed the same way as a similar exit in Alabama. Drivers are more likely to understand guide signs that they have seen before, even in locations with which they are unfamiliar. A driver in an unfamiliar location may become confused upon seeing an unexpected guide sign. Nationwide uniformity is particularly important for guide signing, since freeway drivers may be from out-of-state (4, 7). Nationwide consistency in guide signing helps to reduce confusion and improve driver expectancy.

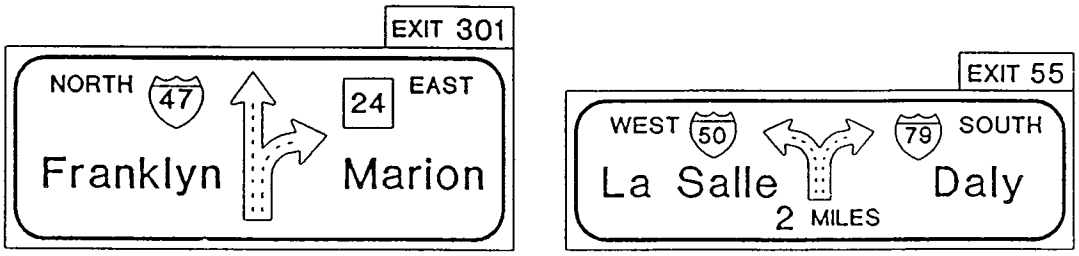
2.1.3 Current Guide Signing Practices in the MUTCD

The MUTCD has gradually developed and improved over time to better serve the seven functions of guide signing described earlier. Guide signing for single lane exits has become fairly uniform throughout the nation. However, as interchanges face recurrent congestion, often there is a need to expand from one to two, three, or even more exit lanes. Although the geometric design for such ramp expansion has become standard practice, the signing practices for such cases has not (8).

Freeway exits may present a confusing situation to the motorist. This possibility is particularly true in the case of a complicated freeway interchange, in which two or more lanes may be leaving the freeway. Many of these multilane exits involve the use of an optional lane and one or more lane drops, from which motorists must leave the freeway.

Two basic signing types have emerged for signing multilane freeway exits. The two types are diagrammatic and non-diagrammatic guide signs. Both types of sign include the designation, destination, and direction of the intersecting route. The difference lies in the method of lane assignment for the upcoming exit. Non-diagrammatic signs use arrows positioned over the lanes to which the instructions apply. Diagrammatic signs give the driver a plan view of the upcoming interchange, and allow the driver to make lane assignment decisions based upon his or her interpretation of the diagram. Examples of non-diagrammatic and diagrammatic guide signs are shown in Figure 1.

Non-Diagrammatic Signs



Diagrammatic Signs

Figure 1. Examples of Diagrammatic and Non-Diagrammatic Signing

2.1.3.1 Categories of Guide Signs

On a typical urban freeway, a series of up to four signs is used to inform drivers of an upcoming multilane exit, according to the MUTCD (2). The first two signs, initial advance signs, are typically 3.2 km and 1.6 km upstream of the gore. The next sign, an advance sign, is usually

around 0.8 km upstream of the gore. The final sign, or exit directional sign, is located immediately upstream of the gore. The term "initial advance" is used for the purposes of this report to denote the difference between initial advance and advance guide signs. The MUTCD groups both into one classification —advance guide signs. Examples of each type of sign are provided in Figures 2 through Figure 4.

Signs in each of the three categories serve a distinct purpose. Initial advance signs simply inform the driver of an upcoming exit. The sign identifies the interchange by route designation, destination, direction of the intersecting route, and interchange number. In addition, the sign gives the distance to the exit. Lane assignment information is not typically given. Upon seeing an initial advance sign, drivers wishing to exit will likely begin to position their vehicles in the right lane to make the upcoming exit, as driver expectancy is that freeway exits will generally occur to the right of the freeway (10). Since a left exit is in violation of driver expectancy (11), an upcoming left exit should be clearly denoted to help the driver overcome the tendency to move to the right to exit.

Advance guide signs give lane assignment information and repeat the message contained in the initial advance signs. Distance to the interchange may be given or omitted. Drivers may rely on these advance guide signs for lane assignment information, because in many cases, the upcoming interchange is not visible. This information is important so that exiting vehicles are assigned to the proper lanes well in advance of the interchange to avoid any sudden, last minute lane changes.

Finally, exit directional signs repeat the message contained on both the advance and initial advance signs, reinforce the lane assignment information on the advance signs, and inform exiting traffic to leave the freeway at that point. The legibility of an exit directional sign is such that any last minute lane changes are accommodated well in advance of the gore area.

A special class of sign exists that can be used in conjunction with overhead advance and exit directional guide signs. Pull-thru signs are used to denote the destination, route designation, and cardinal direction of the freeway mainlanes. Pull-thru signs may also include downward lane assignment arrows. The use of pull-thru signs is usually limited to situations in which the geometrics of an interchange are complex and/or in violation of driver expectancy. Overlapping routes are one example of complex informational needs.

2.1.3.2 Sign Mounting

For multilane interchanges, and in most urban situations, freeway guide signs should be mounted overhead. Overhead mounting makes the task of lane assignment easier. Furthermore, overhead signs command more attention than side mounted signs (12).

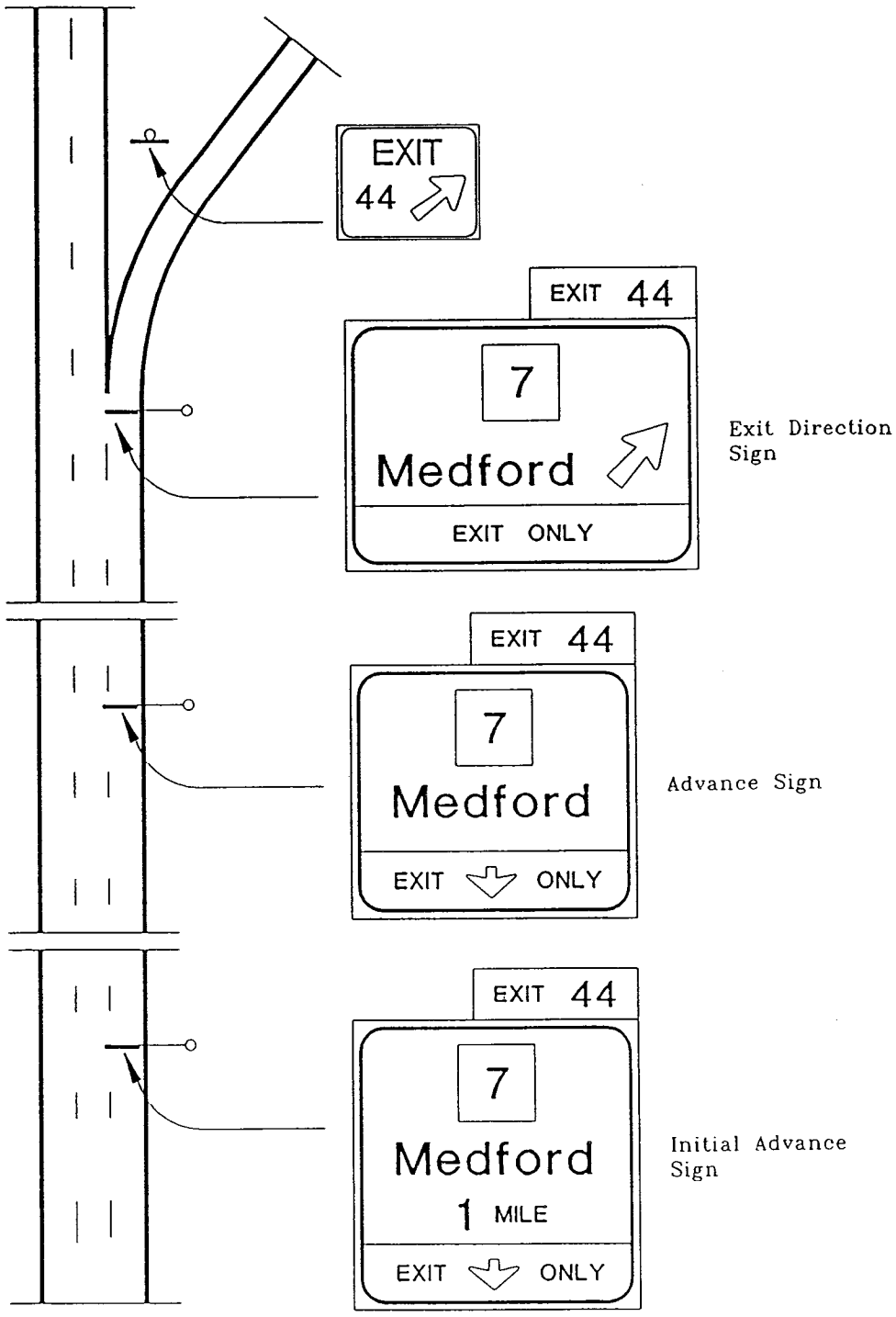


Figure 2. Recommended Signing for a Single Lane Drop
Source: Reference (2)

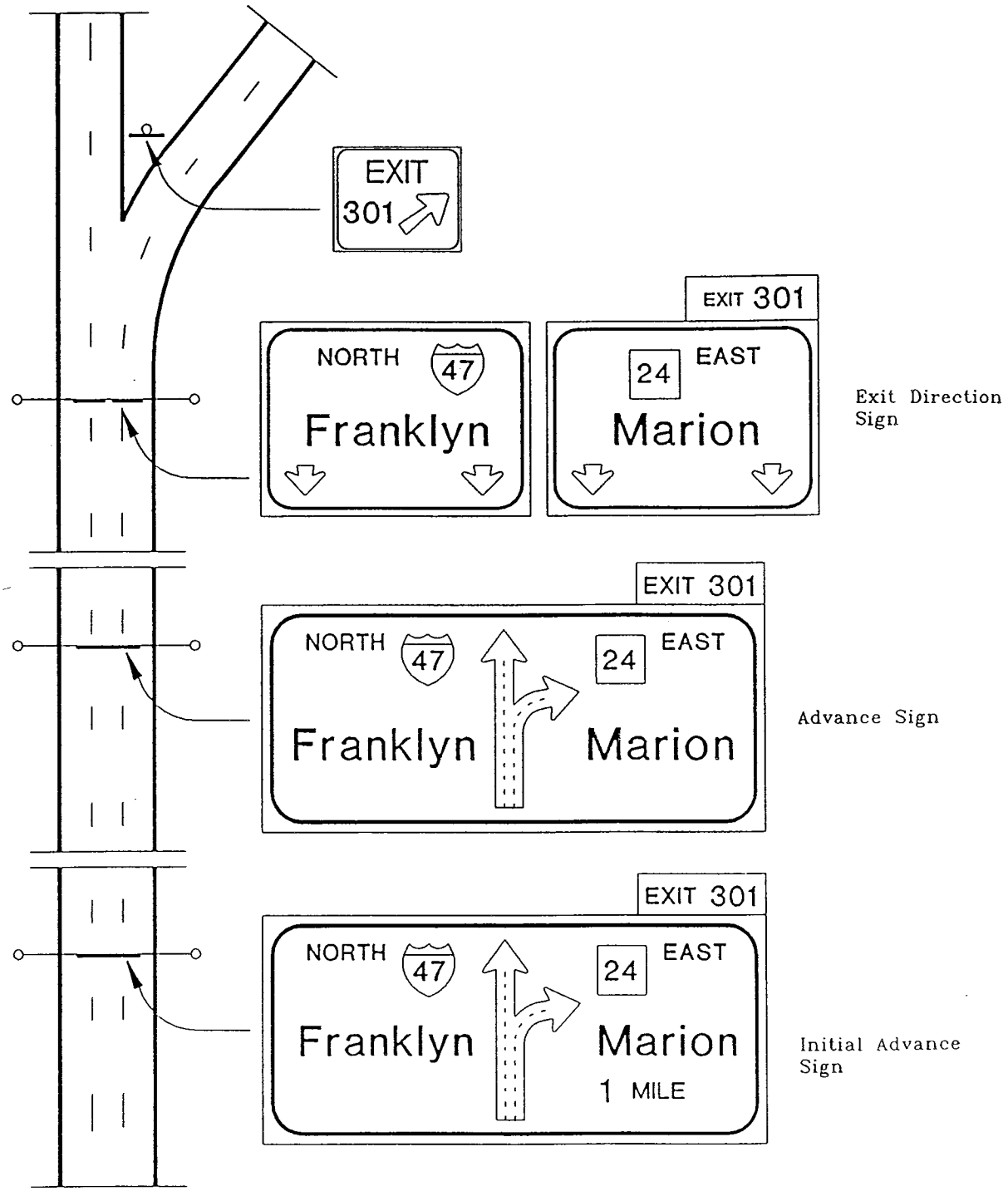


Figure 3. Diagrammatic Signing Treatments for Multilane Exits
Source: Reference (2)

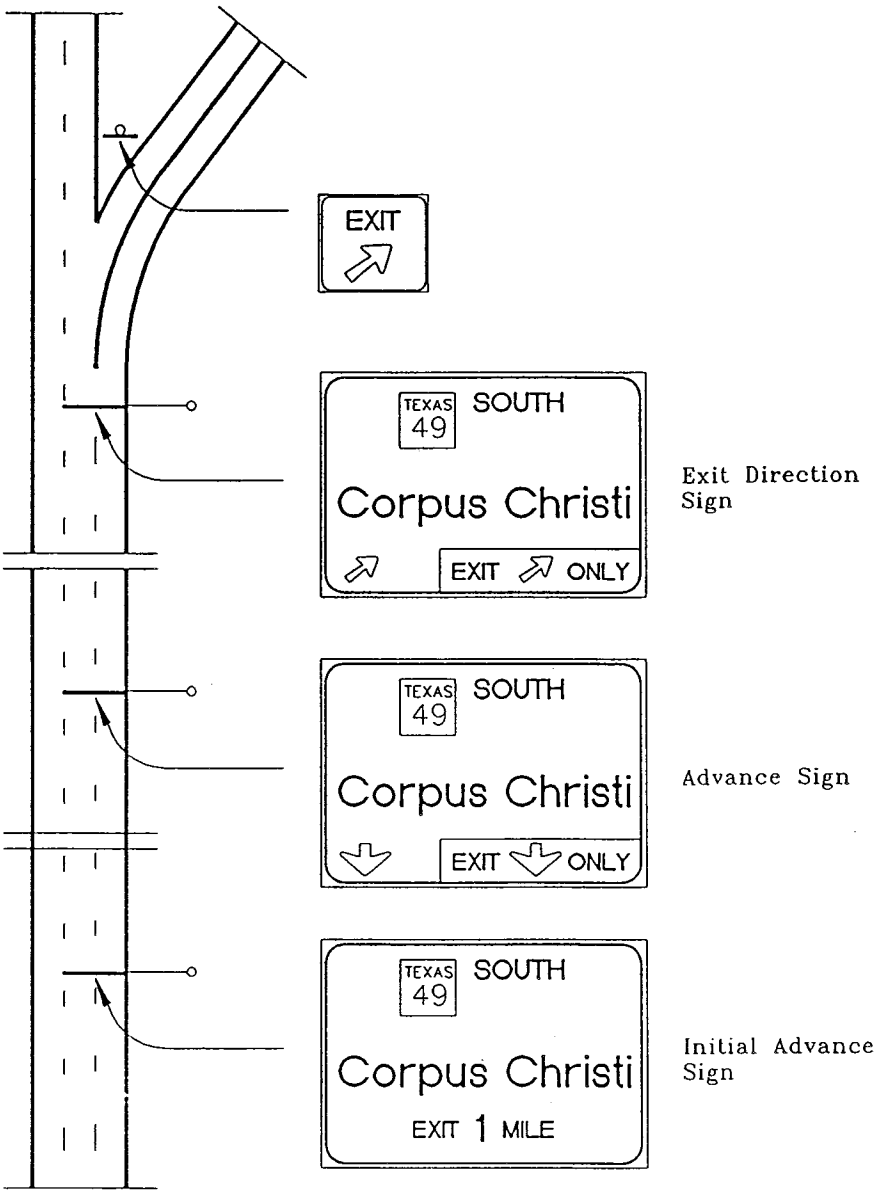


Figure 4. Signing for Multilane Exit with an Optional Lane as Recommended by the Texas MUTCD
Source: Reference (3)

2.1.3.3 Arrows

Arrows are included on guide signs to indicate either lane assignment or direction of travel. Down arrows, centered over the lane to which they refer, are used for assigning traffic to a particular lane. These arrows may also be tilted to emphasize roadway separation. Upward

slanted arrows are used on exit direction signs to indicate the direction of departure from the freeway (2).

2.1.3.4 Signing for Lane Drops

Lane drops are specifically addressed in MUTCD Section 2F-25 "Signing for Interchange Lane Drops." The MUTCD, starting with the 1971 edition, recommends the use of a yellow panel with the words "EXIT ONLY" written in black to denote a lane drop. The 1978 MUTCD was the first to require the use of the panel (1). The panel may also include a down black arrow in the space between EXIT and ONLY for lane assignment purposes. This panel is mounted on the bottom of the guide sign. A previous research study (13) indicates that drivers understand this method of communicating a lane drop. The National MUTCD method of signing for a one-lane exit with an exit only condition is illustrated in Figure 2.

2.1.3.5 Signing for Optional Lanes and Multilane Exits

The National MUTCD does not specifically address either the issue of optional lanes, or the topic of multilane exits. The Manual does, however, contain some examples of multilane exits, as shown in Figure 3. The examples shown imply that diagrammatic signing is recommended for multilane exits with optional lanes, although no explicit guidelines are mentioned. The Manual does recognize this shortcoming; "Highway departments are encouraged to continue experimentation with other diagrammatic signing so that standards as contained herein may be updated in future editions of the Manual." Insufficient advance information is a frequent complaint of freeway users; therefore, advance guide signing has been identified as an area for further research, as evidenced by Bracket et al., Shapiro et al., and Skowronek (14, 15, 16). Whereas the signing treatments for lane drops as recommended by the MUTCD are explicit, signing for optional lanes and multilane exits is not clearly stated in the MUTCD and represents an area requiring further research (1).

The difficulty in signing for optional lanes may arise from the fact that explicit messages to indicate driver options are not widely used. Prohibitive conditions are commonly communicated through the words "NO" and "NOT." Examples of prohibitive signs include "NO RIGHT TURN," "DO NOT PASS," "NO PARKING," and "DO NOT STOP ON TRACKS." On the other hand, signs for mandatory conditions have also been developed, using the words "ONLY" and "MUST." Examples of mandatory condition signs include "RIGHT LANE MUST TURN RIGHT," "EXIT ONLY," and "RIGHT LANE MUST EXIT." Optional situations in which the driver is presented with a choice do not have the explicit wordings of signs indicating prohibitive and mandatory conditions. The only exception, is the use of the letters "OK" that are infrequently used in sign R3-6 (Lane-Use Control Sign with Divergent Arrow).

2.2 SIGNING METHODS USED IN TEXAS

Texas has developed signing treatments specifically for multilane exits with optional lanes. The Texas MUTCD recommends other signing methods, in addition to those specified by the National MUTCD. The Texas Highway Operations Manual contains additional guide sign guidelines as well. Many different treatments are used around the state for signing multilane interchanges.

2.2.1 Texas MUTCD Signing Method

Texas has developed a method of signing multilane exits different from that in the National MUTCD. For a multilane exit with a lane drop and an optional lane, the Texas MUTCD recommends the signing strategy shown in Figure 4 (3). In addition, the Texas MUTCD sign R3-21 (Right [or Left] Lane Must Exit) is sometimes used to supplement the EXIT ONLY guide sign. Use of the sign is optional.

Three previous research studies indicated that drivers have a good understanding of the black on yellow EXIT ONLY panel used to indicate a lane drop (1, 14, 16). However, drivers often fail to comprehend the meaning of the white arrow on a green background, when used in conjunction with an EXIT ONLY panel (1, 14, 17). This technique is the common way of communicating an optional lane situation at a multilane exit. Studies indicate that perhaps over a third of all drivers do not understand this signing technique (1, 14, 16). With the EXIT ONLY panel well recognized and understood by the driving public, the emphasis for further research focuses on developing signing treatments for optional lanes that are better understood by drivers (1).

For a two-lane exit with a lane drop for both lanes, the Texas MUTCD recommends the signing method shown in Figure 5. A previous study (1) shows that comprehension is again high for the EXIT ONLY panel in this situation. However, comprehension rates were not as high for the inside exiting lane as for the outside lane.

2.2.2 Texas Highway Operations Manual Method

The Texas Highway Operations Manual (18) further details signing treatments to be used at multilane interchanges. The manual incorporates signing for ramp splits or secondary splits, a fairly common geometric feature on freeways. For exit ramps with a ramp split, the Texas Highway Operations Manual recommends the signing treatment shown in Figure 6. The sign denotes both route designations and destinations of the ramp, and the bifurcation is indicated by a thin white vertical line.

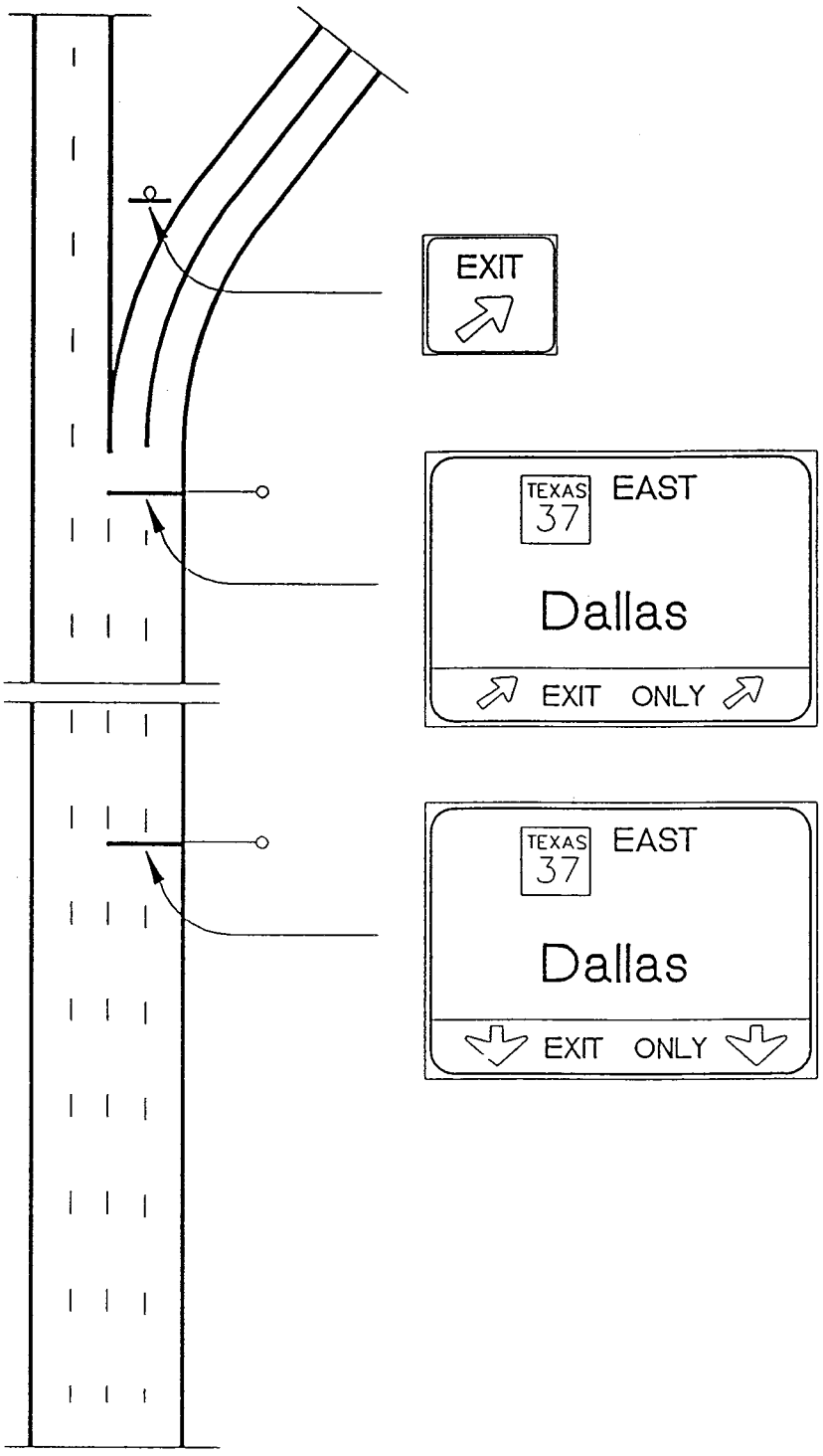


Figure 5. Signing for a Double Lane Drop Exit as Recommended by Texas MUTCD
Source: Reference (3)

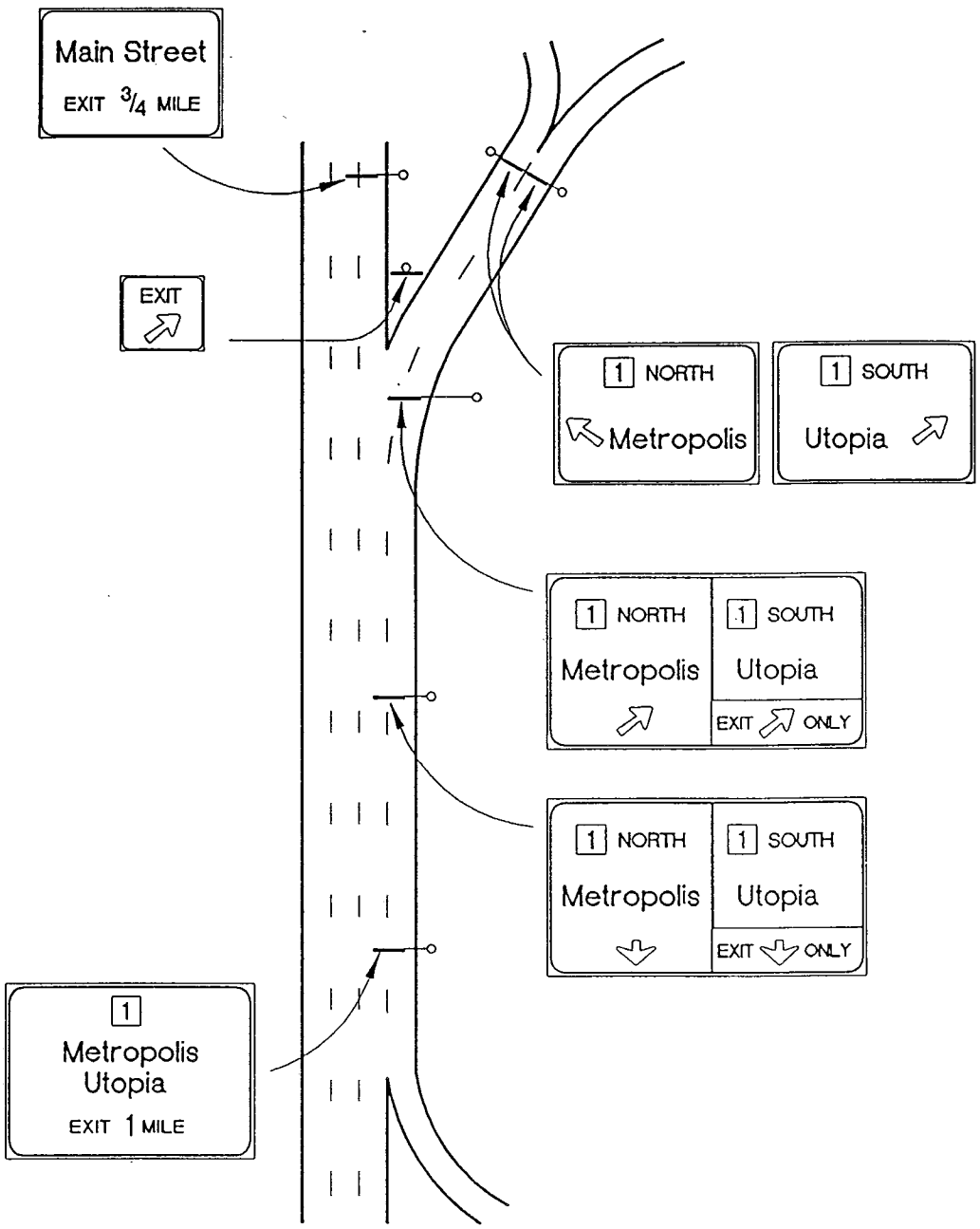


Figure 6. Signing Recommended for a Multilane Exit with a Secondary Split
Source: Reference (18)

2.2.3 Inventory of Practices Used in Selected Texas Cities

A review of signing practices by the research team in Dallas, Fort Worth, Houston, and San Antonio revealed the signing practices currently used on Texas freeways. This review considers the signing practices that are actually used, rather than those set forth in current guidelines. Many practices currently in use differ from those set forth in the National MUTCD and the Texas MUTCD, due to complications such as simultaneous right and left exits, close interchange spacing, ramp bifurcations, other complex geometric situations, limitations or placement of overhead sign bridges, and the use of older signing guidelines.

Texas has a large number of freeways in its metropolitan areas. In addition, the freeways intersect at several points creating interchanges with high ramp volumes. To accommodate urban traffic volumes, several multilane interchanges were incorporated in the Texas freeway network. Multilane interchanges with optional lanes in Texas are signed by different methods.

Photographs were taken of freeway guide signs for multilane exits at several sites in each city. Although only a few of the photographed sites are discussed in this report, many other interchanges use signing methods similar to those discussed. Some of the methods are peculiar to certain cities while other methods are common at sites throughout the state. In fact, several of the analyzed sites use the signing methods recommended by the Texas MUTCD for multilane interchanges.

2.2.3.1 Multiple Lane Drops

The first site analyzed by the research team was the I-635 and I-35E interchange in North Dallas. Northbound I-35E intersects eastbound I-635 with a double lane drop. The signing for this interchange is shown in Figure 7. Signing at this location meets the requirements set forth in the current edition of the Texas MUTCD. The exit is indicated by a black on yellow EXIT ONLY panel covering the bottom of the guide sign, along with black arrows for lane assignment information. In the advance guide sign, arrows point down and are centered over the lanes which will exit. In the exit directional sign, arrows are again centered over the lanes to which they apply, but are slanted upward to indicate departure of the two lanes from the freeway. In this case, no destination is given on the sign, perhaps due to the fact that I-635 is a loop route encircling Dallas.

The second site is the I-45 South intersection with I-30 in Dallas. Again, the ramp geometry is that of a double lane drop. Signing for this interchange is shown in Figure 8. However, in this case, the ramp splits for I-30 East and I-30 West. A series for four signs (two advance and two exit directional) is used to inform drivers of the exit. The first sign gives lane assignment information for the exit, but does not inform the driver of the secondary split or destinations. The second advance sign informs the driver of the secondary split, but again neglects to give destination information. The final sign uses downward lane assignment arrows rather than the upward arrows reserved for exit directional signing. The sign is apparently of an

older design, as EXIT ONLY panels were added to an older sign. In addition, the vertical line used to represent the secondary split does not cover the entire sign. Throughout the first three signs, destination information was not provided. The last sign bridge is used to communicate the secondary ramp split. The signs on the bridge use a combination of downward lane assignment arrows and up diagonal directional arrows. The right fork of the ramp is a single lane drop, and an EXIT ONLY panel is used to supplement the directional arrow. Another sign directing motorists to Fair Park via I-30 East is included on the sign bridge. The sign contains a down directional arrow as well, directing traffic to the left fork of the ramp split.

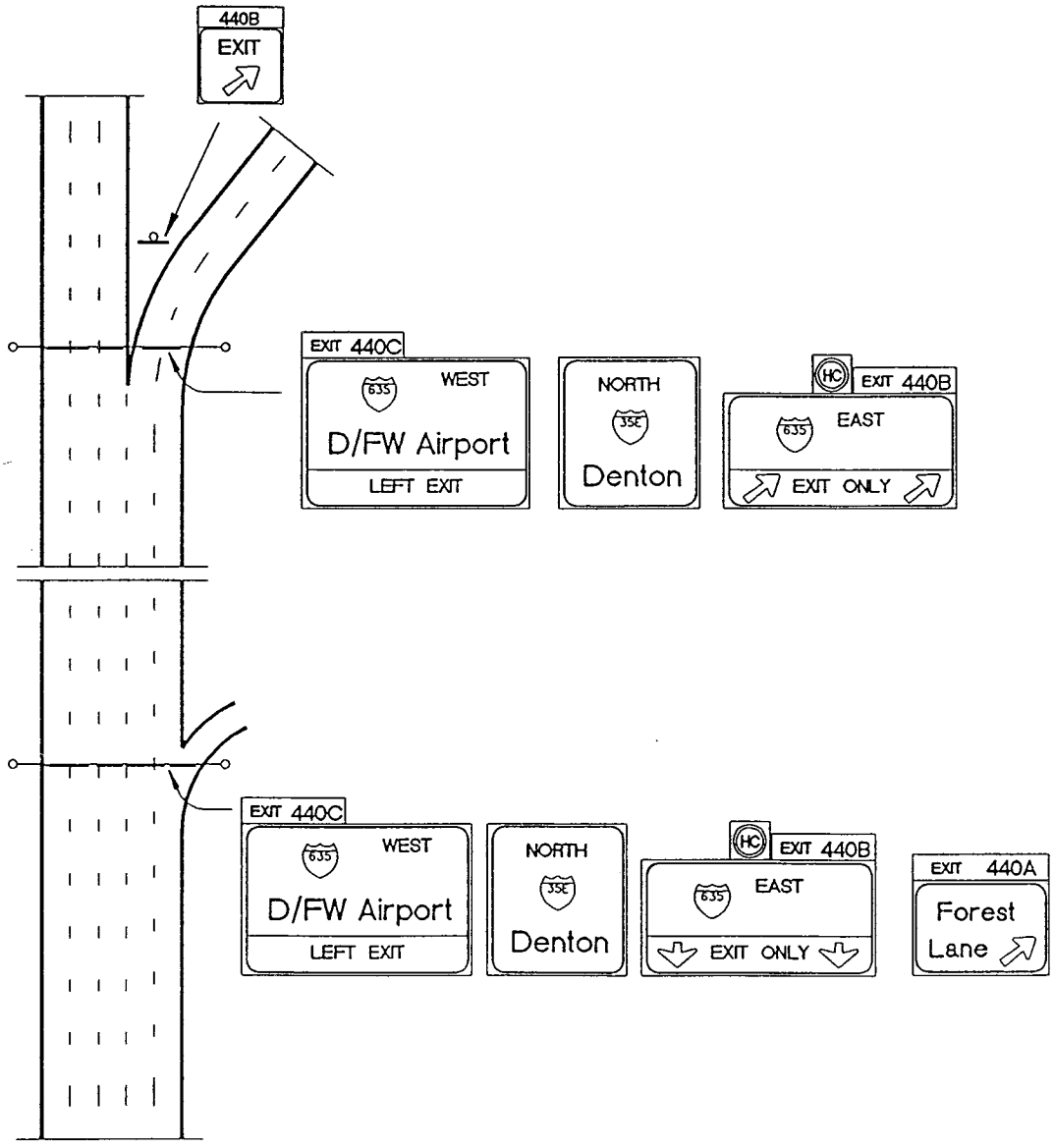


Figure 7. Guide Signing for I-35E North to I-635 East Exit Ramp

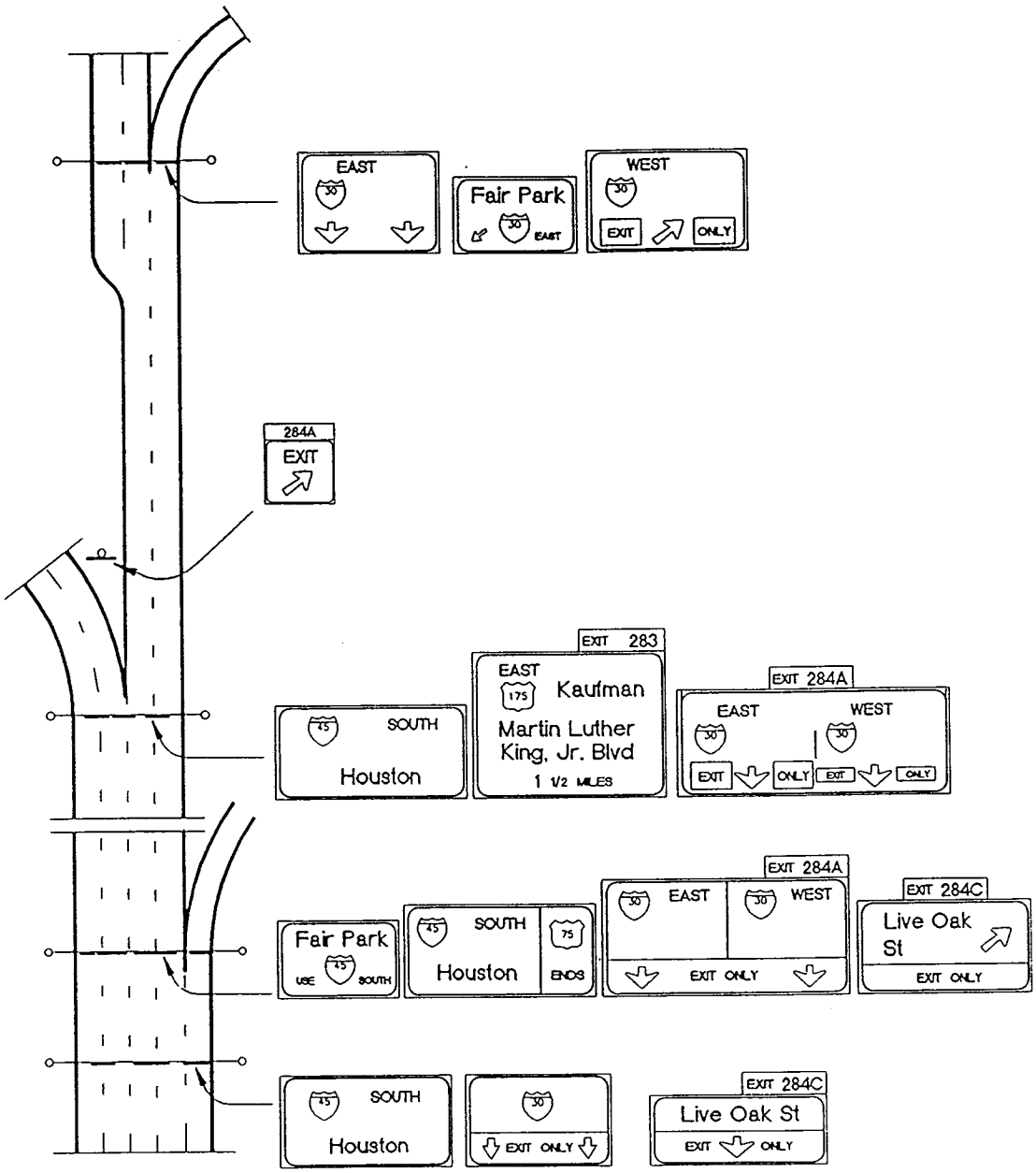


Figure 8. Guide Signing for I-45 South to I-30 Exit Ramp

Another example of multilane exits is in the vicinity of the I-10 West interchange with I-45 North in Houston. Signing for this interchange is shown in Figure 9. The task of guide signing is complicated as two multilane exits are spaced within 1.6 km of each other. The first exit is for downtown streets (San Jacinto and Main) and the second exit is for I-45 North to Dallas. The

initial advance sign provides 1.6 km notice of the Dallas exit, but provides no lane assignments. The Texas MUTCD method is used to indicate the lane drop and optional lane exit for the downtown streets in both the advance and exit direction signs. A modified diagrammatic sign for the Dallas exit is provided approximately 0.8 km from the exit. This sign indicates route numbers and cardinal directions for three different freeway routes. The exit direction sign uses the EXIT ONLY panel with double arrows to indicate the two-lane drop exit. This sign includes the destination (Dallas) without a cardinal direction. A pull-through sign for the through route (1-10 West to San Antonio) is displayed next to the exit direction sign, but there is no sign for the I-45 South exit at this location.

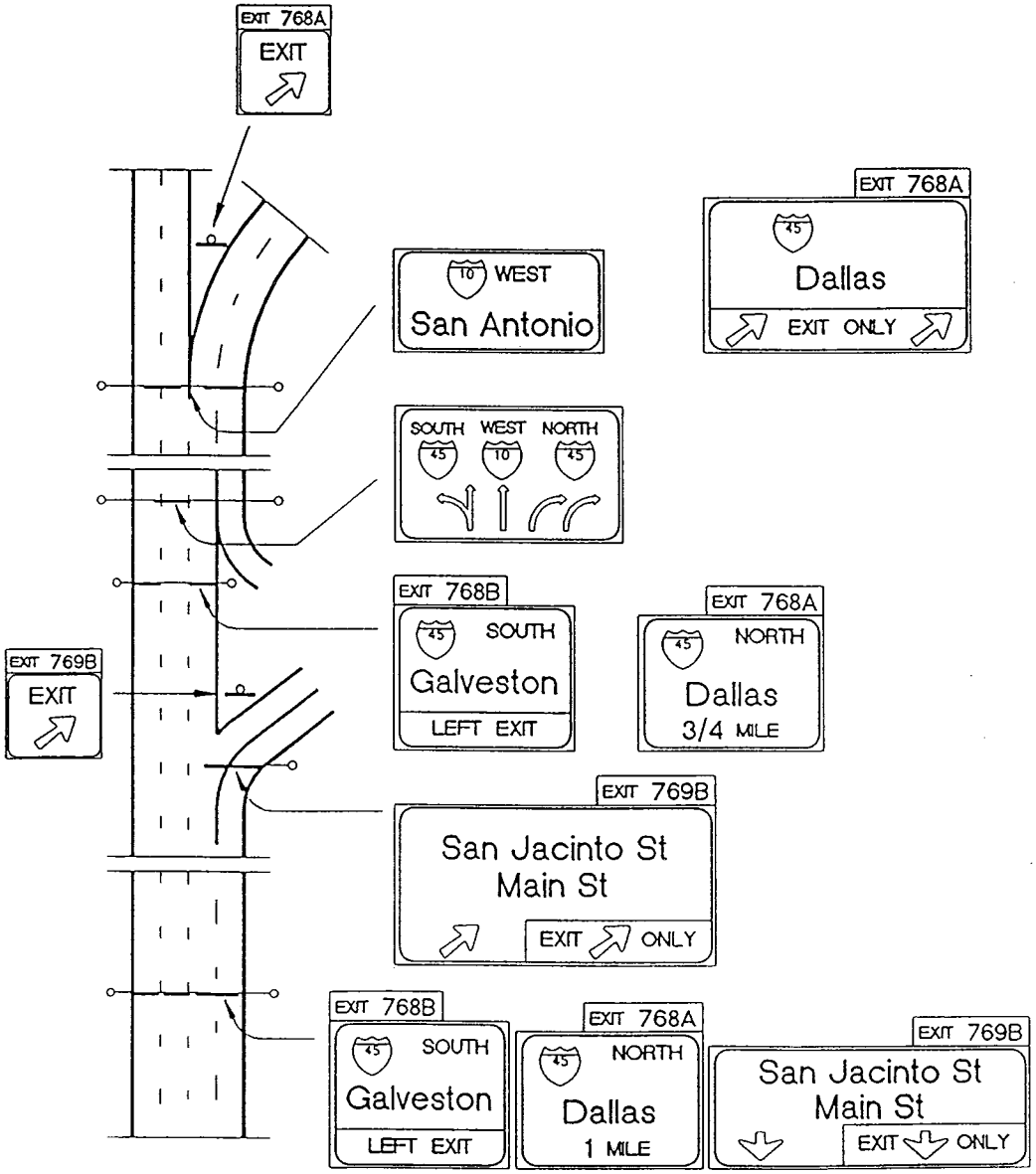


Figure 9. Guide Signing for I-10 West to I-45 North Exit Ramp

Another example of a two-lane drop exit is the I-35 North intersection with U.S. 281 and I-37 South in San Antonio. Signing for this interchange is shown in Figure 10. In this instance, the exit ramp splits, complicating the task of guide signing. The interchange is signed by an advance sign, denoting the destination and route designation of the intersecting route. The sign also offers lane assignment information through the inclusion of two separate EXIT ONLY panels for each part of the ramp split. The exit directional sign also uses downward lane assignment arrows, and repeats the information given in the advance sign. Exit directional signing is also used on the exit ramp to indicate the secondary ramp split.

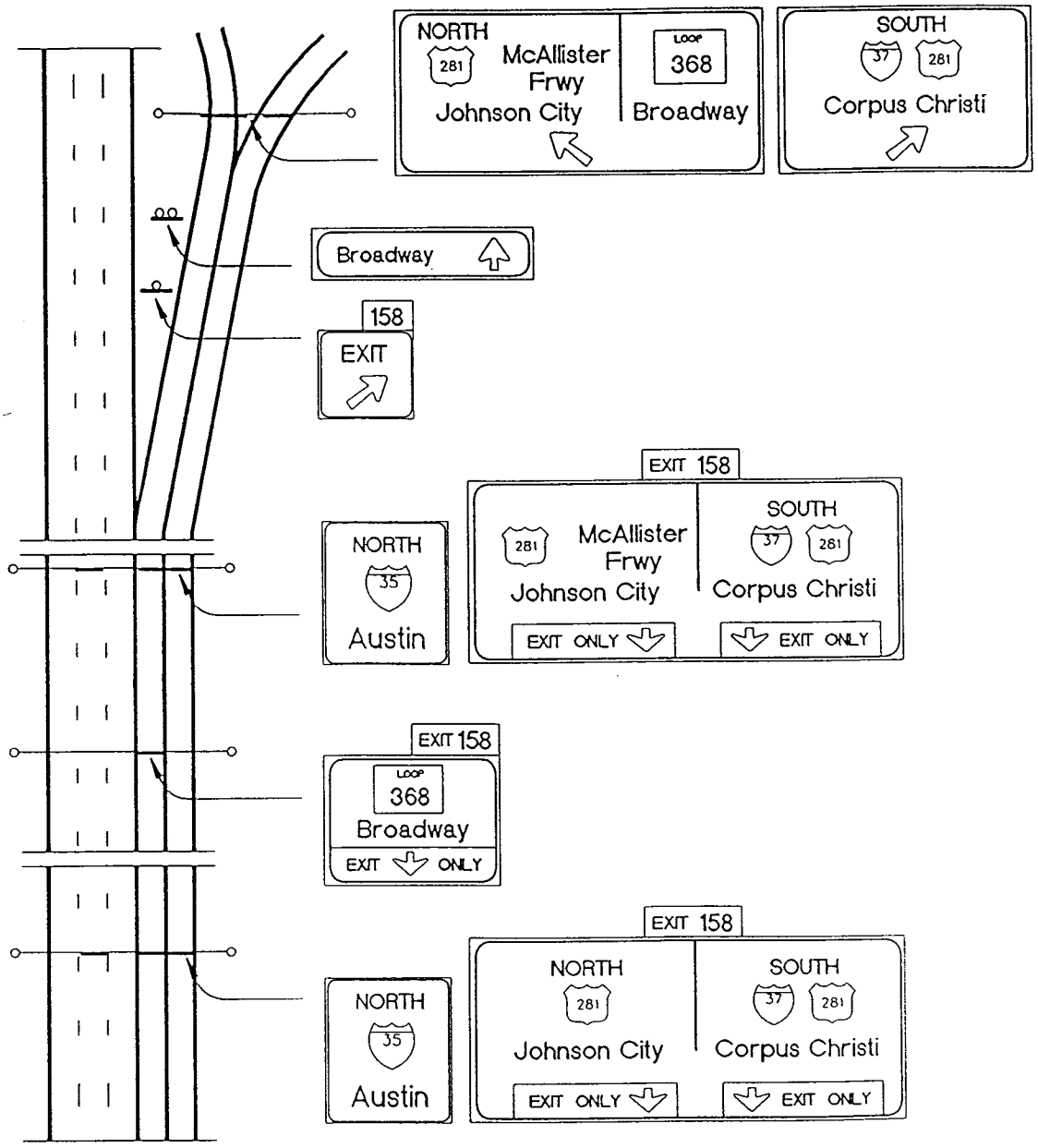


Figure 10. Guide Signing for I-35 North to I-37 South Exit Ramp

The final example for a multiple lane drop analyzed was in the Dallas area. The I-30 East/I-45 South interchange with Lamar and Griffin Street is a two-lane exit ramp signed in a unique manner. Signing for this interchange is depicted in Figure 11. Two advance signs are used in advance of the interchange. Signing includes the use of downward white lane assignment arrows, with a supplementary EXIT ONLY panel added to the sign. In addition, a lighted diagrammatic sign is included on the sign bridge. This sign may be for safety reasons as much as guidance, since the exit ramp occurs in a relatively sharp horizontal curve.

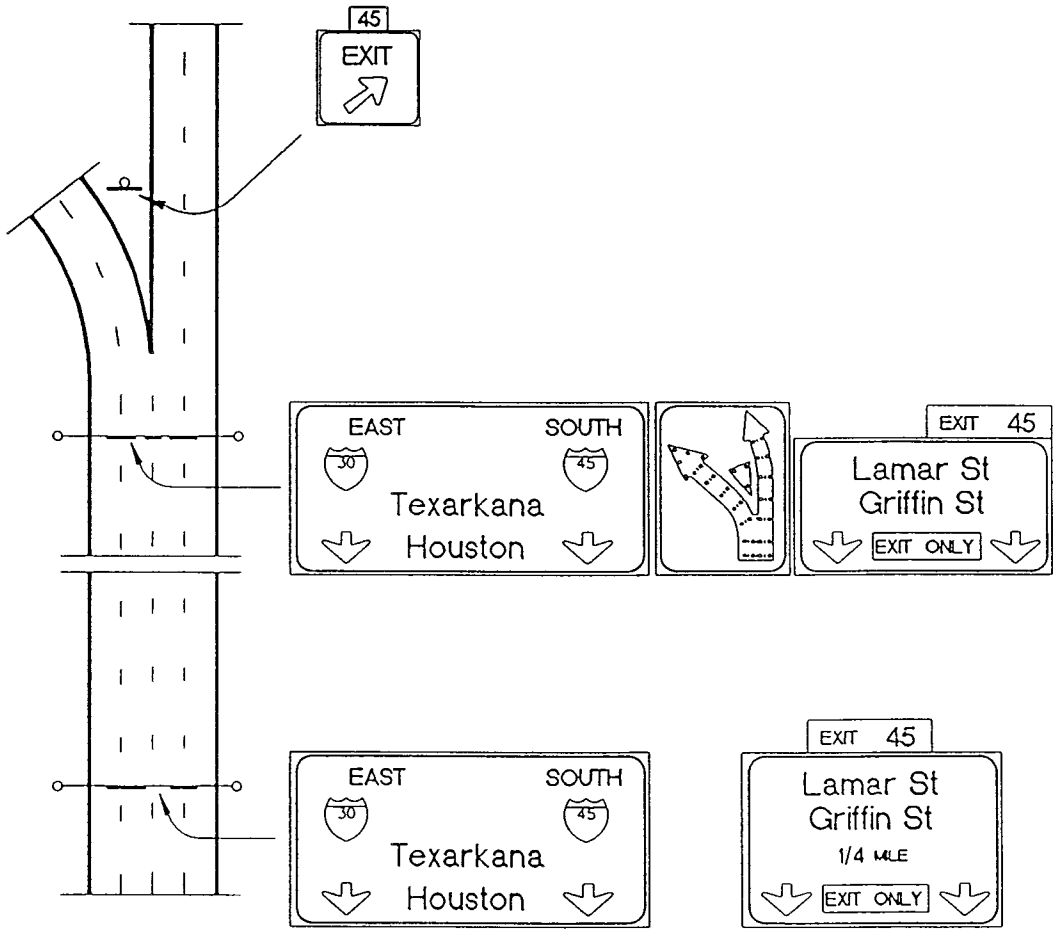


Figure 11. Guide Signing for I-30 East/I-45 South to Lamar/Griffin St. Exit Ramp

2.2.3.2 Multilane Exit Ramps with Optional Lanes

The other type of multilane exit is that of an optional lane in addition to one or more lane drops. Again, the researchers examined sites in Houston, San Antonio, Dallas, and Fort Worth.

The first site analyzed was the I-10 East interchange with I-610 in Houston. The interchange is a two-lane exit, with one lane as an optional lane. Signing used at the interchange is shown in Figure 12. The geometric situation is further complicated by a secondary ramp split. Four signs are used in advance of the interchange, and an additional sign is used to communicate the secondary ramp split. The first sign in the sequence is an initial advance guide sign with lane assignment information. The method of lane assignment is the same as found in the Texas MUTCD. The second sign is essentially a pull-thru sign. However, the sign is unique in that the phrase "LEFT 3 LANES" is used in lieu of lane assignment arrows. The third sign in the sequence is a modified diagrammatic sign. The final sign is an exit directional sign, as specified in the Texas Highway Operations Manual, without the vertical line used to denote a secondary ramp split. Finally, exit directional signing is used to indicate the secondary ramp split.

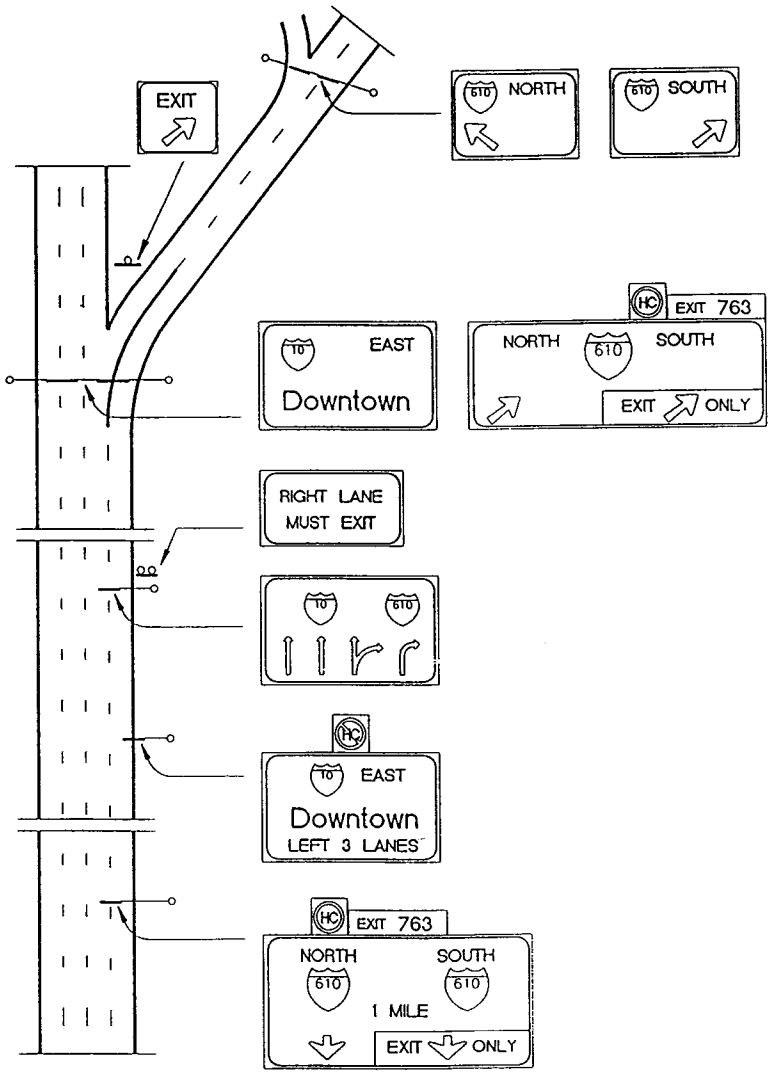


Figure 12. Guide Signing for I-10 East to I-610 Exit Ramp

The second site analyzed was the I-610 East interchange with U.S. 59 in North Houston. The interchange is a two-lane exit, with one lane as an optional lane. Signing for the interchange is shown in Figure 13. The situation at this site is further complicated because the U.S. 59 South exit ramp is only a short distance downstream from the U.S. 59 North multilane exit ramp. A series of four signs is used for the U.S. 59 North exit ramp. The first sign in the sequence is simply an initial advance guide sign, 1.2 km upstream from the exit ramp. The second sign in the sequence is a modified diagrammatic, informing drivers of the geometry associated with both the U.S. 59 North and South exits. The third sign is an advance sign, conforming to the design recommended in the Texas MUTCD. The fourth and final sign is an exit directional sign. The sign design is again that which is recommended by the Texas MUTCD

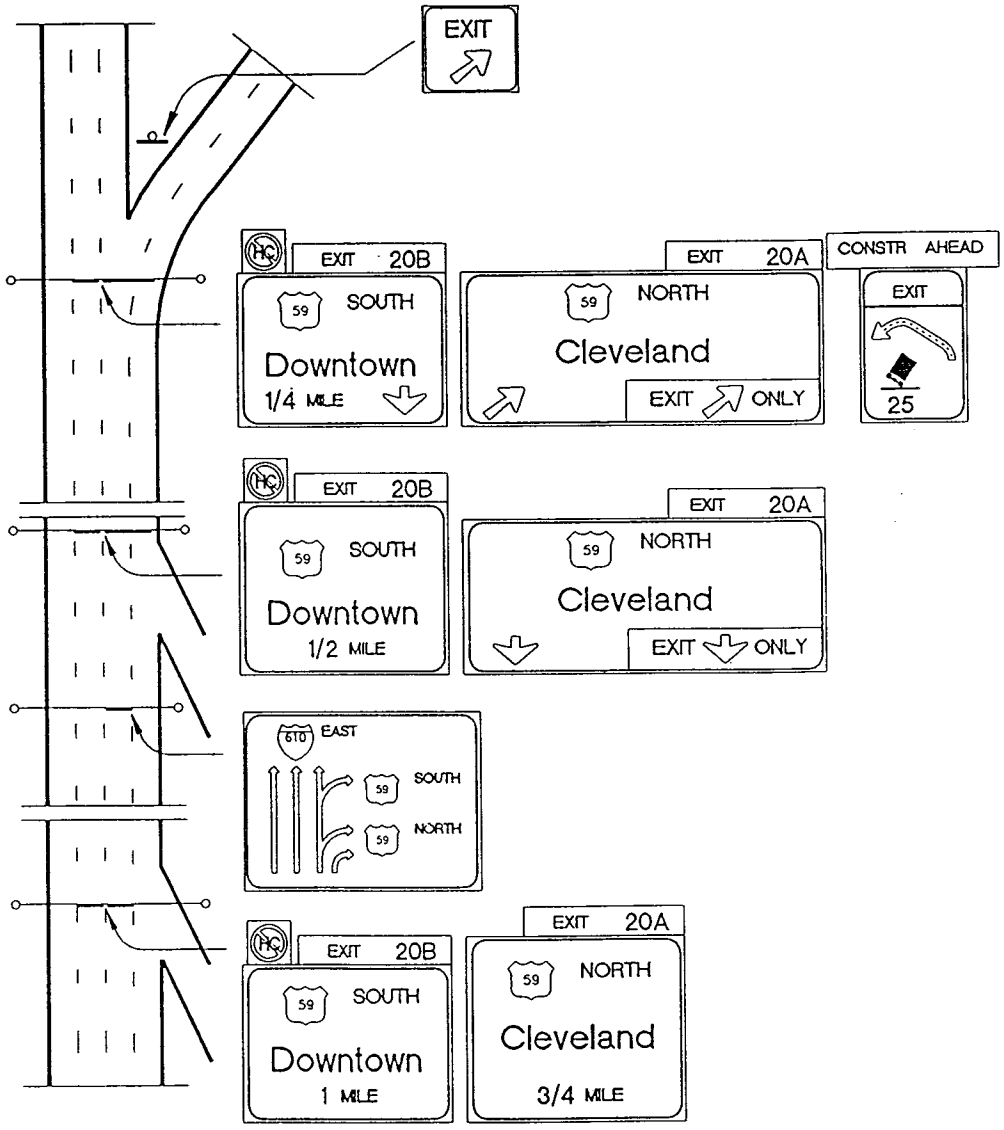


Figure 13. Guide Signing for I-610 East to U.S. 59 North Exit Ramp

The third site analyzed was the U.S. 90 West interchange with I-35 in San Antonio. Signing for the interchange is shown in Figure 14. The interchange is a two-lane exit, with one lane as an optional lane. The signing problem for this site is complicated by the addition of several overlapping routes, the presence of a secondary ramp split, and the fact that the lane drop is an auxiliary or acceleration lane. A series of four signs is used to inform the driver of the exit ramp. The first sign is placed 3.4 km in advance of the exit. The sign designates each intersecting route on the sign, in addition to listing three destinations. A single downward lane assignment arrow is placed above the right lane of the freeway. The secondary ramp split is indicated by a thin vertical line dividing the sign. Finally, the phrase "JCT 2 1/10 MILE" indicates distance to the exit ramp. The second and third signs repeat the information given on the first sign. The second sign contains the phrase "JCT 8/10 MILE," again to indicate distance to the exit ramp. The third sign is at the exit gore, repeating the information provided on the first two guide signs in the sequence. Specific lane assignment information is not provided on any of the signs. Pavement markings, including lane use arrows are used upstream of the ramp. The final sign indicates the ramp bifurcation through downward lane assignment arrows.

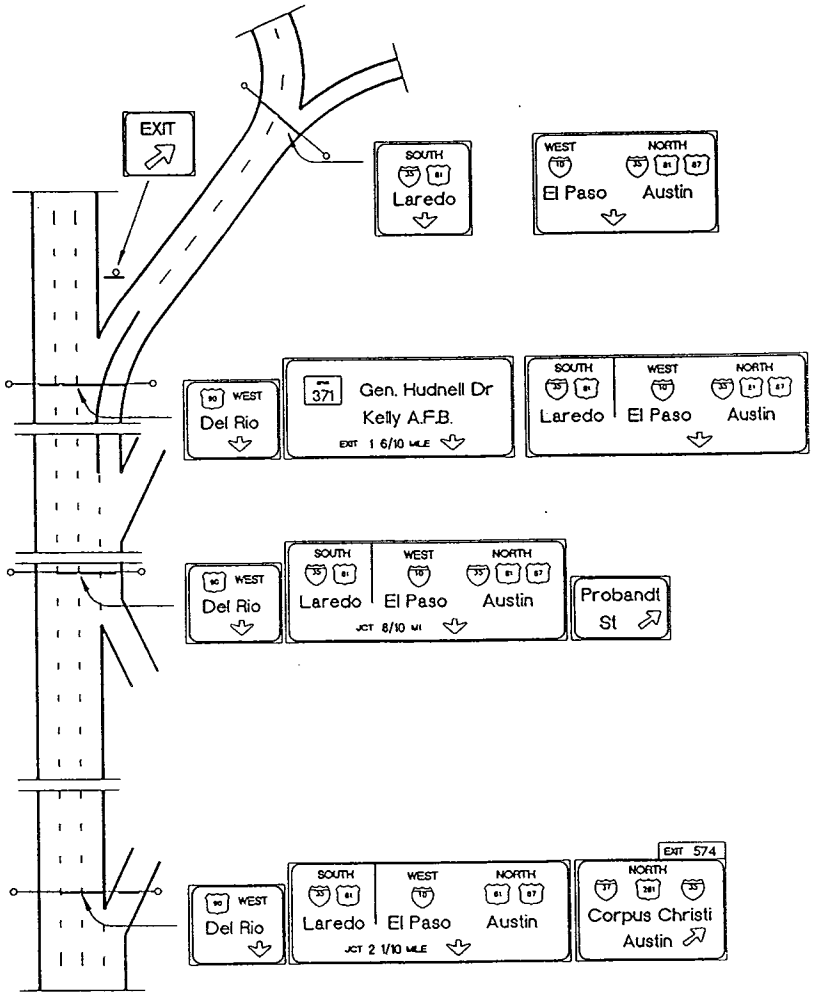


Figure 14. Guide Signing for U.S. 90 West to I-35 Exit Ramp

The fourth site was the interchange of North SH 121 with I-635 East in northwest Dallas. Signing for the interchange is shown in Figure 15. The exit ramp is two lanes, with one lane acting as an optional lane. An advance sign gives lane assignment information for the interchange. Two white lane assignment arrows are used, with a supplemental EXIT ONLY panel added above the right arrow. A small white vertical line, normally reserved for lane splits, lies between the two arrows. The exit directional sign uses two white upward diagonal arrows over both of the exiting lanes. A supplemental EXIT ONLY panel has been placed between the two arrows, although only one lane is a lane drop. Destinations are not given in either of the two signs.

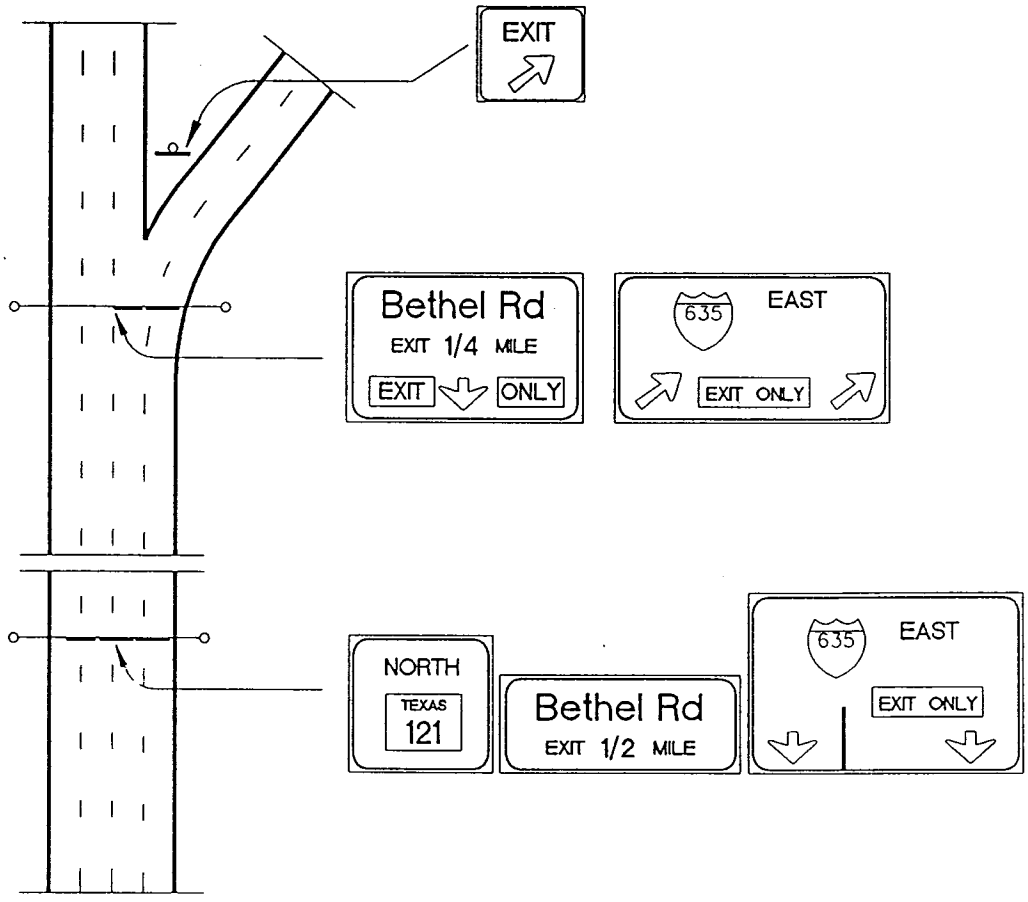


Figure 15. Guide Signing for SH 121 North to I-635 East Exit Ramp

The fifth site was the I-30/I-20 freeway split west of Fort Worth. Signing for the interchange is shown in Figure 16. The left portion of the split is a three-lane ramp, with two lane drops and an optional lane. The right portion of the split consists of two lanes: a lane drop and

the optional lane. Three signs are used to inform drivers of the interchange. The first two are diagrammatic signs. The first sign in the sequence adds the phrase "3/4 MILE." The final sign in the sequence uses downward lane assignment arrows to indicate the route designation, direction, and destination of both portions of the lane split.

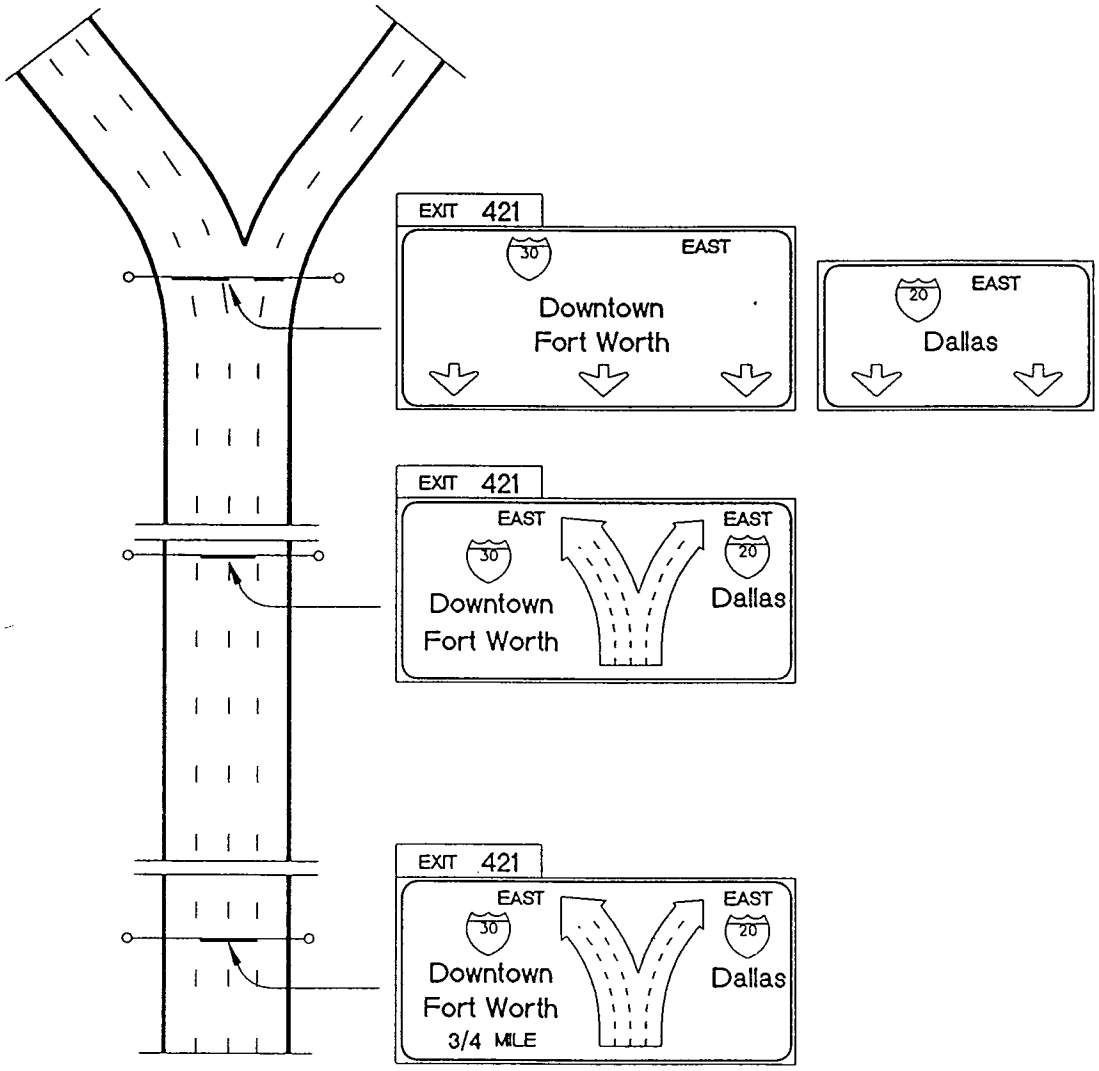


Figure 16. Guide Signing for I-30 East/I-20 East Freeway Split

The sixth and final site was the North I-820 interchange with I-30 in west Fort Worth. The signing for this interchange is shown in Figure 17. The ramp consists of two lanes with an optional lane. The ramp also features a secondary split. An additional exit ramp upstream of the I-30 ramp complicates sign design and placement. The first sign in the sequence gives route designation and destination of the exit ramp. The destinations are stacked on top of one another, rather than side by side. In addition, a white lane assignment arrow, without an EXIT ONLY panel, is centered over the rightmost lane. The second sign in the series is an exit directional sign.

Two upward slanted arrows are centered over each lane of the exit ramp. Again, EXIT ONLY panels are omitted from the sign design. In this sign, the destinations are placed side by side. The final signs in the sequence are used to indicate the secondary split of the exit ramp. An additional destination, "Downtown," is included.

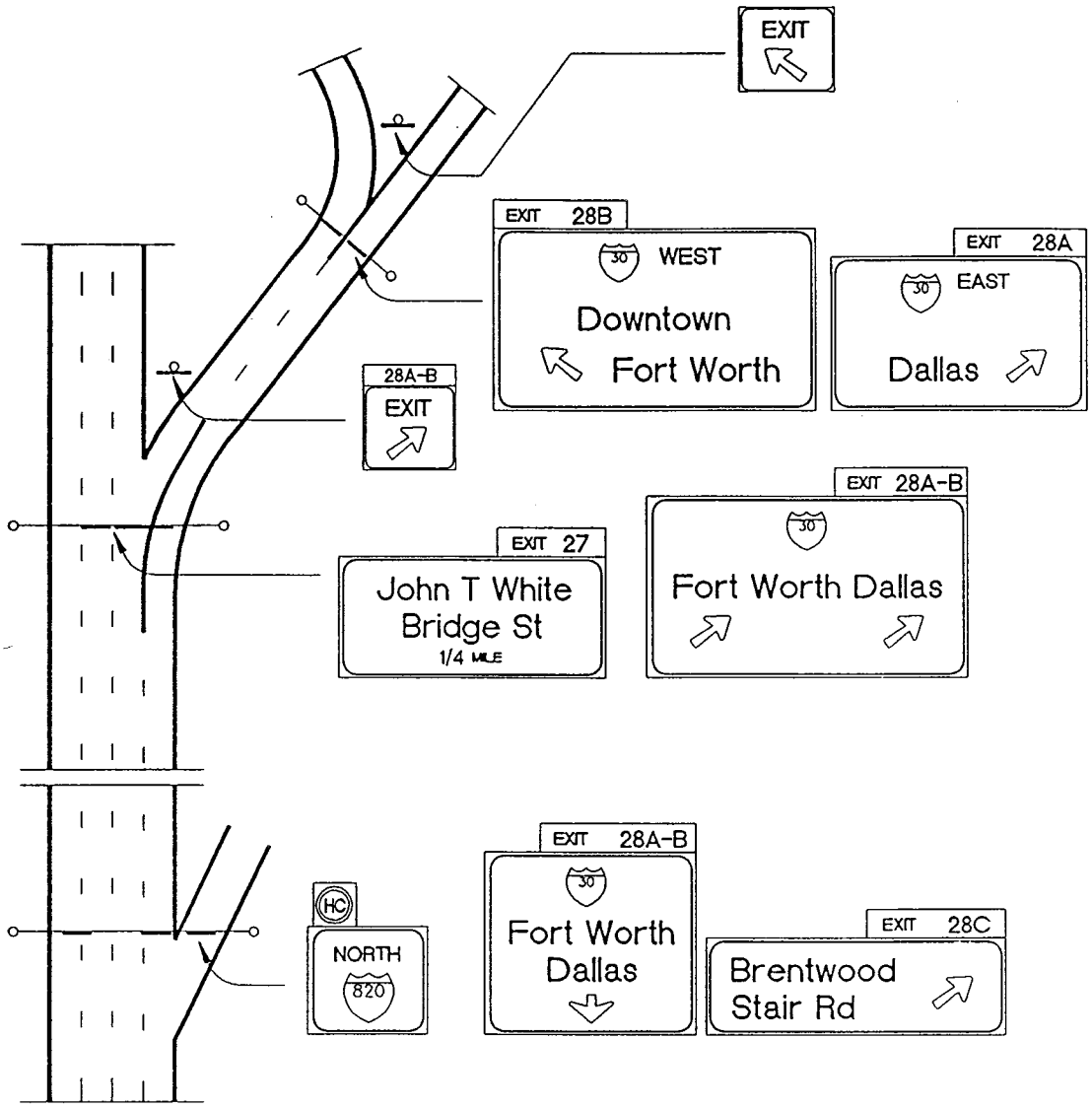


Figure 17. Guide Signing for I-820 North to I-30 West Exit Ramp

Again, this report describes signing treatments for only a few of the situations meeting the described geometric criteria. The descriptions do not include the many sites that use the signing methods recommended in the Texas MUTCD and the Texas Highway Operations Manual. This discussion has been offered only to show a few of the differences between real world application and established recommendations. These differences may be the result of a particular engineer's sign design; as he or she accommodates site specific geometric conditions not included in signing

manuals. In addition, many signs simply represent older practices, and require updating to conform with the state of the practice. Finally, the signing described in the preceding paragraphs is not intended to recommend the signing used in one area over that of another. Different signing treatments around the state are simply described.

2.3 SIGNING TREATMENTS EMPLOYED AROUND THE NATION

The lack of explicit instruction for signing multilane interchanges has left the individual state transportation departments with the task of developing guide signing. This lack of instruction has resulted in a wide range of treatments. This practice is in direct conflict with the nationwide uniformity objective of the MUTCD. The resulting signing practices vary between states. Some states use diagrammatic signs, others use non-diagrammatic signs, and some use a combination. Signing practices are diverse and non-uniform throughout the nation (8).

2.3.1 Signing Methods Used in Other States

To determine signing methods used in other states, the TTI research team sent a questionnaire to the state traffic engineer of each state. The questionnaire showed a diagram of how Texas signs a two-lane exit with an optional lane and a ramp bifurcation, similar to the diagram shown in Figure 9 and described in the Texas Highway Operations Manual. The questionnaire asked the engineer to indicate any changes to the Texas signing method to illustrate the signing used in his or her respective state. A copy of the questionnaire has been included in Appendix A.

In response to the questionnaire, several states returned information on how each deals with the problem of signing multilane exits with optional lanes. The situation also featured a secondary ramp split. Of the 49 states questioned (Texas not surveyed), 39 responded. Of those responses, 15 states indicated treatments different from those used in Texas. The following paragraphs discuss the signing methods used in states other than Texas.

2.3.1.1 California Method

California, noted for its extensive freeway system, has developed some unique guide signing treatments. California uses pull-thru signs in combination with both their advance and exit directional signing. A downward lane assignment arrow on the right side of the pull-thru sign, in combination with a lane assignment arrow on the advance guide sign, denotes optional lanes at multilane exits, as shown in Figure 18. On the exit directional sign, the arrow orientation changes to an upward slant. In essence, two arrows are used to convey lane assignment information for one lane. Also note in the figure, the inclusion of the word "ONLY" to indicate a lane drop. The word is written in a white on green format, in contrast with the black on yellow EXIT ONLY recommended in the National MUTCD. Other states that recommend the use of pull-thru signs at multilane exits include Kansas, Oklahoma, Minnesota, Michigan, Illinois, and Ohio.

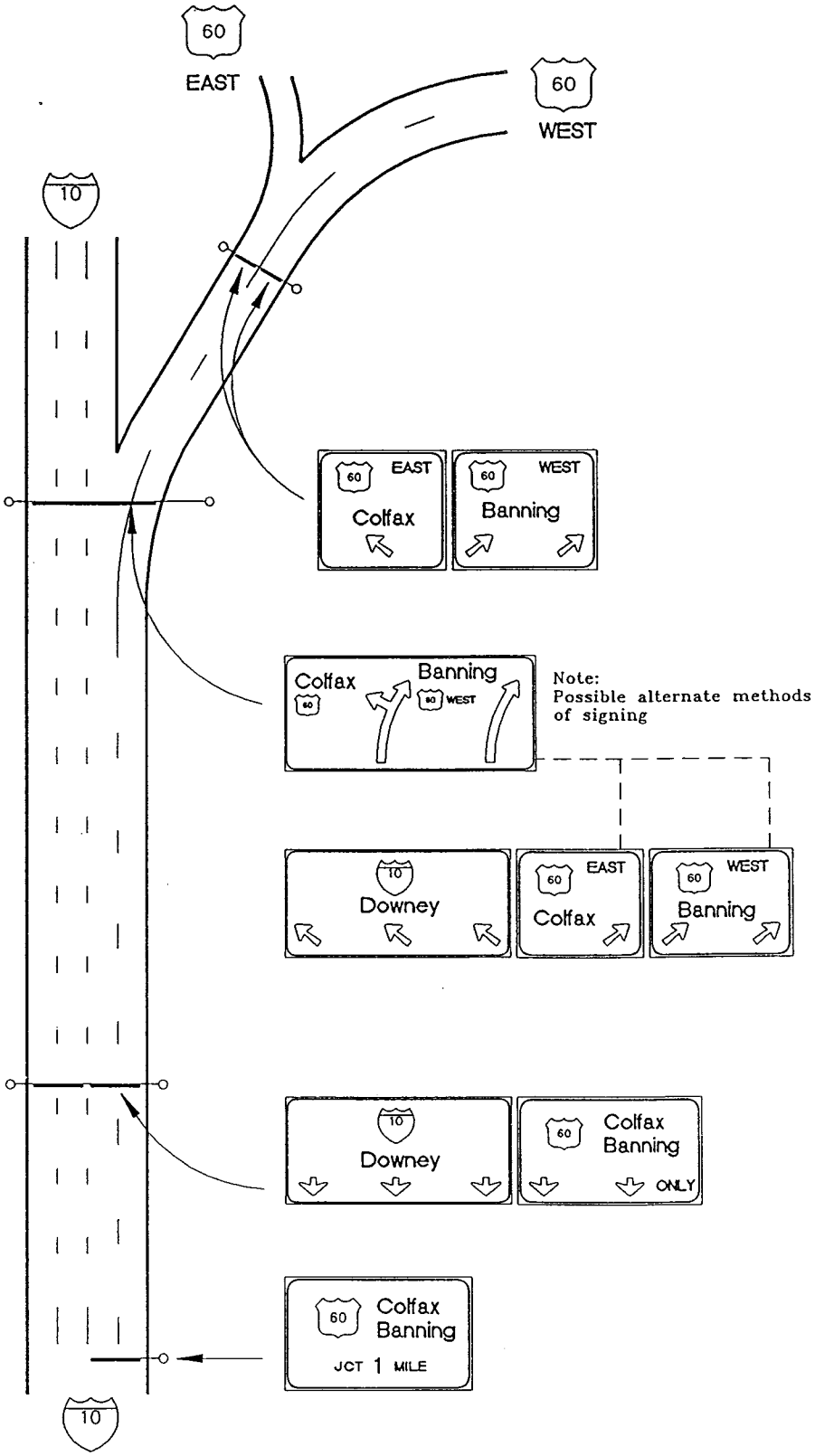


Figure 18. California Standard Method of Signing

2.3.1.2 Minnesota Method

The Minnesota method of guide signing is unique in that downward slanted arrows are used at the exit directional sign instead of upward arrows. In addition, the sign uses no message to communicate the optional lane or the lane drop at the interchange. Minnesota also relies on pull-thru signs for multilane exits. A diagram of the Minnesota method for signing optional lanes at multilane exits is shown in Figure 19

2.3.1.3 Ohio Method

Ohio also uses pull-thru signs in a fashion somewhat similar to the California method of signing to indicate an optional lane. However, the Ohio method uses down diagonal arrows in advance guide signing for assigning traffic to the optional lane. Both a pull-thru and an advance exit sign have a diagonal arrow, pointing to the optional lane, denoting that both the exit and through destinations can be reached in that lane. Figure 20 depicts the Ohio method of signing.

2.3.1.4 Mississippi Method

Although the survey response indicated that Mississippi uses the same type of guide signing as Texas, visual observation of one site indicates that Mississippi employs a different type of guide signing for multilane exits with optional lanes. A pull-thru and advance guide sign are combined into one large guide sign for the interchange. The pull-thru and advance signs are divided by a thin white vertical line. A downward arrow is placed below the line, and serves as the lane assignment arrow for the optional lane. Although the signing practice is similar to that used in Texas, the sign is unique to Mississippi. Figure 21 shows the signing practice used in Mississippi for a two-lane exit with an optional lane.

2.3.1.5 Other Methods

A few states recommended signing methods that did not specifically address the secondary ramp split and optional lane geometrics. Other states recommended diagrammatic signing treatments. Massachusetts indicated that diagrammatic signing is more appropriate for a multilane exit with an optional lane and secondary ramp split. New York also explicitly recommended the use of diagrammatic signing. Massachusetts included excerpts of their sign policy, defining how to sign using both non-diagrammatic and diagrammatic signing. Figure 22 shows the non-diagrammatic method of signing used in Massachusetts.

Massachusetts uses a variation of the Right Lane Must Exit sign, as prescribed by the Texas MUTCD. The message instead reads "This Lane Must Exit" and includes a downward slanted arrow pointing to the right lane. This method is used in lieu of the EXIT ONLY panel on the overhead guide signs. Massachusetts makes no effort to sign for the optional lane, apparently relying on the driver's ability to visually judge the interchange geometry to make lane assignment decisions.

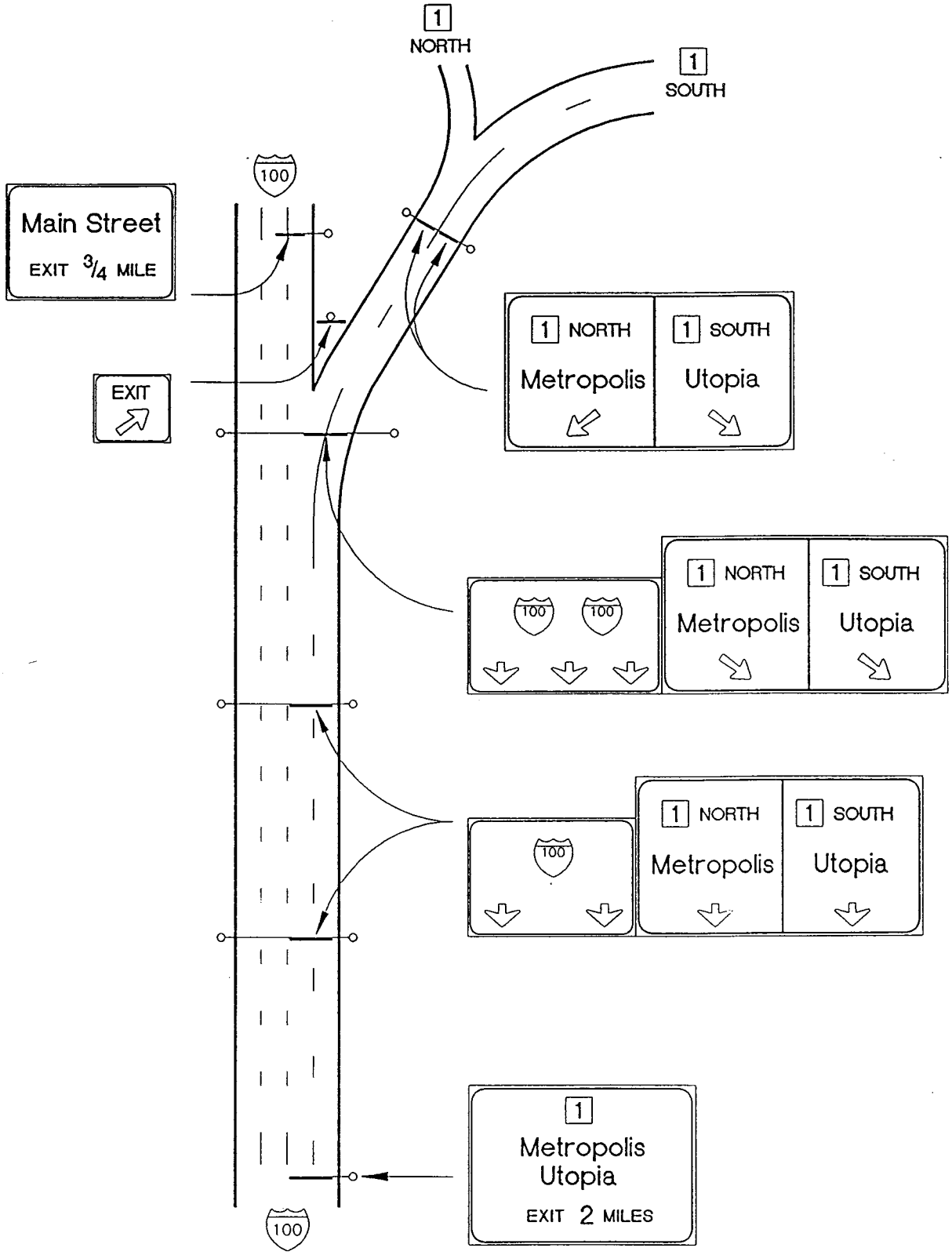


Figure 19. Minnesota Standard Method of Signing

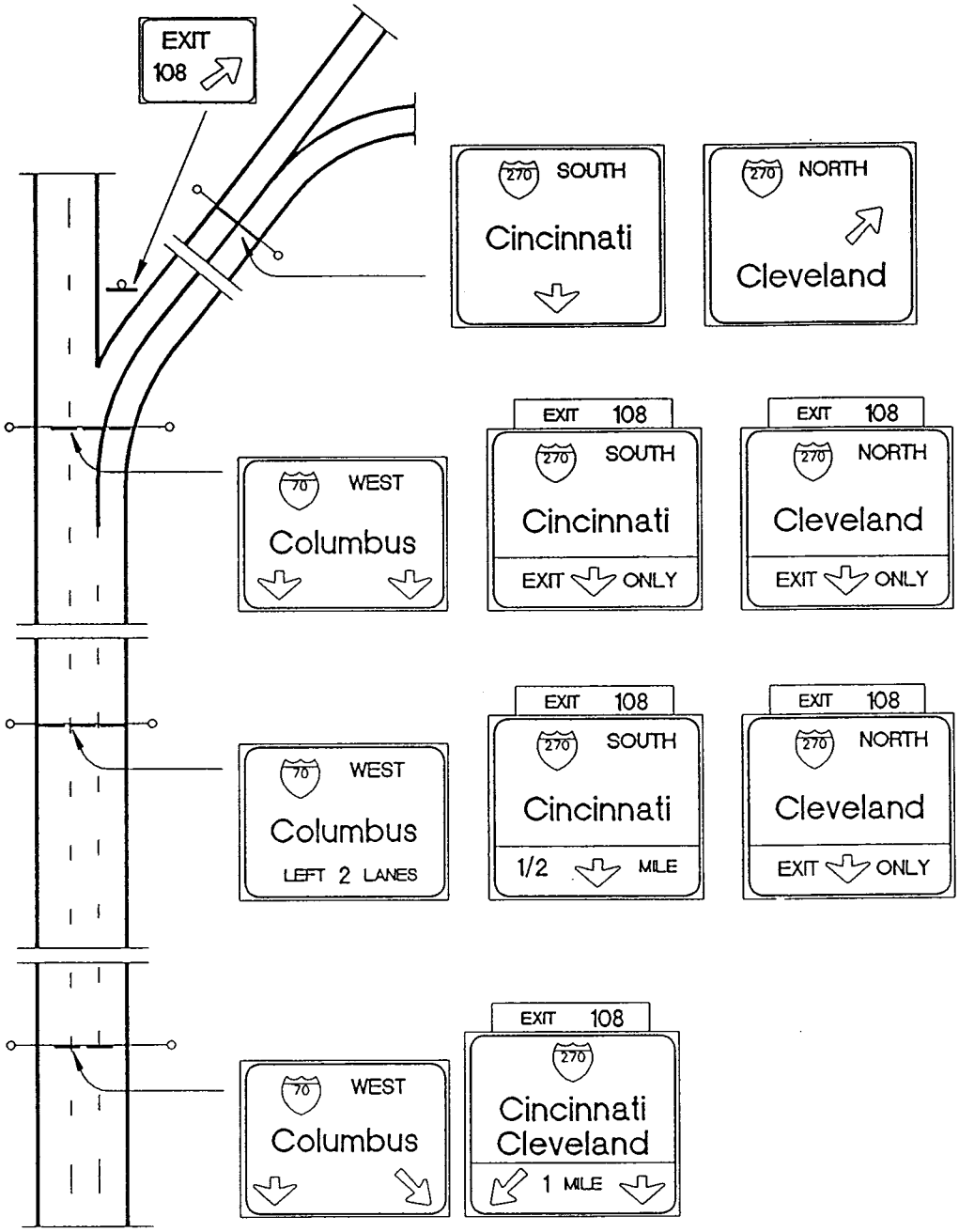


Figure 20. Ohio Standard Method of Signing

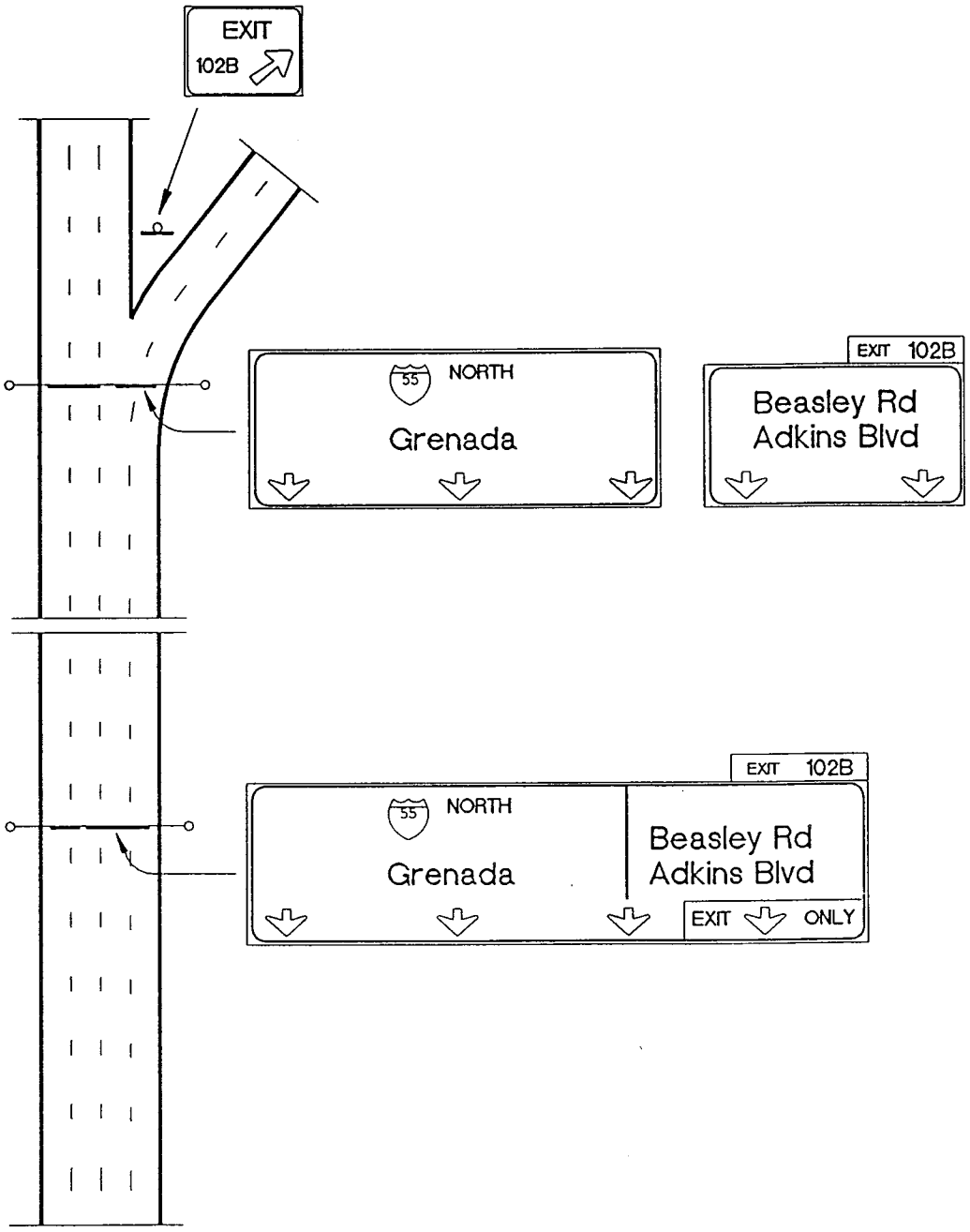


Figure 21. Mississippi Method of Signing

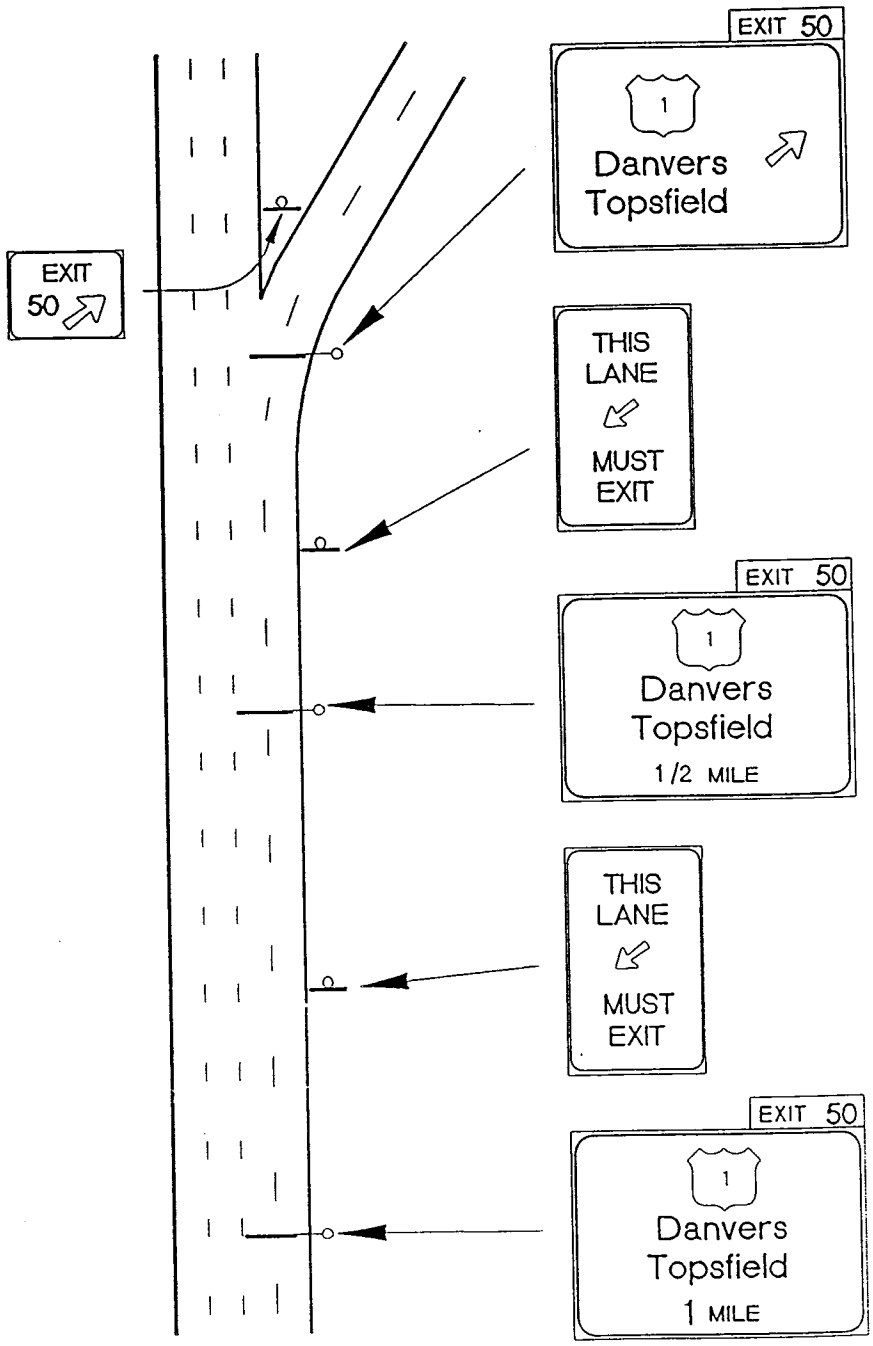


Figure 22. Massachusetts Standard Method of Signing

Tennessee uses a simple method of signing for multilane exits, which is similar to methods used by other states. The signing trend is to sign explicitly for the lane drop, and offer little or no lane assignment information for the optional lane. As was the case for Massachusetts, Tennessee apparently relies on the driver's visual interpretation of the exit geometry for lane

choices. Tennessee also recommends the use of pavement markings for communicating the optional lane situation. The Tennessee method of guide signing is shown in Figure 23. Iowa and Indiana use signing treatments similar to those used in Tennessee.

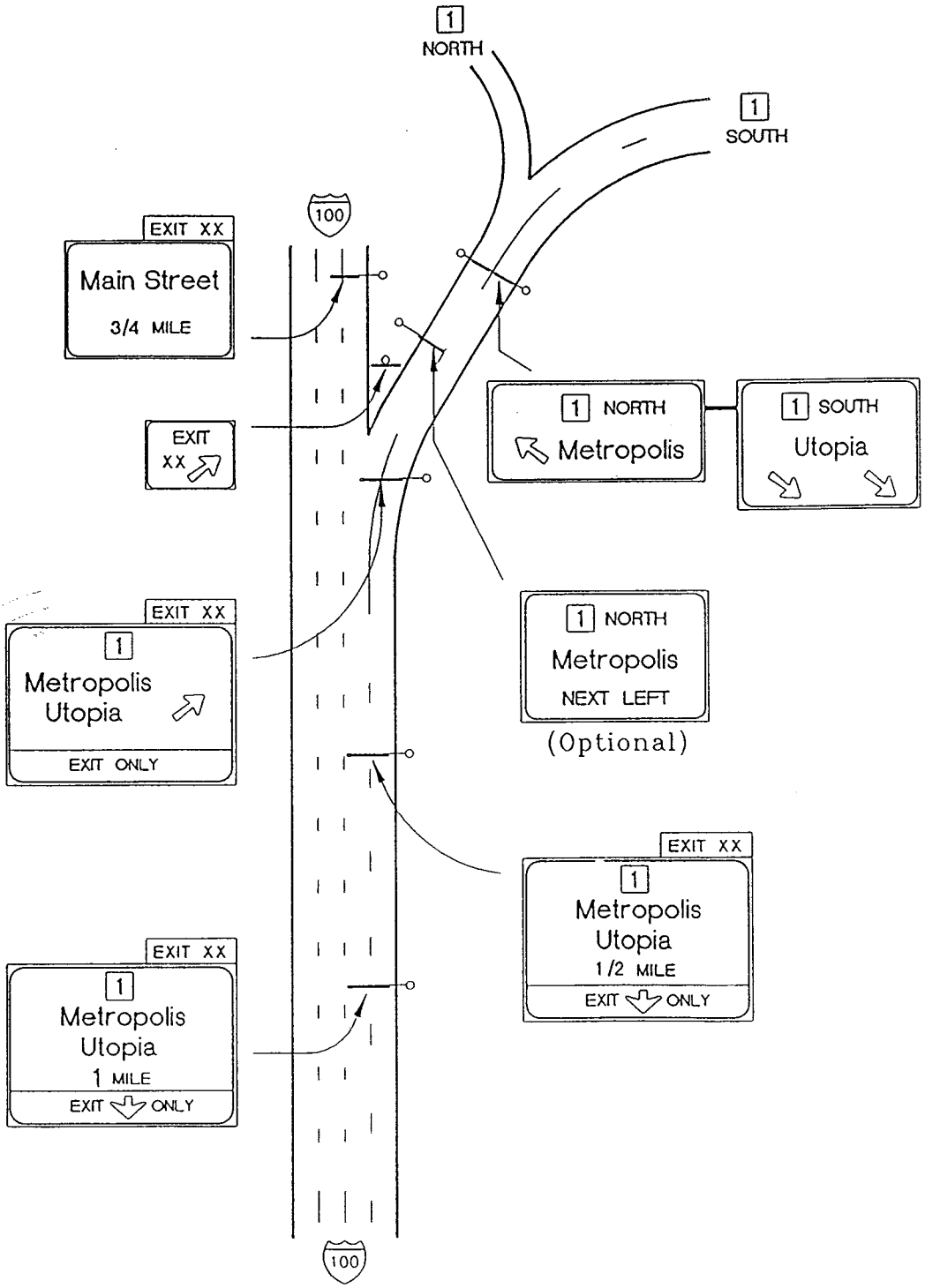


Figure 23. Tennessee Standard Method of Signing

Of all the states surveyed, Utah offered the simplest solution to the signing problem. Utah's method of signing is identical to the signing used for a single lane tapered exit, with the exception that guide signs are mounted overhead for a multilane exit. The Utah and Tennessee methods have been discussed to show the simplicity of treatments that are often used for signing multilane exits. Again, these states apparently rely on drivers to visually interpret the roadway for themselves. Utah's method of signing is shown in Figure 24.

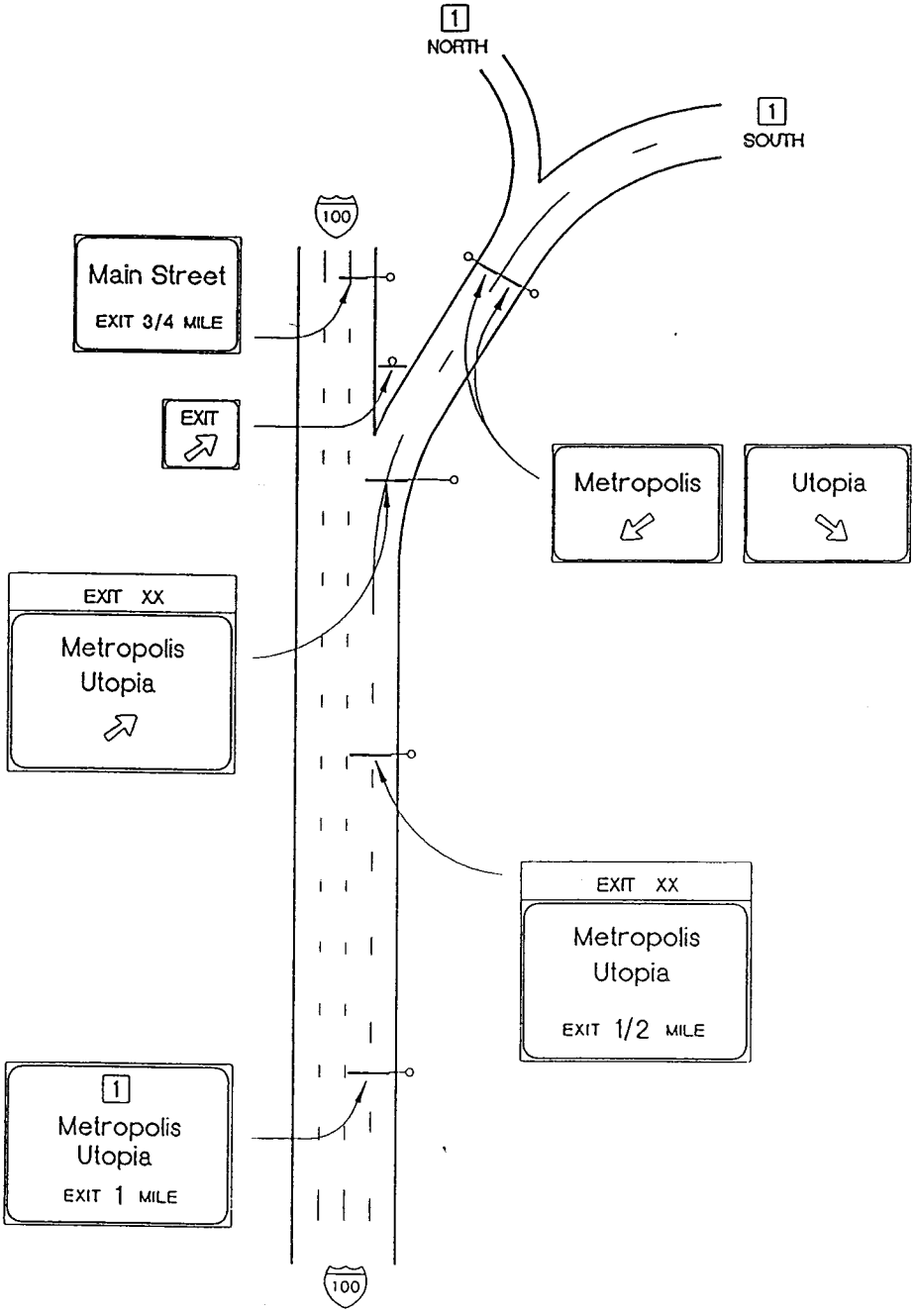


Figure 24. Utah Standard Method of Signing

2.4 OTHER PREVIOUS STUDIES

Leisch (8) points out that several options are used around the country to communicate a multilane exit with an optional lane. He further indicates that signing formats at multilane exits (other than freeway-to-freeway exits) have not been addressed by either the Transportation Research Board (TRB) or the Institute of Transportation Engineers (ITE). Leisch suggests that the amount and type of signing should vary between system and service interchanges. Some of the variations noted by Leisch are indicated in Figure 25.

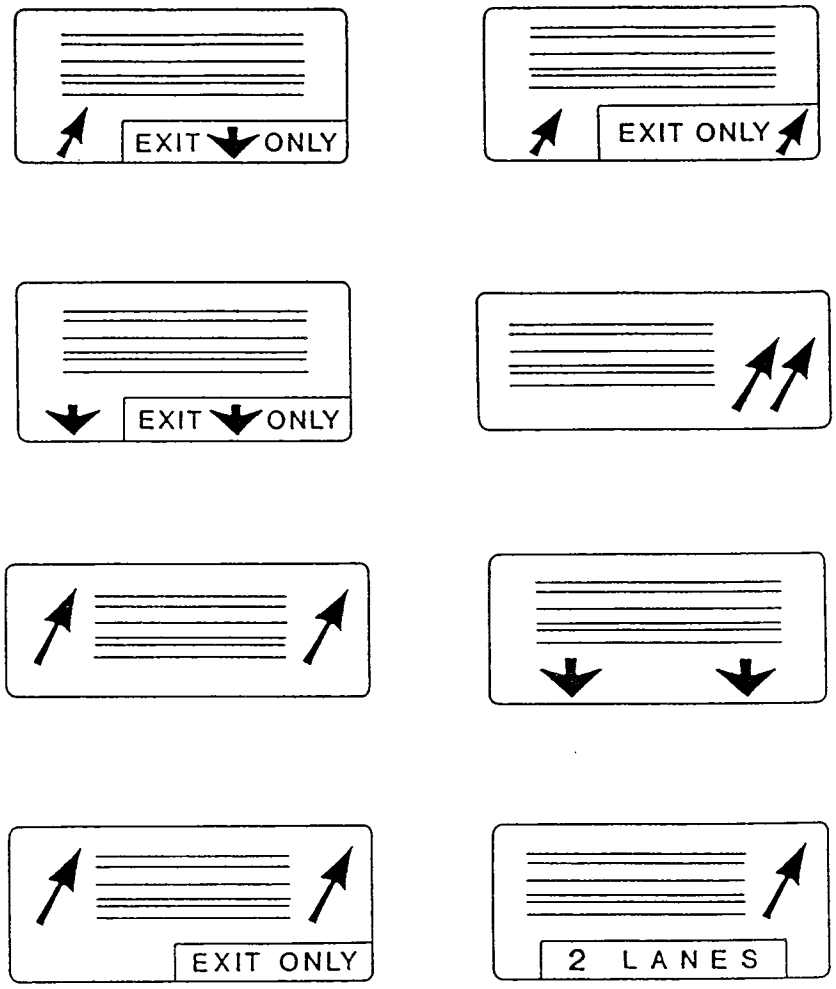


Figure 25. Sign Format Possibilities for Two-Lane Exit Ramps

2.4.1 Modified Diagrammatic Signing

Skowronek (16) found in his investigation of guide signing at exits in Houston, Texas, that drivers frequently misunderstood optional lane exits. Skowronek identified 23 problem sites, of which fourteen sites involved exits with an optional lane. Skowronek tested a "modified

diagrammatic" sign to address the problem sites with exits containing optional lanes. This type of sign incorporates design principles from diagrammatic and non-diagrammatic signing, and was fairly well interpreted by the subjects tested in Skowronek's laboratory experiment in communicating optional lanes. However, only 18 subjects participated in that laboratory experiment. Skowronek points out the lack of comprehension of the white arrow on non-diagrammatic guide signs, and identifies this aspect of signing as an area needing further research. Finally, he suggests that insufficient advance information is the most common driver complaint about guide signing. An example of "modified diagrammatic" guide signs is shown in Figure 26. The sign in Figure 26 was developed for a three-lane exit with an optional lane. The situation is further complicated by the existence of an additional exit just downstream of the exit ramp.

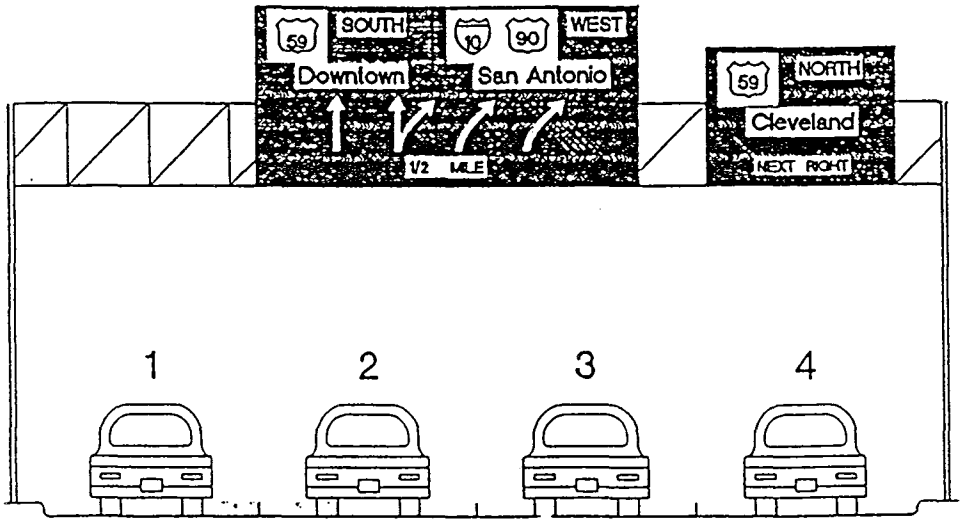


Figure 26. "Modified Diagrammatic" Signing for a Three-Lane Exit with an Optional Lane

A recent study by the Ontario Ministry of Transportation, which was done to make recommendations for bilingual guide signs, (19) tested a form of signing similar to the modified diagrammatic signing. The study tested several alternatives in a laboratory format. A total of 261 participants from the Toronto and North Bay areas were tested, and the participants indicated lane choices and confidence in their responses after viewing an alternative sign for a period of 5 seconds. The recommended advance signing alternative is shown in Figure 27. The sign shown in the figure centers each of the two arrow shafts over the lane to which the arrows apply. The current method of signing simply identifies the interchange, and uses the phrase "2 LANES" to identify that the upcoming interchange is two lanes with an optional lane.

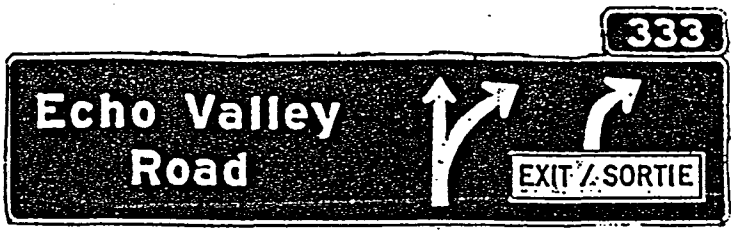


Figure 27. Experimental Signing Developed for Use in Toronto

2.4.2 Diagrammatic Guide Signs

The use of diagrammatics has shown to be both an effective and a popular way of communicating complex interchanges to motorists. Roberts (20) showed in his study that diagrammatic signs, when installed at left exits, reduced driver confusion. His study also looked at the effectiveness of diagrammatics with and without lanes drawn on the diagram. Roberts suggests that diagrammatics command more attention due to the greater amount of white space on the sign. McGuinness' (21) survey indicates that some drivers find diagrammatic signs helpful in reducing congestion in certain areas. The survey also indicated that many drivers, particularly unfamiliar freeway users, prefer diagrammatics to non-diagrammatic signs. The survey questioned a limited number of participants in the Columbus, Ohio area.

Other studies have shown diagrammatic signs to be less effective than non-diagrammatic signs. Gordon (22) suggests that non-diagrammatic signs are slightly more effective than the diagrammatic signs. This was true in both the case of driver response time and correctness of the responses. Zajkowski and Nees (23) support the findings of Gordon's research. They suggest that diagrammatic signs produce no significant benefit over non-diagrammatic signs for the cases tested. Finally, McNees and Messer believe that properly worded verbal signs may be as effective as diagrammatics (24).

Gordon suggests that diagrammatics may be applicable in situations that violate driver expectancy (T- and Y- interchanges and left exits.). It should be noted that Gordon's research dealt primarily with right exits, whereas Roberts' dealt with some left exits. This may suggest that diagrammatics are effective at left exits, but are unnecessary at right exits. Eberhard and Berger (25) add that diagrammatics aid drivers in areas with closely spaced merge and diverge points. Other studies have been conducted on the design and effectiveness of diagrammatics.

In any case, diagrammatics are significantly more expensive and cumbersome to construct than non-diagrammatic guide signs. Each diagrammatic guide sign must be specially made to fit a particular situation, so there is not a set of standard, easily reproducible graphics. In addition, diagrammatics are typically larger than non-diagrammatic guide signs. Therefore, additional

material is required for fabrication, and the sign support structure must be large enough to support a heavier wind load.

2.5 SUMMARY

In this chapter, guide signing practices used at multilane exits in Texas and other states were inventoried. In addition, the research team reviewed literature relevant to the topic of guide signing at multilane exits. This part of the research effort was performed to gain expertise and determine the state-of-the-art for freeway guide signing.

The statewide inventory of guide signing practices found that different methods were used in the cities of Houston, Dallas, San Antonio, and Fort Worth. Many of the observed signing strategies were different between, and even within, the particular cities.

The responses to the nationwide survey of guide signing practices yielded the same result: many diverse guide signing treatments are used throughout the different states to indicate an upcoming multilane exit. Whereas many states agreed with the signing treatments recommended in the Texas MUTCD, many others indicated different signing treatments. The conclusion of this survey and the inventory of Texas guide signs indicates that guide signing treatments for multilane interchanges are non-uniform.

The literature review included previous research on guide signing, and a comprehensive review of guide signing practices recommended in the National and the Texas MUTCD. The literature search indicated that freeway guide signing is generally adequate on Texas highways (1, 14, 17). Previous research indicates that although signing for lane drops is fairly well understood by drivers, signing for multilane exits with optional lanes is misunderstood by a significant portion of the Texas driving population (1, 14). More specifically, the white arrow adjacent to EXIT ONLY panels on freeway guide signs may not effectively communicate the upcoming optional lane situation. This misinterpretation has been identified as an area for further research. Other literature discussed the informational requirements for freeway guide signs.

A failure to understand signing practices for optional lanes may lead to a combination of reduced capacity and safety in the optional lane. This could be particularly critical in locations with high traffic volumes and/or a high percentage of unfamiliar drivers. Capacity may be reduced through the failure of several drivers to realize that the optional lane is intended for both through and exiting traffic. In other words, drivers in the optional lane wishing to continue on the main freeway may mistakenly change lanes, thinking that the optional lane is a lane drop. On the other hand, a driver wishing to exit the freeway may change lanes into the lane marked "EXIT ONLY," mistakenly thinking that the optional lane only allows drivers to continue on the freeway. This inability to understand the upcoming optional lane exit could also contribute to lower roadway capacity and safety because of the increased number of unnecessary lane changes, which in turn increases the number of vehicular conflicts.

A potential problem situation may also arise when drivers feel that they have to make an immediate lane change in order to reach their destination. These erratic lane changes could become particularly significant in high volume segments where accidents may have a greater chance of occurring. Freeway capacity and safety issues demonstrate the importance of easily comprehensible freeway guide signs for exit ramps.

The potential capacity and safety problems described in the previous paragraphs may not be as relevant with a driving population composed of familiar drivers. Familiar drivers tend to understand a roadway after driving it on a daily basis. The familiar drivers will, therefore, understand an exit ramp configuration and other highway geometrics simply through experience, and may not rely on guide signing at all.

Signing in urban areas is often complicated by the use of multilane exits, closely spaced interchanges, and high traffic volumes that distract driver attention from signs. Signing content should be carefully considered during the design phase to address these concerns. Signing should present enough information to adequately convey the upcoming geometric condition to drivers, but not be so much as to overload the driver's ability to process the information. In addition, signing practices should be consistent not only between states, but at sites within a particular state, so that drivers develop a familiarity with the signing information presented to them.

The results of the technical background pointed to two basic guide signing deficiencies. Insufficient lane assignment information is a common driver complaint and may contribute to erratic maneuvers in or near the exit gore. At the very least, this deficiency may cause drivers to make a wrong decision, adding to travel time and driver frustration. Uniformity is often a problem in guide signing practices between sites, as well. Many different treatments are used in Texas and throughout the nation to sign for multilane interchanges. The low level of nationwide guide signing uniformity may be attributable to the failure of the National MUTCD to adequately address the topic of guide signing for multilane interchanges.

3.0 DEVELOPMENT AND TESTING OF INITIAL GUIDE SIGN ALTERNATIVES

In an attempt to solve some of the difficulties described in the previous chapter, a number of alternative guide signs were developed and tested. Because the methods for signing lane drops are understood fairly well, researchers specifically designed alternatives to better communicate optional lane exits to drivers. As mentioned earlier, the issue of signing for multilane exits with optional lanes is not specifically discussed in the National MUTCD.

3.1 DEVELOPMENT OF ALTERNATIVE GUIDE SIGNS

The development of the alternatives was approached with the goal of making small changes to the established guide signing practices for multilane exits with optional lanes as stipulated in the Texas MUTCD. The current method of signing for a two-lane exit with an optional lane is shown again in Figure 28. Five new alternatives were initially created for the purpose of more effectively communicating optional lanes as freeway exits. The alternatives were developed to be tested against the current method of freeway guide signing used in Texas. Testing involved a driver survey designed to test driver comprehension of both the standard and alternative designs. The survey was administered at the 1994 Houston Auto Show, between January 28 and February 6.

3.1.1 MAY EXIT and EXIT OK

The first two alternatives used wording to communicate the optional lane arrow, similar to the fashion in which EXIT ONLY panels are used. The initial idea was to include the phrase "EXIT OPTIONAL with a lane assignment arrow. However, the word "OPTIONAL" was too long to fit into the available space. The concept was retained, and synonymical phrases were developed. The new phrases were EXIT OK, MAY EXIT, and EXIT OPTNL. The latter, an abbreviation of the word "OPTIONAL," was dropped, due to the fact that the MUTCD discourages the use of abbreviations that are not unmistakably recognizable. The research team agreed on the phrases "EXIT OK" and "MAY EXIT" as the best two alternatives. The word "OK" may be utilized in lane use control signing to indicate an option. However, the use of the word "MAY" is not mentioned for any sign in the MUTCD.

The next issue was to determine what color to make the lettering, arrow, and background of the modifications. Initially, two alternatives were developed: black arrows and letters on a yellow background similar to that used in EXIT ONLY panels, and white arrows and lettering on a green background. After considering both alternatives, the white on green format was selected, due to the connotation of EXIT ONLY that may be inherent with the black on yellow. Examples of the developed signing alternatives are given in Figures 29 and 30.

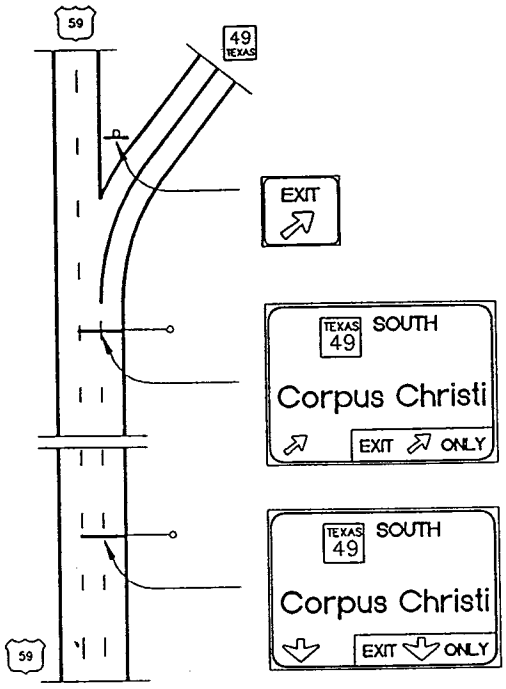
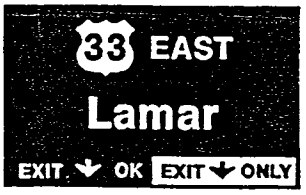
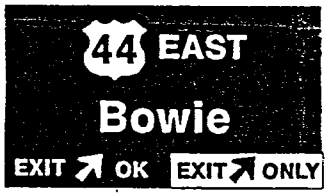


Figure 28. Signing for Multilane Exit with an Optional Lane as Recommended by the Texas MUTCD

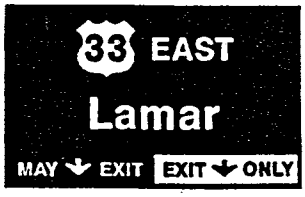


Advance Sign



Exit Directional Sign

Figure 29. EXIT OK Alternatives



Advance Sign

Exit Directional Sign

Figure 30. MAY EXIT Alternatives

3.1.2 Divergent Arrow

The other major alternative involved the use of a divergent arrow. This arrow would go directly over the optional lane, and take the place of the up diagonal arrow on exit directional signs. The divergent arrow concept is not unfamiliar to drivers, as divergent arrows are used in lane use control signs and conventional guide signing, as shown in Figure 31. With the divergent arrow, the MUTCD states, "The letters 'OK' may be added to the legend of the R3-6 sign (2)." Many areas also use divergent arrows in pavement markings at intersections.

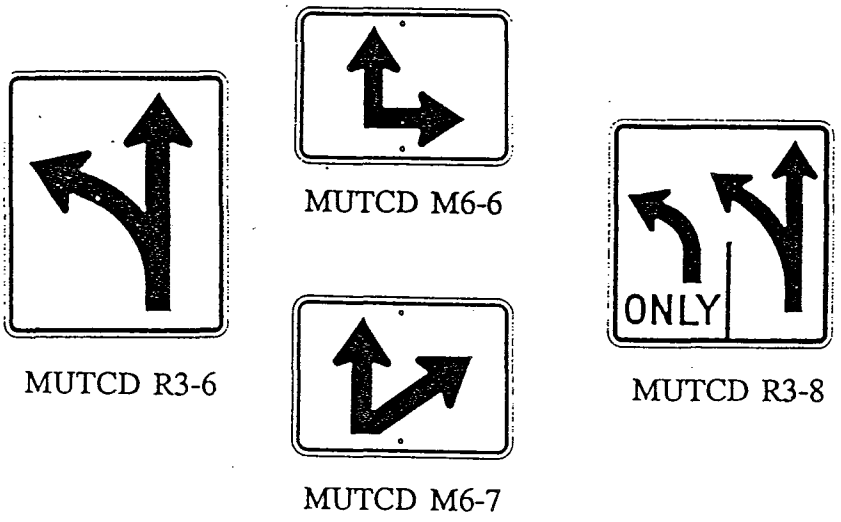


Figure 31. Examples of Divergent Arrows in MUTCD

The problem perceived with the divergent arrow was that it may present conflicting information to the driver. Whereas the divergent arrow is likely to give the driver a good idea that the lane under the arrow is indeed an optional lane, the arrow may communicate that one can continue on the freeway to reach the exit destination shown on the sign. In other words, the sign is likely to give good guidance information, but ambiguous navigational information. The sign design included moving the destination, direction, and route designation of the intersecting route to the far right of the sign to hopefully alleviate the potential navigational problem.

The alternatives included signs with the divergent arrow alone, and signs with the arrow and phrases "MAY EXIT" and "EXIT OK." Since "OK" may be used with the R3-6 sign, the phrase "EXIT OK" is desirable for consistency reasons, if any wording is to be used. Examples of the developed signs are shown in Figure 32.

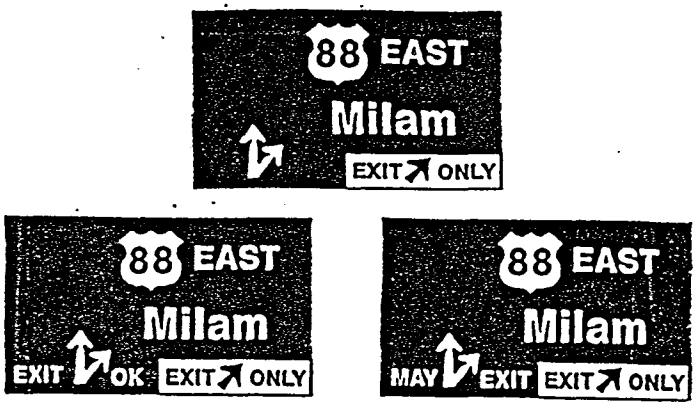


Figure 32. Exit Directional Sign Alternatives Using Divergent Arrow

3.2 DEVELOPMENT OF SURVEY

Following the development of the initial guide sign alternatives, the researchers prepared a survey to test the comprehension of both the alternative and the standard designs. The survey included thirteen multiple choice and two open-ended questions. The survey design involved special care not to word or place any questions in a way that could bias or skew results. For example, the words "may" and "ok" were omitted from the text so as not to influence answers, as these words were included on some of the alternative signs. In addition, the survey questions were written in simple terms so that the survey could be easily understood.

The survey was divided into three sets. Each set consisted of the different wordings used on the alternative and standard guide signs (i.e., none, "EXIT OK," and "MAY EXIT"). Each set was constructed so that participants would see a picture of a sign on the left side, and then view questions about the sign on the facing page as shown in Figure 33. The different survey sets and corresponding answer forms were color coded to avoid any confusion by mixing question sets. The wording of the questions is the same for all three sets; hence, only the graphics differ between sets. A copy of the questions and figures for each survey set has been provided in Appendix B.

The thirteen multiple choice questions concerned the participants interpretation of the guide signs presented. For Questions 1-9 and 11-13, participants were asked to interpret the lane assignment information shown on the guide signs. An example of lane numbering for the illustrations that accompanied Questions 1-9 and 11-13 is shown in Figure 34.

The questions were phrased, "If you are in Lane (2, 3, or 4), and cannot change lanes, you. . .

A. Must continue on the freeway.
B. Must exit the freeway and go to (destination and route shown on the exit guide sign).
C. Can either continue on the freeway or exit.
D. Not sure."

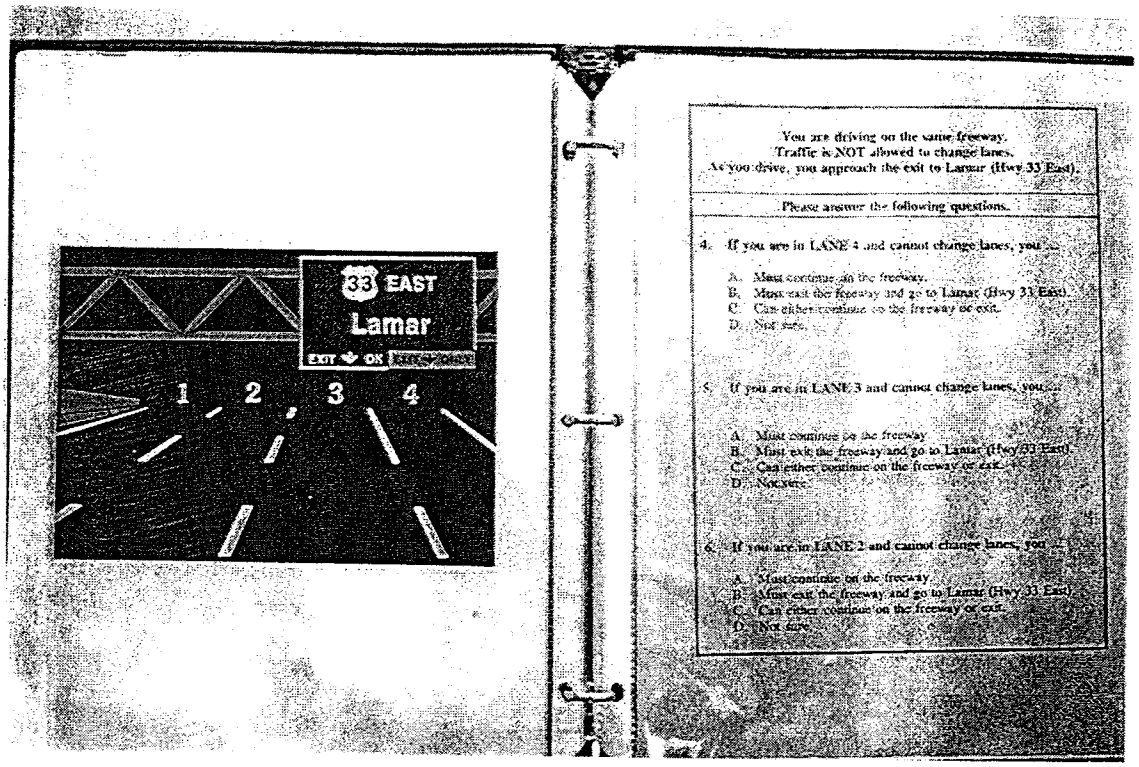


Figure 33. Layout of Question Books Used in Driver Survey

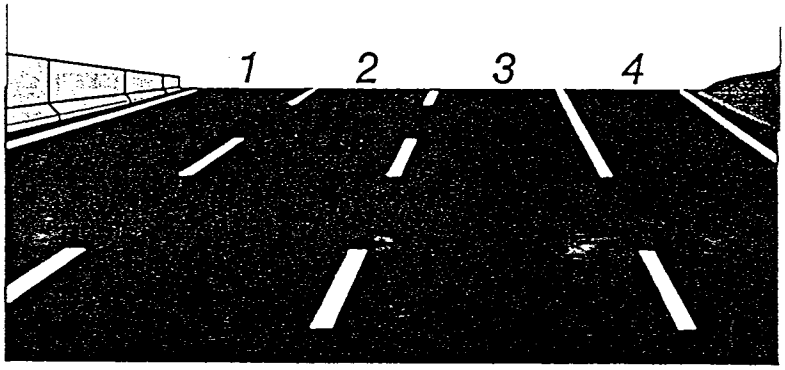


Figure 34. Example of Lane Numbering Used in Driver Survey

Question 10 was intended to deal with the participants' interpretation of the divergent arrow alternatives for exit directional signing as shown in Figure 32. The question was to determine whether or not drivers felt that they could reach the destination given on the sign by staying on the freeway. Again, four possible multiple choice answers were provided. Participants marked the letter corresponding with their answer on the provided answer sheet.

The first three questions of the survey were designed to test participants' knowledge of standard guide signing practices used in Texas. A pull-thru guide sign was added, showing the route designation and destination of the freeway mainlanes. The questions were concerned with the guidance information for each lane.

In the next three questions (4, 5, and 6), participants were questioned about their understanding of advance guide signs recommended in the current edition of the Texas MUTCD versus the EXIT OK and MAY EXIT alternatives for a multilane exit with an optional lane. Again, the questions were concerned only with guidance information for each lane.

Questions 7, 8, and 9 were designed to test the comprehension of guidance information presented by exit directional signs. Again, the current Texas MUTCD sign was tested versus the EXIT OK and MAY EXIT options.

Questions 10, 11, 12, and 13 were designed to test driver comprehension of the divergent arrow options for exit directional signing. In addition, it was desired to determine whether or not the phrases "MAY EXIT" and "EXIT OK" increased or decreased driver comprehension. Question 10 was designed to determine how well participants comprehended the navigational information presented on the sign. As discussed in Section 3.1.2, ambiguous navigational information may be presented through the use of divergent arrows. Questions 11, 12, and 13 dealt with the guidance information presented through a divergent arrow.

Question 14 was designed to determine how drivers interpret the message "EXIT ONLY" when it is used on guide signs. The response was left open-ended, to allow participants to make any response.

Question 15 was designed to determine how drivers would interpret the use of an up arrow in freeway guide signing, as opposed to a down arrow. Up arrows are a common feature in conventional guide signing, and may be useful in freeway guide signing as well.

3.3 ANALYSIS OF SURVEY DATA

The survey was administered to 548 participants at the Houston Auto Show during the week of January 29 through February 6, 1994. Of the 548 participants who took the survey, 180 took the blue survey (no wording), 180 took the red survey (EXIT OK), and 188 took the green survey (MAY EXIT).

The sample did not depict a representative sample of the Texas driving population. In comparison to the Texas general and driving population, the survey samples represented higher proportions of males, younger ages, white background, and higher education. As indicated in Table 1, the participants did, however, represent many socio-demographic elements of the Texas driving population.

Table 1. Survey Sample Characteristics (Percentages)

Characteristic		Blue Set	Red Set	Green Set	Total	Texas Population #	Texas Drivers+
Sex	Male	63.1	64.0	68.8	65.4	49.3	51.5
	Female	36.9	36.0	31.2	34.6	50.8	48.5
Age	Less than 25	30.7	26.4	26.8	28.0	39.3	15.2
	25 to 39	39.8	40.2	38.2	39.4	26.4	37.2
	40 to 54	23.9	27.0	30.0	27.0	16.6	25.2
	55 or over	5.7	6.3	4.9	5.6	17.6	22.4
Family Background	Anglo/White	74.4	78.1	76.0	76.2	60.6	---
	African American/Black	8.5	7.5	6.6	7.5	11.7	---
	Hispanic	14.2	10.9	9.3	11.4	25.3	---
	Asian	1.7	2.3	3.8	2.6	1.8	---
	Native American	0.6	0.6	1.6	0.9	0.3	---
	Other	0.6	0.6	2.7	1.3	0.1	---
Primary Language	English	97.2	95.4	91.8	94.8	---	---
	Other	2.8	4.6	8.2	5.2	---	---
Educational Level	< High School	6.9	7.4	6.6	6.9	28.1*	---
	High School Graduate	24.0	19.4	21.3	21.6	25.9*	---
	Tech/Trade School	6.3	3.4	6.0	5.3	4.9*	---
	Some College	32.0	30.9	27.9	30.2	22.9*	---
	College Degree(s)	30.9	38.9	38.3	36.0	18.1*	---
Driving is a Major Part of Job	Yes	28.3	33.3	30.6	30.8	---	---
	No	71.7	66.7	69.4	69.2	---	---
Driving Location	Urban	66.9	64.7	68.0	66.5	---	---
	Rural	5.7	5.8	5.0	5.5	---	---
	Split	27.4	29.5	27.1	28.0	---	---
Sample Size	---	180	180	188	548	---	---

Notes: Numbers are given in percentages.
Source: 1990 Census
+ Source: Texas Department of Public Safety
* Statistic based on Texas population 18 years of age and older

The data obtained from the Auto Show survey may be useful in determining specific trends in sign comprehension. In instances where the responses to a particular question showed a prominent difference between standard and alternative freeway guide signs, the results may be used to recommend the use of a particular sign. Comprehension data based on a representative sample may be desired before any final recommendations are made on the use or abandonment of a particular sign.

3.3.1 Statistical Testing of Data

The comprehension levels for each question are reported as a percentage of the total selecting each response. In some cases, a participant may not have answered all of the questions in a survey set. Therefore, the sample size for a specific question may be less than the sample size for the full set. The response percentages reported in this chapter represent the percentage of the question sample size, not necessarily the survey sample size. The difference between the question and set sample sizes was usually small, typically only one or two participants, if any at all. The response percentages provided most of the information needed to analyze the survey results.

For some of the questions, comparisons are made within a set or between sets, To make these comparisons, the researchers assumed the survey responses represented a binomial distribution. The large sample size makes this a reasonable assumption. The statistical test for comparing two binomial proportions is a z test. The hypothesis, test statistic, and rejection regions for this test are shown below.

Null hypothesis, H_o: $\pi_1-\pi_2=0$

Alternative hypothesis, H_a: $\pi_1-\pi_2=0$

Test statistic:

$$z=\frac{\hat{\pi}_1-\hat{\pi}_2}{\sigma_{\hat{\pi}_1-\hat{\pi}_2}}$$

where

$$\sigma_{\hat{\pi}_1-\hat{\pi}_2}=\sqrt{n(1-\pi)(1/n_1+1/n_2)}$$

and π is approximated by

$$\hat{\pi}=\frac{y_1+y_2}{n_1+n_2}$$

Rejection Region: For a given value of α, reject H_o if $|z| > z_{\alpha/2}$

The α value, or probability of a Type I error, is 0.10 and 0.05 for the statistical analysis. This represents the probability that H_o will be rejected when it is true for a two-tailed test with α=0.10 and 0.05, and z=1.645 and 1.96, respectively. This is the z value against which the test comparisons are made. The normal approximation to the binomial distribution is described as follows:

- There are n identical trials;
- Each trial results in one of two outcomes;

- The probability of success on a single trial is π, and π remains the same from trial to trial;
- The number of successes in n trials is y;
- The standard deviation of the distribution is $\sqrt{n\pi(1-\pi)}$; and
- Both $n\pi$ and $n(1-\pi)$ must be larger than 5.

3.3.2 Analysis of Multiple Choice Questions

The researchers compared the multiple choice questions using the statistical analysis described in the previous section. Data were analyzed using the two-tailed test for normal distributions, at both a 90 and 95 percent confidence interval. The analysis of the survey data yielded the results discussed in the following sections.

3.3.2.1 Questions 1-3

Questions 1-3 dealt with the participants' understanding of guide signing practices recommended in the Texas MUTCD for multilane exits with optional lanes. One set of questions asked participants to interpret standard signing for a two lane exit in which each exit serves as a lane drop. Figure 35 depicts the signs shown to the participants for Questions 1-3. Tables 2 through 4 show the response percentages. Correct responses are denoted by an asterisk (*) and are written in *italics*. The interpretation of the participants' responses follow the tables.

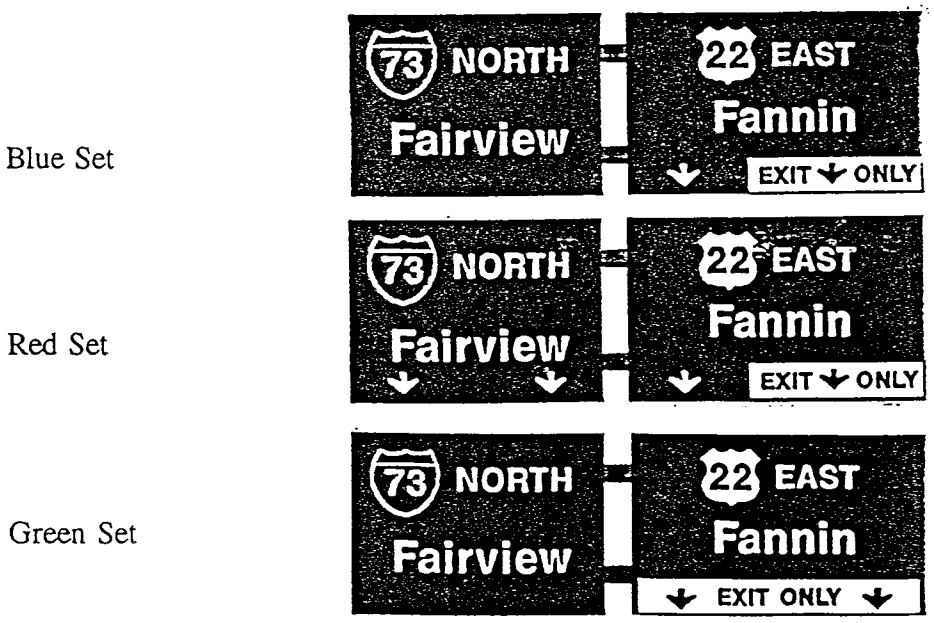


Figure 35. Signs Shown in Survey Questions 1 thru 3

Table 2. Survey Results for Question 1

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Pull-thru	**Red Set Pull-thru with Arrows**	**Green Set Double Lane Drop**	
7.2	8.4	8.0	Must continue on the freeway.
86.7	*81.0*	*85.1*	** Must exit the freeway and go to Fannin (Hwy 22 East).*
5.0	8.9	6.4	Can either continue on the freeway or exit.
1.1	1.7	0.5	Not sure.

Table 3. Survey Results for Question 2

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Pull-thru	**Red Set Pull-thru with Arrows**	**Green Set Double Lane Drop**	
42.2	45.2	11.2	Must continue on the freeway.
3.3	6.8	** 77.1*	*Must exit the freeway and go to Fannin (Hwy 22 East).*
** 53.9*	** 48.0*	11.2	Can either continue on the freeway or exit.
0.6	0.0	0.5	Not sure.

Table 4. Survey Results for Question 3

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Pull-thru	**Red Set Pull-thru with Arrows**	**Green Set Double Lane Drop**	
92.7	*86.9*	*87.6*	** Must continue on the freeway.*
2.2	2.8	5.9	Must exit the freeway and go to Fannin (Hwy 22 East).
3.9	9.7	4.8	Can either continue on the freeway or exit.
1.1	0.6	1.6	Not sure.

The analysis of the results of Question 1 (lane drop) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this applies to only one lane of the freeway. Comprehension levels for the EXIT ONLY panels in communicating a lane drop are similar to those obtained in previous research studies (1, 14).

The statistical analysis of the results of Question 2 (optional lane) implies that there is no improvement or degradation of comprehension between the red and blue sets. This is true at both a 90 percent and 95 percent confidence level. Note that this analysis applies only to one lane of the freeway.

The red and blue sets both depict current signing used for a two-lane exit with an optional lane. The number of correct responses for the optional lane information is low. For the red set, the number of correct responses is below 50 percent. This suggests that the current guide signing practices for communicating optional lanes are misunderstood by perhaps half of the Texas driving population.

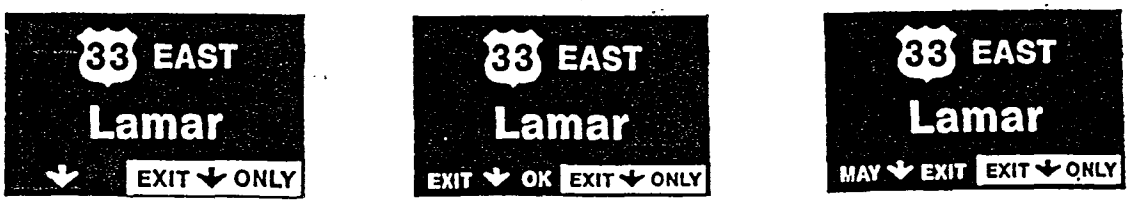
The green set depicts a double lane drop situation. Participants did not understand assignment information for Lane 3 as well as for Lane 4. A previous research study also found that comprehension levels for the inside lane drop were not as high as those associated with the outside lane (1).

The difference in comprehension levels for the red and blue set for this question is significant at a 90 percent confidence level. This suggests that the addition of lane assignment arrows with the pull-thru guide sign may degrade driver comprehension. This may be due to overloading the driver's capability to process information on the sign with the inclusion of the arrows. Note that this applies to only one lane of the freeway.

3.3.2.2 Questions 4-6

Questions 4-6 dealt with the participants' understanding of advance guide signing practices for multilane exits with an optional lane. Two sets displayed the MAY EXIT and EXIT OK advance guide sign alternatives, and the other set displayed the guide signing practice recommended in the Texas MUTCD. Figure 36 depicts the signs shown to the participants for Questions 4-6. Tables 5-7 show the response percentages. Again, the correct responses are denoted by an asterisk (*) and are written in *italics*.

The statistical analysis of the results of Question 4 (lane drop) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this analysis applies to only the outside lane of the freeway. The results of this question further indicate that participants comprehend the lane drop situation communicated by the sign, as the correct response rate is high.



Blue Set Red Set Green Set

Figure 36. Signs Shown in Survey Questions 4 thru 6

Table 5. Survey Results for Question 4

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
6.1	6.8	8.0	Must continue on the freeway.
88.3	*87.6*	*86.2*	** Must exit the freeway and go to Lamar (Hwy 33 East).*
4.4	4.5	5.3	Can either continue on the freeway or exit.
1.1	1.1	0.5	Not sure.

Table 6. Survey Results for Question 5

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
33.9	18.5	10.1	Must continue on the freeway.
6.7	7.3	5.4	Must exit the freeway and go to Lamar (Hwy 33 East).
58.3	*73.6*	*84.5*	** Can either continue on the freeway or exit.*
1.1	0.6	0.0	Not sure.

Table 7. Survey Results for Question 6

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
95.0	*94.3*	*93.0*	** Must continue on the freeway.*
2.8	3.4	2.7	Must exit the freeway and go to Lamar (Hwy 33 East)
1.7	1.7	4.3	Can either continue on the freeway or exit.
0.6	0.6	0.0	Not sure.

The statistical analysis of Question 5 (optional lane) implies that comprehension is improved through the use of the phrases "MAY EXIT" and "EXIT OK" for those traveling in Lane 3. Both phrases improve comprehension over the standard sign, and MAY EXIT is statistically better than EXIT OK. The bulk of those answering incorrectly felt that Lane 3 was simply a freeway mainlane, rather than an optional lane. In the case of the standard guide sign with no wording, over a third of the survey participants felt that Lane 3 was a mainlane, and less than two-thirds responded correctly.

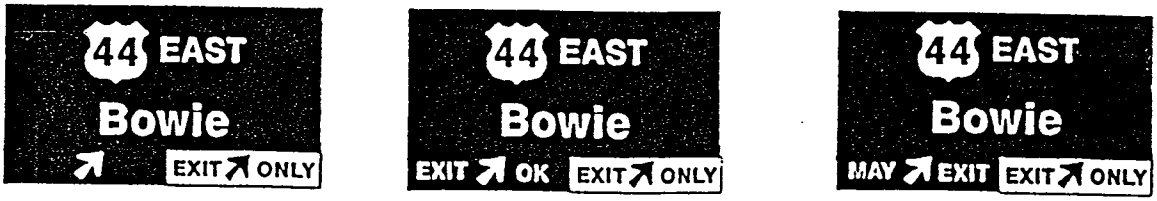
It also appears that comprehension of the optional lane situation actually increased through the omission of the pull-thru guide sign shown for Questions 1, 2, and 3. This phenomenon can be observed by comparing the results in Table 6 for the Blue Set to those found in Table 3 for both the Red and Blue Sets. This implies that adding the pull-thru guide sign over the freeway mainlanes offers no benefit at isolated multilane interchanges. Note that this applies to only the optional lane of the freeway.

The statistical analysis of the results of Question 6 (through lane) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this analysis applies to only one lane of the freeway. Participants understood well that Lane 2 was indeed a mainlane, without the use of a pull-thru sign. Again, comprehension rates were somewhat higher for Lane 2 assignment information with the omission of the pull-thru sign.

3.3.2.3 Questions 7-9

Questions 7-9 dealt with the participants' understanding of exit directional guide signing practices for multilane exits with optional lane. The signs used with Questions 7-9 were similar to the signs for Questions 4-6, except that diagonal up arrows were used instead of down arrows. Two sets displayed the MAY EXIT and EXIT OK advance guide sign alternatives, and the other set displayed the guide signing practice recommended in the Texas MUTCD. Figure 37 depicts

the signs shown to the participants for Questions 7-9. Tables 8-10 show the response percentages. The correct responses are denoted by an asterisk (*) and are written in *italics*.



Blue Set Red Set Green Set

Figure 37. Signs Shown in Survey Questions 7 thru 9

Table 8. Survey Results for Question 7

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
5.0	6.8	4.3	Must continue on the freeway.
92.7	*89.3*	*90.9*	** Must exit the freeway and go to Bowie (Hwy 44 East).*
1.7	4.0	4.3	Can either continue on the freeway or exit.
0.6	0.0	0.5	Not sure.

Table 9. Survey Results for Question 8

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
10.6	11.8	7.5	Must continue on the freeway.
19.0	4.5	3.7	Must exit the freeway and go to Bowie (Hwy 44 East).
69.3	*83.2*	*88.3*	** Can either continue on the freeway or exit.*
1.1	0.6	0.5	Not sure.

Table 10. Survey Results for Question 9

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Current	**Red Set EXIT OK**	**Green Set MAY EXIT**	
94.4	*95.5*	*92.6*	** Must continue on the freeway.*
1.7	2.3	2.1	Must exit the freeway and go to Bowie (Hwy 44 East).
2.8	1.7	5.3	Can either continue on the freeway or exit.
1.1	0.6	0.0	Not sure.

The statistical analysis of the results of Question 7 (lane drop) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this analysis applies to only one lane of the freeway. Again, comprehension rates are high for the lane drop information given in the EXIT ONLY panel.

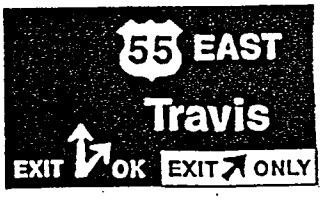
Two conclusions can be drawn from the analysis of responses to Question 8 (optional lane). First, it appears that participants interpret the up diagonal arrow of the exit directional sign better than the downward lane assignment arrow of the advance sign. Second, both alternative signs (MAY EXIT and EXIT OK) are interpreted better by drivers than the standard sign. This difference is significant at both a 90 percent and 95 percent confidence level. However, the difference between the EXIT OK and the MAY EXIT alternatives is not statistically significant for the exit directional sign, as was the case in the advance guide sign. This implies that neither exit directional signing alternative is interpreted better than the other, but both are understood better than the current signing. Note that this applies to only one lane of the freeway.

In the statistical analysis of Question 9 (through lane), one minor statistical difference was observed. The difference in Answer "C" (Can either continue on the freeway or exit) was statistically significant between the Blue and Green Sets at a 90 percent confidence level. No basis for this difference could be determined. Again, most of the participants understood lane assignment information for Lane 2. Note that this applies to only one lane of the freeway.

3.3.2.4 Question 10

Question 10 was included to test the participants' understanding of the navigational information provided by the divergent arrow. Figure 38 depicts the signs shown to the participants for Question 10. Table 11 shows the response percentages.

Blue Set



Red Set

Green Set

Figure 38. Signs Shown in Survey Question 10

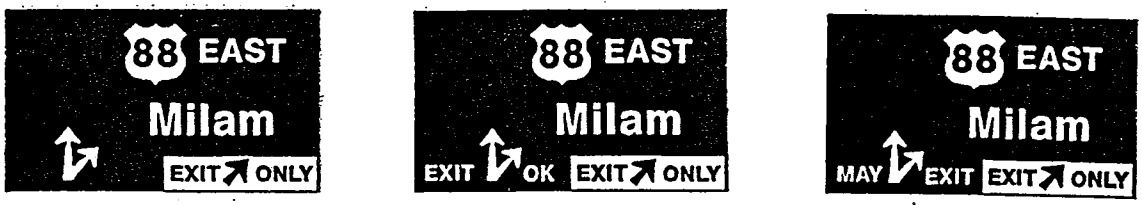
Table 11. Survey Results for Question 10

What direction should you go to get to Travis?			
Response Percentages			**Responses**
Blue Set No Wording	**Red Set EXIT OK**	**Green Set MAY EXIT**	
0.6	2.8	0.5	Continue straight on the freeway.
66.5	*69.7*	*85.6*	** Exit the freeway to Hwy 55 East.*
29.6	21.9	10.7	Either continue on the freeway or exit. Both the freeway and Hwy 55 East go to Travis.
3.4	5.6	3.2	Not sure.

The survey results indicate that a significant percentage of drivers is confused by the use of the divergent arrow. The results indicate that several think that they can either stay on the freeway or exit to reach the destination given on the sign. In this case, the use of the phrase "MAY EXIT" with the divergent arrow was a better alternative than EXIT OK and no wording, at both the 90 percent and 95 percent confidence. The MAY EXIT alternative has an 85.6 percent comprehension, and from a navigational standpoint, appears to be the best alternative of the three.

3.3.2.5 Questions 11-13

Questions 11-13 dealt with the participants' understanding of exit directional guide signing for multilane exits with an optional lane. Whereas Question 10 was designed to test for the navigational understanding of the signs, Questions 11-13 were designed to deal with the lane assignment and guidance information presented in the signs. As with Question 10, the signs depicted the exit directional alternatives with a divergent arrow. Figure 39 depicts the signs shown to the participants for Questions 11-13. Tables 12-14 show the response percentages.



Blue Set Red Set Green Set

Figure 39. Signs Shown in Survey Questions 11 thru 13

Table 12. Survey Results for Question 11

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set No Wording	**Red Set EXIT OK**	**Green Set MAY EXIT**	
1.7	1.7	1.6	Must continue on the freeway.
97.2	*94.9*	*94.7*	** Must exit the freeway and go to Milam (Hwy 88 East).*
0.6	3.4	2.7	Can either continue on the freeway or exit.
0.6	0.0	1.1	Not sure.

Table 13. Survey Results for Question 12

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set No Wording	**Red Set EXIT OK**	**Green Set MAY EXIT**	
6.2	5.1	4.3	Must continue on the freeway.
6.2	4.6	2.7	Must exit the freeway and go to Milam (Hwy 88 East).
87.2	*90.3*	*92.6*	** Can either continue on the freeway or exit.*
0.6	0.0	0.5	Not sure.

Table 14. Survey Results for Question 13

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set No Wording	**Red Set EXIT OK**	**Green Set MAY EXIT**	
92.2	*95.5*	*94.2*	** Must continue on the freeway.*
4.5	2.3	2.7	Must exit the freeway and go to Milam (Hwy 22 East).
2.8	1.7	3.2	Can either continue on the freeway or exit.
0.6	0.6	0.0	Not sure.

The statistical analysis of the results of Question 11 (lane drop) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this applies to only one lane of the freeway. Correct comprehension levels were high again for the lane drop information presented by the EXIT ONLY panel. Correct comprehension levels were higher for the EXIT ONLY panel when included on a sign with a divergent arrow than with a single arrow. This may be due to the diagrammatic information that is developed in the sign, as the divergent arrow sign somewhat resembles a modified diagrammatic sign. Hence, the divergent arrow possibly affects the comprehension of the lane drop situation.

The analysis of Question 12 (optional lane) shows that the MAY EXIT alternative is better than the alternative of no wording at all. However, this is true only at a 90 percent confidence, and not at 95 percent confidence. It should be noted that MAY EXIT is not statistically better than EXIT OK, and EXIT OK is not statistically better than no wording at all. This suggests that the MAY EXIT alternative should be used, if any wording is to be used at all. Comprehension rates for all three alternatives were high for the optional lane. The divergent arrow adequately communicates guidance information to drivers for optional lane exits.

The statistical analysis of the results of Question 13 (through lane) implies that there is no improvement or degradation of comprehension between the three signs tested. This is true at both a 90 percent and 95 percent confidence level. Note that this applies to only one lane of the freeway. Participants again understood the lane assignment information for the freeway mainlanes. Correct response rates for Question 13 were high.

3.3.3 Analysis of Open-Ended Questions

The Houston survey contained two open-ended questions in addition to the thirteen multiple choice questions. The analysis of these questions was more in-depth, due to the diversity

of answers provided by the participants. The open-ended questions did not require the same statistical analysis as was required in the multiple choice questions. The questions were the same in all three question sets, so data was not compared between sets.

For Question 14, shown in Figure 40, answers were judged as either correct, substantially correct, or incorrect. Most of the answers could easily be categorized in one of the three classes. Table 15 shows the breakdown of responses.

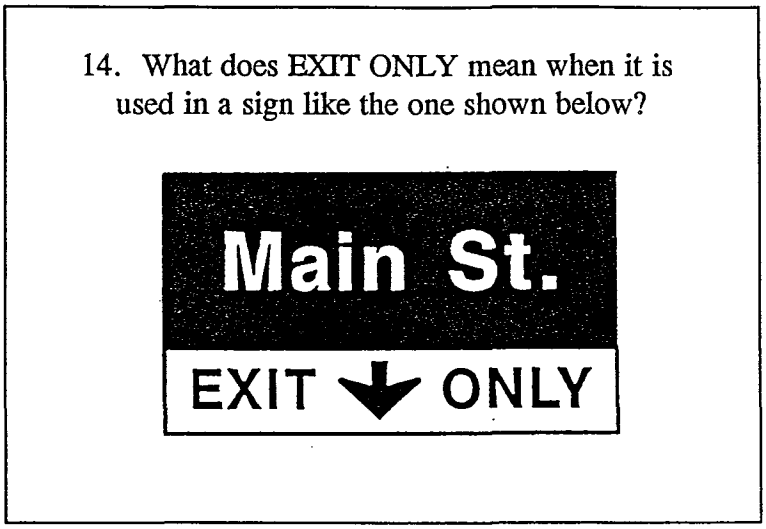


Figure 40. Question 14 of Driver Survey

Table 15. Breakdown of Responses to Question 14

	Blue Set	Red Set	Green Set	Total
Correct	58%	56%	56%	56.3%
Substantially Correct	26%	29%	26%	27.0%
Incorrect/No Answer	17%	16%	18%	16.6%

The answers that were judged as correct contained any similar variation to the phrase "lane must exit." The logic is that the phrase "EXIT ONLY" means that one must exit, and the arrow in the sign means that this applies only to a particular lane. A correct answer represents a participant's complete understanding of the information provided by the sign. Some examples of correct answers include:

- "If in indicated lane, only option is to exit. Of course if traffic allows you may change lanes;"
- "A lane that goes to Main St. only, and you must exit if you are in that lane;"

- "It means that to go to Main you got to [sic] exit now on the lane shown;" and
- "That lane must exit."

A substantially correct answer represents some understanding of the sign. The participant has an understanding of basic concepts, but lacks a complete understanding. In some cases, the participant may fully understand the sign, but did not put down enough information to indicate full comprehension. The more common answers said simply "must exit," without acknowledging the fact that the sign pertains to a particular lane. Again, participants with this answer may realize that the sign does pertain to a particular lane, but the incomplete answer fails to convey a full comprehension. Other answers judged as substantially correct implied that the exit only lane was the only lane exiting, which may not be the case. It should be noted that those answering with substantially correct answers are likely to act properly when encountering a guide sign with an "EXIT ONLY" panel. Answers judged as substantially correct include the following:

- "Must exit;"
- "If you want to get off there, you must be in that lane;"
- "It means that is the only lane you can be in to exit for that particular street or highway name;" and
- "Exit only to Main Street must exit."

An answer was judged as incorrect if the participant displayed little or no comprehension of the sign. Participants providing answers judged as incorrect are likely to respond incorrectly when the sign is encountered during driving. Answers judged as incorrect include the following:

- "No entrance back onto the freeway from that street;"
- "Only exit to Main Street;"
- "You have to exit, the freeway will not continue;" and
- "Leave off of highway to exit."

The researchers then compared the answers given in Question 14 to the answers given in the multiple choice questions for the same EXIT ONLY situation. A similarity occurs upon adding the correct and substantially correct percentages, then comparing that figure to the percentage responding correctly to the multiple choice questions pertaining to the same lane drop situation. The comparison of results are shown in the Table 16.

Table 16. Multiple Choice vs. Open Ended Responses for Lane Drop Situation

Percentage Responding Correct or Substantially Correct to ...	Blue Set	Red Set	Green Set	Total
Question #1	86.7	81.0	85.1	84.3
Question #4	88.3	87.6	86.2	87.3
Question #14	83.3	84.4	82.4	83.4

Figure 41 illustrates the signs and question format used in Question 15. The analysis took a different approach for Question 15. Due to the diversity of answers, and the fact that the up arrow sign is not an existing sign, it was impossible to categorize the answers in the same manner used in Question 14. Instead, answers were grouped into categories of similar responses. This analysis provided a more logical approach, as many responses were very similar. Answers were further grouped as to how drivers interpret the up arrow and the down arrow. The two signs were judged independently of one another, although the signs were used in the context of the same question. The "correct" answer for this question is that the up arrow implies a direction; a continuation on the main lanes of the freeway, while the down arrow is applicable only to a particular lane. Several participants gave this response, and their answers are grouped as one of the major categories. The categories and frequencies of responses are given in Table 17 and Table 18.

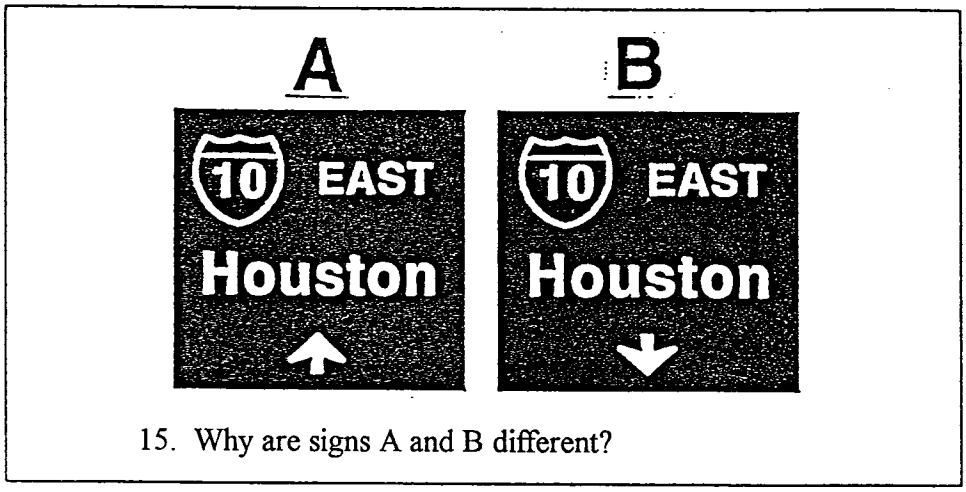


Figure 41. Question 15 of Driver Survey

The analysis of this question indicates that most of the participants felt that the up arrow symbolized a continuation of the freeway, or that the sign means ahead. Other less popular responses suggest that many tried to compare the two signs together, rather than look at each sign separately. Although the up and down arrows were presented together, it was hoped that participants would analyze each separately.

The variety of responses led to the inclusion of several more categories for the down arrow situation than those for the up arrow situation. Many responded correctly, that the arrow assigns traffic to a particular lane. Another heading suggests that several associate the down arrow with an exit, whether it refers to that particular lane or not. Further analysis suggests the trend that many think the sign refers to the point directly below the sign. A suggestion for further research is to restate this question in a multiple choice format, using some of the more popular responses given in this survey.

Table 17. Breakdown of Responses for "Up Arrow" Sign in Question 15

	Blue Set	Red Set	Green Set	Total
Continue/Ahead	50.0%	66.7%	59.6%	58.8%
Upper Level	4.4%	1.7%	2.7%	2.9%
Ahead, This Lane	3.9%	5.6%	3.2%	2.6%
Same/No Difference as Down Arrow	2.2%	5.0%	3.7%	3.6%
Directional (N, S, E, etc.)	5.0%	1.7%	6.4%	4.4%
Don't Know/No Answer	20.5%	16.1%	14.4%	17.0%
Other	8.3%	7.2%	10.1%	8.6%

Table 18. Breakdown of Responses for "Down Arrow" Sign in Question 15

	Red Set	Blue Set	Green Set	Total
At that Point/On Route	13.3%	8.9%	13.3%	11.9%
Lane Assignment	22.2%	22.8%	23.9%	23.0%
Lane Drop	8.9%	10.6%	8.5%	9.3%
Lower Level	5.6%	2.2%	2.7%	3.5%
Direction	2.8%	1.7%	5.9%	3.5%
Exit	11.1%	20.6%	14.9%	15.5%
Behind/Backwards	4.4%	3.9%	2.1%	3.5%
Same/No Difference as Up Arrow	2.2%	5.0%	3.7%	3.6%
Don't Know/No Answer	19.4%	16.7%	14.9%	17.0%
Other	10.0%	7.8%	10.1%	9.3%

3.4 INITIAL SURVEY CONCLUSIONS

From the analysis of the Houston survey, several conclusions and preliminary recommendations can be made concerning the use of freeway guide signs. In addition, the analysis raises some additional questions that suggest several areas for further research.

3.4.1 Survey Results

Some aspects of standard guide signs appear to be well interpreted by drivers. The EXIT ONLY panel used to signify a lane drop was correctly interpreted by approximately 85 percent of the participants. This figure replicates the comprehension rate observed in similar studies (1,

14). Also, participants showed a good comprehension of how guide signing is used to designate a freeway mainlane. This figure was as high as 95 percent correct comprehension in some instances.

However, many drivers misinterpret the current guide signing practice recommended in the Texas MUTCD for communicating optional exits. The results of this survey suggest that less than two-thirds, and in some cases less than half, of drivers understand the Texas method of communicating optional lanes. This percentage is comparable to those obtained by previous research (1, 14). This comprehension rate suggests the need for modifications to the existing system of guide signing.

The major recommendation drawn from this survey is that the addition of the phrase "MAY EXIT" to the standard guide sign used for a multilane exit with an optional lane clarifies lane assignment information presented to the driver. Of the alternatives tested, the MAY EXIT alternative provides the greatest improvement in driver comprehension of freeway guide signing. To a lesser extent, the use of the phrase "EXIT OK" also proves to be beneficial.

The divergent arrow proved to be a good alternative from a guidance standpoint, but the sign offers ambiguous navigational information that confused many of the survey participants. Refinements to the divergent arrow may result in an effective signing technique.

The use of pull-thru guide signs over the freeway mainlanes appears to offer little benefit at isolated, multilane interchanges. In fact, the use of pull-thru guide signs appears to degrade, rather than improve, driver comprehension. However, this conclusion is based on a very limited amount of research. Solid conclusions on the use or disuse of pull-thru guide signs should be based on a more detailed study.

3.4.2 Suggestions for Further Research Raised by the Initial Survey

The analysis of the survey raises many questions about freeway guide signing. First, does pull-thru guide signing over freeway mainlanes enhance a driver's interpretation of the roadway? The results of this survey suggest that these signs actually degrade driver comprehension at isolated interchanges. However, the research in this area was modest, and a more detailed study should be undertaken to assess the validity of this conclusion.

Second, can the divergent arrow principle be modified to benefit both the guidance and navigational information presented to the driver? The survey suggests that the divergent arrow gives excellent guidance information to drivers, but often confuses the driver with ambiguous navigational information. The divergent arrow concept successfully clears the hurdle of communicating an optional lane, and refinements may reduce or even eliminate the navigational ambiguity that the sign presents.

Third, can the phrase "MAY EXIT" and "EXIT OK" be used throughout the country, or for that matter, Texas? These terms were tested only in Houston, and the phrases may be interpreted differently in other parts of the state or nation. If indeed the terms are colloquial, one phrase that is universally understood should be developed for nationwide application.

The final recommendation of the survey calls for further testing of the better alternative (MAY EXIT). The above results are based solely on a survey. In the survey, participants were given an unlimited amount of time to both look at and make decisions on the information presented on a guide sign. This allows one to totally concentrate on the meaning of the sign. Real world distractions and limitations such as time, visibility, legibility, and other traffic constraints are discounted in this experiment. Any changes to the existing guide signing system should be based on this and additional studies that factor in some of these elements. These studies may involve follow-up surveys, lab experiments and simulations, field installation and testing, and limited real world application. Some, if not all, of these studies may need to be undertaken before any changes to the existing guide signing principles are effected.

4.0 DETAILED STUDY DESIGN

The next step by the research team was to develop and conduct a detailed laboratory study, which was designed to test the effectiveness of different methods of guide signing for multilane exits with an optional lane. A separate part of the laboratory study involved testing signing for a multilane exit with an optional lane and a secondary ramp split. Signs were tested to determine the comprehension level of each sign, and the comprehension rates for each sign were then compared to determine which of the alternatives was the most effective in communicating the desired information. Comprehension refers to a participant's ability to process and correctly interpret the information given in a sign. This chapter documents the procedure that was used to develop the detailed study.

4.1 SELECTION OF SIGNING ALTERNATIVES

The first step in the design process was to select which signs would be tested. Several alternatives were considered, and three were chosen for testing. The signing methods considered were diagrammatic signs, "modified diagrammatic" signs, the Mississippi method, California method, Ohio method, Texas MUTCD method, Texas Highway Operations Manual, Canadian bilingual signs, and the EXIT OK and MAY EXIT alternatives depicted in the previous chapter. Each of these types of signing has been described in previous chapters.

4.1.1 Signing Alternatives for Ramps Without Secondary Splits

The alternatives that were chosen for testing included the Texas MUTCD method, the MAY EXIT method from the Houston Auto Show survey, and the Ohio method. These methods are for signing a multilane exit without a secondary ramp split. Each method is described in the following section.

4.1.1.1 Texas MUTCD Method

The first type of sign chosen for testing was the method recommended in the current edition of the Texas MUTCD. The signing recommended for a two lane exit with an optional lane is shown in Figure 42. This method represents the current standard for signing in Texas. It was chosen to offer a basis for recommending an alternative guide sign for use. If any recommendation for a change in signing results from the analysis of the study, the standard signing method must be tested to validate such a change. This method of signing represents a signing standard, making it the official method of signing for multilane exits with optional lanes in Texas.

The Texas MUTCD specifies that a white arrow be placed above the optional lane. The lane drop is specified by an EXIT ONLY panel placed over the lane drop. Arrows are oriented in two ways. For the advance guide sign, the arrows are standard lane assignment arrows,

pointed downward. In the exit directional sign, arrows are oriented diagonally up and to the right, to indicate separation of the exit ramp from the freeway. For the lane drop, arrows are placed in the space between the two words in the EXIT ONLY panel, for both the advance and exit directional signs.

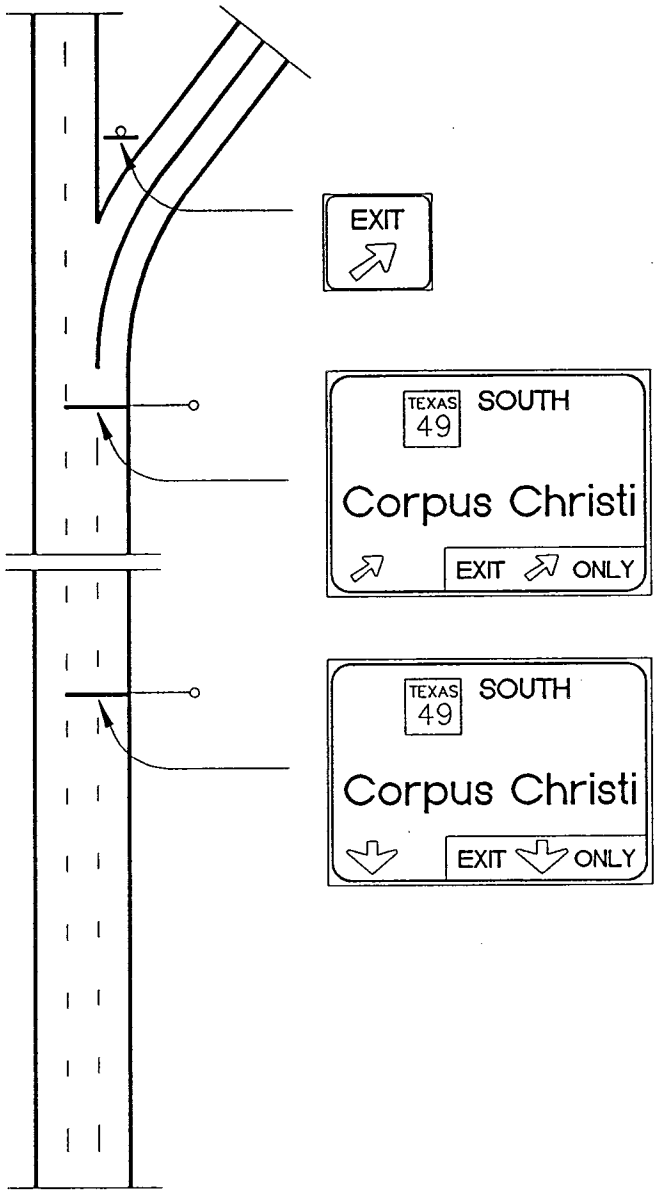


Figure 42. Guide Signing for a Two Lane Exit with an Optional Lane as Recommended by the Texas MUTCD

4.1.1.2 MAY EXIT Alternative

The MAY EXIT alternative tested in the initial survey conducted at the Houston Auto Show was identified as an effective method of signing for a multilane exit with an optional lane. The results of the research indicated that the MAY EXIT alternative was better understood by the survey participants than the Texas MUTCD method. One recommendation of the initial survey was further testing of the MAY EXIT alternative. The signing method is illustrated in Figure 43.

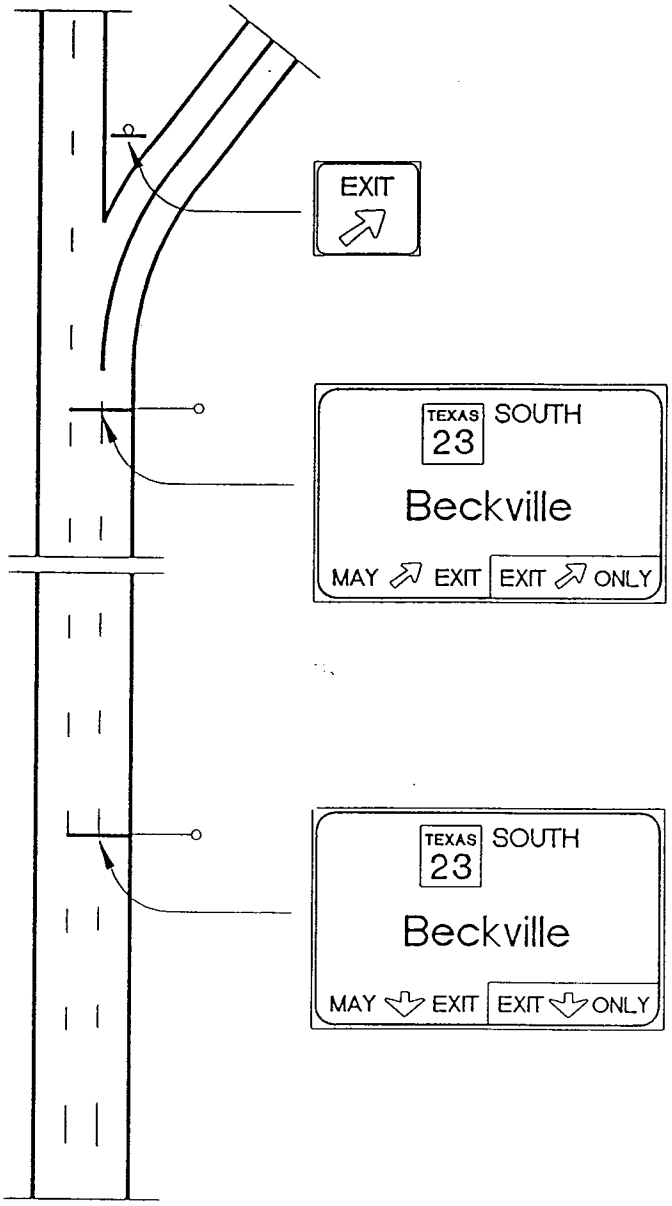


Figure 43. MAY EXIT Alternative for Guide Signing for a Two Lane Exit with an Optional Lane

The MAY EXIT alternative is identical to the Texas MUTCD method with one variation. The words "MAY EXIT" are used to indicate the optional lane, similar to the fashion in which the words "EXIT ONLY" are used for a lane drop. Arrows are again placed in the space between the words "MAY" and "EXIT." Both the words "MAY" and "EXIT" and the arrows are white on a green background.

4.1.1.3 Modified Ohio Method

As illustrated in the previous chapter, the method of guide signing recommended in the Ohio MUTCD (26) uses two diagonal arrows to communicate the optional lane situation at multilane exits as shown again in Figure 44. The example in the figure depicts a two lane exit with an optional lane and a secondary ramp split.

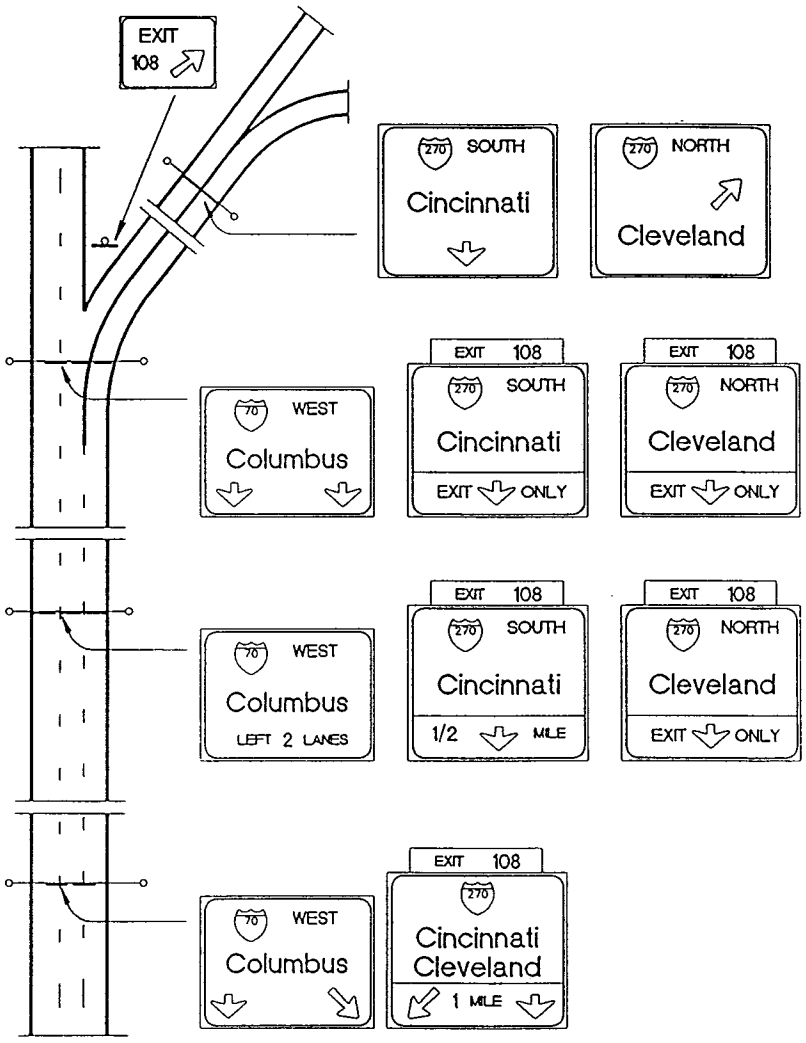


Figure 44. Guide Signing for a Two Lane Exit with an Optional Lane and Secondary Ramp Split as Recommended by the Ohio MUTCD

Two diagonal arrows, one in a pull-thru sign and the other in an advance exit guide sign, are placed in such a fashion that both arrows point to the optional lane. The two arrows are intended to communicate to the driver that destinations on both the pull-thru and exit guide sign can be reached via the optional lane.

The Ohio MUTCD method depicted in Figure 44, was modified so the distance information was not shown in the advance guide sign. Instead, an EXIT ONLY panel with a downward lane assignment arrow was placed above the lane drop, and a diagonal white arrow was placed so that it pointed to the optional lane in the exit guide sign. The pull-thru sign was left unchanged. Figure 45 illustrates the modified Ohio method.

The distance information in the modified Ohio method was not included for similarity of comparison. Since distance information was not included on either the Texas MUTCD alternative or the MAY EXIT alternative, it was not included on the modified Ohio to offer equal basis for comparing the alternatives; however, distance information could be easily included on all three of the signing methods, if desired.

The pull-thru sign used in the exit directional sign uses the phrase "LEFT 2 LANES," rather than lane assignment arrows. In the modified Ohio Method developed for the detailed study, the same type of pull-thru sign was used with the exit directional sign specified in the Texas MUTCD. The two signs were placed immediately upstream of the exit gore to serve as exit directional signs.

4.1.2 Signing Alternatives for Secondary Ramp Splits

After finalizing the signing to be tested for a simple exit without a secondary ramp split, three signing methods for a ramp with a secondary split were chosen. These methods included the Texas Highway Operations Manual method, the MAY EXIT method, and the modified Ohio method. Descriptions of each method are provided in the following sections.

4.1.2.1 Texas Highway Operations Manual Method

The Texas MUTCD does not address the topic of exit ramps with secondary splits. The Texas Highway Operations Manual, however, offers a suggested method of signing for a two lane exit with an optional lane and a secondary ramp split. This method of guide signing is illustrated in Figure 46.

The Texas Highway Operations Manual specifies that destinations, cardinal directions, and route designations of both ramp forks be given on the sign. The secondary ramp split is then separated by a thin white vertical line. This method of signing is currently used in Texas for a two lane exit with an optional lane and a secondary ramp split.

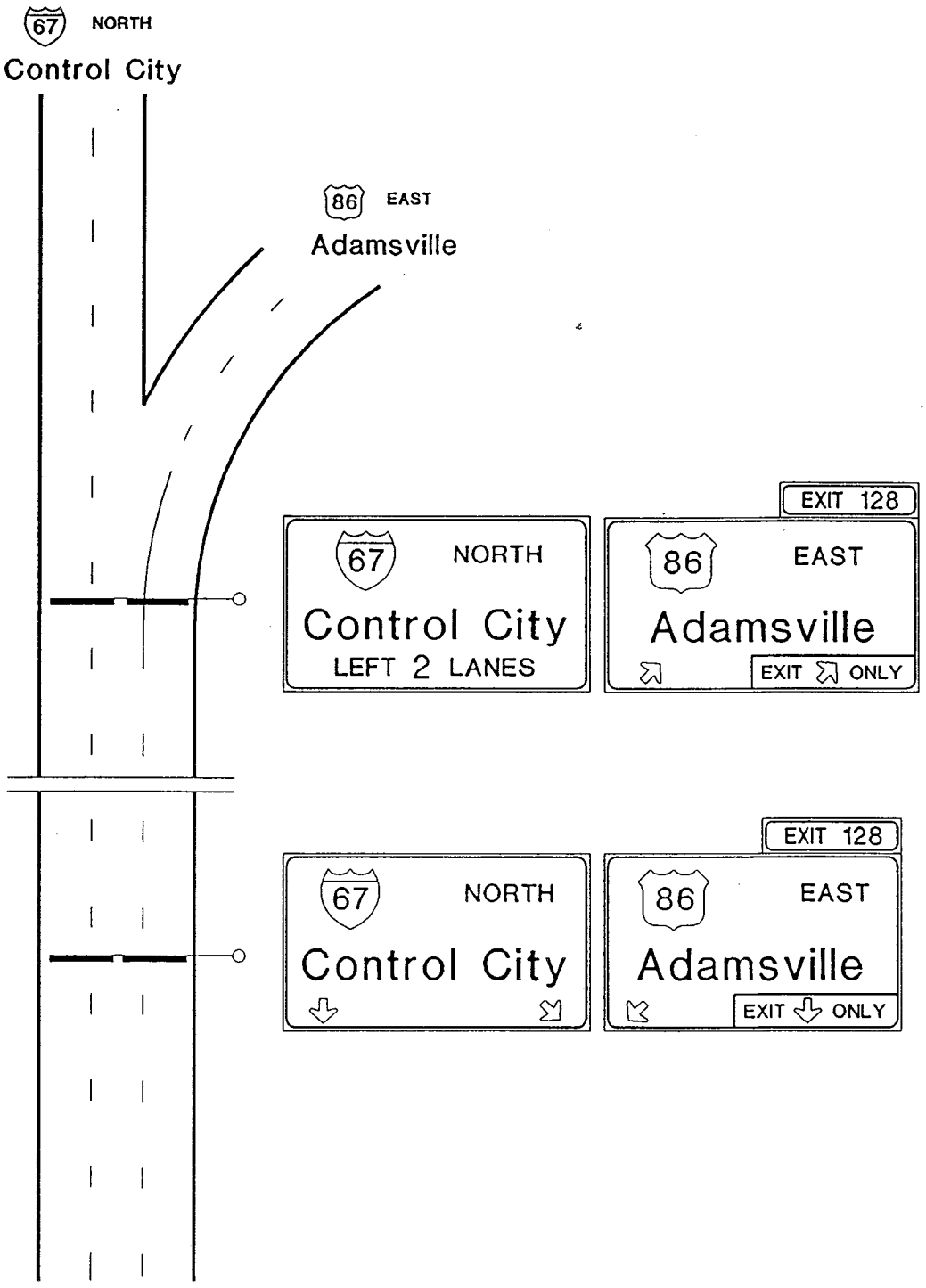


Figure 45. Modified Ohio Method for Guide Signing for a Two Lane Exit with an Optional Lane

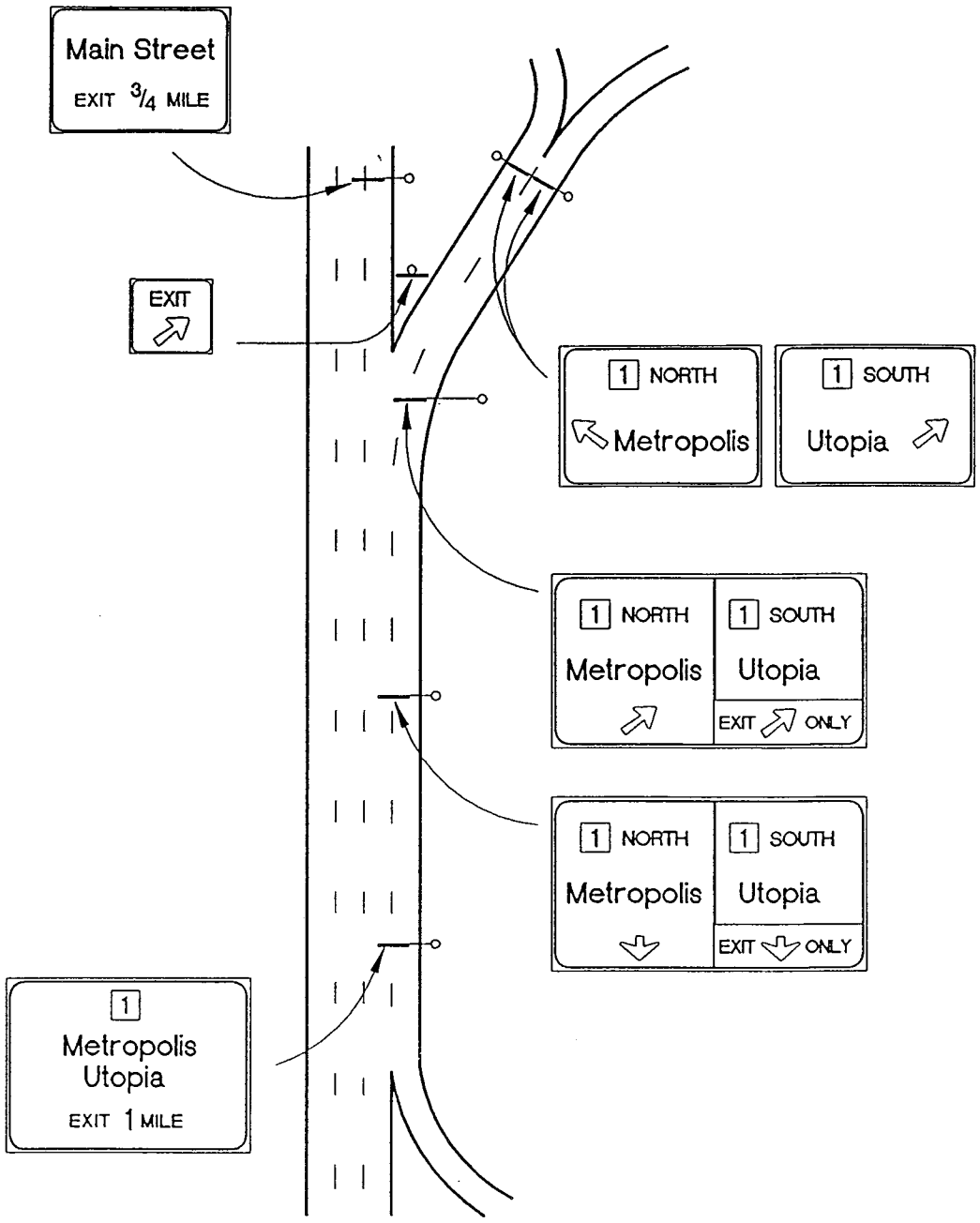


Figure 46. Guide Signing for a Two Lane Exit with an Optional Lane and Secondary Ramp Split as Recommended by the Texas Highway Operations Manual

4.1.2.2 MAY EXIT Method

The MAY EXIT method was developed to complement the MAY EXIT signing that was tested for a simple exit ramp without a secondary split. As in the case without a secondary ramp

split, the words "MAY EXIT" were added to the sign to indicate the driver's choice to either continue on or exit the freeway. Again, the lane assignment arrow was placed in the space between the words "MAY" and "EXIT." Signing using the MAY EXIT alternative for a two lane exit with an optional lane and secondary ramp split is shown in Figure 47.

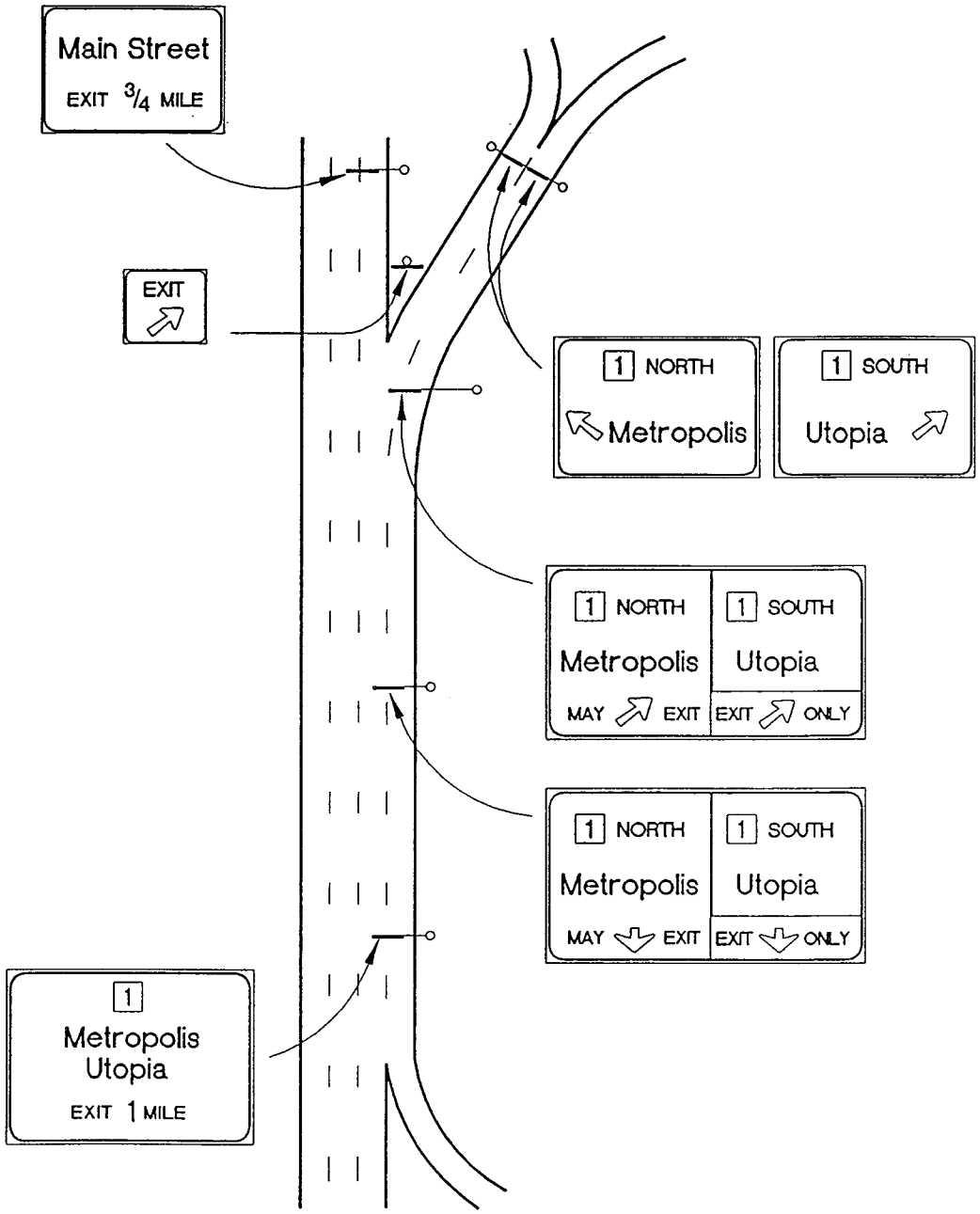


Figure 47. Guide Signing for a Two Lane Exit with an Optional Lane and Secondary Ramp Split Using the MAY EXIT Alternative

4.1.2.3 Modified Ohio Method

The modified Ohio method was again used for an exit ramp with a secondary split. Again, slight changes were made to the recommended practice given in the Ohio MUTCD. Diagonal arrows were used in the advance guide signs to indicate the optional lane. For the exit directional sign, the pull-thru sign with the phrase "LEFT 2 LANES" was again selected, and mounted with the exit directional sign shown in the Texas Highway Operations Manual. The modified Ohio method for signing a two-lane exit with an optional lane and secondary ramp split is shown in Figure 48.

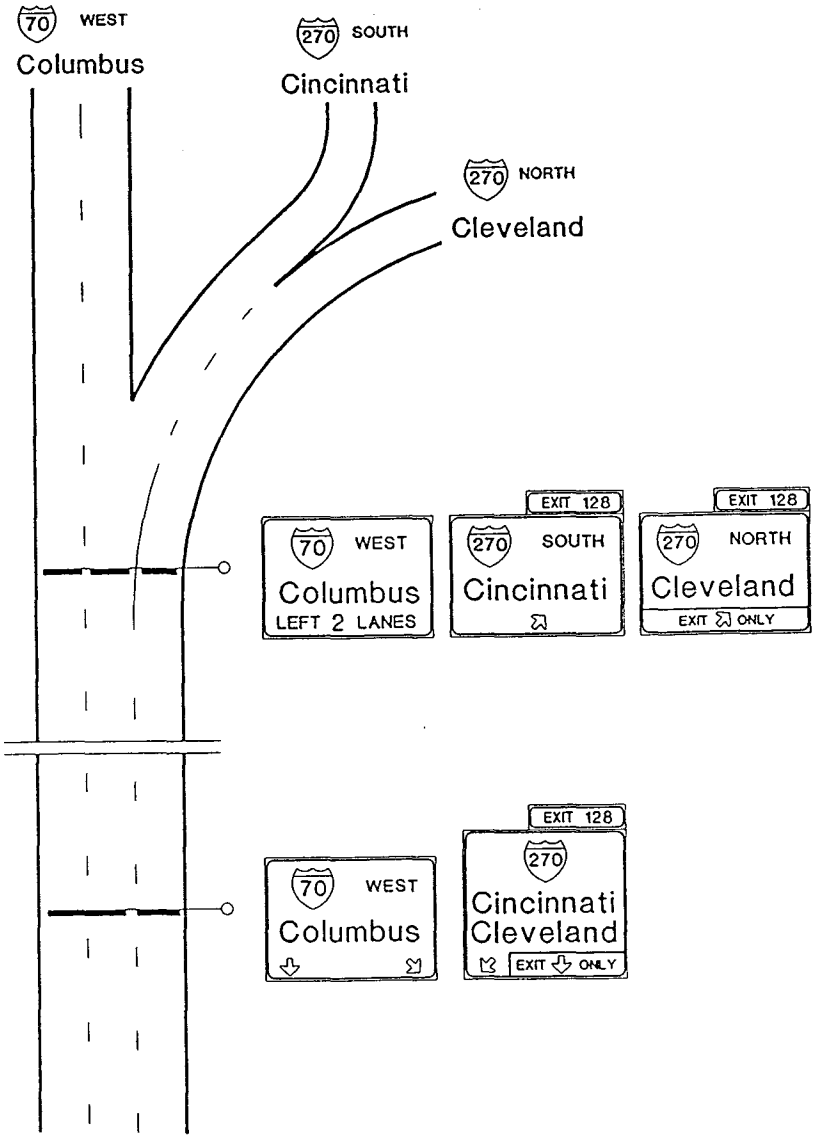


Figure 48. Modified Ohio Method for Guide Signing for a Two Lane Exit with an Optional Lane and Secondary Ramp Split

4.1.3 Signing Alternatives Selected

In all, twelve signs, composed of advance and exit directional signs for each of the three signing methods, were selected for testing. This equates to six signs for the simple exit and six additional signs for the exit ramp with a secondary split. The twelve signing combinations chosen for testing are shown in Tables 19 and 20. Figure 49 shows the exit geometry to which the signing applies. Each situation involves a four-lane freeway with a two lane exit ramp.

Table 19. Signing Options Chosen for Two Lane Exit with an Optional Lane

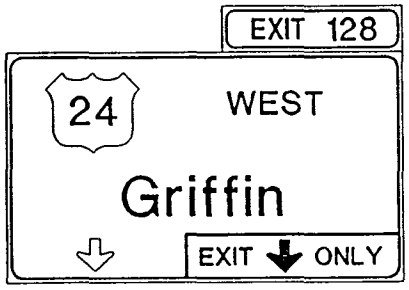
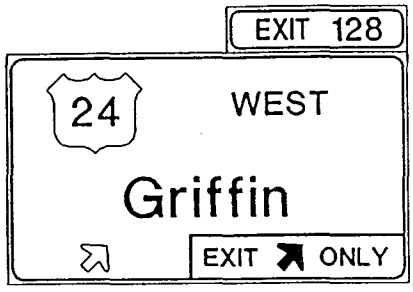
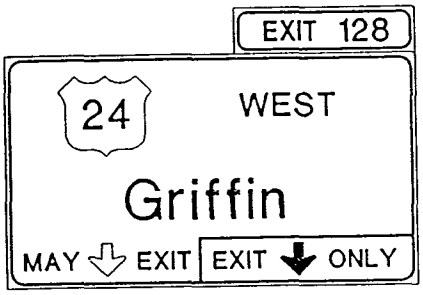
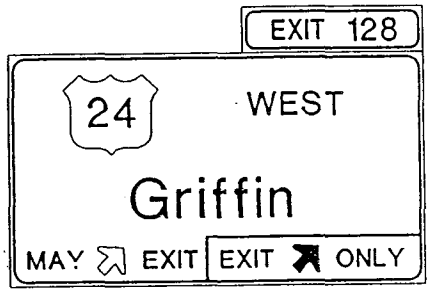
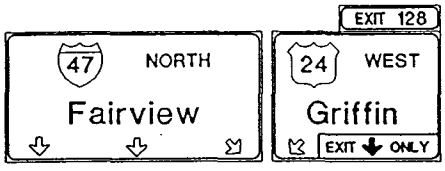
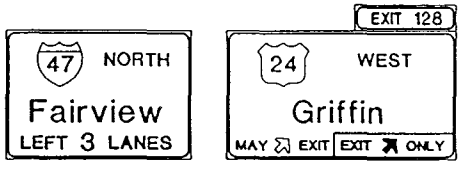
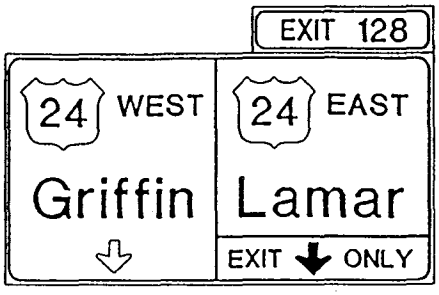
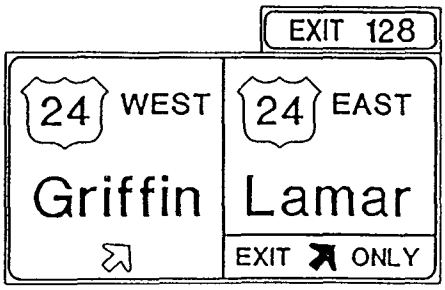
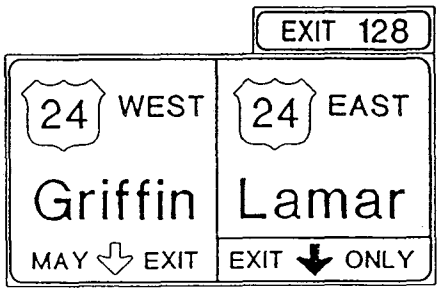
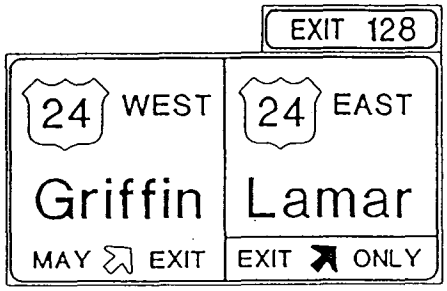
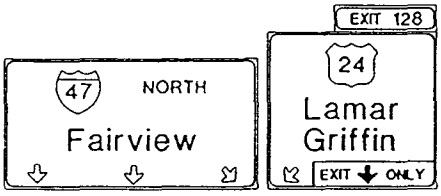
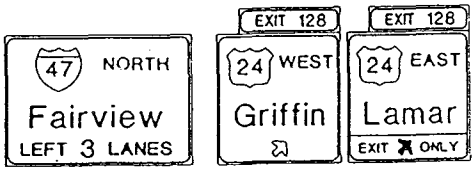
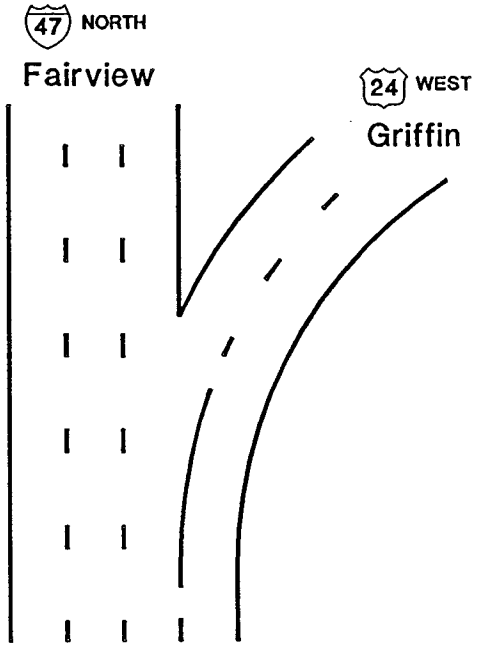
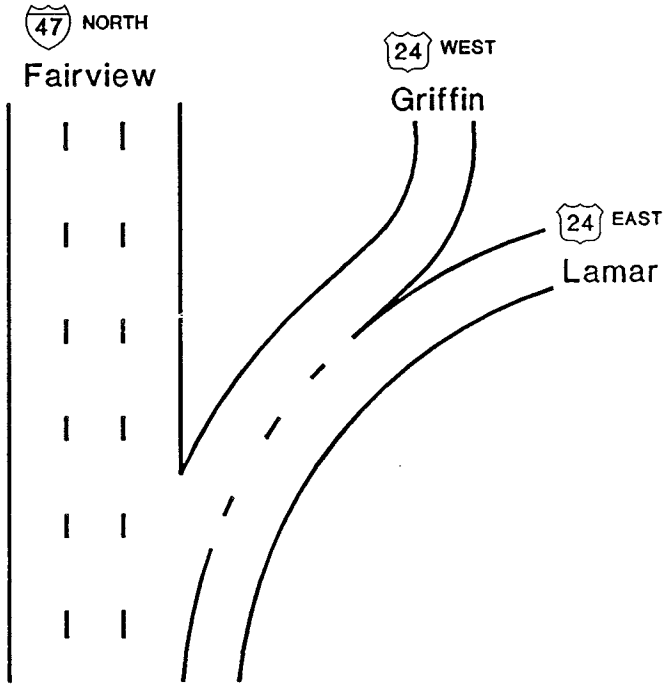
	Advance Sign(s)	Exit Directional Sign(s)
Texas MUTCD Method		
MAY EXIT Method		
Modified Ohio Method		

Table 20. Signing Options Chosen for Two Lane Exit with an Optional Lane and Secondary Ramp Split

	Advance Sign(s)	Exit Directional Sign(s)
Texas Highway Operations Manual Method		
MAY EXIT Alternative		
Modified Ohio Method		



Two-lane Exit with Optional Lane



Two-lane Exit with Optional Lane and Secondary Ramp Split

Figure 49. Geometric Configuration for Tested Guide Signing

4.1.4 Signing Alternatives Not Selected

Obviously, not all of the alternatives that were previously examined were chosen for further testing. The research team focused on signing methods that could be implemented with only sight changes to existing signs and guidelines. As a result, diagrammatic, modified diagrammatic, and other effective signing methods were not selected or tested. It is safe to assume that any of the three selected methods could be supplemented with modified diagrammatic or diagrammatic signing used in advance of the exit.

4.2 DEVELOPMENT OF TESTING STRATEGY

After choosing the signing methods to be tested, a testing strategy was devised. The basic idea was to test the signs by showing the study participants slides of the various signing methods. The slides were to display simulated guide signs and the freeway to which the signs applied. The signs would be displayed for a predetermined time period, which corresponded with the time the sign would be visible from a moving vehicle. The participants would then be asked questions concerning lane assignment information on the sign.

4.2.1 Time of Exposure

The time duration was estimated using previous research on legibility distances and by estimating travel speed. By determining the legibility distance of the sign, and knowing the speed at which the vehicle is approaching the sign, one can estimate the time the sign is visible by simply dividing legibility distance by travel speed.

Forbes' study on legibility distances (27) estimated 0.6 meters of legibility distance for each millimeter of letter height. Forbes' study involved Series D lettering, whereas lettering on freeway guide signs uses Series E Modified. A later study by Forbes (28) analyzed Series E lettering, similar to the lettering currently used on freeway guide signs. Forbe's study concluded that there are 0.66 meters of legibility distance for each millimeter of Series E letter height. Because the Series E lettering closely matches the lettering used on guide signs, a value of 0.66 meters of legibility per millimeter of letter height was chosen.

The lettering on the freeway guide signs is Series E Modified. Letter heights on the tested guide signs ranged from 400 millimeters for destinations to 300 millimeters for cardinal directions and "EXIT ONLY" messages (2). Thus, 300 millimeters was chosen as the critical letter height, as it is the smallest lettering size that would be used. Using the 300 millimeter letter height, and the 0.66 meter of legibility distance per millimeter for Series E lettering estimate, researchers estimated that the sign would be legible from a distance of 200 meters.

Next, the travel speed of approaching vehicles was estimated. Since 112 kilometers per hour is frequently used as a freeway design speed, the same value was used. A vehicle

approaching one of the guide signs will therefore cover the 200 meters of legibility distance in 6.4 seconds.

The 6.4 seconds may not accurately reflect the time that the driver is able to concentrate on the sign. In urban situations, where multilane exits most often occur, drivers must pay increased attention to the driving task, due to heavier traffic volumes, more decision points, etc. Therefore, an exposure of five seconds was chosen for displaying the slide, hypothesizing that this would be the maximum amount of time that one could concentrate on the meaning of the sign, while still driving in a safe manner. Also, Forbes' legibility studies used participants with perfect (20/20) vision. Many areas license drivers with less than perfect vision. Finally, the five second exposure time was also used in the Ontario laboratory study on guide signs discussed previously (19).

4.2.2 Sample Size

A sample size was determined using the binomial estimation for sample size. The equation for determining the sample size is as follows (29):

$$n = \frac{z^2_{\alpha/2} p(1-p)}{d^2}$$

Where:

n	=	sample size;
$z^2_{\alpha/2}$	=	normal z statistic corresponding to desired confidence level;
p	=	probability of a correct response; and
d	=	percent error.

Using a 90 percent confidence and 10 percent error, and assuming that 65 percent of the responses would be correct (previous research indicates that 65 percent is an average correct response rate for previous studies testing similar signs), an ideal sample size of 61.2 was computed. Therefore, sixty participants were sought to produce a credible study.

4.2.3 Question Phrasing

A potential question phrasing was then determined. The goal was to attempt to extract the participants' interpretation of the guidance information presented in each signing alternative for the optional lane. In other words, it was desired to determine whether or not participants understood that one can both stay on and exit the freeway from the optional lane.

Several question and answer formats, including the following, were considered:

1. If you are in Lane 3 [the optional lane], and cannot change lanes, then you:
    a) Must exit the freeway
    b) Must continue on the freeway
    c) Can either exit or continue
    d) Not sure

2. If you are in Lane 3 and cannot change lanes then you MUST EXIT.
    a) True
    b) False

3. If you are in Lane 3 and cannot change lanes, can you exit to Griffin [exit destination]?
    a) Yes
    b) No

4. Which lane or lanes could you get into to reach Griffin [exit destination]? (circle all that apply.) 1 2 3 4

With alternatives 2, 3, and 4, the phrasing of the questions could be changed so that multiple questions could be asked. For example, with alternative 2 the phrase "MUST EXIT" could be changed and rephrased as must continue, cannot exit, or can exit, but it would take a multiple series of questions to extract the participants' full interpretation of the sign for each of alternative 2, 3, and 4.

Alternative 4 was settled upon as the best alternative. Research (4, 6, 24) shows that drivers are destination oriented, making this question format perhaps the most realistic question that drivers ask themselves during the driving task. The slides would be shown once asking the question, "Which lane or lanes could you get into to stay on the main freeway?" The slides would then be shown again, asking the question, "Which lane or lanes could you get into to exit to (exit destination)?" In this fashion, participants could concentrate on reaching a single particular destination while answering the questions.

A participant's full interpretation of the sign may be extracted only by asking lane choices with respect to both exiting and continuing on the freeway. Questions concerning lane choice to continue on the freeway and exit the freeway must be asked, since a driver has the choice of continuing on or exiting the freeway. With respect to exits with secondary splits, the participants are shown the slide set three times. First, participants would be asked to circle lanes to continue on the freeway. Second, participants would be asked their lane choice for one of the exit secondary split destinations. Third, participants would be asked their lane choice for the other exiting destination.

The resulting question sequence was of the following format:

Two Lane Exit with Optional Lane:

Question 2A - "Which lane or lanes could you get into to continue on the freeway (I-47 North)?"

Question 2B - "Which lane or lanes could you get into to exit the freeway to U.S. 24 West to Griffin?"

Two Lane Exit with Optional Lane and Secondary Ramp Split:

Question 3A - "Which lane or lanes could you get into to continue on the freeway (I-47 North)?"

Question 3B - "Which lane or lanes could you get into to exit the freeway to U.S. 24 West to Griffin?"

Question 3C - "Which lane or lanes could you get into to exit the freeway to U.S. 24 East to Lamar?"

The disadvantage of this question strategy is that, in reality, a driver chooses only one of the lanes. In several cases, participants would have to circle more than one lane, subtracting from the laboratory's ability to accurately recreate the driving task.

4.2.4 Order of Slide Presentation

The order of slide presentation was crucial to the success of the experiment. Participants could not be asked just to respond to the 12 signs shown in Tables 19 and 20. It was believed that the participants would quickly understand that all the signs were for the same geometric condition. Thus, an alternative strategy was developed to ensure that participants were being tested on their understanding of the signs, and not their ability to take the laboratory test.

A series of "distractor" signs were also developed to minimize conditioning of the participants during testing. Participants would be shown a distractor guide sign that related to a totally different geometric condition. The use of distractors was an effective way to keep participants from recognizing that several of the signs were for the same geometric condition (that of a multilane right exit with an optional lane). Some examples of the distractor signs included signing for multiple lane drops, left exits, single lane drops, and multilane left exits.

The slides were then organized into two sets. The first set of slides involved the two-lane exit with an optional lane and no secondary ramp split. The second set of slides involved the two-

lane exit with an optional lane and a secondary ramp split. Several distractor signs were developed for each set of slides.

The actual testing signs were placed in the slide sequence among the distractors. The sequence for each set consisted of one distractor, the first alternative, two distractors, the second alternative, another distractor, and the last alternative. In this manner, participants would see a variety of geometric situations, rather than just the two-lane exit with an optional lane.

The slide sets were arranged in the following manner:

Slide Number	**Set 1 - Two-lane exit with optional lane**	**Set 2 - Two-lane exit with optional lane and secondary ramp split**
1 & 8	Distractor - Left Exit	Distractor - Right Lane Drop
2 & 9	Scenario 1	Scenario 1
3 & 10	Distractor - Double Lane Drop to Left	Distractor - Left Multilane Exit with Optional Lane
4 & 11	Distractor - Right Exit	Distractor - Double Lane Drop with Secondary Ramp Split
5 & 12	Scenario 2	Scenario 2
6 & 13	Distractor - Double Lane Drop	Distractor - Left Lane Drop
7 & 14	Scenario 3	Scenario 3

Slides 8 through 14 repeated the same cycle as Slides 1 through 7, thus the same geometric feature was shown in Slides 1 and 8, 2 and 9, 3 and 10, and so forth. The difference was that in the first seven slides, the advance sign for the particular exit was shown, and in the second seven slides (8 thru 14), the exit directional signs were shown. For each space marked "Scenario," a slide was shown for one of the alternatives identified previously for testing.

In order not to "pair" correct answers, the slides were divided into advance and exit directional. All advance signs were shown in Slides 1 thru 7, and the corresponding exit directional signs were shown in the same order in Slides 8 thru 14. Initially, it was envisioned to show a slide depicting an advance sign, followed by the corresponding exit directional sign for the same situation. Since both the advance sign and exit directional sign would have been for the same type of exit, participants would likely answer in "pairs" upon noticing this pattern. This trend was observed in one pilot study.

Again, only the MAY EXIT, modified Ohio, and Texas standard methods were tested. To randomize the effect that any conditioning of participants might have, the slides were placed in mixed orders in the spaces marked scenarios. In other words, one group may have seen the

MAY EXIT method, followed by the Texas standard method, followed by the modified Ohio method. The next group may have seen the modified Ohio method, followed by the MAY EXIT method, followed by the Texas standard method. It was felt that participants would develop a better understanding of guide signing during the test; by mixing the order of presentation, this effect would be equal for all three methods. If the slides were shown in the same order to all groups, the data could be skewed to favor one signing method unfairly over another.

Therefore, six slide sequences were followed. The sequences are shown in Table 21, with Position number 1 being Slides 2 and 9 in the sequence, Position 2 representing Slides 5 and 12, and Position 3 representing Slides 7 and 14.

Table 21. Sequences for Slide Presentation

Position	Order 1	Order 2	Order 3	Order 4	Order 5	Order 6
1	MAY EXIT	MAY EXIT	Modified Ohio	Modified Ohio	Texas Standard	Texas Standard
2	Modified Ohio	Texas Standard	MAY EXIT	Texas Standard	MAY EXIT	Modified Ohio
3	Texas Standard	Modified Ohio	Texas Standard	MAY EXIT	Modified Ohio	MAY EXIT

4.2.5 Format of Instructions and Answers

A series of instruction and answer sheets was developed to give to each of the participants. The sheets were organized in a manila folder to serve as an answer packet for each participant. A copy of the answer packet has been included in Appendix C.

Prior to testing, participants were required to sign an "Informed Consent" form, as required by the Texas A&M Institutional Review Board. The form gave a very brief description of the study procedure.

The first form in the answer packet was a introductory form. The form thanked each participant for their participation. The form then instructed each participant to begin filling out "Form 1," containing demographic information for each participant.

The next forms consisted of five answer sheets, each preceded by an instruction sheet. Answer forms were numbered 2A and 2B for the first set of slides. Forms 3A through 3C were for the second set of slides. The final sheet in the packet simply thanked each subject for their participation in the study, and asked each to place all forms in the manila folder.

4.3 OTHER PREPARATIONS

The development of the study took many iterations and revisions before being finalized. The advice of signing, human factors, and engineering experts was sought to help devise the most effective, unbiased testing strategy possible. Pilot testing was performed to locate and remedy any possible flaws in the testing strategy.

Permission also had to be granted by the Texas A&M University Institutional Review Board (IRB) before proceeding with any testing of subjects. A proposal describing the testing process was submitted to the IRB describing the testing procedure. After agreeing upon the format, the IRB approved the experiment.

A suitable location to administer the study also had to be selected. A large conference type room was sought, so that multiple participants could be tested simultaneously. Facilities at the Texas Transportation Institute (TTI) main building on campus were used for testing during the evening hours. Facilities at the TTI Communications Division in the Texas 707 complex were used during daytime hours.

Finally, participants were scheduled. The participants for the study were identified using a TTI list of participants from previous studies. In addition, many TTI employees were scheduled for the study. In scheduling participants, an effort was made to get proportions of males, females, and ages representative of the Texas driving population.

5.0 DETAILED STUDY RESULTS

The detailed study was administered at the TTI building on the Texas A&M campus and in the TTI Communications facilities at the Texas 707 office complex. The study was administered to groups of two to five participants from November 15 through December 1, 1994. Each testing session lasted 30 to 45 minutes.

5.1 CHARACTERISTICS OF THE STUDY PARTICIPANTS

As mentioned in the previous chapter, an effort was made to test a sample representative of the Texas driving population with respect to ages and gender. Table 22 shows the actual demographic information of the sample, the general Texas population, and the Texas driving population.

The study participants did not completely depict a representative sample of the Texas population. Additionally, the sample size was too small to make comparisons between different socio-demographic categories. In comparison to the Texas general population, the survey samples represented higher proportions of white ethnic backgrounds and higher educational levels. However, as indicated in Table 22, the participants represented many socio-demographic elements of the Texas driving population. In addition, the sample closely represents age and gender distributions of the Texas driving population.

The data obtained from the laboratory experiment may be useful in determining specific trends in sign comprehension. In instances where the responses to a particular question showed a prominent difference between standard and alternative freeway guide signs, the results may be used to recommend the use of a particular sign. Comprehension data based on a representative sample may be desired before any final recommendations are made on the use or abandonment of a particular sign.

5.2 ANALYSIS OF DETAILED STUDY

An analysis of the study responses was conducted using a version of the chi-squared test and the two sample test of proportions. In addition, each signing method was critiqued to determine which methods of signing were most appropriate for field application.

5.2.1 Statistical Analysis of Responses

Answers were grouped into responses for advance and exit directional guide signs. Since five sequences of signs were shown, and each sequence showed both an advance and exit directional guide sign for each of the three selected signing methods, ten statistical comparisons were made.

Table 22. Socio-Demographic Characteristics of the Laboratory Participants

Characteristic		Lab Sample	Texas Population §	Texas Drivers *
Gender	Male	51.7 (31)	49.2 (30)	51.5 (31)
	Female	48.3 (29)	50.8 (30)	48.5 (29)
Age	Less than 25	16.7 (10)	39.3 (24)	15.2 (9)
	25 to 34	25.0 (15)	18.4 (11)	25.0 (15)
	35 to 44	25.0 (15)	15.0 (9)	22.8 (14)
	45 to 54	11.7 (7)	9.7 (6)	14.6 (9)
	55 to 64	10.0 (6)	7.6 (5)	10.4 (6)
	65 or over	11.7 (7)	10.1 (6)	12.0 (7)
Race	Anglo/White	88.3 (53)	60.8 (37)	---
	African American/Black	1.7 (1)	11.7 (7)	---
	Hispanic	8.3 (5)	25.3 (15)	---
	Asian	1.7 (1)	1.8 (1)	---
	Native American	0.0 (0)	0.3 (0)	---
	Other	0.0 (0)	0.1 (0)	---
Primary Language	English	98.3 (59)	---	---
	Other	1.7 (1)	---	---
Educational Level	< High School	1.7 (1)	28.1 (17)✡	---
	High School Graduate	21.7 (13)	25.9 (16)✡	---
	Tech/Trade School	3.3 (2)	4.9 (3)✡	---
	Some College	31.7 (19)	22.9 (14)✡	---
	College Degree	18.3 (11)	12.6 (8)✡	---
	Advanced College Degree	23.3 (14)	5.5 (3)✡	
Driving is a Major Part of Job	Yes	13.3 (8)	---	---
	No	86.7 (52)	---	---
Driving Location	Urban	53.3 (32)	---	---
	Rural	5.0 (3)	---	---
	Split	38.3 (23)	---	---
	No Answer	3.3 (2)		
Sample Size	---	60	---	---

Notes: Numbers are given in percentages and (sample size out of 60 participants).
§) Source: 1990 U.S. Census
*) Source: Texas Department of Public Safety, 1991 Statistics
✡) Statistic based on Texas population 18 years of age and older

Each of the three methods was tested to see if any differences existed among the three distributions. This comparison was done using a chi-squared (X^2) test for homogeneity among

dichotomous populations. If differences did exist, the two sample test of proportions was used to determine which particular distributions were different.

The statistical equations and methods used for analysis of the laboratory responses were taken from Devore's *Probability and Statistics for Engineering and the Sciences* (30). First, to determine if the response distributions were different, the X^2 test was used. The test statistic is derived from the following equation:

$$X^2=\sum \frac{(Value_{observed}-Value_{expected})^2}{Value_{expected}}$$

Where:

X^2	=	Calculated chi-squared value;
$Value_{observed}$	=	Observed number of responses in a particular category; and
$Value_{expected}$	=	Estimated number of responses in a particular category.

The data were arranged into contingency tables and analyzed using the method described by Devore. X^2 values were calculated by summing values for six categories (incorrect and correct responses for each of the three signing methods). X^2 values were then calculated for each of the ten statistical comparisons.

The responses to each question were analyzed to determine if the null hypothesis (H_o: $p_1=p_2=p_3$) was true. The calculated X^2 values were compared to a statistical table given by Devore for critical X^2 values. Given the degrees of freedom (d.f.) and a significance level (α) (in the case of this study 2 and 0.05, respectively), a tabulated X^2 value could be determined. If the calculated X^2 value exceed the tabulated X^2 value, H_o was rejected (at least two of the distributions were different). Conversely, if the tabulated X^2 value exceed the calculated X^2 value, there was no evidence that differences existed among the distributions.

If the X^2 test showed that statistically significant differences existed between the data sets, then the two sample test of proportions was applied to determine which particular distributions were different. The two sample test of proportions uses the z statistic to determine which of the distributions were different. The following equation is used to derive the z statistic:

$$z=\frac{(p_1-p_2)}{\sqrt{pq(1/m+1/n)}}$$

Where:

z	=	test statistic;
p_1, p_2	=	percentage responding correctly for treatments 1 and 2;
m, n	=	sample sizes for treatments 1 and 2;
p	=	(number responding correctly for treatment 1 + number responding correctly for treatment 2) / (m + n); and
q	=	1 - p.

The calculated z value was then compared to the tabulated z value for the desired confidence level. Again, the tabulated value was provided by Devore. For a 95 percent confidence, the tabulated z value equals 1.645. If the absolute value of the calculated z value exceeded 1.645, then the two distributions are different at a 95 percent confidence. The results of the statistical analysis are given in Appendix B in spreadsheet format.

5.2.2 Discussion of Responses

5.2.2.1 Scenario 1: Two Lane Exit with an Optional Lane

As previously discussed in Chapter 4, the first set of signs tested were for a four lane freeway approaching a two lane exit with an optional lane to the right. In this case, traffic in the left two lanes would be forced to continue on the freeway. Traffic in the right lane would have to exit. Traffic in the lane third from the left (the optional lane) would have the choice of continuing on the freeway or exiting.

Questions 2A and 2B pertained to the described geometric situation. In Question 2A, participants were asked to denote their lane choices for continuing on the freeway. The correct response to the question was to circle Lanes 1, 2, and 3. In Question 2B, participants were asked to denote lane choices with regard to the upcoming exit. The correct response was to circle Lanes 3 and 4. Tables 23 through 26 show the distribution of responses to Questions 2A and 2B. In each table, the response percentages are given, along with the number of responses in parentheses. Correct responses are shown in *italics* and are indicated with an asterisk (*).

Table 23. Form 2A Responses (Advance Signs)

Which lane or lanes would you position your vehicle in to continue on the main freeway?	**Percent Selecting Indicated Lanes**		
Signing Method	**1 and 2**	**1, 2, and 3**	**Other**
Texas MUTCD	20.0	*78.3**	1.7
Modified Ohio	11.7	*85.0**	3.3
MAY EXIT	26.7	*73.3**	0.0

The responses shown in Table 23 exhibited no significant differences among distributions. The results indicate that the participants understand each signing method as well as any other. Correct response rates were fairly high, indicating that most participants understood that one may continue on the main freeway from the optional lane.

Table 24. Form 2A Responses (Exit Directional Signs)

Which lane or lanes would you position your vehicle in to continue on the main freeway?	**Percent Selecting Indicated Lanes**		
Signing Method	**1 and 2**	**1, 2, and 3**	**Other**
Texas MUTCD	28.3	*71.7**	0.0
Modified Ohio	8.3	*90.0**	1.7
MAY EXIT	16.7	*83.3**	0.0

The responses for the exit directional signs, as shown in Table 24, reveal that only one difference was observed among methods. The modified Ohio method proved statistically better than the Texas MUTCD method. This improvement is probably due to the inclusion of the message "LEFT 3 LANES" on a pull-thru sign in the modified Ohio method. The Texas MUTCD method does not include pull-thru signing. Again, this statistically significant difference was observed only in the exit directional signing, and not in the advance signing. This difference indicates that the inclusion of the pull-thru sign in the modified Ohio method of signing improved drivers' comprehension of the optional lane situation. The improvement comes in the communication that drivers may continue on the freeway from the optional lane. Again, correct response rates were fairly high for the exit directional signs, as was the case for the advance guide signs.

Question 2B asked the participants to indicate lane choices for exiting the freeway. Again, the questions were asked for both advance and exit directional signing. Table 25 gives the response breakdown for the advance signs, while Table 26 shows responses for the exit directional signs.

Table 25. Form 2B Responses (Advance Signs)

Which lane or lanes would you position your vehicle in to exit the main freeway to Griffin?	**Percent Selecting Indicated Lanes**		
Signing Method	**4**	**3 and 4**	**Other**
Texas MUTCD	10.0	*90.0**	0.0
Modified Ohio	15.0	*85.0**	0.0
MAY EXIT	10.0	*90.0**	0.0

Table 26. Form 2B Responses (Exit Directional Signs)

Which lane or lanes would you position your vehicle into exit the main freeway to Griffin?	**Percent Selecting Indicated Lanes**		
Signing Method	**4**	**3 and 4**	**Other**
Texas MUTCD	10.0	*90.0**	0.0
Modified Ohio	15.0	*85.0**	0.0
MAY EXIT	6.7	*93.3**	0.0

As shown in Tables 25 and 26, the correct response rates were consistently high for all three signing methods, for both advance and exit directional signing. No statistically significant differences were calculated among any of the three methods for either the advance or exit directional signing. The results suggest that each method is as effective as the others in communicating lane assignment information for the upcoming exit.

From Questions 2A and 2B for the exit without a secondary ramp split, only one major conclusion can be drawn. The inclusion of a pull-thru sign using the phrase "LEFT 3 LANES" appears to help to communicate to motorists that one may continue on the freeway from the optional lane. No decline in sign comprehension results in communicating that one may also exit from the optional lane.

5.2.2.2 Scenario 2: Two Lane Exit with an Optional Lane and a Secondary Ramp Split

As discussed in Chapter 4, the second set of signs tested were for a four-lane freeway approaching a two-lane exit with an optional lane to the right. The two-lane ramp then splits, with one lane in each of the ramp "forks." In this case, traffic in the left two lanes would be forced to continue on the freeway. Traffic in the right lane would have to exit. Traffic in the lane third lane from the left (the optional lane) would have the choice of continuing on the freeway or exiting. In addition, exiting traffic in the third lane would be required to take the left fork of the secondary ramp split, while traffic in the rightmost lane would be required to take the right fork.

For the second set of signs, three questions were asked. Question 3A asked the participants to indicate their lane choices for continuing on the freeway. In Question 3B, the respondents denoted their lane choices for exiting the freeway and taking the left fork of the exit ramp. In Question 3C, participants were asked to indicate lane choices for exiting the freeway and taking the right fork of the exit ramp. The correct responses were Lanes 1, 2, and 3 for Question 3A, Lane 3 for Question 3B, and Lane 4 for Question 3C. Again, responses were grouped and analyzed according to the sign type -- either advance or exit directional.

Tables 27 and 28 give the answer frequencies for Question 3A. Tables 29 and 30 summarize the responses for Question 3B. Tables 31 and 32 give the response percentages for Question 3C.

Table 27. Form 3A Responses (Advance Signs)

Which lane or lanes would you position your vehicle in to continue on the main freeway?	**Percent Selecting Indicated Lanes**		
Signing Method	**1 and 2**	**1, 2, and 3**	**Other**
Texas Highway Operations Manual	35.0	*65.0**	0.0
Modified Ohio	6.7	*91.7**	1.7
MAY EXIT	21.7	*78.3**	0.0

As shown in Table 27, two statistically significant differences were observed for the advance signs. The modified Ohio method proved better than both the Texas Highway Operations Manual method and the MAY EXIT method. This improvement may be due to the fact that the modified Ohio method does not attempt to communicate the secondary ramp split in the advance sign. The Texas Highway Operations Manual method does, requiring additional information, perhaps decreasing the correct comprehension for continuing on the freeway. Also, the pull-thru sign with the diagonal arrow is added to the modified Ohio method, providing additional information for those wanting to continue on the freeway. No other statistically significant differences were noted for the advance signs.

Table 28. Form 3A Responses (Exit Directional Signs)

Which lane or lanes would you position your vehicle in to continue on the main freeway?	**Percent Selecting Indicated Lanes**		
Signing Method	**1 and 2**	**1, 2, and 3**	**Other**
Texas Highway Operations Manual	41.7	*56.7**	1.7
Modified Ohio	13.3	*86.7**	0.0
MAY EXIT	18.3	*81.7**	0.0

In the statistical analysis of the responses to the exit directional signs for Question 3A, two differences were observed. Both the modified Ohio and the MAY EXIT methods were understood better than the Texas Highway Operations Manual method. As was the case with an exit ramp without a secondary split, the pull-thru sign with the phrase "LEFT 3 LANES" helped

to increase driver comprehension of the optional lane. The use of the phrase "MAY EXIT" also helped to communicate that drivers may continue on the freeway from the optional lane, perhaps making clearer the message that an exit is indeed "optional," and not mandatory, from the optional lane.

The correct response percentages were generally high, with the exception of the Texas Highway Operations Manual. Less than two thirds of the participants answered correctly for the Texas Highway Operations Manual method for the advance sign. Just over one half answered correctly for the Texas Highway Operations Manual exit directional sign.

Questions 3B and 3C asked the participants to indicate lane choices for exiting the freeway. In Question 3B participants were required to circle their choice for the left fork of the exit secondary ramp split. Then, in Question 3C, participants circled lane choices for the right fork. Again, the questions were asked for both advance and exit directional signing. Tables 29 and 31 give the response breakdowns for the advance signs, while Tables 30 and 32 show those for the exit directional signs.

For the advance signs, as shown in Tables 29 and 31, two statistically significant differences were observed among the three signing methods. The differences were observed between the Texas Highway Operations Manual method and the modified Ohio method, and between the MAY EXIT and the modified Ohio method. The modified Ohio method was poorly understood. This poor comprehension may be due to the fact that the advance guide sign in the modified Ohio method simply assigns traffic for the upcoming exit, and not for each of ramp forks. The Texas Highway Operations Manual and MAY EXIT methods were both well understood. These conclusions are true for both Questions 3B and 3C.

For the exit directional signs, no differences were observed in the response distributions for either Question 3B or 3C. Correct response rates were good for each of the three signing methods, generally in the neighborhood of 85 percent.

Table 29. Form 3B Responses (Advance Signs)

Which lane or lanes would you position your vehicle in to exit the main freeway to Griffin?	**Percent Selecting Indicated Lanes**		
Signing Method	**3 and 4**	**3**	**Other**
Texas Highway Operations Manual	10.0	*86.7**	6.7
Modified Ohio	86.7	*6.7**	10.0
MAY EXIT	20.0	*75.0**	5.0

Table 30. Form 3B Responses (Exit Directional Signs)

Which lane or lanes would you position your vehicle in to exit the main freeway to Griffin?	**Percent Selecting Indicated Lanes**		
Signing Method	**3 and 4**	**3**	**Other**
Texas Highway Operations Manual	11.7	*88.3**	0.0
Modified Ohio	13.3	*86.7**	0.0
MAY EXIT	10.0	*88.3**	1.7

Table 31. Form 3C Responses (Advance Signs)

Which lane or lanes would you position your vehicle in to exit the main freeway to Lamar?	**Percent Selecting Indicated Lanes**		
Signing Method	**3 and 4**	**4**	**Other**
Texas Highway Operations Manual	5.0	*95.0**	0.0
Modified Ohio	81.7	*15.0**	3.3
MAY EXIT	13.3	*86.7**	0.0

Table 32. Form 3C Responses (Exit Directional Signs)

Which lane or lanes would you position your vehicle in to exit the main freeway to Lamar?	**Percent Selecting Indicated Lanes**		
Signing Method	**3 and 4**	**4**	**Other**
Texas Highway Operations Manual	11.7	*88.3**	0.0
Modified Ohio	11.7	*88.3**	0.0
MAY EXIT	13.3	*86.7**	0.0

5.3 SUMMARY OF RESULTS

The results of Questions 3A through 3C suggest that the MAY EXIT method offers modest benefits over the Texas Highway Operations Manual method. These benefits are due to

the better ability of the MAY EXIT method in communicating that one may continue on the freeway from the optional lane.

The modified Ohio method, while effective in communicating that one can continue on the freeway from the optional lane, had low response rates for the advance sign in communicating lane assignment for the two ramp destinations. This lack of comprehension is due to the fact that the signing makes no effort to assign traffic to each of the ramp destinations; traffic is simply assigned to the exit.

The pull-thru signing methods used with the modified Ohio method of signing seems to be effective in communicating the optional lane to drivers. Particularly, the additional sign gives drivers extra assurance that they may continue on the freeway from the optional lane. This improvement was true for exits with and without secondary ramp splits.

5.4 PRACTICAL ANALYSIS OF RESULTS

After compiling the findings of the study, the results were compared to those found in previous research. On the average, correct comprehension rates for the laboratory study were higher than those observed in previous studies. This difference may be due to the relatively high educational level of the study participants. Also, the higher comprehension rate could be attributed to the differences in the study design. The studies that were reviewed primarily used written surveys to test the effectiveness of signing methods.

The clear comprehension differences in the MAY EXIT and Texas MUTCD methods observed in the initial survey conducted at the Houston Auto Show were not as dramatic in the detailed study. The detailed study showed very marginal benefits of the MAY EXIT method over the Texas MUTCD method. The initial survey showed that the MAY EXIT method was comprehended much better than the Texas MUTCD method.

A question arises as to how well each method lends itself to field application. The modified Ohio method of using diagonal arrows falls short in this area, because it requires a large pull-thru sign, covering all lanes that may continue on the freeway. This sign, in addition to being more costly, may not be useful in areas with closely spaced exits. In many cases, sign bridges are used to sign for more than one exit; the modified Ohio method could be devoted to only one exit, without regard to any of the surrounding roadway geometry. The MAY EXIT and Texas MUTCD methods lend themselves better to real-world application by not requiring pull-thru signing.

While the detailed study does indicate some improvements of using alternative guide signs, the improvements are fairly modest. The detailed study suggests that the modified Ohio method and MAY EXIT methods are slightly preferred over the Texas MUTCD and Texas Highway Operations Manual methods; however, none of the tested signing methods should be abandoned as a result of this study.

6.0 SUMMARY

The intent of this project was to develop and test signing strategies for multilane interchanges in Texas. Since previous research has focused primarily on signing for interchange lane drops, this study focused on developing signing treatments for optional lanes at multilane exits.

6.1 FINDINGS

6.1.1 Summary

The researchers developed a technical background to gain expertise in the subject of freeway guide signing. This was done by first identifying the recommended guide signing practices found in the MUTCD and the Texas MUTCD. Next, the research team contacted representatives from the Department of Transportation of each state and asked them to identify the way their state would sign for a multilane exit with an optional lane and secondary ramp split. The researchers inventoried guide signing practices at multilane exits in Houston, San Antonio, Dallas, and Fort Worth to determine the different signing methods used in Texas. The researchers also developed modifications to guide signing practices found in the Texas MUTCD, and then tested the effectiveness of the modifications in a written survey in Houston. The survey was designed to test comprehension of the alternative guide signs to the guide signing recommended for a two-lane exit with an optional lane in the current edition of the Texas MUTCD to determine what, if any, increased comprehension could be expected through the use of alternative signs.

Finally, modifications to guide signing practices found in the Texas MUTCD were developed and tested in a detailed study under laboratory conditions. A modification to the signing practice recommended in the Ohio MUTCD was tested in the same study. The study was designed to test comprehension of the standard guide signs for a two-lane exit with an optional lane in the current edition of the Texas MUTCD. In addition, the two alternative methods were tested in the same fashion to determine what, if any, increased comprehension could be expected through the use of alternative guide signs. Exit ramps with and without secondary ramp splits were tested.

6.1.2 Technical Background

The literature search indicated that freeway guide signing is generally adequate on Texas highways (1, 14, 17). The signing for multilane exits with optional lanes, however, is misunderstood by a significant portion of the Texas driving population (1, 14). More specifically, the white arrow adjacent to EXIT ONLY panels on freeway guide signs may not effectively communicate the upcoming optional lane situation.

Signing in urban areas is often complicated by the use of multilane exits, closely spaced interchanges, and high traffic volumes that distract driver attention from signs. Signing content should be carefully considered during the design phase to address these concerns. This signing should present enough information to adequately convey the upcoming geometric condition to drivers, but not be so much as to overload the driver's ability to process information. In addition, signing practices should be consistent between states and between sites within a particular state so that drivers develop a familiarity with the signing information presented to them.

The results of the technical background pointed to two basic guide signing deficiencies. Insufficient lane assignment information is a common driver complaint and may attribute to erratic maneuvers in or near the exit gore. At the very least, this deficiency may cause drivers to make a wrong decision, adding to travel time and driver frustration. Uniformity is often a problem in guide signing practices between sites. Many different treatments are used in Texas and throughout the nation to sign for multilane interchanges. The low level of nationwide guide signing uniformity may be attributable to the failure of the National MUTCD to specifically address the topic of guide signing for multilane interchanges.

6.1.3 Initial Alternatives Survey

The research team developed alternatives to the current Texas MUTCD method of guide signing for multilane exits with optional lanes. The alternatives included slight modifications of the existing signs to help communicate the optional lane. These alternatives included the phrases "MAY EXIT" and "EXIT OK," along with a lane assignment arrow to communicate an optional lane. The other set of alternatives used a divergent arrow to indicate an optional lane. Alternatives included signs with the divergent arrow alone, and in combination with the phrases "MAY EXIT" and "EXIT OK" to communicate an optional lane. In all cases, the modifications were placed directly above the optional lane on an overhead guide sign to communicate the desired information.

The results of the initial survey mimic the findings of previous research. In some cases, less than half of the survey participants understood the current method recommended in the Texas MUTCD of signing for a multilane exit with an optional lane. At the same time, driver comprehension levels for lane drop guide signing were high; approximately 85 percent gave correct responses to the questions dealing with lane drops and EXIT ONLY panels.

The alternative including the standard white arrow and the phrase "MAY EXIT" was the most effective means in communicating the optional lane situation to the survey participants. The alternative with the phrase "EXIT OK" was also effective in communicating lane assignment and directional information for the optional lane, but to a lesser degree than the alternative using "MAY EXIT." Both the MAY EXIT and EXIT OK alternatives were better understood than the current means of signing described in the Texas MUTCD.

From a lane assignment stance, divergent arrow alternatives were very successful in communicating optional lane exits to drivers. Use of the divergent arrow alternatives must be approached with caution, though. Many of the surveyed drivers felt that they could reach the exit destination as shown on the sign by staying on the freeway. In other words, the sign did not accurately convey navigational and route choice information to the driver.

6.1.4 Detailed Study

The results of the detailed study also showed that the alternative methods offer some improvement over the current standard methods used in Texas. The improvements are modest, and the study should not be used as a sole means of recommending one signing method over another. A discussion of the performance of each signing method in the detailed study follows.

6.1.4.1 Texas MUTCD and Texas Highway Operations Manual Methods

Both of the standard methods used for signing multilane interchanges with optional lanes in Texas were understood reasonably well by the laboratory participants. Comprehension rates were somewhat higher in this study than those observed in previous studies. Nevertheless, the methods tend to be somewhat misunderstood in communicating optional lanes. Improvements to the signing method have been recommended in previous studies. The signing method should not, however, be abandoned at this time.

6.1.4.2 MAY EXIT Method

The MAY EXIT method was better understood than the Texas Highway Operations Manual method for signing secondary ramps with splits. The method did not provide any improvement at ramps without secondary splits; however, if the MAY EXIT method is used at ramps with secondary splits, as the study results indicate that it should be, the method should be used for all applicable situations, including ramps with secondary splits. If approved for widespread use, the MAY EXIT method could be added easily onto existing signs used in Texas; however, the decision to change the method of signing should not be based solely on the results of this laboratory study.

As is the case with the Texas MUTCD and the Texas Highway Operations Manual methods, the MAY EXIT method of signing can easily be implemented in the field. The sign requires that for lane assignment purposes, the lane configuration at the point of signing be the same as that at the exit ramp.

6.1.4.3 Modified Ohio Method

The modified Ohio method was perhaps the best understood of the three signing methods tested. The diagonal arrows proved to be an effective way of communicating an optional lane. In addition, the pull-thru sign with the phrase "LEFT 3 LANES" at the exit proved to aid driver

comprehension of the optional lane situation. This pull-thru sign could be tested when used with the "MAY EXIT" sign panel described in this study as another possible signing alternative.

The implementation of this signing method, however, requires a full sign bridge and a large pull-thru guide sign. In addition, the modified Ohio method of signing could not be easily added to most existing signs and signing systems. In any case, the decision to implement a signing method of this type should be based on this and additional research findings.

The modified Ohio method was ineffective in assigning traffic to the particular ramp forks of the secondary ramp split. Changes should be made to the signing method to better assign traffic to the two ramp forks of the exit.

6.2 CONCLUSIONS

The many variables that affect freeway signing require that interchange signing be dealt with on a case-by-case basis. Many interchanges present unique challenges in signing, due to complex geometric features. The content of each sign should be carefully selected to insure that the driver is provided enough information, but is not overloaded with too much information. At the same time, sign content should be consistent with other guide signs, so that drivers may become familiar with the message each sign attempts to communicate. Finally, the information in a sign should not conflict with or contradict information given on other signs. For these reasons, sign design and content at exits with complex geometrics should reflect current recommended practices and the use of sound engineering judgement. Some specific issues and considerations for guide signing at multilane exits are listed below and discussed in the following paragraphs.

- Driver Issues
- Lane Drops
- Optional Lanes
- Uniformity
- Arrow Orientation
- Pull-thru Signing

6.2.1 Driver Issues

Driver understanding of freeway exit and optional lane signing can be significant from both a safety and an operational/capacity standpoint. The safety standpoint relates to the potential for last minute erratic maneuvers in order to exit at the desired location. These erratic lane changes could be significant in high volume segments where accidents may have a greater chance of occurring. Capacity may be reduced through the failure of drivers to realize that the optional lane is intended for both through and exiting traffic. In other words, drivers in the optional lane wishing to continue on the main freeway may mistakenly change lanes, thinking that the optional lane is a lane drop. On the other hand, a driver wishing to exit the freeway may

change lanes into the lane marked "EXIT ONLY," mistakenly thinking that the optional lane only allows drivers to continue on the freeway. The result is that the optional lane is only lightly used by drivers continuing on the freeway or the lane drop exit lane may be overutilized by exiting drivers. The potential misunderstanding of optional lane exit signing could also contribute to lower roadway capacity because of the increased number of unnecessary lane changes, increasing the number of intervehicular conflicts. Freeway safety and capacity issues demonstrate the importance of easily comprehensible freeway guide signs for exit ramps.

The potential safety and capacity issues described above may not be as relevant on freeways with a high proportion of familiar drivers. Familiar drivers tend to understand a roadway after driving it on a daily basis. The familiar drivers will therefore understand an exit ramp configuration simply through experience, and may not rely on guide signing at all. As a result, the familiar drivers will utilize the available capacity in either direction of the optional lane.

6.2.2 Lane Drops

Lane drops refer to lanes that exit the freeway and discontinue at the exit ramp. Lane drops should be signed using black on yellow EXIT ONLY panels. Arrow placement and orientation should follow the specifications described in section 6.2.6 (Arrow Orientation). Previous research and the results of the initial driver survey suggest that drivers clearly understand that the EXIT ONLY panel indicates a lane drop.

In describing lane drop signing, the Texas MUTCD differs somewhat from the National MUTCD. The National MUTCD recommends that a white diagonal arrow should be used outside of the black on yellow EXIT ONLY panel for exit directional signing at a lane drop. The Texas MUTCD allows a black arrow to be placed within the EXIT ONLY panel, positioned in the space between the words "EXIT" and "ONLY." Even though this practice is different from the recommended practice in the National MUTCD, the results of the driver survey indicate that the survey participants had a good understanding of the signing recommended in the Texas MUTCD.

One signing alternative that warrants further evaluation is the potential use of the phrase "MUST EXIT" rather than that of "EXIT ONLY." "MUST EXIT" is more consistent with wording used on some other signs, and the research results indicate that it may be better understood than "EXIT ONLY." In addition, if the phrase "MAY EXIT" is used on guide signs, "MUST EXIT" would likely be more compatible than the current "EXIT ONLY."

6.2.3 Optional Lanes

Optional lanes refer to lanes that split at an interchange, giving the driver the option to either exit or to continue on the freeway. Optional lanes have many advantages and can be used to improve operations at interchanges by providing the flexibility to accommodate variations in continuing and exiting traffic volumes. However, optional lanes can also be difficult to sign, due

to the dual nature of the lane, particularly at multilane exits. Current Texas practice for multilane exits is to use a white arrow for the optional lane, while a black arrow with the "EXIT ONLY" panel is used for the drop lane.

The study evaluated several different alternatives for improving driver understanding of optional lanes at multilane exits, but the results were not conclusive enough to recommend changes to the current practice. The initial driver survey indicated that "MAY EXIT" has the potential for improving understanding. However, the detailed laboratory evaluation found that the "MAY EXIT" alternative was only marginally better understood than the current Texas method. The results were promising enough to justify future evaluations of this practice.

The modified Ohio method, which uses two downward diagonal arrows pointing to the same lane, was also found to be slightly better understood than the current method. However, the results were not conclusive enough to support its adoption in Texas, although the practice also appears promising enough to warrant future evaluation. To the researchers' knowledge, this detailed study is the only test of comprehension performed on the Ohio method of signing.

The evaluations conducted as part of this research effort tested only a small number of drivers, and the findings cannot justify widespread implementation of either signing alternative. More research, including field studies and written surveys, should be performed to better quantify the benefits of the "MAY EXIT" and modified Ohio methods of signing. Until more research can be conducted, the practices described in the Texas MUTCD should continue to be used for a two-lane exit with an optional lane. Recommended signing for a two-lane exit with an optional lane is shown in Figure 4.

Divergent arrows, while useful in communicating optional lanes, should generally be avoided based on the limited results of this research. The combination of a divergent arrow and a route destination presents conflicting navigational information to the driver.

6.2.4 Uniformity

Uniformity refers to the practice of signing identical roadway geometrics in the same fashion, regardless of location. However, practices are inconsistent between states, and in some cases, within states. When drivers are posed with an unfamiliar situation, a familiar sign format helps to guide the driver to his or her destination, while inconsistent signing may further confuse and frustrate the driver.

Statewide practices are diverse, often differing from city to city, and in some cases within cities. This can be attributed to the difficulty of updating older signs with newer signing practices recommended in the National MUTCD, Texas MUTCD, or the Texas Highway Operations Manual. A statewide inventory of guide signs and subsequent updating of older signs may prove to be beneficial in eliminating inconsistency problems in Texas. Freeway guide signing

applications for similar geometric situations should be uniform and consistent among sites. Consistent signing applications should be adhered to.

6.2.5 Arrow Orientation

Arrows used in overhead freeway guide signing may be oriented in one of three ways: up, down, and diagonal (or tilted). Down arrows should be used in advance guide signing to indicate lane assignment. Diagonal up arrows (tilted to the left or right depending on the exit direction) should be used in exit directional signing to indicate the departure and direction of exiting lanes. Arrows should be centered above the lane to which they apply.

Up arrows are not included in either the Texas or National MUTCDs. However, the results of one question on the driver survey indicate that up arrows may be useful on pull-thru signs to indicate the direction of the continuing freeway. The use of up arrows on freeway guide signs is an area that merits additional research.

6.2.6 Pull-thru Signing

Pull-thru signing is used to denote the route designation, direction, and destination of the freeway mainlanes. The National MUTCD and Texas MUTCD recommend the use of pull-thru signing "when the geometrics of a given interchange are such that it is not clear to the driver as to which is the through roadway (2, 3)." Results of the Houston survey indicate that a multilane interchange with an isolated optional lane should not warrant a pull-thru sign.

6.3 RECOMMENDATIONS

Although initial research identified several promising methods for signing multilane exits, the detailed study showed that any improvements resulting from alternative signing methods are modest. The evaluations conducted for this study involved only a small number of drivers, thus, the study should not be used as a means of recommending one signing method over another. It is therefore recommended that the current method of signing for multilane exits continue to be used.

6.4 FUTURE RESEARCH

In conducting this research, additional research needs were identified. The developed alternatives were tested in controlled environments, a driver survey, and a laboratory study. The evaluations did not address many factors that are included in the actual driving task. The survey focused completely on driver comprehension of the signs presented. This method of testing discounts elements such as legibility, distractions associated with the driving task, and time that one can look at the sign. While the laboratory study attempted to place some degree of control on some of these factors, the procedure was not intended to be an accurate representation of a driving environment. Further testing should be done to determine the adequacy of signing

practices recommended by this study. Future testing may include driver surveys, field testing in a controlled environment, and limited real-world application. Additional studies may be desired before any of the suggested changes in guide signing practices are made on a large scale basis.

Many participants identified up arrows to indicate direction or the word "ahead." The responses to the open ended question included in the Houston survey indicate that up arrows may be a concept worth including in freeway guide signs. Up arrows are not specifically recommended for use in non-diagrammatic guide signs in the MUTCD. However, up arrows could possibly be used to effectively communicate direction of freeway mainlanes, following further research.

The MAY EXIT and EXIT OK alternatives were tested only in Houston. The research effort did not examine if these phrases were colloquial. Study should be done to determine if these phrases are understood as well in other parts of the nation and the state. One phrase that is well understood throughout the nation should be determined for use in freeway guide signs.

The best solution to the problem would be to test all possible signing formats for multilane exits with optional lanes nationwide. In this manner, all possible means of signing could be compared to one another. In addition, understanding of the various signing treatments around the nation could be quantified to determine if sign comprehension is higher or lower in a certain area. Also, one signing treatment that is well understood throughout the United States could be chosen for nationwide application and inclusion in the national MUTCD.

Finally, other freeway geometry could be analyzed to determine effective signing treatments. These geometric features may include, but are not limited to, simultaneous left and right exits, closely spaced interchanges, and multilane left exits. Some of the complex freeway exit geometries featured in many freeway designs are not discussed in the National or Texas MUTCD. Many related research topics are available, due to the multitude of different geometric configurations included in interchange designs throughout Texas and the nation.

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8.0 APPENDIX A

STATE TRAFFIC ENGINEER QUESTIONNAIRE

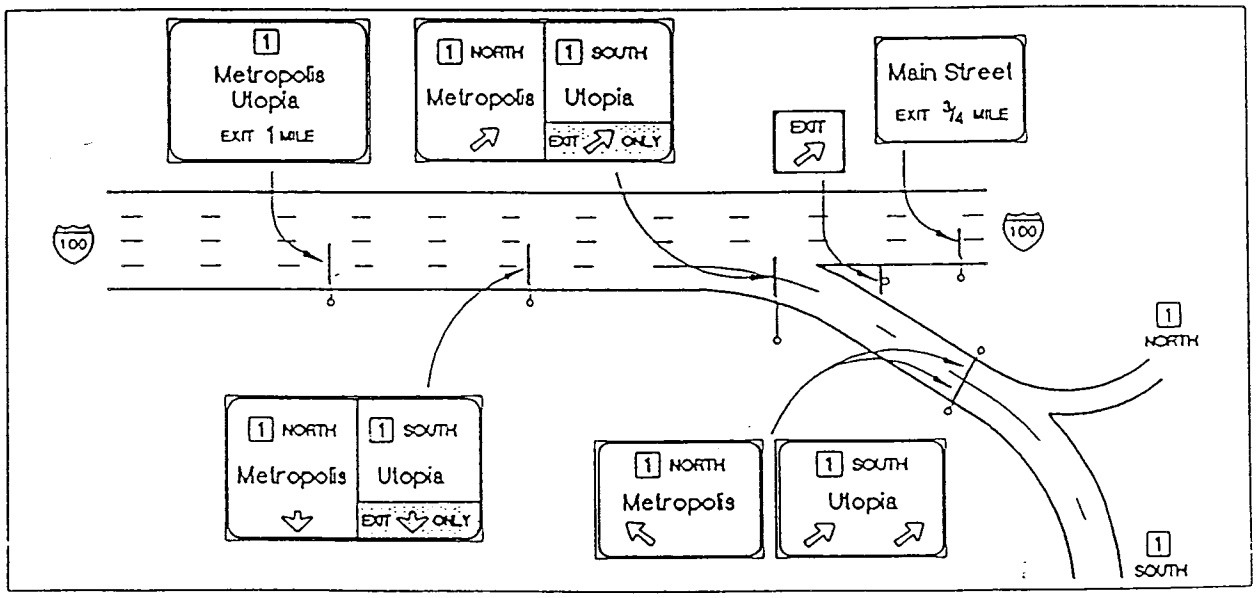
PART IV. FREEWAY GUIDE SIGNING

TTI is evaluating guidelines for the use of advance signing on multilane freeway exits. This research is focusing upon signing for the optional lane and advance lane assignments for exits located beyond the initial exit from the freeway.

1. Has your agency developed guidelines for freeway guide signing which are different from or more detailed than those in the MUTCD?

   ☐ Yes (if yes, please indicate where these guidelines are located or provide a copy of these guidelines)
   ☐ No
   Comments:

2. The figure below illustrates the typical signing used in Texas for a multilane freeway exit. Please indicate on this figure how the exit would be signed in your state.



Thank you for your assistance. Please return this survey to:

H. Gene Hawkins, Jr.
Texas Transportation Institute
Texas A&M University System
College Station, TX 77843-3135

Phone: (409) 845-6004

9.0 APPENDIX B

HOUSTON AUTO SHOW SURVEY

FREEWAY

EXIT SIGN

SURVEY

Prepared by the

Texas Transportation Institute

Texas A&M University System

for the

Texas Department of Transportation

This survey has been prepared to help us evaluate the exit signs used on Texas freeways. Before you take the survey,

PLEASE READ THE FOLLOWING INSTRUCTIONS.

1. THIS IS NOT A TEST. There are no right or wrong responses. The responses you give will help us determine how freeway signs are being used.

2. Please respond to the questions as best as you can based on your personal opinion.

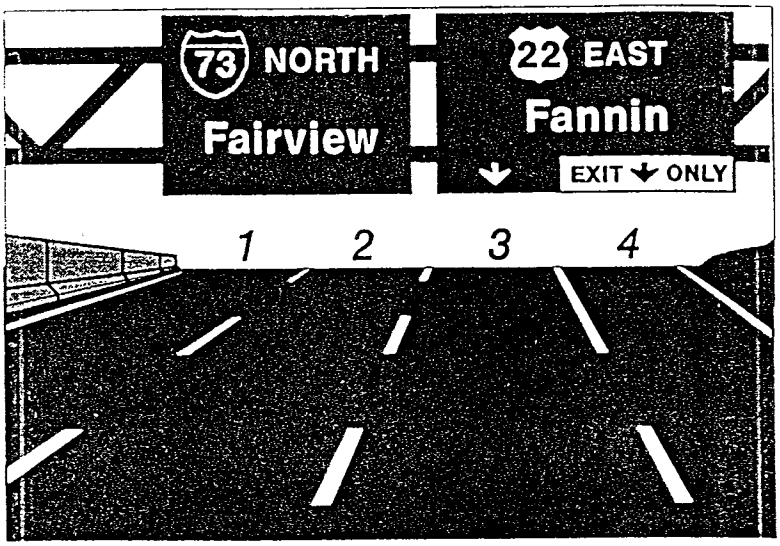
3. PLEASE WRITE YOUR RESPONSE ON THE PAGE THAT IS THE SAME COLOR AS THIS BINDER.

4. Once you have selected your response to a question, DO NOT GO BACK AND CHANGE YOUR RESPONSE.

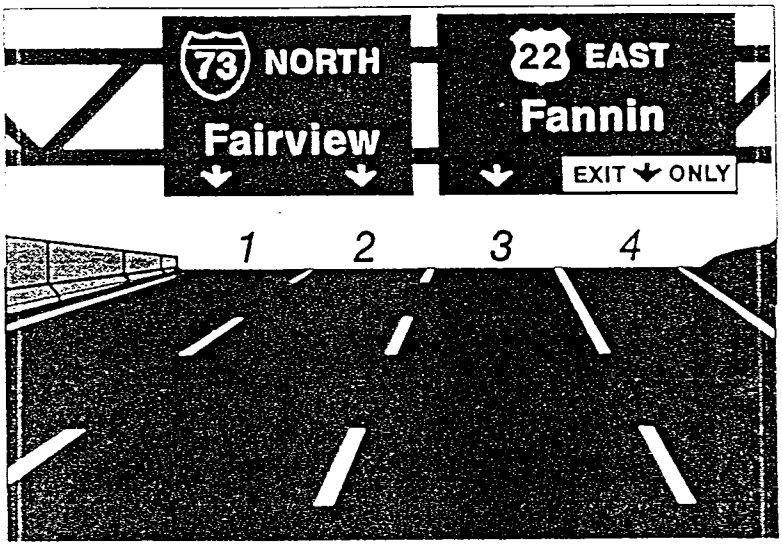
5. PLEASE COMPLETE THE SURVEY ALONE. Do not ask a friend to help you select a response.

Thank you for your help.

Blue Set



Red Set



Green Set

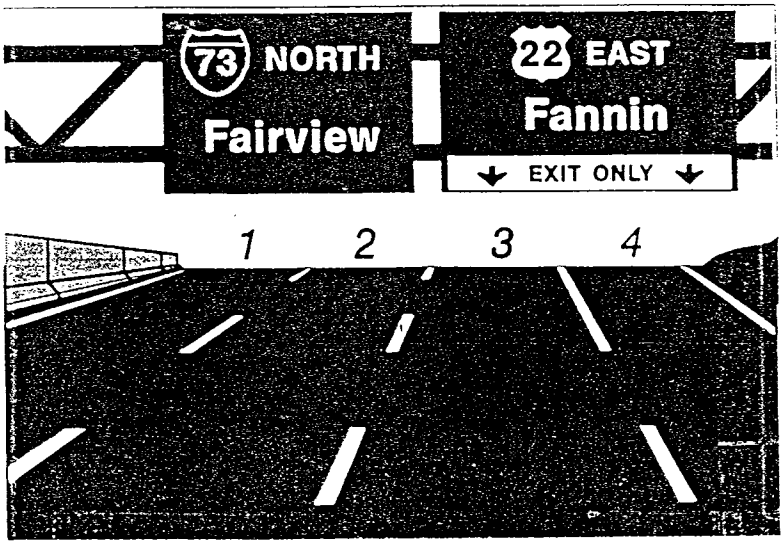


Figure B-1. Guide Sign Pictures Used for Questions 1, 2, and 3

You are driving North on Interstate 73 toward Fairview.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Fannin (Hwy 22 East).

Please answer the following questions.

1. If you are in LANE 4 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Fannin (Hwy 22 East).
C. Can either continue on the freeway or exit.
D. Not sure.

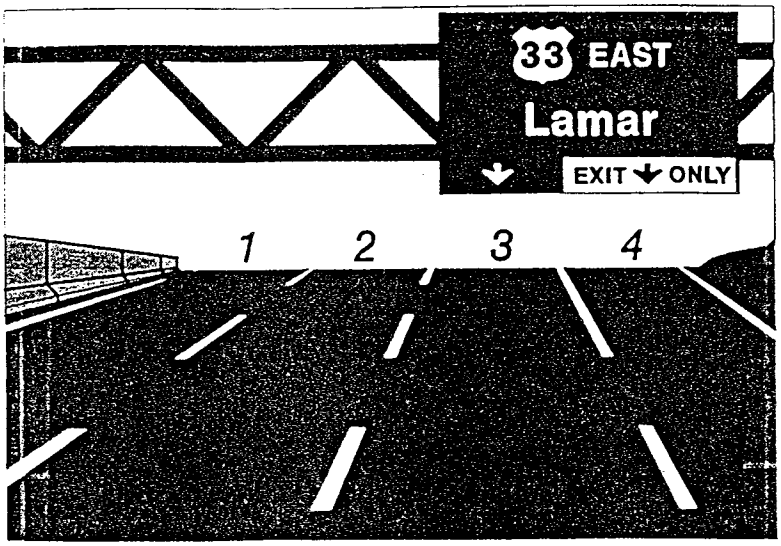
2. If you are in LANE 3 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Fannin (Hwy 22 East).
C. Can either continue on the freeway or exit.
D. Not sure.

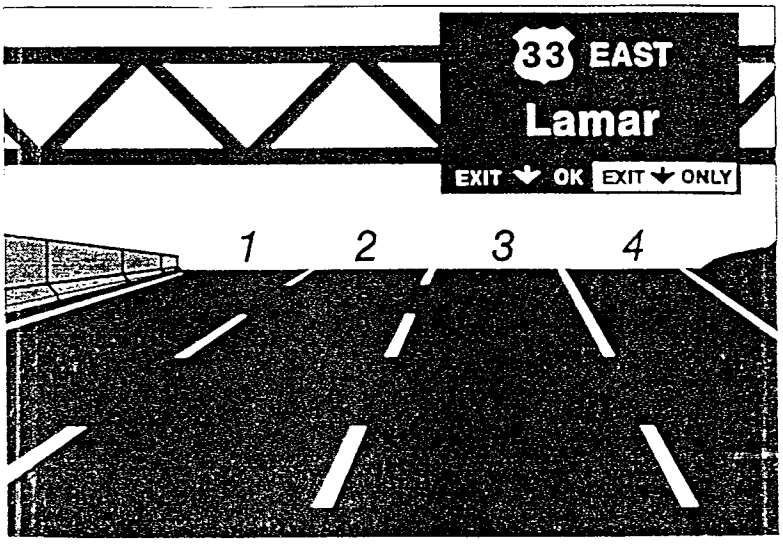
3. If you are in LANE 2 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Fannin (Hwy 22 East).
C. Can either continue on the freeway or exit.
D. Not sure.

Blue Set



Red Set



Green Set

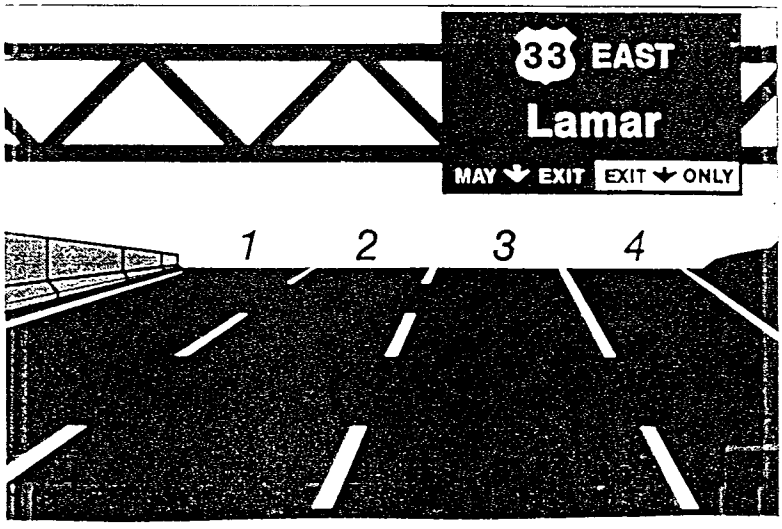


Figure B-2. Guide Sign Pictures Used for Questions 4, 5, and 6

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Lamar (Hwy 33 East).

Please answer the following questions.

4. If you are in LANE 4 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Lamar (Hwy 33 East).
C. Can either continue on the freeway or exit.
D. Not sure.

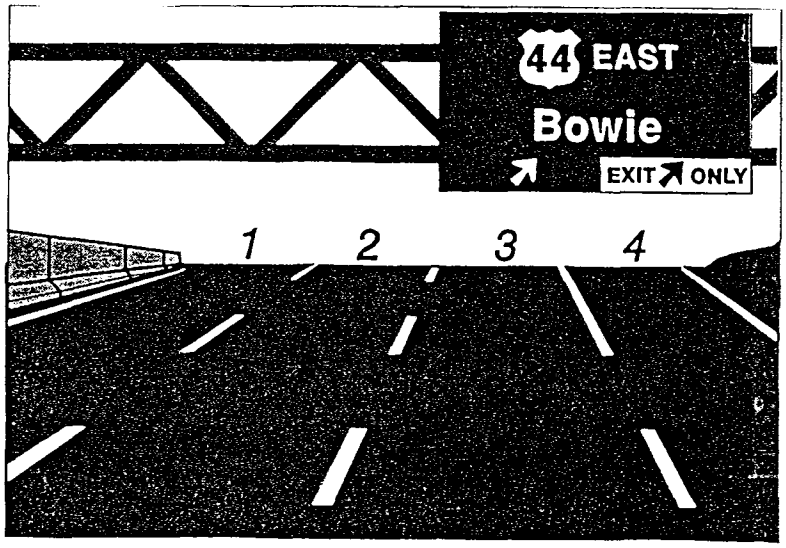
5. If you are in LANE 3 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Lamar (Hwy 33 East).
C. Can either continue on the freeway or exit.
D. Not sure.

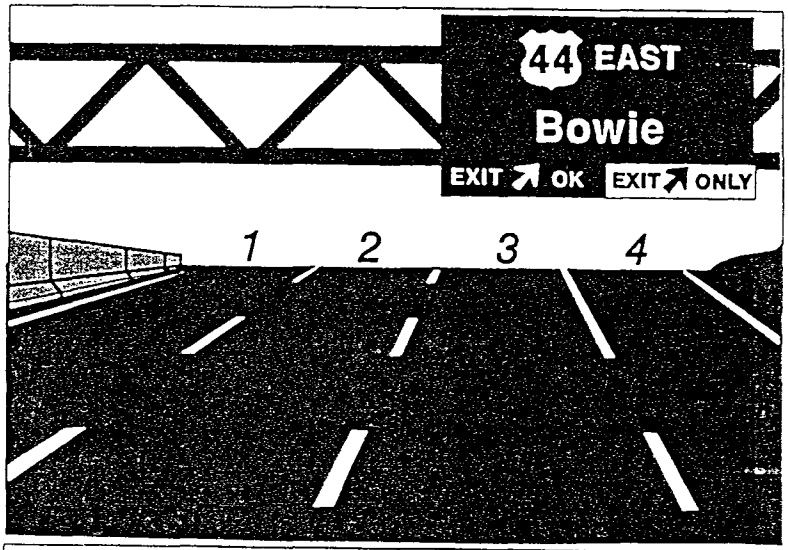
6. If you are in LANE 2 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Lamar (Hwy 33 East).
C. Can either continue on the freeway or exit.
D. Not sure.

Blue Set



Red Set



Green Set

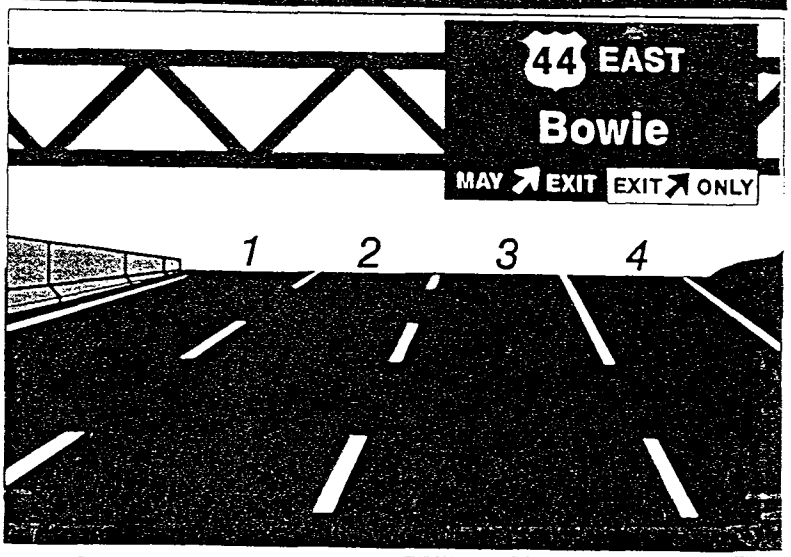


Figure B-3. Guide Sign Pictures Used for Questions 7, 8, and 9

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Bowie (Hwy 44 East).

Please answer the following questions.

7. If you are in LANE 4 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Bowie (Hwy 44 East).
C. Can either continue on the freeway or exit.
D. Not sure.

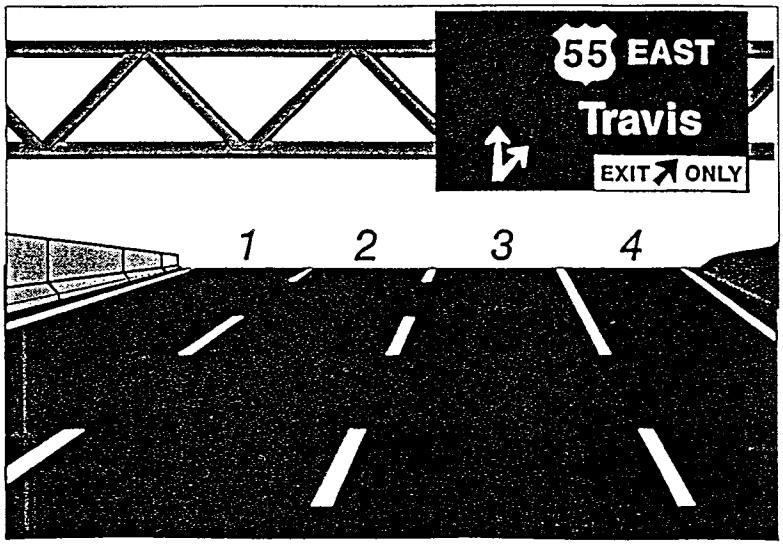
8. If you are in LANE 3 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Bowie (Hwy 44 East).
C. Can either continue on the freeway or exit.
D. Not sure.

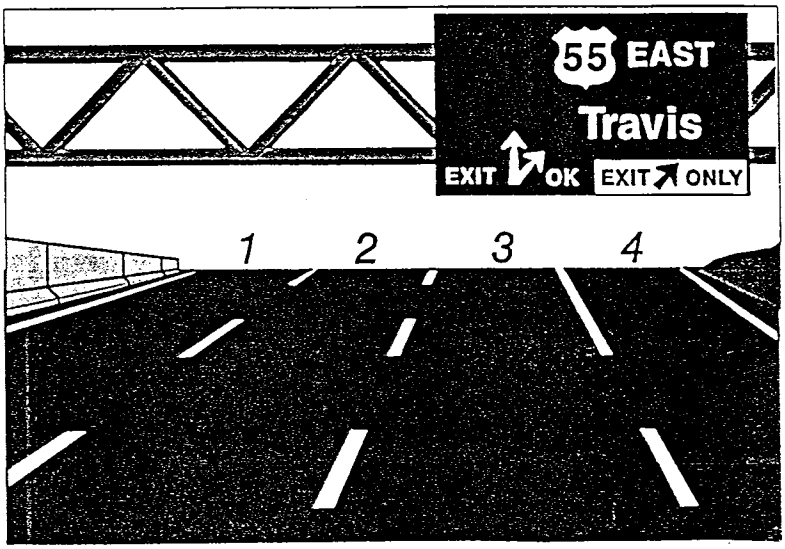
9. If you are in LANE 2 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Bowie (Hwy 44 East).
C. Can either continue on the freeway or exit.
D. Not sure.

Blue Set



Red Set



Green Set

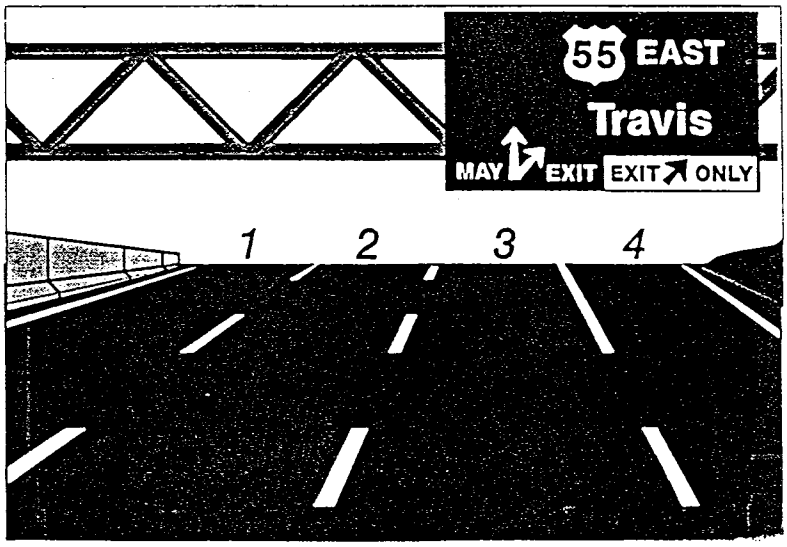


Figure B-4. Guide Sign Pictures Used for Question 10

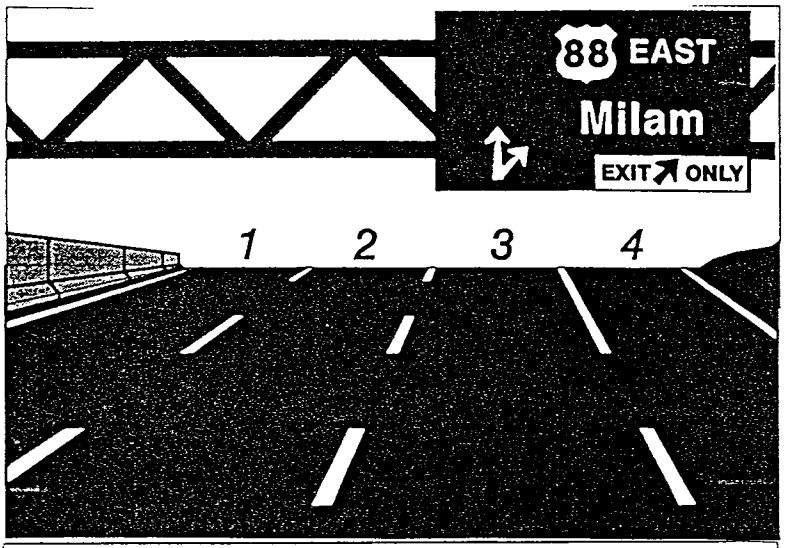
You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach an exit.

Please answer the following question.

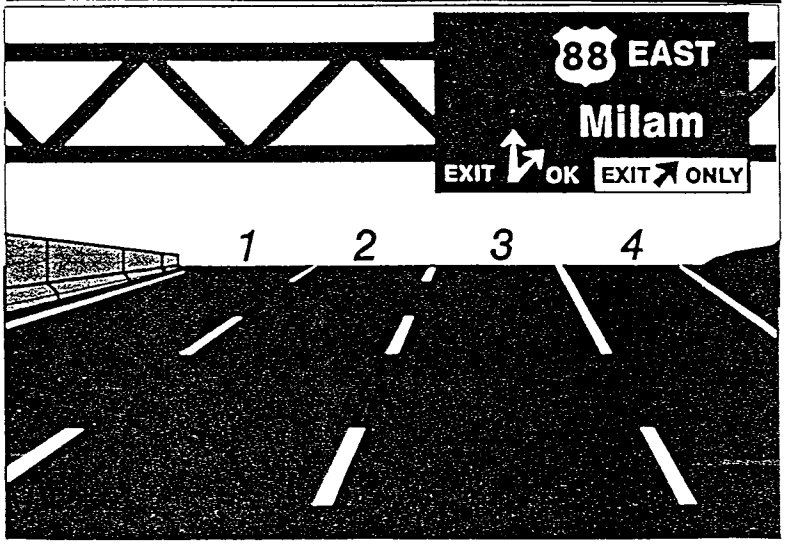
10. What direction should you go to get to Travis?

A. Continue straight on the freeway.
B. Exit the freeway to Hwy 55 East.
C. Either continue on the freeway or exit. Both the freeway and Hwy 55 East go to Travis.
D. Not sure.

Blue Set



Red Set



Green Set

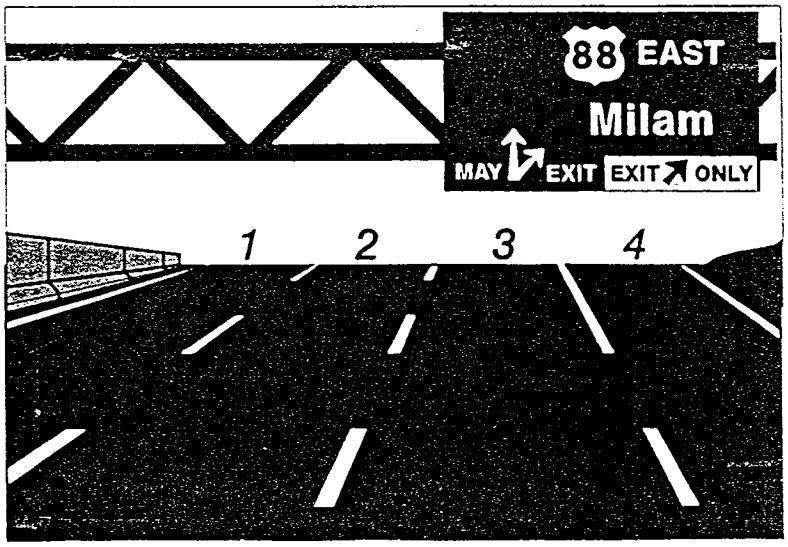


Figure B-5. Guide Sign Pictures Used for Questions 11, 12, and 13

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Milam (Hwy 88 East).

Please answer the following questions.

11. If you are in LANE 4 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Milam (Hwy 88 East).
C. Can either continue on the freeway or exit.
D. Not sure.

12. If you are in LANE 3 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Milam (Hwy 88 East).
C. Can either continue on the freeway or exit.
D. Not sure.

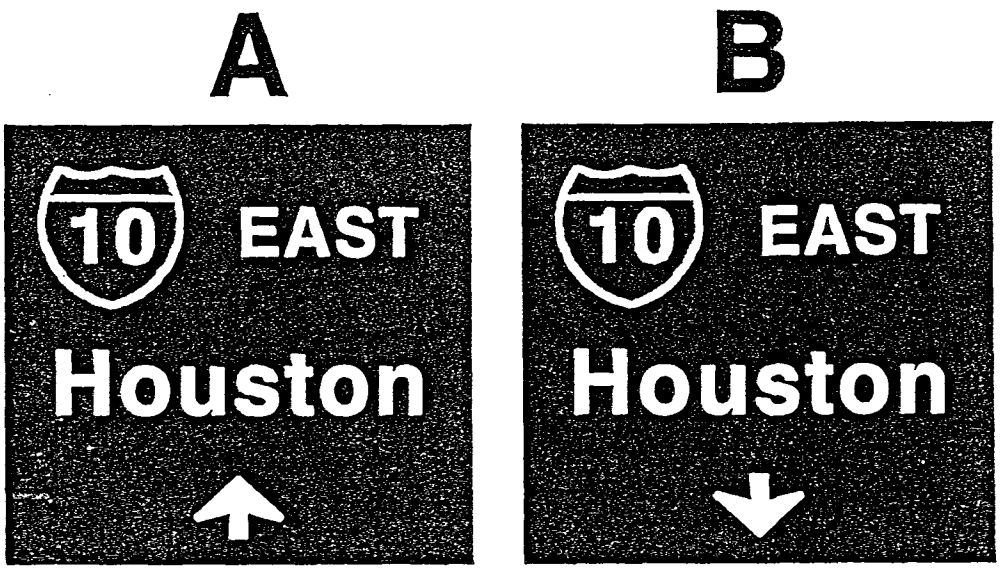
13. If you are in LANE 2 and cannot change lanes, you ...

A. Must continue on the freeway.
B. Must exit the freeway and go to Milam (Hwy 88 East).
C. Can either continue on the freeway or exit.
D. Not sure.

14. **What does EXIT ONLY mean when it is used in a sign like the one shown below?**

Please write your answer on the answer sheet.

15. **In the signs below, the arrow in Sign A is pointing up and the arrow in Sign B is pointing down.**



Why are Signs A and B different?

Please write your answer on the answer sheet.

CONFIDENTIAL BACKGROUND INFORMATION

Please answer the background questions on the answer sheet.

1. **What is your sex?**
   A. Male B. Female
2. **What is your age?**
   A. Less than 25 C. 40-54
   B. 25-39 D. 55 +
3. **What is the highest level of school you have completed?**
   A. Less than high school
   B. High school (or equivalent)
   C. Technical/Vocational school
   D. Some college
   E. College degree(s)
4. **What is your family background?**
   A. Anglo/White
   B. African-American/Black
   C. Hispanic
   D. Asian or Pacific Islander
   E. American Indian or Alaskan Native
   F. Other
5. **Is English your primary spoken language?**
   A. Yes B. No
6. **Is driving a vehicle a major part of your job? (i.e., professional driver, outside salesperson, taxi driver, delivery person, etc.)**
   A. Yes B. No
7. **Where do you spend most of your driving time?**
   A. Mostly in a city or urban area.
   B. Mostly in the country or rural area.
   C. Divided between city and country areas.

THANK YOU

FOR YOUR PARTICIPATION

FREEWAY EXIT SIGN SURVEY ANSWER SHEET

BINDER COLOR (circle one): Blue Red Green

SURVEY RESPONSES

Please circle your answer to each question.

1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D
11.	A	B	C	D
12.	A	B	C	D
13.	A	B	C	D

Write your answer to questions 14 and 15 in the boxes below.

CONFIDENTIAL BACKGROUND INFORMATION

Please check one box for each question.

1. **What is your sex?**
   - ☐ Male ☐ Female
2. **What is your age?**
   - ☐ Less than 25 ☐ 40-54
   - ☐ 25-39 ☐ 55 or over
3. **What is the highest level of school you have completed?**
   - ☐ Less than high school
   - ☐ High school (or equivalent)
   - ☐ Technical/Vocational school
   - ☐ Some college
   - ☐ College degree(s)
4. **What is your family background?**
   - ☐ Anglo/White
   - ☐ African-American/Black
   - ☐ Hispanic
   - ☐ Asian or Pacific Islander
   - ☐ American Indian or Alaskan Native
   - ☐ Other
5. **Is English your primary spoken language?**
   - ☐ Yes ☐ No
6. **Is driving a vehicle a major part of your job? (i.e., professional driver, outside salesperson, taxi driver, delivery person, etc.)**
   - ☐ Yes ☐ No
7. **Where do you spend most of your driving time?**
   - ☐ Mostly in a city or urban area.
   - ☐ Mostly in the country or rural area.
   - ☐ Divided between city and country areas.

14. _____

_____

_____

15. _____

_____

_____

You are driving North on Interstate 73 toward Fairview.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Fannin (Hwy 22 East).

Table B-1. Survey Results for Question 1

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
7.2	8.4	8.0	Must continue on the freeway.
86.7	*81.0*	*85.1*	** Must exit the freeway and go to Fannin (Hwy 22 East).*
5.0	8.9	6.4	Can either continue on the freeway or exit.
1.1	1.7	0.5	Not sure.

Table B-2. Survey Results for Question 2

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
42.2	45.2	11.2	Must continue on the freeway.
3.3	6.8	*77.1*	Must exit the freeway and go to Fannin (Hwy 22 East).
53.9	*48.0*	11.2	Can either continue on the freeway or exit.
0.6	0.0	0.5	Not sure.

Table B-3. Survey Results for Question 3

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
92.7	*86.9*	*87.6*	** Must continue on the freeway.*
2.2	2.8	5.9	Must exit the freeway and go to Fannin (Hwy 22 East).
3.9	9.7	4.8	Can either continue on the freeway or exit.
1.1	0.6	1.6	Not sure.

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Lamar (Hwy 33 East).

Table B-4. Survey Results for Question 4

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
6.1	6.8	8.0	Must continue on the freeway.
88.3	*87.6*	*86.2*	** Must exit the freeway and go to Lamar (Hwy 33 East).*
4.4	4.5	5.3	Can either continue on the freeway or exit.
1.1	1.1	0.5	Not sure.

Table B-5. Survey Results for Question 5

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
33.9	18.5	10.1	Must continue on the freeway.
6.7	7.3	5.4	Must exit the freeway and go to Lamar (Hwy 33 East).
58.3	*73.6*	*84.5*	** Can either continue on the freeway or exit.*
1.1	0.6	0.0	Not sure.

Table B-6. Survey Results for Question 6

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
95.0	*94.3*	*93.0*	** Must continue on the freeway.*
2.8	3.4	2.7	Must exit the freeway and go to Lamar (Hwy 33 East).
1.7	1.7	4.3	Can either continue on the freeway or exit.
0.6	0.6	0.0	Not sure.

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Bowie (Hwy 44 East).

Table B-7. Survey Results for Question 7

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
5.0	6.8	4.3	Must continue on the freeway.
92.7	*89.3*	*90.9*	** Must exit the freeway and go to Bowie (Hwy 44 East).*
1.7	4.0	4.3	Can either continue on the freeway or exit.
0.6	0.0	0.5	Not sure.

Table B-8. Survey Results for Question 8

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
10.6	11.8	7.5	Must continue on the freeway.
19.0	4.5	3.7	Must exit the freeway and go to Bowie (Hwy 44 East).
69.3	*83.2*	*88.3*	** Can either continue on the freeway or exit.*
1.1	0.6	0.5	Not sure.

Table B-9. Survey Results for Question 9

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
94.4	*95.5*	*92.6*	** Must continue on the freeway.*
1.7	2.3	2.1	Must exit the freeway and go to Bowie (Hwy 44 East).
2.8	1.7	5.3	Can either continue on the freeway or exit.
1.1	0.6	0.0	Not sure.

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach an exit.

Table B-10. Survey Results for Question 10

What direction should you go to get to Travis?			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
0.6	2.8	0.5	Continue straight on the freeway.
66.5	*69.7*	*85.6*	** Exit the freeway to Hwy 55 East.*
29.6	21.9	10.7	Either continue on the freeway or exit. Both the freeway and Hwy 55 East go to Travis.
3.4	5.6	3.2	Not sure.

You are driving on the same freeway.
Traffic is NOT allowed to change lanes.
As you drive, you approach the exit to Milam (Hwy 88 East).

Table B-11. Survey Results for Question 11

If you are in LANE 4 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
1.7	1.7	1.6	Must continue on the freeway.
97.2	*94.9*	*94.7*	** Must exit the freeway and go to Milam (Hwy 88 East).*
0.6	3.4	2.7	Can either continue on the freeway or exit.
0.6	0.0	1.1	Not sure.

Table B-12. Survey Results for Question 12

If you are in LANE 3 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
6.2	5.1	4.3	Must continue on the freeway.
6.2	4.6	2.7	Must exit the freeway and go to Milam (Hwy 88 East).
87.2	*90.3*	*92.6*	** Can either continue on the freeway or exit.*
0.6	0.0	0.5	Not sure.

Table B-13. Survey Results for Question 13

If you are in LANE 2 and cannot change lanes, you ...			
Response Percentages			**Responses**
Blue Set Standard	**Red Set EXIT OK**	**Green Set MAY EXIT**	
92.2	*95.5*	*94.2*	** Must continue on the freeway.*
4.5	2.3	2.7	Must exit the freeway and go to Fannin (Hwy 22 East).
2.8	1.7	3.2	Can either continue on the freeway or exit.
0.6	0.6	0.0	Not sure.

10.0 APPENDIX C

INSTRUCTION AND ANSWER SHEETS

FOR DETAILED STUDY

Informed Consent

This research is being conducted to assist the Texas Department of Transportation in a study of freeway guide sign comprehension in Texas. The comprehension of new alternatives to freeway guide signs will be specifically addressed. About 60 research participants are needed for this study.

You must have a valid drivers license to participate in this study. You will be paid $10 for your participation in this study.

At first, you will be required to fill out a form to record basic demographic information (your age, education, years of driving experience, etc.). Then you will view several slides of signs, and be asked a series of questions about each one. We will give you a full explanation of how this part of the research will be conducted before we start, so that you will have a full idea of what you are supposed to do.

Detailed instructions will be provided before the commencement of the study. **Participation in the study is voluntary and you may quit at any time without penalty. Please note that, you won't be paid the $10 compensation, if you withdraw prior to the completion of the study.** We will ask some questions related to your driving. For the survey questionnaire, you may refuse to answer any question(s) that make you uncomfortable. The information we get from you will only be reported in summary form and never with your name or any other identifying information.

This research study has been reviewed and approved by the Institutional Review Board- Human Subjects in Research, Texas A&M University. For research related problems or questions regarding research participants rights, the Institutional Review Board may be contacted through Dr. Richard E. Miller, IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (409) 845-1812.

I have read and understood the explanation provided to me and I voluntarily agree to participate in this study. I have received a copy of this consent form.

Signature of Research Participant Date	Signature of Researcher Date

If I have further questions, I may contact:

Andy Somers (409) 845-9949 or Gene Hawkins (409) 845-6004
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

THANK YOU for your participation in our study.

This study is designed to determine how well you understand guide signs that are used on Texas freeways. At any time during the study, please stop me if there is any part of the study that you do not understand.

Before we begin, please fill out the information indicated on Form 1, the next page in your folder. This information will be used only to determine the characteristics of our participants, and will only be used in summary form with the study report. In no way will the information be reported with your name. **Do not include your name anywhere on any of the answer forms.**

FORM 1
CONFIDENTIAL BACKGROUND INFORMATION

1. **What is your gender?**
   - ☐ Male ☐ Female

2. **What is your age?**
   - ☐ Less than 25 ☐ 35-44 ☐ 55-64
   - ☐ 25-34 ☐ 45-54 ☐ 65 or over

3. **What is the highest level of education you have completed?**
   - ☐ Less than high school
   - ☐ High school graduate (or equivalent)
   - ☐ Technical/Vocational school graduate
   - ☐ Some college
   - ☐ College graduate (B.A., B.S., or equivalent)
   - ☐ Advanced college degree(s) (M.S., Ph.D., M.D., etc.)

4. **What is your family background?**
   - ☐ Anglo/White
   - ☐ African-American/Black
   - ☐ Hispanic
   - ☐ Asian or Pacific Islander
   - ☐ American Indian or Alaskan Native
   - ☐ Other

5. **Is English your primary spoken language?**
   - ☐ Yes ☐ No

6. **Is driving a vehicle a major part of your job? (i.e., professional driver, salesperson, taxi driver, delivery person, etc.)**
   - ☐ Yes ☐ No

7. **Where do you spend most of your driving time?**
   - ☐ Mostly in a city or urban area.
   - ☐ Mostly in the country or rural area.
   - ☐ Divided between city and country areas.

Please remove Form 2A, the next page in your folder.

For this part of the experiment, I want you to pretend that you are driving along a freeway in your car, and wish to stay on the main freeway. First, you will see a slide that shows a four lane freeway, with lanes numbered 1, 2, 3, and 4, like the slide on the screen. I will ask you a question about a guide sign which you will see in an upcoming slide. You will then be shown a slide for 5 seconds that displays a freeway with a guide sign. After looking at the slide, circle the number or numbers that you could get into to reach your destination. If you feel that you can be in more than one lane, then circle all the lane numbers which you think would be appropriate. **Let me repeat, you can circle more than one lane number!** A slide showing the freeway after you pass the sign will be shown after the first slide. You may look at this slide while you mark your answers. **For the first set of signs and questions, the freeway is Interstate 47 North to Fairview.**

I will read the questions to you once, and the questions are printed on your answer sheet in case you do not understand what I say. Are there any questions at this time?

Let's do a sample question. Which lane or lanes would you get into to continue on the freeway, I-47 North?

Are there any final questions before we get underway?

FORM 2A

Which lane or lanes would you position your vehicle in to continue on the main freeway (I-47 North)?

Circle all lanes that apply; you can circle more than one lane.

Example	1	2	3	4
Slide #1	1	2	3	4
Slide #2	1	2	3	4
Slide #3	1	2	3	4
Slide #4	1	2	3	4
Slide #5	1	2	3	4
Slide #6	1	2	3	4
Slide #7	1	2	3	4
Slide #8	1	2	3	4
Slide #9	1	2	3	4
Slide #10	1	2	3	4
Slide #11	1	2	3	4
Slide #12	1	2	3	4
Slide #13	1	2	3	4
Slide #14	1	2	3	4

Please remove Form 2B, the next page in your folder.

Again, I want you to pretend that you are driving along a freeway in your car, and wish to reach a particular destination. I am going to show you another set of slides, only this time **you wish to exit the freeway to Highway 24 West to Griffin.** Again, I will ask you a question about a guide sign which you will see in an upcoming slide. You will then be shown a slide for 5 seconds that shows a freeway with a guide sign. After viewing the slide, circle the number or numbers that match the lane or lanes that you could position your car in to reach your destination. **Again, if you feel that you can be in more than one lane, then circle all the lane numbers which you think are appropriate.** A slide showing the roadway after you pass the sign will be shown after the first slide. You may look at this slide while you mark your answers.

Let's do another example. Which lane or lanes would you get into to exit the freeway to Highway 24 West to Griffin?
This is exactly like the first set of slides, only this time you want to exit the freeway to Griffin. Are there any final questions before we get underway?

FORM 2B

Which lane or lanes would you position your vehicle in to exit the main freeway to Griffin (U.S. 24 West)?

Circle all lanes that apply; you can circle more than one lane.

Example	1	2	3	4
Slide #1	1	2	3	4
Slide #2	1	2	3	4
Slide #3	1	2	3	4
Slide #4	1	2	3	4
Slide #5	1	2	3	4
Slide #6	1	2	3	4
Slide #7	1	2	3	4
Slide #8	1	2	3	4
Slide #9	1	2	3	4
Slide #10	1	2	3	4
Slide #11	1	2	3	4
Slide #12	1	2	3	4
Slide #13	1	2	3	4
Slide #14	1	2	3	4

Please remove Form 3A, the next page in your folder.

Again, I want you to pretend that you are driving along a freeway in your car, and wish to reach a particular destination. **For this set of slides, I want you to pretend that you wish to stay on the main freeway, I-47 North.** Again, I will ask you a question about a guide sign which you will see in an upcoming slide. You will then be shown a slide for 5 seconds that displays a freeway with a guide sign. Then, circle the number or numbers that match the lanes you could get into to reach your destination. **Again, if you feel that you can be in more than one lane to reach your destination, then circle all the lane numbers which you think would be appropriate.** A slide showing the roadway after you pass the sign will be shown after the first slide. You may look at this slide while you mark your answers.

Are there any final questions before we get underway? Again, keep in mind that you wish to **continue on the main freeway, I-47 North.**

FORM 3A

Which lane or lanes would you position your vehicle in to continue on the main freeway (I-47 North)?

Circle all lanes that apply; you can circle more than one lane.

Slide #1	1	2	3	4
Slide #2	1	2	3	4
Slide #3	1	2	3	4
Slide #4	1	2	3	4
Slide #5	1	2	3	4
Slide #6	1	2	3	4
Slide #7	1	2	3	4
Slide #8	1	2	3	4
Slide #9	1	2	3	4
Slide #10	1	2	3	4
Slide #11	1	2	3	4
Slide #12	1	2	3	4
Slide #13	1	2	3	4
Slide #14	1	2	3	4

Please remove Form 3B, the next page in your folder.

For these questions, I want you to pretend that you wish to exit the main freeway to Highway 24 West to Griffin. Again, I will ask you a question about guide sign which you will see in an upcoming slide. You will then be shown a slide for 5 seconds that displays a freeway and a guide sign. After viewing the slide, circle the appropriate number or numbers under the appropriate destination. These numbers should match the lane or lanes that you could position your car in to reach your desired destination. **Again, if you feel that you can be in more than one lane, then circle all the lane numbers which you think would be appropriate.** A slide showing the roadway after you pass the sign will be shown after the first slide. You may look at this slide while you mark your answers.

Again, you wish to **exit the freeway to U.S. Highway 24 West to Griffin.** Are there any questions at this time?

FORM 3B

Which lane or lanes would you position your vehicle in to exit the main freeway to Griffin (U.S. 24 West)?

Circle all lanes that apply; you can circle more than one lane.

Slide #1	1	2	3	4
Slide #2	1	2	3	4
Slide #3	1	2	3	4
Slide #4	1	2	3	4
Slide #5	1	2	3	4
Slide #6	1	2	3	4
Slide #7	1	2	3	4
Slide #8	1	2	3	4
Slide #9	1	2	3	4
Slide #10	1	2	3	4
Slide #11	1	2	3	4
Slide #12	1	2	3	4
Slide #13	1	2	3	4
Slide #14	1	2	3	4

Please remove Form 3C, the next page in your folder.

For these questions, I want you to pretend that you wish to exit the main freeway to Highway 24 East to Lamar. I will ask you a question about a guide sign which you will see in an upcoming slide. You will then be shown a slide for 5 seconds that displays a freeway and guide sign. Again, after viewing the slide, circle the appropriate number or numbers that match the lane or lanes that you could position your car in to reach your desired destination. **Again, if you feel that you can be in more than one lane, then circle all the lane numbers which you think would be appropriate.** A slide showing the roadway after you pass the sign will be shown after the first slide. You may look at this slide while you mark your answers.

Remember, you wish to **exit the freeway to U.S. Highway 24 East to Lamar.** Are there any questions at this time?

FORM 3C

Which lane or lanes would you position your vehicle in to exit the main freeway to Lamar (U.S. 24 East)?

Circle all lanes that apply; in some cases you should circle more than one lane.

Slide #1	1	2	3	4
Slide #2	1	2	3	4
Slide #3	1	2	3	4
Slide #4	1	2	3	4
Slide #5	1	2	3	4
Slide #6	1	2	3	4
Slide #7	1	2	3	4
Slide #8	1	2	3	4
Slide #9	1	2	3	4
Slide #10	1	2	3	4
Slide #11	1	2	3	4
Slide #12	1	2	3	4
Slide #13	1	2	3	4
Slide #14	1	2	3	4

When you are finished, please place all forms in the provided manila folder. Check again to be sure that you have included all the requested information in Form 1, and be sure to take your copy of the first form, marked "Informed Consent" with you as you leave.

THANK YOU again for your participation.
After you have signed for and received your $10,
you are free to leave.

11.0 APPENDIX D

STATISTICAL ANALYSIS

Statistical Testing
Form 2A (Advance Sign)

	observed responses				estimated expected		
	correct	incorrect	row total		correct	incorrect	row total
TX	47	13	60	TX	47.33333	12.66667	60
MO	51	9	60	MO	47.33333	12.66667	60
ME	44	16	60	ME	47.33333	12.66667	60
Total	142	38	180	Total	142	38	180

Chi-squared (calc.) = 2.468495
Chi-squared (Table) = 5.992

Differences? = NO

Statistical Testing
Form 2A (Exit Directional Sign)

Chi-Squared Test

	observed responses				estimated expected		
	correct	incorrect	row total		correct	incorrect	row total
TX	43	17	60	TX	49	11	60
MO	54	6	60	MO	49	11	60
ME	50	10	60	ME	49	11	60
Total	147	33	180	Total	147	33	180

Chi-squared (calc.) = 6.90167
Chi-squared (Table) = 5.992

Differences? = YES

2 Sample Test of Proportions

	TX	MO	ME
Percentage Correct	0.716667	0.9	0.833333
Percentage Incorrect	0.283333	0.1	0.166667

	TX-ME	MO-ME
Calculated z value =	1.53026	1.074172
Tabulated z value =	1.645	1.645

Statistical Testing
Form 2B (Advance Sign)

	observed responses		
	correct	incorrect	row total
TX	54	6	60
MO	51	9	60
ME	54	6	60
Total	159	21	180

	estimated expected		
	correct	incorrect	row total
TX	53	7	60
MO	53	7	60
ME	53	7	60
Total	159	21	180

Chi-squared (calc.) = 0.97035
Chi-squared (Table) = 5.992

Differences? = NO

Statistical Testing
Form 2B (Exit Directional Sign)

	observed responses		
	correct	incorrect	row total
TX	54	6	60
MO	51	9	60
ME	56	4	60
Total	161	19	180

	estimated expected		
	correct	incorrect	row total
TX	53.66667	6.333333	60
MO	53.66667	6.333333	60
ME	53.66667	6.333333	60
Total	161	19	180

Chi-squared (calc.) = 2.236025
Chi-squared (Table) = 5.992

Differences? = NO

Statistical Testing
Form 3A (Advance Sign)

	observed responses		
	correct	incorrect	row total
TX	39	21	60
MO	55	5	60
ME	47	13	60
Total	141	39	180

	estimated expected		
	correct	incorrect	row total
TX	47	13	60
MO	47	13	60
ME	47	13	60
Total	141	39	180

Chi-squared (calc.) = 12.56956
Chi-squared (Table) = 5.992

Differences? = YES

2 Sample Test of Proportions

	TX	MO	ME
Percentage Correct	0.65	0.916667	0.783333
Percentage Incorrect	0.35	0.083333	0.216667

	TX-ME	MO-ME
Calculated z value =	1.62066	2.04524
Tabulated z value =	1.645	1.645
Different?	NO	YES

Statistical Testing
Form 3A (Exit Directional Sign)

	observed responses		
	correct	incorrect	row total
TX	34	26	60
MO	52	8	60
ME	49	11	60
Total	135	45	180

	estimated expected		
	correct	incorrect	row total
TX	45	15	60
MO	45	15	60
ME	45	15	60
Total	135	45	180

Chi-squared (calc.) = 16.53333
Chi-squared (Table) = 5.992

Differences? = YES

2 Sample Test of Proportions

	TX	MO	ME
Percentage Correct	0.566667	0.866667	0.816667
Percentage Incorrect	0.433333	0.133333	0.183333

	TX-ME	MO-ME
Calculated z value =	2.965118	0.750195
Tabulated z value =	1.645	1.645
Different?	YES	NO

Statistical Testing
Form 3B (Advance Sign)

	observed responses				estimated expected		
	correct	incorrect	row total		correct	incorrect	row total
TX	52	8	60	TX	33	27	60
MO	2	58	60	MO	33	27	60
ME	45	15	60	ME	33	27	60
Total	99	81	180	Total	99	81	180

Chi-squared (calc.) = 98.72054
Chi-squared (Table) = 5.992

Differences? = YES

2 Sample Test of Proportions

	TX	MO	ME	
Percentage Correct	0.866667	0.033333		0.75
Percentage Incorrect	0.133333	0.966667		0.25

	TX-ME	MO-ME
Calculated z value =	-1.62345	-8.04172
Tabulated z value =	1.645	1.645
Different?	NO	YES
Phat	0.808333	0.391667

Statistical Testing
Form 3B (Exit Directional Sign)

	observed responses				estimated expected		
	correct	incorrect	row total		correct	incorrect	row total
TX	53	7	60	TX	52.66667	7.333333	60
MO	52	8	60	MO	52.66667	7.333333	60
ME	53	7	60	ME	52.66667	7.333333	60
Total	158	22	180	Total	158	22	180

Chi-squared (calc.) = 0.103567
Chi-squared (Table) = 5.992

Differences? = NO

Statistical Testing
Form 3C (Advance Sign)

	observed responses		
	correct	incorrect	row total
TX	57	3	60
MO	9	51	60
ME	52	8	60
Total	118	62	180

	estimated expected		
	correct	incorrect	row total
TX	39.33333	20.66667	60
MO	39.33333	20.66667	60
ME	39.33333	20.66667	60
Total	118	62	180

Chi-squared (calc.) = 102.7939
Chi-squared (Table) = 5.992

Differences? = YES

2 Sample Test of Proportions

	TX	MO	ME
Percentage Correct	0.95	0.15	0.866667
Percentage Incorrect	0.05	0.85	0.133333

	TX-ME	MO-ME
Calculated z value =	-1.5818	-7.85178
Tabulated z value =	1.645	1.645
Different?	NO	YES

Statistical Testing
Form 3C (Exit Directional Sign)

	observed responses		
	correct	incorrect	row total
TX	53	7	60
MO	53	7	60
ME	52	8	60
Total	158	22	180

	estimated expected		
	correct	incorrect	row total
TX	52.66667	7.333333	60
MO	52.66667	7.333333	60
ME	52.66667	7.333333	60
Total	158	22	180

Chi-squared (calc.) = 0.103567
Chi-squared (Table) = 5.992

Differences? = NO