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# Studies to Improve Temporary Guide Signs in Work Zones

Technical Report 0-7046-R1

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Cooperative Research Program

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COLLEGE STATION, TEXAS

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Federal Highway Administration and the  
Texas Department of Transportation  
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16. Abstract This report documents the efforts and results of a one-year research project aimed at improving temporary guide signs in long-term work zones. The researchers held discussions with Texas Department of Transportation personnel to gather information about their experiences with temporary guide signs in work zones. The researchers also performed positive guidance assessments at 21 long-term work zones in Texas. Based on these two research activities, specific issues were identified and prioritized.  A human factors study was designed and administered to over 500 online participants. The goal of the study was to obtain driver feedback on practices related to the use of temporary lane guidance signs, strategies for exit lane drops, use of orange signs to provide guide sign information, and the location of the exit number on temporary guide signs. Based on the findings, the researchers developed guidelines and recommendations for improving temporary guide signs in long-term work zones.					
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# **STUDIES TO IMPROVE TEMPORARY GUIDE SIGNS IN WORK ZONES**

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## **DISCLAIMER**

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was LuAnn Theiss, P.E. #95917.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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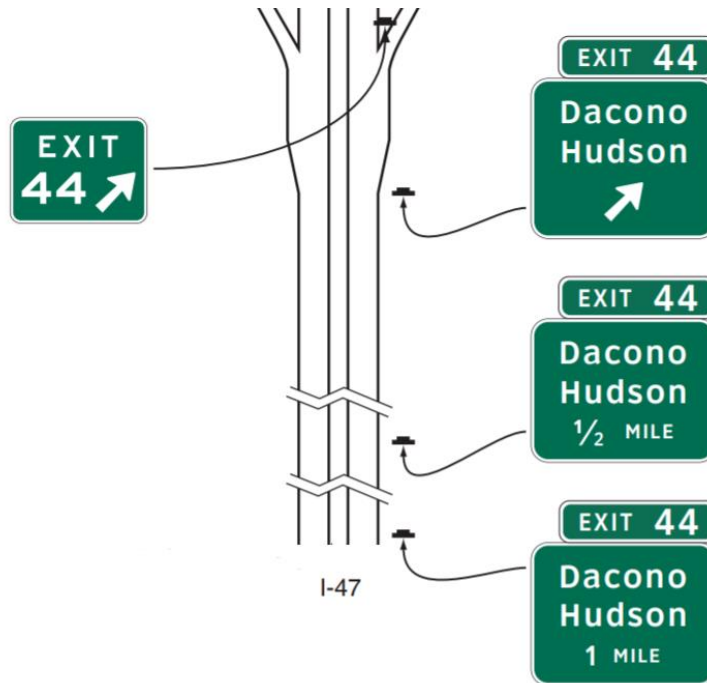
# CHAPTER 1: INTRODUCTION

## BACKGROUND

Freeway guide signs are primarily designed for the benefit and direction of road users who are not familiar with the route or area. The signs provide road users with clear instruction for orderly progress to their destination, which may include exiting the freeway. The *Texas Manual on Uniform Traffic Control Devices* (TMUTCD) (1) states that the basic requirements of all signs are that they be legible to motorist and understandable in time to permit a proper response. Desirable attributes include high visibility and legibility (i.e., adequately sized letters, symbols, or arrows, and a short legend for quick comprehension by motorists). Simplicity and uniformity in design, position, and application are important. In addition, standardized colors and shapes are specified for various types of signs so that different types of signs can be promptly recognized (e.g., guide signs are rectangular, and warning signs are diamond shaped). Sign design details can be found in the *Standard Highway Sign Designs* (SHSD) manual (2) and the *Freeway Signing Handbook* (FSH) (3).

Section 2E of the TMUTCD provides standards, support, and guidance for a uniform and effective system of signing freeways and expressways, including configuration, sequencing, and spacing of guide signs. Figure 1 shows an example of a sign sequence for an interchange exit ramp. The sequence typically includes:

- One or more *advance guide signs* that give notice well in advance of the exit point of the principal destinations served by the next interchange and the distance to that interchange (e.g., 1 mile or ½ mile).
- An *exit direction sign* that repeats the route and destination information that was displayed on the advance guide signs. This is intended to assure road users of the destination(s) served by the interchange. The arrow on the sign confirms whether the road user needs to exit to the right or left. The exit direction sign is normally placed at the beginning of the deceleration lane (if present) or at the beginning of the departure point.
- An *exit gore sign* that indicates the exiting point or place of departure from the main roadway. Consistent placement of this sign in the gore area is important for good guidance (1).



**Figure 1. Interchange Exit Ramp Sign Sequence from TMUTCD (I).**

Figure 2 shows examples of *pull-through signs*, which are overhead guide signs intended for through traffic (i.e., traffic not intending to exit the freeway). Pull-through signs should be used where the geometrics of a given interchange are such that it is not clear to the road user as to which lanes are the through roadway, or where additional route guidance is desired. The TMUTCD notes three situations where pull-through signs with down arrows should be used:

- Where the alignment of the through lanes is curved and the exit direction is straight ahead.
- Where the number of through lanes is not readily evident.
- At multi-lane exits where there is a reduction in the number of through lanes.



(a) Pull-through sign

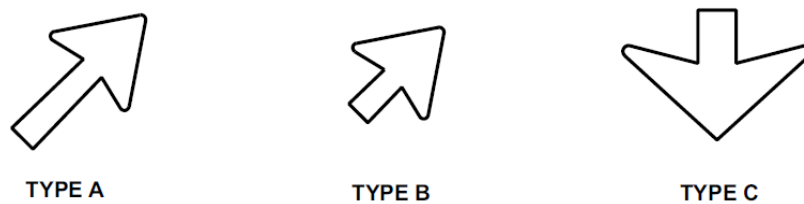


(b) Pull-through sign with down arrows

**Figure 2. Examples of Interchange Pull-Through Signs from TMUTCD (I).**

A closer look at Figure 1 and Figure 2 shows two different types of arrows that are used on guide signs. The FSH describes guide sign arrows in more detail, as shown in Figure 3 and summarized as follows:

- Type A arrows are upward-angled arrows that are primarily used on exit direction and exit gore signs where a single lane exits (as shown in Figure 1). The upward angle slants left or right, depending on the direction of the exit.
- Type B arrows are similar to Type A arrows, except shorter, and are used for multi-lane exit signs.
- Type C arrows are downward-pointing arrows that are used only on overhead guide signs to indicate the use of specific lanes to reach specific destination(s) or route(s) (as shown in Figure 2[b]). Type C arrows must not be used unless an arrow can point to each lane that can be used to reach the destination or route shown on the sign (2,3).



**Figure 3. Guide Sign Arrow Types from FSH (3).**

During freeway reconstruction projects, exit ramps are often temporarily relocated, and the interchange signs must be adjusted accordingly for the temporary conditions. For the design of temporary guide signs, Section 6F.55 refers to the design standards established for permanent guide signs in Part 2 of the TMUTCD (1). The only other standard that is included in this section requires that additional temporary guide signs used in work zones have a black legend and border on an orange background. Thus, most freeway work zones have both permanent (white legend and border on a green background) and temporary (black legend and border on orange background) guide signs mixed together. Regardless of color, the interchange sign sequence should remain the same while the work zone is present.

Lanes may also be shifted and no longer line up with the overhead pull-through signs during construction. When this happens, the overhead signs should be adjusted so that they do not provide inaccurate information or conflict with pavement markings. In other cases, the overhead sign structures must be removed to make way for construction, and guide sign information must be displayed using temporary guide signs that are placed along the roadside.

Ideally, all guide signs in work zones should conform to the standard established for permanent guide signs. However, freeway construction projects often have limited space available for large guide signs. The SHSD manual (2) states that the use of signs that are smaller than “nominal” size may sometimes be justified. When a variation in the sign size is necessary, a reduced letter

height, interline, and edge spacing may be used but should be as nearly comparable to standards as possible. Thus, smaller temporary guide signs may be designed, fabricated, and installed in some work zones. The TMUTCD assumes a legibility distance of 30 feet/inch (*l*). In other words, every 1-inch reduction in letter height reduces the available legibility distance of a sign by 30 feet, which then reduces the available time a motorist has to perceive and react to the information on the sign. Use of non-standard fonts can further reduce the legibility distance of the signs. Collectively, these losses in available perception-reaction time to a sign can contribute to last-minute lane changes by unfamiliar road users, which can create more turbulence in the flow of traffic through the interchange, as well as contribute to increased crash risk.

## **REPORT ORGANIZATION**

Chapter 1 contains the introduction for this report. Chapter 2 documents efforts made to identify specific problems with work zone guide signs. This includes documentation of the information-gathering discussions with Texas Department of Transportation (TxDOT) personnel, outcomes from the positive guidance assessments of guide signs in real work zones in Texas, and proposed research questions for the project. Chapter 3 documents the human factors study that was performed using an online survey. Chapter 4 includes guidelines and recommendations that were developed as a result of all the research findings. The appendix provides details of the experimental plan developed for the human factors study.



## **CHAPTER 2: PROBLEM IDENTIFICATION**

### **METHODOLOGY**

To address real-world issues faced by TxDOT regarding temporary guide signs in freeway work zones, the research team sought to identify the major problems and challenges. This was accomplished by:

- Having discussions (via phone) with TxDOT district personnel who manage freeway construction projects.
- Conducting positive guidance assessments of freeway work zones around the state.

### **DISCUSSIONS WITH TXDOT DISTRICT PERSONNEL**

A written discussion guide was developed to ensure that respondents were asked the same questions. The discussion questions were as follows:

- How and by whom are temporary guide signs designed on your freeway construction projects?
- What are some of the challenges faced with designing, fabricating, and installing those signs?
- Do you have any ideas about how those problems could be solved?
- Are there any work zones in Texas that you think we should review during this research project?

The research team used TxDOT's online Project Tracker (4) to identify TxDOT personnel that were managing freeway reconstruction projects in urban areas (where conditions are typically more constrained and work zones tend to be more complex, particularly at freeway interchanges). The researchers completed 13 discussions by phone with personnel from the Austin, Bryan, Fort Worth, Houston, San Antonio, Tyler, and Waco Districts. Individual responses to the questions were recorded and are summarized as follows:

- Sign design process:
  - Signs are typically included in the plans, designed by TxDOT or the consultant.
  - Sometimes existing (permanent) guide signs can be relocated.
  - Sometimes portable changeable message sign (PCMS) messages are used in lieu of temporary guide signs.
  - Sometimes smaller fonts or sign sizes may be used if the work zone has space constraints.

- Design challenges:
  - Sometimes both TxDOT and the contractor might miss the need for a temporary guide sign during an upcoming phase or traffic shift.
  - If a necessary sign was not designed and included in the plan set, TxDOT can quickly create a computer-aided design (CAD) file and provide it to the contractor.
- Fabrication challenges:
  - If a necessary sign was not included in the plan set, it often must be fabricated quickly.
- Installation challenges:
  - Many temporary guide signs are located behind barriers, so crashworthiness is not an issue.
  - Sometimes when lane widths are reduced, there is little or no shoulder available for placement of signs.
  - Larger signs on sandbag-ballasted T-leg posts can be knocked down by passing traffic or blown over by wind.
- Solutions:
  - Large signs can typically be fabricated in seven to ten days.
  - PCMS messages can be used temporarily until a static sign is designed, fabricated, and installed.
- Work zones to review:
  - None of the respondents suggested work zones that they felt should be included in this research project.

## **POSITIVE GUIDANCE ASSESSMENTS OF FREEWAY WORK ZONES**

In November 2019, the research team downloaded a list of 16,312 projects from TxDOT's online Project Tracker (4). The downloaded list was sorted and reduced to active freeway construction projects that were currently under way. The research team then focused on projects that involved widening the road, adding lanes, or constructing frontage roads. Greater attention was given to those projects located in urban districts. Twenty-one sites, shown in Table 1, were selected for inclusion in the positive guidance assessments.

The researchers developed and used a standardized data collection form to document basic project information for each site. The researchers visited each site, drove through the work zone, and documented the work zone conditions. A dash-mounted, in-vehicle video camera documented driver views of the work zone conditions as the researchers made several passes through the work zone from various approaches. In addition, global positioning system (GPS) locations of various points of interest (i.e., guide signs, pavement markings, and work zone signs) were recorded. This was accomplished by connecting a GPS receiver to a laptop and using a program that continuously captured the GPS coordinates in a text file. The researchers used

laptop keystrokes to mark the desired locations in the file. The video and GPS data were stored so that they could be reviewed in the office at a later date.

**Table 1. Projects Selected for Positive Guidance Assessments.**

Site No.	Freeway	District	Project Number	Work Type	Project Length (Miles)
1	US-69	Beaumont	020011095	Add lanes	3.6
2	US-69	Beaumont	006507062	Add lanes	2.3
3	US-59	Houston	002712105	Add lanes	3.2
4	US-59	Houston	002712106	Add lanes	4.1
5	US-59	Houston	008909058	Add lanes	2.3
6	US-59	Houston	008909065	Add lanes	2.9
7	US-59	Houston	008909066	Add lanes	3.5
8	US-59	Houston	008909067	Add lanes	2.2
9	IH-10	Houston	027104071	Add lanes	5.8
10	IH-10	Yoakum	027103046	Add lanes	3.0
11	IH-10	Yoakum	027103060	Add lanes	3.4
12	IH-10	Yoakum	027103061	Add lanes	1.0
13	IH-10	Yoakum	027102055	Add lanes	2.8
14	IH-10	Yoakum	027102049	Add lanes	6.9
15	US-183	Austin	026501080	Construct toll lanes	1.3
16	IH-35	Austin	001513379	Add shoulders and auxiliary lanes	1.7
17	SH-130	Austin	044006018	Add lanes	11.2
18	IH-45	Bryan	067507096	Add lanes	6.7
19	IH-45	Bryan	067507101	Add lanes	5.7
20	IH-30	Fort Worth	106802076	Interchange reconstruction	2.7
21	IH-820	Fort Worth	000813179	Replace bridges	0.1

The researchers analyzed the work zone documentation dataset to identify work zone guidance issues. The most notable issues with the work zone guide signs included:

- Substandard sign design.
- Inconsistent sequence and placement of signs
- Improper use of overhead guide signs.
- Information overloading.

Each of these issues is discussed, and examples found in the work zones are provided.

### **Substandard Sign Design**

Figure 4 shows an example of a sign with a smaller legend. In this case, limited space was available for sign deployment. In this phase of construction, the exit ramps for all three arterials

were combined into a single exit ramp. In addition, the exit number is typically shown on a separate plaque mounted at the top of the sign, as shown in Figure 1.



**Figure 4. Exit Direction Sign with Smaller Legend.**

Figure 5 shows two signs that appear to be providing guidance information, but these signs are diamond-shaped, like typical work zone warning signs. Warning signs are used to notify road users of specific situations or conditions that might not otherwise be apparent. This does not include destination information. The shape of these signs is inconsistent with guide sign expectations. Thus, motorists looking for guidance information may not expect to find it on signs of this shape.



(a) Advance guide sign



(b) Exit direction sign

**Figure 5. Temporary Guide Sign Information on Diamond-Shaped Signs.**

## Inconsistent Sequence and Placement of Signs

Several work zones were deficient in displaying the standard sequence of exit signs (i.e., advance guide sign, exit direction sign, and exit gore sign). In one case, there was no advance guide sign present upstream of the exit direction and exit gore signs (shown in Figure 6). A review of project progress and online mapping indicates that the exit has not changed locations but that the existing permanent sign was likely removed to make way for construction. The researchers believe that a temporary advance guide sign was present in a previous phase but was not upright (Figure 7). Signs being blown over or knocked over were a concern that came out of the discussions with TxDOT district personnel. Nonetheless, the advance guide sign was not present when the researchers visited the work zone. The absence of this sign may leave drivers unprepared for the exit and create last-minute decisions near the gore area.

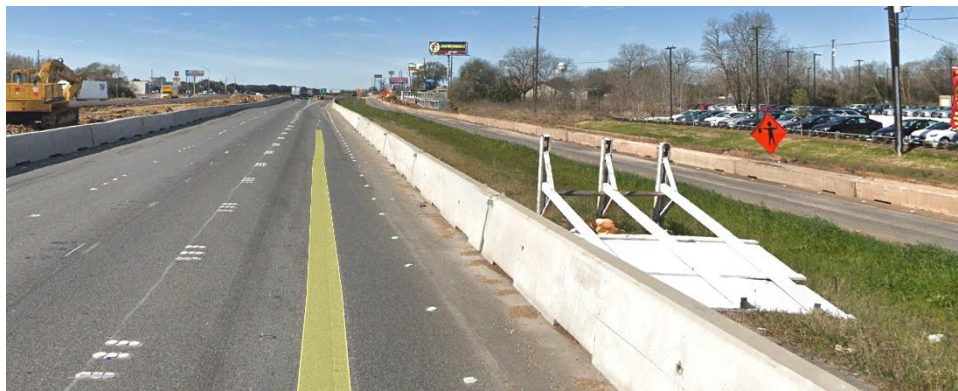


(a) Exit direction sign



(b) Exit gore sign

**Figure 6. Advance Guide Sign Missing from Sign Sequence.**



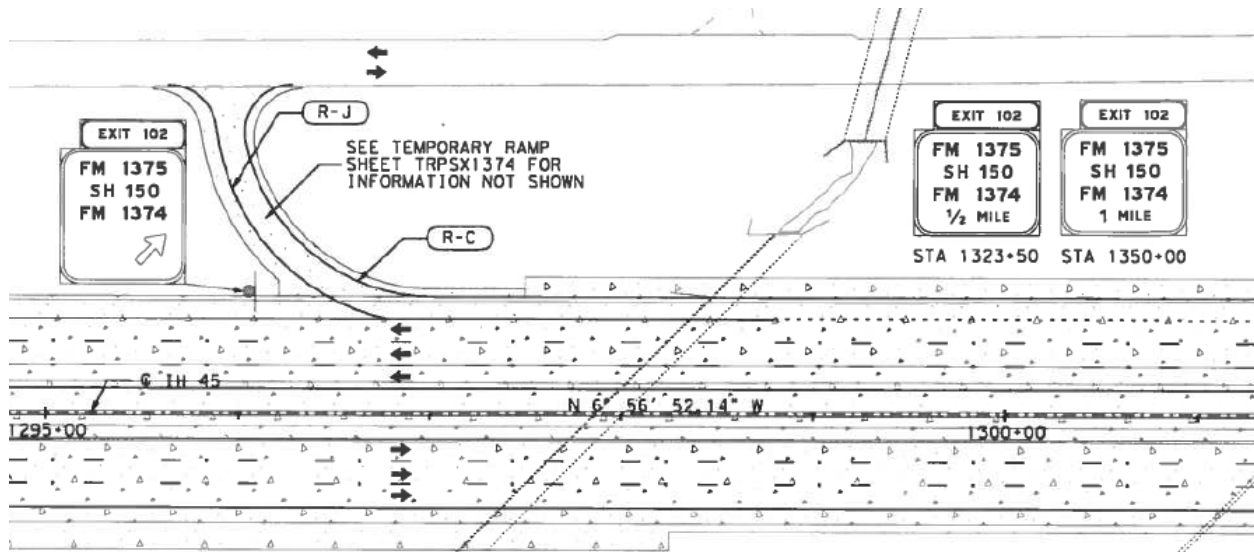
**Figure 7. Advance Guide Sign in January 2019 (5).**

Figure 8 shows another example. In this case, the exit ramp locations for all three roadways had been moved to a single exit. The images in Figure 8(a) and (b) show the advance guide signs, while Figure 8(c) shows the exit direction sign located where the exit gore sign typically would have been placed. A review of the constructions plan sheets for this project showed that the signs were placed in accordance with those plans (Figure 9). It is not known if a lack of space where the exit direction sign would have normally been placed led the designers to move the sign to the exit gore sign location. However, this sign location significantly violates driver expectancy, given that drivers normally see this sign before the need to make an exit maneuver.



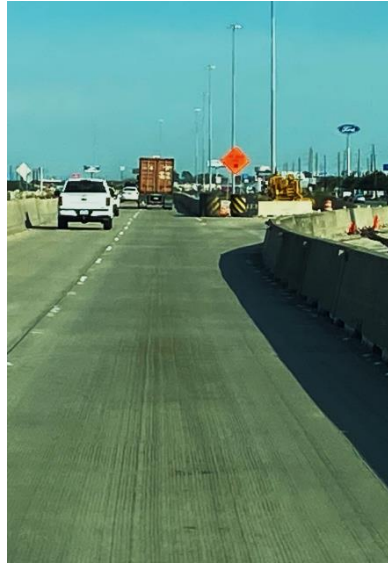
(a) First advance guide sign      (b) Second advance guide sign      (c) Exit direction sign

**Figure 8. Placement of Exit Direction Sign in Exit Gore.**



**Figure 9. Construction Plans Showing Placement of Exit Direction Sign.**

Another example (Figure 10) shows the exit direction sign placed in the gore area. The use of a smaller font decreased the legibility of the sign. Also, the exit gore sign was fabricated using a diamond shape instead of the rectangular shape that would normally be used for guide signs. Both of these factors violate driver expectancy.



(a) FM 2218 exit area



(b) Exit gore sign

**Figure 10. Improper Placement and Substandard Design of Exit Direction Sign.**

In one work zone, two exits were closed, and this traffic was being temporarily diverted to another exit ramp located several miles upstream. The temporary advance guide signs for exits 112 and 113, shown in Figure 11(a), were located approximately 0.3 miles upstream of the permanent advance guide sign for exit 109, shown in Figure 11(b). Given the spacing between the advance guide signs, it is not known if motorists understand that a single exit is in use for all destinations and routes on these signs.



(a) Exits 112 and 113



(b) Exit 109

**Figure 11. Advance Guide Signs for Exit 109.**

The temporary exit direction signs for exits 112 and 113, shown in Figure 12(a), were located much closer (approximately 700 feet) to the permanent exit direction sign for exit 109, shown in Figure 12(b). It is not known if maintaining the original exit number(s) on temporary signs that move around is better understood by motorists than changing the exit number to match the new exit location (e.g., exit 109).



(a) Exits 112 and 113



(b) Exit 109

**Figure 12. Exit Direction Signs for Exit 109.**

Figure 13 shows the exit gore sign for exit 109. It is not known if motorists understand that this is also the appropriate exit point for exits 112 and 113.



**Figure 13. Exit Gore Sign for Exit 109.**

### **Improper Use of Overhead Signs on the Roadside**

Figure 14 and Figure 15 show some lane guidance signs found at one of the work zones. In Figure 14, the sign with two down arrows was located on the roadside of a four-lane freeway section. While this sign is similar to a pull-through sign, down arrows are only allowed on overhead signs (where there is one arrow per lane). In Figure 14, it is not clear to which lanes the signs are referring. In Figure 15, the sign with two up arrows was located on the roadside of



another four-lane freeway section. While this sign is similar to an overhead arrow-per-lane sign, it does not conform to any guide sign standard found in the TMUTCD.



**Figure 14. Temporary Lane Guidance Sign with Down Arrows Used on Roadside.**



**Figure 15. Temporary Lane Guidance Sign with Up Arrows Used on Roadside.**

In another example at the same work zone, temporary lane guidance signs were located on both sides of the road (Figure 16). In this case, the intent of the signs is to provide one arrow per lane (i.e., two left lanes for SH-71 and two right lanes for US-183). It is unclear if this signage would be as effective in heavier traffic (where motorists may not be able to see both signs at the same time).



**Figure 16. Temporary Lane Guidance Signs at Interchange Exit.**

### **Information Overloading**

Figure 17 shows an overhead guide sign that appears to provide information for seven destinations or routes. In this case, the construction project included two different cities, which had each independently assigned street names to their respective segments of these arterials. Previous research performed at the Texas A&M Transportation Institute (TTI) indicated that motorists' route-selection accuracy decreases as the number of route choices increases (6). In addition, TMUTCD and FSH guidelines state that no more than two destination names or street names should be shown on any advance guide sign or exit direction sign (1,3).



**Figure 17. Information Overloading on Temporary Guide Sign.**

### **POTENTIAL RESEARCH QUESTIONS**

The various issues identified during the field review do indicate a need for specific guidance tailored to the development and implementation of temporary guide signing for freeway work zones. For many of the issues observed, existing guidance and previous research can be used to generate work-zone-specific guidance. For example, decisions on using smaller letter heights for

signing should be based on the amount and type of information to be included on the sign to ensure that unfamiliar drivers are able to scan through all the information within the available legibility distance of the sign. Legibility distance is also critical when attempting to use temporary roadside guide signs to convey lane information on multi-lane freeway sections because signs become ineffective once they are beyond 10 degrees from the driver's line of sight out of the windshield. However, a few issues need additional research to better understand their implications upon the driving public. Based on the discussions with TxDOT personnel and information obtained through the work zone positive guidance assessments, the researchers developed a list of key issues for further study:

- The use of temporary lane guidance signs (with arrows) for work zone lane assignments.
- Strategies for signing exit lane drops.
- The use of orange signs to provide guide sign information.
- The combination of the exit number with other information on guide signs.
- Font selection for guide signs.

Specific study questions were developed for the human factors study that is described in the following chapter of this report.



## **CHAPTER 3: HUMAN FACTORS STUDY**

### **INTRODUCTION**

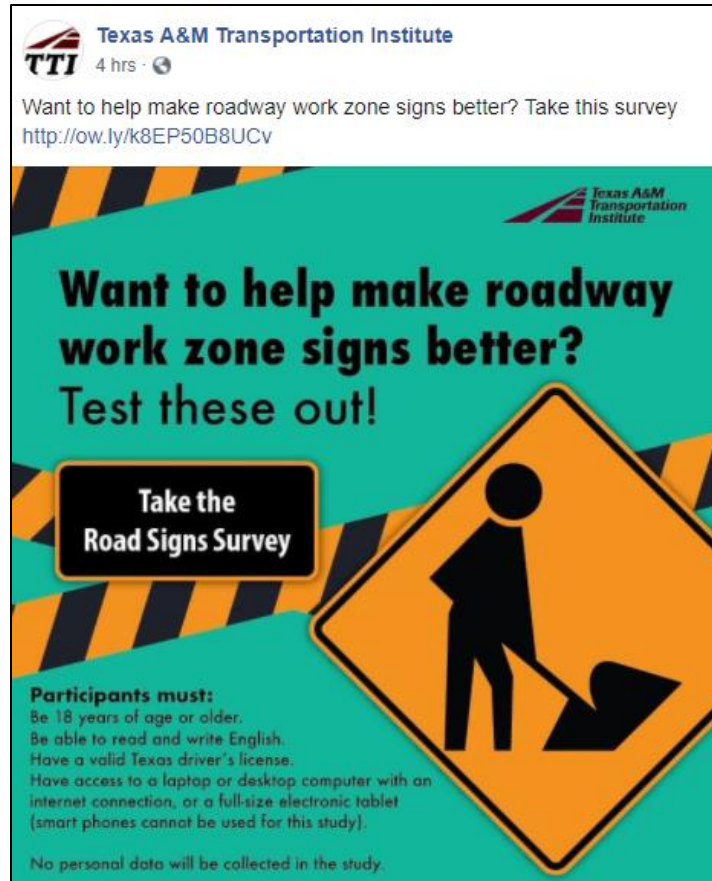
Based on the work zone guide sign issues previously identified and prioritized, the researchers determined that the following questions should be addressed in the human factors study:

- What are the impacts of using temporary lane guidance signs (with arrows) placed on the roadside for lane assignment?
- What are effective strategies for signing exit lane drops in work zones?
- What are the differences in driver responses between using signs with black legend on orange background versus white legend on green background?
- What are the impacts of combining the exit number with other information on advance guide and exit direction signs (i.e., all information on one sign instead of using a plaque)?
- What are the differences in driver responses between using mixed-case (uppercase and lowercase) letters versus all capital letters on exit signs?

### **METHODOLOGY**

Researchers originally planned to prepare and conduct in-person computer-based evaluations to obtain feedback from 100 drivers regarding the various alternatives for work zone guide signs. Each participant was to be paid \$50 for completing the survey. COVID-19 restrictions prohibited researchers from administering the evaluations in person as originally planned. Instead, the evaluation protocol was changed to allow online survey administration using online survey software. Participants who successfully completed the survey were not compensated because the anticipated completion time was no more than 15 minutes. Researchers revised the evaluation protocol, which The Texas A&M University System's Human Research Protection Program (HRPP) reviewed and approved. All questions in the survey were designed to help researchers understand the participants' preferences regarding different sign layouts or understanding of guidance being conveyed by the sign(s).

Survey participants were recruited using social media posts on TTI's public information accounts, as shown in Figure 18. In order to qualify for the survey, participants were required to be drivers licensed in Texas, over 18 years of age, able to understand English, and able to complete the survey from a computer or tablet. Smartphone screens were not allowed since the images used in the survey would likely not be legible on small devices.



**Figure 18. Social Media Post to Recruit Study Participants.**

As required by the HRPP-approved protocol, interested respondents who followed the survey link were provided information about the study and then asked to provide their consent to participate in the study. The study information included the title of the study survey (i.e., Designing Work Zone Guide Signs), the principal investigator's name and contact information, a brief explanation of the study, and an explanation of how the information would be used. The study information page also provided an opportunity for the respondent to provide consent to participate. If the respondents agreed to participate, the next page asked a series of questions to determine their eligibility to participate in the study. Figure 19 shows the eligibility questions and response choices. Participants were asked to provide their age group and gender, and then verify that they had a valid Texas driver license. They were also asked what type of device they were using to complete the survey.

What is your age? Please select your age category below.

18-24
25-34
35-44
45-54
55-64
65-74
75-84
85+

(a) Participant age group

Are you male or female?

Male
Female
Prefer not to answer

(b) Participant gender

Do you hold a valid Texas driver's license?

Yes
No

(c) Participant driver licensing

Are you completing this survey on a laptop or desktop computer, OR on a full-size electronic tablet?

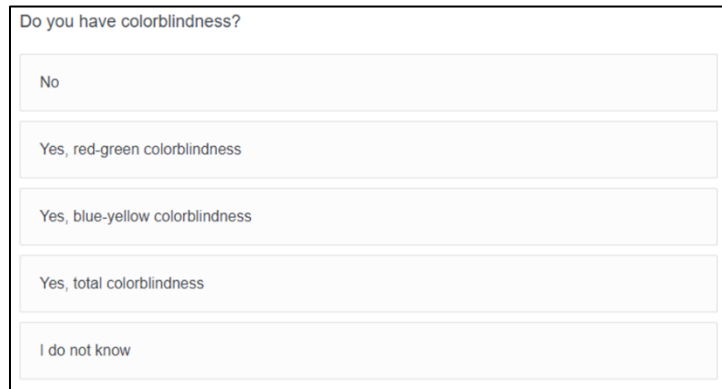
Yes, laptop computer
Yes, desktop computer
Yes, full size electronic tablet
No

(d) Participant device utilization

**Figure 19. Eligibility Questions and Responses.**

If any questions were answered in a manner that would disqualify the respondents from participating, they were shown a screen notifying them of their disqualification and thanking them for their time. If all questions were answered in a manner that qualified the respondents, they were accepted as participants in the study.

Participants were also asked if they had any type of colorblindness. Any response for this question was acceptable, and participants were not disqualified if they had any colorblindness. One of the questions in the survey pertained to sign color, and researchers wanted to have the ability to analyze those responses with respect to participant colorblindness.



Do you have colorblindness?

No

Yes, red-green colorblindness

Yes, blue-yellow colorblindness

Yes, total colorblindness

I do not know

**Figure 20. Colorblindness Question and Responses.**

The qualified participants were then shown sample questions prior to completing the survey. The sample questions were used to show participants the format and timing of the survey questions. Each sample question included an introduction that explained what the participants needed to look for in the image, namely lane position and sign information. This was important because several survey questions included images that were displayed on the screen for a very short period of time (3 seconds). All participants saw the same sample questions. Figure 21 and Figure 22 show the introductions, images, and two-part questions with response choices.



On the next screen, you will see a "driver's view" of a 4-lane freeway and a road sign. Look for the lane you (the driver) are in, and the information on the sign.

You will see the picture for 3 seconds. Click the arrow to proceed.



(a) Introduction



(b) Image shown for 3 seconds

What was the name of the destination on the exit sign?

Glennon

Golden

Glidden

Gadsden

Not sure

(c) Part 1 question with response choices

What lane position was the driver in?

Left lane

2nd lane from the left

2nd lane from the right

Right lane

(d) Part 2 question with responses choices

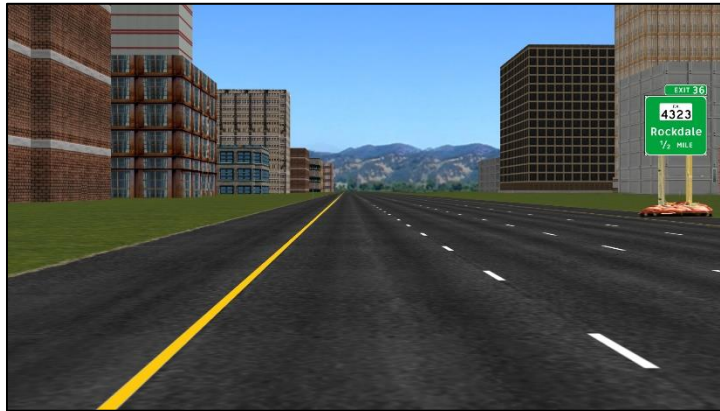
**Figure 21. Sample Question A.**

On the next screen, you will see a "driver's view" of a 4-lane freeway and a road sign. Look for the **lane you (the driver) are in**, and the **information on the sign**.

You will see the picture for 3 seconds. Click the arrow to proceed.



(a) Introduction



(b) Image shown for 3 seconds

What was the name of the destination on the exit sign?

Riverdale

Rochester

Richardson

Rockdale

Not sure

(c) Part 1 question with response choices

What lane position was the driver in?

Left lane

2nd lane from the left

2nd lane from the right

Right lane

(d) Part 2 question with responses choices

**Figure 22. Sample Question B.**

Upon completion of the sample questions, participants were presented with a series of survey questions. The survey was constructed to investigate driver understanding of the following:

- Four different designs of roadside work zone interchange signing:
  - Using two separate roadside signs (one with associated lane arrows for each leg of the interchange on the appropriate side of the freeway for that leg) versus showing all of the lane arrows for both legs of the interchange on the same roadside sign.
  - Showing the lanes that are exiting with and without a yellow EXIT ONLY plaque.
- Two different designs for work zone advance guide signs:
  - Using separate plaques for exit numbers.
  - Embedding the exit number into the advance guide sign.
- A traditional white-on-green exit gore sign versus a black-on-orange exit gore sign.


Participants were shown two versions of the roadside interchange signing designs, one where the sign contains arrows for all lanes and the other where only partial lanes are shown (the assumption is that the arrows for the other lanes on the opposite side of the freeway are obscured by traffic in adjacent lanes or simply not seen by the participant driver). Figure 23 and Figure 24 show examples. Participants were also shown two versions of the work zone advance guide sign, one with the exit number on a separate plaque and the other with the exit number embedded in the sign. Figure 25 and Figure 26 show examples. Participants were shown only one version of the exit gore sign, as shown in Figure 27.

For each sign design being tested, the research team identified the various combinations of decisions and behaviors that would be possible. For example, a driver approaching an interchange in a given lane may be in the correct lane for staying on the current route or may have to change lanes to remain on that route. The same could exist for a driver who needs to take the exit lanes to the other roadway. For the advance guide sign designs, the driver may be looking for the cross-street name or be looking for an exit number. In some cases, the sign may indicate the exit that the driver needs to take or may indicate a different exit such that the driver would need to remain on the roadway and not exit. Randomization of all driver behaviors and the different sign designs (taken five at a time for each participant) yielded 144 different test scenarios. These were all programmed into the survey software that sequenced through each scenario to assign one to each survey participant.

On the next screen, imagine that you are traveling on **State Highway 71**, in the **2nd lane from the right**.

You want to **stay on State Highway 71**.

You will see the picture for 3 seconds. Click the arrow to proceed.




(a) Introduction



(b) Image shown for 3 seconds

Based on the sign you saw, do you need to change lanes to stay on State Highway 71?




(c) Question with response choices

**Figure 23. Temporary Lane Guidance Sign (with Arrows for All Lanes) Question.**

On the next screen, imagine that you are traveling on **Interstate 10 (I-10) East**, in the **right lane**.

You want to **exit onto I-45 South**.

You will see the picture for 3 seconds. Click the arrow to proceed.



(a) Introduction



(b) Image shown for 3 seconds

Based on the sign you saw, do you need to change lanes to exit onto I-45 South?

No


Yes, I need to move one lane to the right

Yes, I need to move two lanes to the right

Yes, I need to move one lane to the left

Yes, I need to move two lanes to the left

Not sure




(c) Question with response choices

**Figure 24. Temporary Lane Guidance Sign (with Arrows for Some Lanes) Question.**

On the next screen, imagine that you are traveling on the road shown and you plan to exit onto Sandy Road.

You will see the picture for 3 seconds. Click the arrow to proceed.



(a) Introduction



(b) Image shown for 3 seconds

Based on the sign you saw, will you exit in 1 mile?

Yes

No


Not sure

(c) Part 1 question with response choices

What was the exit number on the sign?

Exit number:

I don't remember the exit number.




(d) Part 2 question with responses choices

**Figure 25. Advance Guide Sign (with Exit Number on Separate Plaque) Question.**

On the next screen, imagine that you are traveling on the road shown and you plan to take **Exit 101**.

You will see the picture for 3 seconds. Click the arrow to proceed.



(a) Introduction



(b) Image shown for 3 seconds

Based on the sign you saw, will you exit in 1 mile?

Yes

No

Not sure

(c) Part 1 question with response choices

What was the road name on the sign?

Road name:

I don't remember the road name.




(d) Part 2 question with response choices

**Figure 26. Advance Guide Sign (with Exit Number Embedded) Question.**

On the next screen, you will see a picture of a **sign at a freeway exit**, followed by two questions about the sign.

There is no time limit; you can look at the sign for as long as you need to answer the questions. Click the arrow to proceed.



(a) Introduction



(b) Image shown with unlimited viewing time

Why do you think that this exit sign is orange instead of green? Rank the following statements from Most Likely (top of list) to Least Likely (bottom of list) by dragging the responses into order.

- 1** The exit ramp is in a new location, and permanent signs have not been installed yet.
- 2** The exit ramp is in the same place it always has been, but I need to watch out for work on or near the exit ramp roadway.
- 3** The exit ramp is in the same place it always has been, but the old exit sign had to be taken down because of work on the main travel lanes, so a temporary sign has been put up.


(c) Part 1 question with response choices

Do you have a preference for one sign color or the other, if the exit is in a work zone?  
(Select ONE of the following.)

I prefer the orange sign, because (specify):

I prefer the green sign, because (specify):

I do not have a preference (comment if you wish):



(d) Part 2 question with responses choices

**Figure 27. Exit Gore Sign Question.**



Upon completion of the final survey question, all participants were shown a page thanking them for their time and input. The survey software stored participant responses so that researchers could later download the complete dataset.

## DATA REDUCTION

Overall, 604 respondents began the survey, answering the age group and gender questions. Sixteen respondents were disqualified because they either failed to answer the licensing question or answered the question by indicating that they did not have a valid Texas driver license. Another 83 respondents were disqualified because they indicated that they were not completing the survey on a laptop, desktop computer, or full-size tablet. Of the remaining respondents, 509 completed some or all of the survey questions.

### Survey Demographics

Table 2 shows a comparison of the demographic distribution of licensed Texas drivers, estimated from data on the Federal Highway Administration website (7) to the demographic data of the survey participants. Overall, the survey dataset contained a higher percentage of females than males, but the age group distribution was fairly well correlated.

**Table 2. Demographic Comparison of Licensed Texas Drivers and Survey Participants.**

Age Group	Percentage of Licensed Drivers			Percentage of Survey Participants		
	Male	Female	Total	Male	Female	Total
18–24	5	5	10	4	11	15
25–34	10	10	20	7	8	15
35–44	9	9	18	8	11	19
45–54	8	9	17	6	12	18
55–64	8	9	17	9	10	19
65–74	5	5	10	5	5	10
75–84	2	3	5	2	2	4
85+	1	1	2	<1	0	<1
Total	49	51	100	41	59	100

Six male participants indicated that they had some degree of red-green colorblindness. A review of their responses to the survey did not indicate any reasons to disqualify their answers from being included in the survey dataset.

### Temporary Lane Guidance Signs for Roadside Use

Table 3 describes the roadside temporary lane guidance sign scenarios used in the survey.

**Table 3. Temporary Lane Guidance Sign Scenarios Used in the Survey.**

Scenario	Sign Style	Exit Side	Sign Placement (Side of Road)	Lanes (Some or All)	Exit-Only Plaque	Lane Position <sup>1</sup>	Action Instructed to Take
A		Left	Left	Some	No	2	Exit
B		Left	Left	Some	No	2	Stay
C		Left	Left	Some	Yes	2	Exit
D		Left	Left	Some	Yes	2	Stay
E		Left	Right	Some	No	4	Exit
F		Left	Right	Some	No	4	Stay
G		Left	Left	All	No	1	Exit
H		Left	Left	All	No	1	Stay
I		Left	Right	All	No	3	Exit
J		Left	Right	All	No	3	Stay
K		Left	Left	All	Yes	1	Exit
L		Left	Left	All	Yes	1	Stay
M		Left	Right	All	Yes	3	Exit
N		Left	Right	All	Yes	3	Stay
O		Right	Left	Some	No	2	Exit
P		Right	Left	Some	No	2	Stay
Q		Right	Right	Some	No	4	Exit
R		Right	Right	Some	No	4	Stay
S		Right	Right	Some	Yes	4	Exit
T		Right	Right	Some	Yes	4	Stay
U		Right	Left	All	No	1	Exit
V		Right	Left	All	No	1	Stay
W		Right	Right	All	No	3	Exit
X		Right	Right	All	No	3	Stay
Y		Right	Left	All	Yes	1	Exit
Z		Right	Left	All	Yes	1	Stay
AA		Right	Right	All	Yes	3	Exit
BB		Right	Right	All	Yes	3	Stay

<sup>1</sup> Lane position: 1 = far left, 2 = center left, 3 = center right, 4 = far right.

Sign scenario variations included factors such as:

- The side of the road that was exiting (left or right).
- The side of the road where the sign was located (left or right).
- The presence of an EXIT ONLY plaque on the sign (yes or no).
- The lane position shown to the participant (1, 2, 3, or 4).
- The action that the participant was instructed to take.

The experimental plan was developed to ensure that the responses to similar questions were merged and that proper statistical comparisons could be made. For example, scenarios A and Q present similar situations that require similar responses, with the only variation being which side of the road the exit and sign were located on. The appendix of this report provides experimental plan details.

The researchers first examined the temporary lane guidance signs with no EXIT ONLY plaques present. The signs with all lanes shown were compared to the signs with some lanes shown. A z-test of proportions was performed (with  $\alpha = 0.05$ ) to determine if the percentage of correct answers was statistically the same or different. Table 4 shows the results.

**Table 4. Comparison of Temporary Lane Guidance Signs without EXIT ONLY Plaques.**

Action to Take	Lane Change Required	All Lanes		Some Lanes			Statistical Significance
		Number of Responses	Percent Correct	Arrows Shown	Number of Responses	Percent Correct	
Exit	No	60	90.0	Exit lanes	83	84.3	No
Exit	Yes	65	89.2	Through lanes	79	13.9	Yes
Stay	No	56	85.7	Through lanes	82	89.0	No
Stay	Yes	57	89.5	Exit lanes	84	66.7	Yes

The percentage of correct responses was high when arrows were shown for all lanes. For example, correct percentages of 90.0, 89.2, 85.7, and 89.5 indicate a good understanding of the temporary lane guidance sign, regardless of the action participants were instructed to take and whether or not a lane change was required for that action. There was no statistically significant difference in the percentage of correct answers given when participants were shown the temporary lane guidance arrows for the action they were instructed to take, even on the signs that only showed some lanes (90.0 percent for signs with all lanes compared to 84.3 percent for signs with some lanes, and 85.7 percent for signs with all lanes compared to 89.0 percent for signs with some lanes). However, the difference in percentage of correct responses is quite significant when participants were shown only the temporary lane guidance arrows for the action they were not instructed to take. For example, 13.9 percent were correct for exiting when only the through-lane arrows were showing, and 66.7 percent were correct for staying on the through lanes when

only the exit lanes were showing. Thus, there was less certainty about whether or not they should change lanes to take the required action when the arrows were not present to confirm that choice.

Next, the researchers examined the temporary lane guidance signs with the EXIT ONLY plaques present over the exit lanes. The signs with all lanes shown were compared to the signs with some lanes shown. Table 5 shows the results.

**Table 5. Comparison of Temporary Lane Guidance Signs with EXIT ONLY Plaques.**

Action to Take	Lane Change Required	All Lanes		Some Lanes			Statistical Significance
		Number of Responses	Percent Correct	Arrows Shown	Number of Responses	Percent Correct	
Exit	No	59	86.4	Exit lanes	79	77.2	No
Exit	Yes	68	85.3	N/A	N/A	N/A	N/A
Stay	No	69	84.1	N/A	N/A	N/A	N/A
Stay	Yes	55	76.4	Exit lanes	78	53.9	Yes

Again, the percentage of correct responses was fairly high when arrows were shown for all lanes and the yellow EXIT ONLY plaque was added for the exit lanes. For example, correct percentages of 86.4, 85.3, 84.1, and 76.4 indicate a good understanding of the temporary lane guidance sign. There was no statistical significance between 86.4 and 76.4 percent. There were no data points for the temporary lane guidance signs with only through lanes because the EXIT ONLY plaques are not mounted to these signs. Thus, when signs with arrows for only some lanes were shown, those were the exit lane arrows. For questions where the participant was asked to take the exit and saw the EXIT ONLY plaque over their lane (i.e., no lane change required), there was no difference in the percentage of correct responses between signs with all lanes shown (86.4 percent) compared to signs with some lanes shown (77.2 percent). However, again, the difference in the percentage of correct responses is quite significant when participants were shown only exit-lane arrows and needed to change lanes to stay on the through lanes as instructed. When the temporary lane guidance sign showed all lanes, 76.4 percent of responses were correct, compared to just 53.9 percent of responses when the temporary lane guidance sign showed only the exit lanes. Thus, even with the addition of the EXIT ONLY plaque, there was still less certainty about whether or not participants should change lanes to take the required action when the arrows were not present to confirm that choice.

The researchers examined the temporary lane guidance signs showing all lanes with and without EXIT ONLY plaques. Table 6 shows the results.

**Table 6. Comparison of Temporary Lane Guidance Signs Showing All Lanes with and without EXIT ONLY Plaques.**

Action to Take	Lane Change Required	With		Without		Statistically Significance Difference
		Number of Responses	Percent Correct	Number of Responses	Percent Correct	
Exit	No	59	86.4	60	90.0	No
Exit	Yes	68	85.3	65	89.2	No
Stay	No	69	84.1	56	85.7	No
Stay	Yes	55	76.4	57	89.5	No

There were no differences in the percentage of correct responses between temporary lane guidance signs showing all lanes with and without the EXIT ONLY plaques. Thus, the addition of the EXIT ONLY plaque really had no impact if arrows for all lanes are shown on the temporary lane guidance sign. This survey did not evaluate scenarios that included “option lanes” (i.e., where a shared lane for both the through lane and an exit lane was present).

The researchers examined the temporary lane guidance signs showing only exit lanes with and without EXIT ONLY plaques. Table 7 shows the results.

**Table 7. Comparison of Temporary Lane Guidance Signs Showing Only Exit Lanes with and without EXIT ONLY Plaques.**


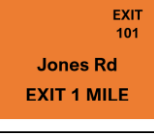


Action to Take	Lane Change Required	With		Without		Statistically Significance Difference
		Number of Responses	Percent Correct	Number of Responses	Percent Correct	
Exit	No	79	77.2	83	84.3	No
Stay	Yes	78	53.9	84	66.7	No

When participants viewed signs showing only the exit lanes (and not the through lanes), the addition of the EXIT ONLY plaque did not have a significant impact on the percentage of correct answers to those questions.

### **Advance Guide Signs**

Table 8 describes the advance guide sign scenarios used in the survey.

**Table 8. Advance Guide Signs Used in the Survey.**

Scenario	Sign Style	Action Instructed to Take	Location of Exit Number Information	Follow-Up Question
a		Exit to Jones Rd.	Plaque	What was the exit number?
b		Take Exit 101	Plaque	What was the road name?
c		Exit to Jones Rd.	Embedded	What was the exit number?
d		Take Exit 101	Embedded	What was the road name?
e		Exit to Sandy Rd.	Plaque	What was the exit number?
f		Take Exit 104	Plaque	What was the road name?
g		Exit to Sandy Rd.	Embedded	What was the exit number?
h		Take Exit 104	Embedded	What was the road name?

These questions were intended to examine participants' ability to recall advance guide sign information (specifically road names and exit numbers) and make the correct decision whether or not to exit. All survey participants had questions that asked about information that matched the information on the advance guide sign displayed. Table 9 provides the results.

**Table 9. Recognition of Matching Information on Advance Guide Signs.**

Action to Take	Location of Exit Number Information	Number of Responses	Percent Correct	Information to Recall	Number of Responses	Percent Correct
Exit Jones Rd.	Plaque	121	96.7	Exit number	120	30.8
Exit 101	Plaque	122	91.0	Road name	121	52.9
Exit Jones Rd.	Embedded	122	93.4	Exit number	122	37.7
Exit 101	Embedded	117	90.6	Road name	117	56.4

When asked to take the action listed, participants were able to recognize that same piece of information on an advance guide sign with a high degree of accuracy (96.7, 91.0, 93.4, and 90.6 percent) regardless of whether the exit number was on a separate plaque or embedded in the sign. However, when asked to recall the other piece of information, participants were not as successful at identifying the correct answer. Given the exit road name, only 30.8 percent of responses were correct when asked to recall the exit number when the exit number was on the plaque. Similarly, only 37.7 percent of responses were correct when asked to recall the exit number when the exit number was embedded in the sign. Given the exit number, 52.9 percent of responses were correct when asked to recall the road name when the exit number was on the

plaque. Similarly, 56.4 percent of responses were correct when asked to recall the road name when the exit number was embedded in the sign. In both of these cases, the location of the exit number information did not create a statistically significant difference in the number of correct responses. These results reflect known driver information scanning behavior when reading advance warning signs. Specifically, drivers search for information that matches their search target and tend to ignore extraneous information.

All survey participants had questions that asked about information that did not match the information on the advance guide sign displayed. Table 10 provides the results. In these questions, the advance guide sign displayed exit information for Smith Street (exit 205). The participants may have been asked if they would take the exit for Sandy Street 1 mile ahead when the sign showed the Smith Street exit was 1 mile ahead. Alternatively, the participants may have been asked if they would take exit 104 1 mile ahead when the sign showed that exit 205 was 1 mile ahead.

**Table 10. Recognition of Mismatched Information on Advance Guide Signs.**

<b>Action to Take</b>	<b>Location of Exit Number Information</b>	<b>Number of Responses</b>	<b>Percent Correct</b>	<b>Information to Recall</b>	<b>Number of Responses</b>	<b>Percent Correct</b>
Exit Sandy St.	Plaque	120	78.3	Exit number	119	5.0
Exit 104	Plaque	122	70.5	Road name	122	27.1
Exit Sandy St.	Embedded	119	66.4	Exit number	119	8.4
Exit 104	Embedded	124	74.2	Road name	121	11.6

When asked to take the action listed, most participants were able to recognize that the road name in the question did not match the road name on the advance guide sign (or that the exit number in the question did not match the exit number on the advance guide sign). There was no statistically significant difference in the percentage of correct answers between those with the exit number on a separate plaque (78.3 and 70.5 percent, respectively) and those with the exit number embedded in the sign (66.4 and 74.2 percent, respectively). Interestingly, these percentages were lower than those from the signs with matching information (shown in Table 9). When drivers are unable to find the information they need, making correct driving decisions can be more difficult.

Table 10 also shows that, given a mismatched exit road name, only 5.0 percent of responses were correct when asked to recall the exit number and the exit number was on the plaque. Similarly, only 8.4 percent of responses were correct when asked to recall the exit number and the exit number was embedded in the sign. Given the mismatched exit number, 27.1 percent of responses were correct when asked to recall the road name and the exit number was on the plaque. Similarly, 11.6 percent of responses were correct when asked to recall the road name and the exit number was embedded in the sign. Recall of this information was poor, and these very low percentages may be a result of two factors:

- The testing method used (which included a very short viewing time of 3 seconds) may have been too difficult for a portion of the participants.
- Drivers typically scan for the information they need, and these participants may not have anticipated being asked about information that was not needed to answer the initial question.

### Exit Gore Sign Color

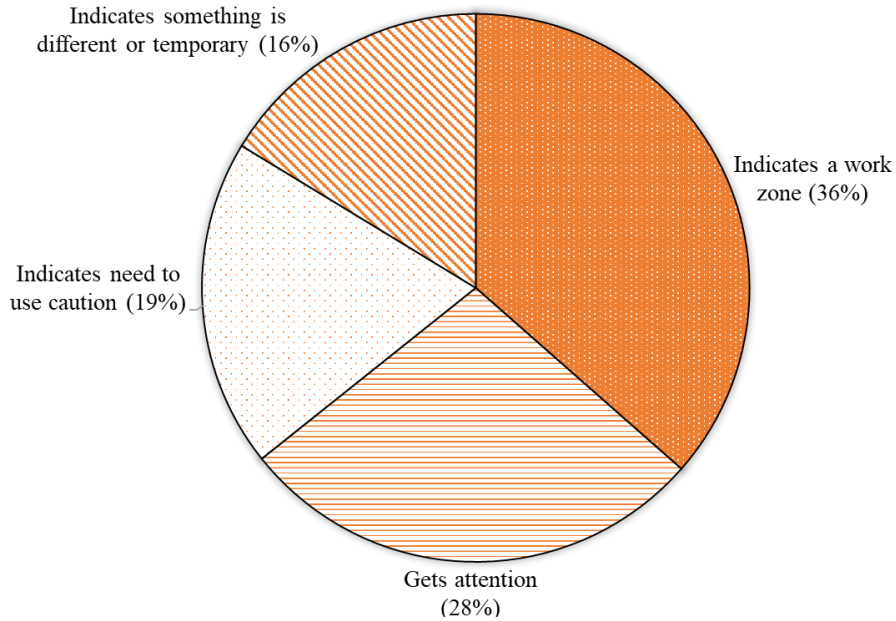
Participants were asked to rank three different responses to explain why an exit gore sign might be orange instead of green, as shown in Figure 27. The top ranking (number 1) indicated the most likely explanation, and the bottom ranking (number 3) indicated the least likely explanation. There were 386 participant responses to this question. Researchers computed a weighted rank score for each response. Table 11 summarizes the results.

**Table 11. Ranking of Explanations for Orange Exit Gore Sign.**

Response	Ranking			Weighted Rank Score
	1	2	3	
The exit ramp is in a new location, and permanent signs have not been installed yet.	140	106	138	2.01
The exit ramp is in the same place it always has been, but I need to watch out for work on or near the exit ramp roadway.	105	126	158	1.88
The exit ramp is in the same place it has always been, but the old exit sign had to be taken down because of work on the main travel lanes, so a temporary sign has been put up.	139	152	93	2.12

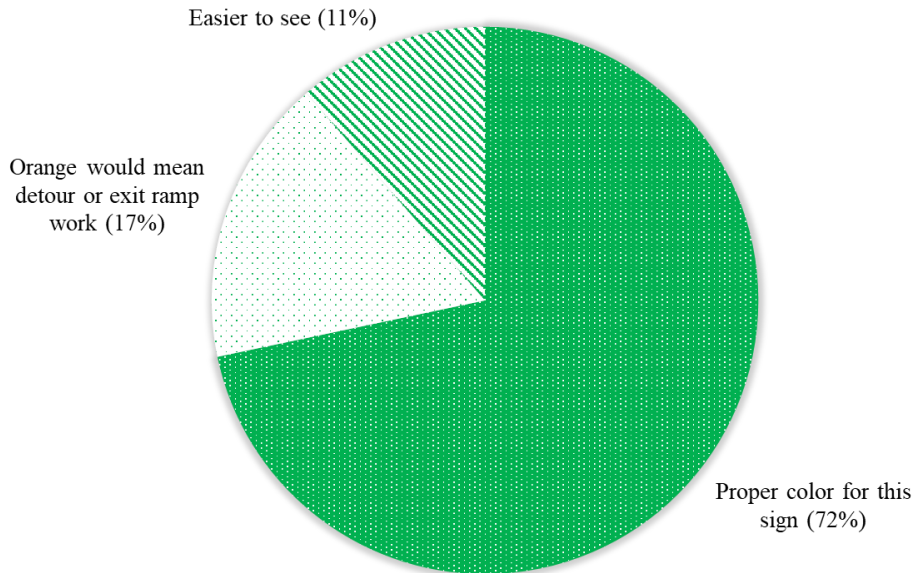
The scores indicate that the most likely explanation for the orange sign was that it was a temporary sign for an exit ramp that had not changed location, but the permanent green exit gore sign had been removed due to construction. To further assess driver understanding of the orange exit gore sign, a follow-up question asked if the survey participant had a color preference for exit gore signs if the exit is in a work zone. Of 474 responses received, 341 (72 percent) preferred orange, 58 (12 percent) preferred green, and 76 (16 percent) had no preference. When those who preferred orange were asked to elaborate on their preference, 392 comments were received, and some comments contained multiple ideas. Individual comments were reviewed and categorized. Figure 28 shows the results.





**Figure 28. Reasons Given for Preferring the Orange Exit Gore Sign.**

For those who expressed preference for a green exit gore sign, 53 individual comments were reviewed and categorized. Figure 29 shows the results.



**Figure 29. Reasons Given for Preferring the Green Exit Gore Sign.**

### MIXED-CASE FONTS ON GUIDE SIGNS

One of the research questions the project panel recommended for study was not included in the survey. That question related to the differences in driver responses between using mixed-case (uppercase and lowercase) letters versus all capital letters on exit signs. This is really a sign legibility question that cannot likely be answered using the type of survey included in this

research project. Legibility studies are best conducted using drivers looking at real signs in real-world conditions and measuring the distance at which drivers can correctly identify words on signs.

The researchers investigated the use of both mixed-case fonts and all capital fonts on existing guide signs. The TMUTCD requires that “all sign lettering shall be in upper-case letters” and the only exceptions are for particular signs or type of messages that are described in the manual (1). The FSH reaffirms this policy, indicating that “sign lettering for word messages on freeway guide signs is uppercase, with the exception of destinations (names of places, streets, and highways). All destinations on guide signs must be composed of lowercase letters with initial uppercase letters” (3). Researchers reviewed the literature on sign fonts to find relevant supporting information for this policy.

Since the 1950s, the Highway Series alphabet has been used as the letter style for freeway guide signs. These fonts included only all capital letters. In the early 1980s, Gordon examined the legibility of cardinal direction words using all capitals and mixed-case lettering (8). Gordon’s team hypothesized that emphasizing the initial letter of the cardinal direction would improve legibility. The results indicated that the cardinal directions could be identified from 10 percent farther away when the mixed-case font was used (8). With the 2011 TMUTCD, TxDOT began using a larger initial letter for cardinal direction words as a standard. However, the Highway Series alphabet is still used for these words.

Past research performed at TTI showed that nighttime recognition distance decreased when Clearview was used in lieu of Highway Series fonts on negative contrast signs (9). Some of the plan sets reviewed during the course of the research project included temporary guide sign legend with Clearview font. Thus, current guidance for the design of work zone guide signs may not be clear to those engaged in roadway plan preparation.

## **CHAPTER 4: GUIDELINES AND RECOMMENDATIONS**

Based on the findings from the discussions with TxDOT personnel, positive guidance assessments of work zones, and the human factors study, the researchers developed the following recommendations:

- Designers should avoid splitting information on temporary lane guidance signs at interchanges. Drivers need to have all arrows (one for each lane) displayed in order to be able to make accurate decisions about whether or not they need to change lanes.
- EXIT ONLY plaques on temporary lane guidance signs do not significantly enhance driver understanding of the signs used in this study. However, the use of EXIT ONLY plaques may be important for interchanges with option lanes, but those signs were not tested.
- The use of a separate exit number plaque on advance guide signs did not have an impact on driver understanding of the sign when compared to a similar sign with the exit number embedded. However, there is evidence that not having sufficient time to view and process all the information shown (e.g., if the sign legend is too small or if too much information is shown) leads to increased uncertainty about whether or not the driver should exit. The TMUTCD provides minimum letter and numeral sizes for advance guide and exit direction signs. If the information that needs to be conveyed on a sign does not fit, the information can be split and displayed on two separate signs. However, those signs should be placed such that the driver has sufficient time between signs to process the information on each sign before encountering another sign.
- No specific recommendations on exit gore sign colors can be provided based on the results of this research. Current practices appear to be consistent with motorist perceptions of the reasons for the use of orange exit gore signs.
- Designers should continue to use Highway Series fonts (not Clearview) for work zone guide sign legends. To clarify, additional policy guidance from TxDOT may be needed for those engaged in roadway plan preparation.



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## APPENDIX

To keep the survey short and to minimize potential learning effects, each participant saw only two questions about temporary lane guidance signs and two questions about advance guide signs.

The temporary lane guidance sign format options (signs showing all lanes versus signs showing only some lanes and signs with and without the EXIT ONLY plaque) were tested for left-exit scenarios (A through N) and right-exit scenarios (O through BB). For each sign option within each of these groups, one scenario instructed participants to exit the road they were currently on (i.e., scenario A), and one scenario instructed participants to stay on the through road (i.e., scenario B).

The survey was structured to present each participant with paired questions, which included a combination of one question from the left-exit scenarios (A through N) and one question from the right-exit scenarios (O through BB). Some scenario combinations from these two groups were judged to be too similar. For example, scenario A and scenario W both ask the participant to exit, both require no lane change to exit, and both have the participant in the EXIT ONLY lane that is closer to the center of the roadway. To avoid potential learning effects, these combinations were eliminated so that a single participant would not see two very similar questions. Table 12 shows the resulting question pair combinations, each marked with an X.

**Table 12. Experimental Plan Details for Temporary Lane Guidance Sign Questions.**

Left-Exit Scenarios	Right-Exit Scenarios														Number of Combinations
	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	
A							X	X		X	X	X		X	6
B							X	X	X		X	X	X		6
C							X	X		X	X	X		X	6
D							X	X	X		X	X	X		6
E								X	X	X		X	X	X	6
F							X		X	X	X		X	X	6
G	X	X		X		X									4
H	X	X	X		X										4
I		X	X	X	X	X									5
J	X		X	X	X	X									5
K	X	X		X		X									4
L	X	X	X		X										4
M		X	X	X	X	X									5
N	X		X	X	X	X									5
Total															72

Each of the 72 paired combinations was presented in both orders (e.g., some participants saw scenario A as the first of two temporary lane guidance sign questions in their survey and scenario U second; others saw scenario U first and scenario A second), for a total of 144 possible

combinations. Each of the 144 pairs was programmed to be randomly selected for presentation by the survey software. The software was also programmed to present the randomly selected pairs evenly, meaning that for every 144 surveys that progressed at least as far as the first temporary lane guidance sign question, each temporary lane guidance sign question pair would be selected one time.

A similar process generated paired question combinations for the advance guide signs. Each participant saw one version of a sign that contained information that matched the information given in the question (e.g., seeing a sign for exit 101/Jones Road when the participants had been told they would be exiting at Jones Road, or that they would be taking exit 101). In addition, each participant saw one version of a sign that contained mismatched information other than what he or she had been given; additionally, each participant saw one question for which he or she was given the road name as advance information, and one question for which he or she was given the exit number as advance information.

Table 13 shows the pair combinations for this question. In this case, lowercase letters were used to identify each scenario so they would not be confused with the temporary lane guidance sign scenarios. As with the temporary lane guidance sign questions, each pair was presented in both orders (e.g., a through f and f through a) for a total of 16 combinations, and was randomly and evenly selected over every 16 surveys that progressed at least to the first advance guide sign question.

**Table 13. Experimental Plan Details for Advance Guide Sign Questions.**

Mismatched Information Scenarios	Matching Information Scenarios				Number of Combinations
	a	b	c	d	
e		X		X	2
f	X		X		2
g		X		X	2
h	X		X		2
Totals					8