

# Driver Comprehension of Regulatory Signs, Warning Signs, and Pavement Markings

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A survey of 1,745 Texas drivers was conducted to assess their comprehension of selected traffic control devices. The survey consisted of a 17-min videotape presentation of 46 devices, of which 38 were regulatory signs, warning signs, or pavement markings. For each question, the survey participant was exposed to an in-context and close-up view of the device. The questions were asked verbally, and the participants selected their answers from a list of four multiple choice responses, of which one was always "not sure." The survey results for questions on regulatory signs, warning signs, and pavement markings are presented. There are 13 regulatory signs in the survey, 18 questions on warning signs, and 7 questions on pavement markings. Desirable response rates ranged from 15.5 to 93.2 percent. The survey results should be interpreted carefully, because some of the questions tested understanding of specific aspects of the sign message, such as the speed message implied by the Curve sign. Response rates for other devices are influenced by the possible response choices. The survey results for individual questions are not directly comparable and must be interpreted in isolation.

Traffic control devices are a vital element of the highway environment. They provide a means of communicating important information about the highway to the driver. Since the beginning of the 20th century, traffic control devices have grown continually in number and complexity. The *Manual on Uniform Traffic Control Devices* (MUTCD) contains the principles that govern the design and application of traffic control devices (1). The signs and markings in the MUTCD use shape, color, symbols, words, or a combination thereof to convey the information needed by a driver. However, these devices serve little purpose if they are not understood. Therefore, this research was initiated to determine how well motorists understand some of the most critical traffic control devices.

The question of how well drivers understand traffic control devices has been a concern for many years. A number of studies evaluating driver comprehension of traffic control devices have been conducted during the last 15 years (2-7). But even though these studies provide much useful information about motorist understanding of traffic control devices, several devices that are widely used in Texas have not been tested in the past. Furthermore, specific aspects of other signs have not been tested. For these reasons and others, the Texas Department of Transportation (TxDOT) sponsored a research study to measure driver comprehension of selected traffic control devices. Driver comprehension was measured

through the use of a survey given to 1,745 Texas drivers; the survey addressed 46 traffic control devices. This paper describes the results of 38 survey questions related to regulatory signs, warning signs, and pavement markings. It also describes the survey methodology behind the development and administration of the survey.

## SURVEY METHODOLOGY

A survey instrument was developed that would

- Administer the survey in a convenient, quick, and consistent manner;
- Include many traffic control devices in the survey (at least 30); and
- Test a large sample of drivers (approximately 2,000) representative of the Texas population.

The process used to develop the survey instrument involved selecting the survey format, choosing the traffic control devices to include in the survey, evaluating the effectiveness of the survey instrument, and developing a plan for administering the survey.

## Survey Format

The research team set several requirements for the format of the survey instrument. It had to address a number of traffic control devices, present in-context and close-up views of each device, and provide the question and response choices verbally. Exposure to a traffic control device had to be consistent for each test subject, and the instrument had to be portable enough to allow for easy travel and setup. These requirements led to a decision to use a videotape as the survey instrument. The videotape was prepared from 35-mm slides.

The videotape began with an introduction to the survey. Each of the devices was then addressed with two photographs. The first was an in-context photograph of a traffic control device in its typical environment. While the in-context photo was being displayed, the narrator in the videotape asked a question about the device. This was followed by a close-up view of the device with the response choices. While the close-up view was displayed, the narrator repeated each of the response choices. Figure 1 illustrates the in-context and close-up views for the question on the Stop Ahead sign.



1. Stop when you see this sign.
2. Be prepared for a STOP sign ahead.
3. At the next STOP sign, you should go straight after you stop.
4. Not sure.

**FIGURE 1** Example of survey question for Stop Ahead sign: top, in-context view; bottom, close-up view with responses.

Sixteen questions at the end of the survey provided information on the demographics and driving experience of the survey participants.

The survey questions were designed to serve as a tool by which to identify problems and not to explain why misunderstandings exist or provide solutions to problematic traffic control devices. Some of the questions were developed to test specific aspects of the intended message of the sign. Multiple-choice responses were selected to reduce the answering time. There were four multiple choice responses for each traffic control device: one "correct" or "desirable" response, two responses within the realm of possible misunderstanding (referred to herein as "incorrect" or "undesirable" responses), and a "not sure" response. In some cases, the incorrect or undesirable responses contained some degree of truth. The survey was administered in English to all of the participants.

### Selection of Traffic Control Devices

A survey that addressed every device in the MUTCD would be cumbersome and time-consuming. Therefore, a ranking procedure was developed to determine which devices were the most appropriate to include. The ranking procedure was necessary because comprehension alone is not sufficient to determine whether a device performs adequately or not, in part because there are no standards that establish a minimum comprehension level for traffic control devices. The ranking procedure evaluated each traffic control device with regard to three major and three minor factors. The major factors were (a) the findings of previous research, (b) the results of

a poll of transportation professionals, and (c) the results of an assessment of the consequences of misunderstanding a device. The minor factors were (a) whether the meaning of a traffic control device was described in the *Texas Drivers' Handbook* (8), (b) the frequency that a traffic control device is used, and (c) any special interest that the research team had about a specific traffic control device.

The major factors were weighted at 25 percent each, and the minor factors were weighted at 8 percent each. A total score for each traffic control device was determined by adding the individual weighted scores for the six factors. Devices with the highest total scores were identified as candidates for the survey.

The results of the ranking process identified 60 traffic control devices for possible inclusion in the survey. These 60 devices were later reduced to 46, as will be described. The 60 devices were neither the least understood nor the highest ranked. Several traffic control devices were not included in the survey for a variety of reasons, including an abundance of prior research indicating that a traffic control device is not adequately understood, the inability to include a traffic control device in the survey format, or the inclusion of a closely related traffic control device in the survey. Once these 60 devices had been agreed upon, questions, responses, and graphics were developed for each device and a 30-min pretest survey instrument was produced.

### Survey Evaluation

The evaluation of the survey instrument was a three-step process involving evaluation of a pretest survey, a pilot survey, and the final survey instrument. All three surveys used the same videotape format. The purpose of the pretest survey was to evaluate the survey questions and answers, identify problems in the survey administration, determine the proper pace of the survey, and identify the traffic control devices that could be deleted. The pretest survey was given to 38 individuals at a local shopping mall and driver licensing station. The results and observations from the pretest survey were used to delete 14 devices with high comprehension levels from the survey and to modify several questions and responses to reduce confusion. The pace of the survey instrument was also increased. The result of these changes was a 17-min pilot survey covering 46 traffic control devices.

The pilot survey was then administered at an automobile show in Houston, Texas. The 17-min videotape presentation was given to 165 walk-up volunteers from those touring the show. The results of the pilot test survey indicated that the survey instrument was effective and no changes were necessary. As a result, the final survey instrument was the same as the pilot survey instrument.

### Survey Administration

The survey was administered at driver licensing stations throughout Texas. Driver licensing stations were chosen as logical places to recruit drivers because the individuals that enter the stations represent a good cross section of demographic and socioeconomic subgroups. The final survey was

administered at stations in 12 Texas cities throughout the state that were selected to represent six regions of the state. In each region the survey was conducted in a large and a small city (with populations of more and less than 50,000, respectively).

A quota sampling plan was selected for the final survey. Quotas were developed for each of the six regions in which the survey was administered. A representative quota sample of 2,000 was targeted. This sample size was determined to provide enough data for meaningful analysis for the various population subgroups—that is, men, women, and different age and ethnic groups—with varying levels of driving experience. Demographic and background information about the survey respondents was obtained from 16 questions at the end of the survey. The quota sample was selected such that it was representative of the driving population of Texas with respect to gender, age, and ethnicity. Other characteristics of interest included language, education, and driving-related variables.

Surveyors were instructed to approach potential respondents without regard to individual characteristics, in order to avoid introducing bias into the sample. The clientele of the licensing station was presumed to match regional demographics. The only screening question was to ascertain that the potential respondent was a driver.

## SURVEY SAMPLE

The survey was administered in the 12 cities over 6 months. The actual sample size obtained in the survey was 1,745. This sample size was determined to be large enough to allow analysis of each of the variables of interest with an acceptable level of precision. The four response choices for each question were classified into two variables: the desired response, and all other responses. Desired responses and other responses were cross-tabulated with subsets of the data representing the sociodemographic and driving-related variables. The relationships between these variables are mentioned in this paper only when statistical significance was found.  $\chi^2$ -tests of significance were used to identify significant relationships among the variables with the level of significance set at  $p \leq .01$ . Table 1 gives the sociodemographic characteristics of the survey sample, and Table 2 presents the driving-related characteristics of the survey sample. The sample size generated frequencies for each of these variables that permitted analysis of the effect of these experience and exposure characteristics.

It is important to note that the sociodemographic variables were covariant—specifically, there were significantly more college-educated respondents in the 25- to 64-year-old group than in other age groups. Additionally, minority ethnic groups were overrepresented in the youngest category. Anglos and the ethnic groups classified as “other” were significantly more likely to be college-educated than Hispanics and African-Americans. As expected, ethnicity and language were highly correlated. Education was associated with language: more non-English-speaking respondents than English-speaking respondents had less than a high school education.

As with the sociodemographic variables, many of the driving-related variables were covariant. Specifically, men were more likely than women to drive on the job, be professional

TABLE 1 Sociodemographic Characteristics of Survey Sample

| Characteristic            | Number       | Percent      |
|---------------------------|--------------|--------------|
| <b>Gender</b>             |              |              |
| Male                      | 894          | 51.2         |
| Female                    | 851          | 48.8         |
| <b>Family Background</b>  |              |              |
| Anglo                     | 1,057        | 60.6         |
| Black                     | 207          | 11.9         |
| Hispanic                  | 391          | 22.4         |
| Other                     | 90           | 5.2          |
| <b>English Language</b>   |              |              |
| Primary                   | 1,529        | 87.6         |
| Secondary                 | 216          | 12.4         |
| <b>Age</b>                |              |              |
| 16 - 24                   | 455          | 26.1         |
| 25 - 64                   | 1,202        | 68.9         |
| 65 +                      | 88           | 5.0          |
| <b>Years of Education</b> |              |              |
| Less than High School     | 282          | 16.2         |
| High School Graduate      | 480          | 27.5         |
| Tech/Business School      | 96           | 5.5          |
| Some College              | 433          | 24.8         |
| College Graduate          | 303          | 17.4         |
| Graduate School           | 151          | 8.7          |
| <b>Total</b>              | <b>1,745</b> | <b>100.0</b> |

drivers, drive a different type of vehicle than a passenger car, drive more miles, and make more long-distance trips.

Several obvious relationships were noted with regard to age and driving experience. For example, the number of years of driving experience was positively associated with age. As in the general driving population, the sample reported fewer miles driven and long-distance trips per year among both the younger and older respondents. Commercial driver licenses were held primarily by middle-aged drivers.

There were significant differences between those who had and those who had not taken driver education on the basis of age, ethnicity, education, language, miles driven, type of miles driven, number of trips per year, and length of time that they had been licensed. Respondents who had taken driver education were more likely to be younger, Anglo, highly educated, and English speaking, as well as to drive more miles on average, take more trips on average, and be newly licensed or licensed within the past 10 years. There were no significant differences between those who had and had not taken driver education on the basis of gender or license type.

## STUDY LIMITATIONS

The survey method used in this research has several limitations that must be kept in mind when evaluating the results. Although the driver licensing stations are ideal venues for finding and questioning drivers, at least some of these drivers may have been more prepared for driving-related questions, depending on their purpose for being in the station on the day of the survey. Most of the respondents were not newly licensed or recently tested; they were more often accompanying someone else doing business at the office or renewing their licenses. The survey stimulus material was auditory and

TABLE 2 Driving Characteristics of Survey Sample

| Characteristic                      | Number       | Percent      |
|-------------------------------------|--------------|--------------|
| <b>Drive for Job</b>                |              |              |
| Yes                                 | 435          | 24.9         |
| No                                  | 1,310        | 75.1         |
| <b>Type of License</b>              |              |              |
| Operator                            | 1,586        | 90.9         |
| Commercial                          | 188          | 6.8          |
| Motorcycle                          | 40           | 2.3          |
| <b>Trips/Year</b>                   |              |              |
| None                                |              |              |
| > 300 mi                            | 300          | 17.2         |
| 1-10                                | 1,262        | 72.3         |
| > 10                                | 183          | 10.5         |
| <b>Years Licensed</b>               |              |              |
| No License                          | 99           | 5.7          |
| < 1                                 | 88           | 5.0          |
| 1-10                                | 475          | 27.2         |
| > 10                                | 1,083        | 62.1         |
| <b>Type of Vehicle Driven</b>       |              |              |
| Passenger Car                       | 1,508        | 86.4         |
| Pickup                              | 205          | 11.7         |
| Diesel                              | 18           | 1.0          |
| Motorcycle                          | 2            | 0.1          |
| Other                               | 12           | 0.7          |
| <b>Driver Education</b>             |              |              |
| Yes                                 | 1,002        | 57.4         |
| No                                  | 743          | 42.6         |
| <b>Years Since Driver Education</b> |              |              |
| None                                | 738          | 42.3         |
| < 1                                 | 116          | 6.6          |
| 1-10                                | 386          | 22.1         |
| > 10                                | 505          | 28.9         |
| <b>Type of Driving</b>              |              |              |
| Within City                         | 930          | 53.3         |
| Outside City                        | 188          | 10.8         |
| Both                                | 627          | 35.9         |
| <b>Miles Driven per Year</b>        |              |              |
| < 10,000                            | 554          | 31.7         |
| 10,000 - 30,000                     | 1,074        | 61.6         |
| > 30,000                            | 117          | 6.7          |
| <b>Total</b>                        | <b>1,745</b> | <b>100.0</b> |

the responses were verbal. This technique was used to compensate for variations in reading ability. However, the videotape was timed such that most responses were required within 3 or 4 sec of hearing the question. It is acknowledged that processing time varies within the population as well. A survey with unlimited response time would probably show higher comprehension levels than a survey with time limitations, as was used in this study. And, although each traffic control device was presented in two formats (in and out of context), neither truly represented the driving environment in which the traffic control devices would be encountered and interpreted.

The use of a multiple-choice format places some restrictions on the interpretation of the survey results. Because multiple-choice questions eliminate drivers' freedom to develop their own explanations of a device, their responses to questions are influenced by the possible choices. The use of multiple-choice questions may also eliminate potential areas of confusion. For example, all of the response choices for the Narrow Bridge

sign were related in some manner to a bridge. Because the possible responses for each question are not always comparable, the response rates cannot be used to provide a relative measure of the effectiveness of any warning sign. The response rates for each question must be interpreted in isolation from other questions.

Some of the questions in the survey test specific aspects of comprehension of warning signs. Therefore, it is inappropriate to assume that the correct response rate for any sign represents the proportion of drivers who understand the sign. As an example, the correct response rate for the Curve sign question was 32.4 percent. However, this does not mean that only 32.4 percent of drivers recognize that the Curve sign indicates a change in horizontal alignment. Instead, it means that only 32.4 percent recognize the speed-related message implied by the Curve sign.

## REGULATORY SIGN RESULTS

The MUTCD states that "regulatory signs shall clearly indicate the requirements imposed by the regulation" (1). The regulatory signs in the survey can be categorized as a word or symbol legend, and some of the signs can also be classified as a particular type, such as signal regulatory signs. Figure 2 indicates the 13 regulatory signs included in the survey. Table 3 gives a summary of the response percentages for each regulatory sign question. However, as previously emphasized, the specific aspect of a regulatory sign studied and the possible choices to a designated question affect the manner in which the results are interpreted.

In the following, the results for each regulatory sign studied in the survey are presented. The regulatory sign name and label are given for each question. The survey questions and responses are shown in the order in which they were given in the survey along with the response percentages for each question. An asterisk is used to indicate the desirable response for each question.

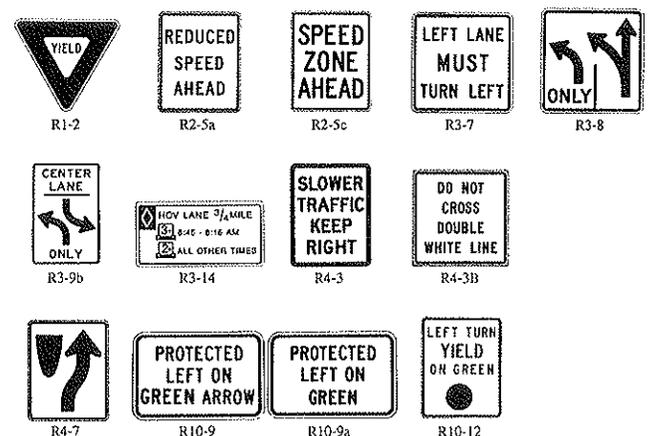


FIGURE 2 Regulatory signs included in survey.

**TABLE 3 Survey Results for Regulatory Signs**

| Sign                            | Sign Label | Percent |           |          |
|---------------------------------|------------|---------|-----------|----------|
|                                 |            | Correct | Incorrect | Not Sure |
| YIELD                           | R1-2       | 79.4    | 19.8      | 0.8      |
| REDUCED SPEED AHEAD             | R2-5a      | 93.2    | 5.6       | 1.1      |
| SPEED ZONE AHEAD                | R2-5c      | 55.0    | 37.3      | 7.7      |
| Mandatory Movement              | R3-7       | 79.5    | 18.9      | 1.6      |
| Double Turn                     | R3-8       | 65.0    | 31.3      | 3.7      |
| Two-Way Left Turn Lane          | R3-9b      | 58.6    | 50.4      | 5.0      |
| HOV Restriction                 | R3-14      | 45.7    | 21.1      | 33.2     |
| SLOWER TRAFFIC KEEP RIGHT       | R4-3       | 70.8    | 27.7      | 1.5      |
| DO NOT CROSS DOUBLE WHITE LINE* | R4-3B      | 72.6    | 21.3      | 6.1      |
| Keep Right                      | R4-7       | 69.9    | 25.1      | 5.0      |
| PROTECTED LEFT ON GREEN ARROW*  | R10-9      | 53.0    | 43.7      | 3.3      |
| PROTECTED LEFT ON GREEN*        | R10-9a     | 15.5    | 82.2      | 2.3      |
| LEFT TURN YIELD ON GREEN Ball   | R10-12     | 74.5    | 17.9      | 7.6      |

\*This sign is contained in the Texas MUTCD but does not appear in the National MUTCD.

**Yield Sign**

When participants were shown a Yield sign (R1-2), they were asked, "What does the Yield sign tell you?"

| Answer Choice  | Percentage |
|--|------------|
| You must slow down before entering the intersection.   | 15.1       |
| You may enter the intersection if it is safe to do so; otherwise, you must stop or slow down until it is safe. | *79.4      |
| You must stop at the intersection before you enter it.   | 4.6        |
| Not sure.  | 0.8        |

Although most drivers know that this sign means to yield, it is of greater importance to determine if they know how the term "yield" applies to them as they approach it. There is some concern that although the legal definition of yielding has not changed, the actual practice of yielding in daily driving has become more "permissive," that is, that slowing is all that is required. For 15.1 percent of drivers, this may well be the case. However, 79.4 percent are knowledgeable about the correct response to a Yield sign.

Previous research (9) has shown an overinvolvement of older drivers (over 65 years) in accidents due to failure to yield right of way at intersections. However, the survey results did not show a significant relationship between age and misunderstanding the Yield sign. Hispanics and those who reported that they did not take any long-distance trips were most apt to indicate that slowing down is the appropriate response to the Yield sign.

**Reduced Speed Ahead Sign**

Signs indicating a reduced speed are used when advance notice is needed to enable the motorist to comply with a posted speed a short distance ahead. Two of the three versions of

the signs for reduced speed were tested in this survey. Participants were first shown a Reduced Speed Ahead sign (R2-5a) and asked, "What does this sign mean?"

| Answer Choice  | Percentage |
|--|------------|
| The speed limit will be higher ahead.                          | 1.9        |
| The speed limit ahead will be strictly enforced by the police. | 3.7        |
| The speed limit will be lower ahead.                           | *93.2      |
| Not sure.  | 1.1        |

The Reduced Speed Ahead sign had the highest desirable response rate (93.2 percent). The dramatically higher percentage of desirable responses for the Reduced Speed Ahead sign than the Speed Zone Ahead sign suggests that the Reduced Speed Ahead sign conveys a clearer meaning of the situation.

**Speed Zone Ahead Sign**

Signs indicating a reduced speed zone are typically used in rural areas when advanced notice is needed to enable the motorist to comply with a posted speed a short distance ahead. The Speed Zone Ahead sign appears to be understood by a lower percentage than the Reduced Speed Ahead sign (R2-5c).

| Answer Choice  | Percentage |
|--|------------|
| The speed limit will be higher ahead.                          | 6.2        |
| The speed limit ahead will be strictly enforced by the police. | 31.1       |
| The speed limit will be lower ahead.                           | *55.0      |
| Not sure.  | 7.7        |

A common association with the message of Speed Zone Ahead was there is enforcement ahead (selected by 31.1 percent of the respondents). This misunderstanding was held by a significantly larger proportion of non-Anglo drivers, drivers with less than high school education, drivers who do not make

long-distance trips, and drivers with few years of driving experience. As respondents increased in age, so did understanding of this sign. The Speed Zone Ahead sign had a higher percentage of "not sure" responses than any other regulatory sign except the HOV [high-occupancy vehicle] Restriction sign.

### Mandatory Movement Sign

Upon being shown a Mandatory Movement sign (R3-7), participants were asked, "What does this sign mean?"

| Answer Choice  | Percentage |
|--|------------|
| Turn right at the next driveway if you are in this lane.     | 14.0       |
| Turn right at the next intersection if you are in this lane. | *79.5      |
| You are not allowed to change lanes after you see this sign. | 4.9        |
| Not sure.  | 1.6        |

The response choices provided for this question were designed to determine how literally this sign is interpreted. Do drivers think that they must turn immediately or that they have no other immediate option but to turn? Approximately 19 percent did. By and large, these were drivers whose primary language was something other than English.

### Double Turn Sign

Participants were shown a Double Turn sign (R3-8) and asked, "Which is the most correct statement about this sign?"

| Answer Choice   | Percentage |
|---|------------|
| To go straight, you must be in the lane on the right.     | *65.0      |
| You may go straight or turn left in the left lane.        | 18.4       |
| You must go straight if you are in the lane on the right. | 13.0       |
| Not sure.   | 3.7        |

The Double Turn sign was not clearly understood by 35 percent of those surveyed. This sign is complicated by the several options presented with the arrows. Likewise, the responses required more thought than most of the other questions because options were presented contingent on lane position. Undesirable responses were given by significantly more Hispanic drivers, drivers with less than high school education, respondents whose primary language was not English, drivers who had not taken driver education, and drivers with little driving experience.

### Two-Way Left-Turn Lane Sign

The Two-Way Left-Turn Lane sign (R3-9b) has three components: the words "center lane," two arrows pointing in opposite directions, and the word "only." The survey attempted to determine how well drivers assemble these components into meaning an exclusive lane for left-turning vehicles: "Which one of the following statements is true when you see this sign?"

| Answer Choice   | Percentage |
|---|------------|
| The center lane is to be used only for making left turns.           | *44.6      |
| You will be able to make only left turns at the next intersection.  | 6.7        |
| The center lane is to be used only for making left and right turns. | 43.7       |
| Not sure.   | 5.0        |

Only 45 percent of the survey respondents gave the desirable response for the sign. The presentation of the two arrows prompted 44 percent of the respondents to say the center lane is usable for making left and right turns. These respondents were more likely to be non-Anglo drivers with little driving experience. In postsurvey interviews, several respondents immediately recognized the error in their thinking. It is not known what the effect of this misinterpretation is in the driving environment.

### HOV Restriction Sign

The HOV Restriction sign (R3-14) was presented to the survey respondents along with the question "It is 7:30 a.m.; what vehicles are allowed to enter the HOV lane?"

| Answer Choice                     | Percentage |
|-----------------------------------|------------|
| Carpools with 2 or more people.   | 9.9        |
| Carpools with 3 or more people.   | *45.7      |
| Carpools with more than 3 people. | 11.2       |
| Not sure.                         | 33.2       |

The number of people in an allowed carpool was the source of confusion for 21 percent of the respondents—that is, 10 percent said vehicles with carpools of two or more people were allowed, and 11 percent said vehicles with carpools of more than three people were allowed. One-third of the drivers surveyed were not sure which vehicles would be allowed in the HOV lane. The drivers that were knowledgeable about this sign tended to be younger, Anglo, higher-educated, English-speaking respondents who had also taken driver education.

### Slower Traffic Keep Right Sign

Survey participants were asked the meaning of a Slower Traffic Keep Right sign (R4-3):

| Answer Choice   | Percentage |
|---|------------|
| If you are driving slower than the speed limit, you should be in the lane on the right.   | 26.6       |
| If you are driving slower than the other traffic, you should be in the lane on the right. | *70.8      |
| If you have car trouble you should pull off on the right side of the road.                | 1.1        |
| Not sure.   | 1.5        |

The *Texas Drivers Handbook* (8) states that those driving slower than the normal stream of traffic are to keep in the right-hand lane. The study hypothesis was that some drivers think that if they are going the speed limit, they should not be considered "slower traffic." Thus, the weaving that this sign is supposed to eliminate would not be eliminated. This proved to be the case for more than a quarter of the drivers surveyed. Undesirable responses were given significantly more

often by those who did not speak English as their primary language. Contrary to expectation, the notion that the right-hand lane is for vehicles traveling slower than the speed limit was not associated with age.

### Do Not Cross Double White Line Sign

The Do Not Cross Double White Line sign (R4-3b) appears in the Texas MUTCD (10) but is not described in the national MUTCD. It is intended to inform motorists of the regulation against changing lanes or turning across double white lines. When asked the meaning of the sign, participants responded as follows:

| <i>Answer Choice</i>                                       | <i>Percentage</i> |
|--|-------------------|
| Do not change lanes or turn across the double white lines. | *72.6             |
| Do not pass. Two-way traffic.                              | 9.6               |
| Do not change lanes.                                       | 11.7              |
| Not sure.  | 6.1               |

The prohibition against crossing the double white lines was understood by 73 percent of the motorists surveyed. Twelve percent interpreted the sign simply as a prohibition against changing lanes, and 10 percent interpreted this sign as a prohibition against passing. Drivers over 75 years old and Spanish-speaking Hispanics were more likely to misinterpret this sign.

### Keep Right Sign

The Keep Right symbol sign (R4-7) is intended for use at the ends of medians, traffic islands, parkways, and so forth. Survey participants were asked, "What is the appropriate response to this sign?"

| <i>Answer Choice</i>               | <i>Percentage</i> |
|------------------------------------|-------------------|
| Turn right.                        | 1.2               |
| Go to the right side of this sign. | *69.9             |
| Stay in the far right lane.        | 23.9              |
| Not sure.                          | 5.0               |

The Keep Right sign is not intended as a lane assignment regulation. However, 24 percent of those surveyed interpreted this sign as a directive to stay in the far right lane. Seventy percent gave the appropriate response choice. This sign was more clearly understood by those who reported they traveled more than 30,000 mi/year and by drivers with commercial licenses.

### Protected Left on Green Arrow Sign

The Protected Left on Green Arrow sign (R10-9) is in the Texas MUTCD (10) but not in the national MUTCD. Participants were asked, "Which one of the following statements is true with regard to a left turn at this intersection?"

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| You are allowed to turn only when the green arrow is on.  | 27.0              |
| You are allowed to turn when the green ball is on if it is safe to do so.   | *53.0             |
| You are protected from oncoming traffic if you turn from the turn lane when either the green arrow or the green ball is on. | 16.6              |
| Not sure.   | 3.3               |

Fifty-three percent recognized the ability to make a left turn when facing a green ball as well as the ability to make a protected left turn when facing a green arrow. However, 27 percent believed that turns are permitted only when facing a green arrow if this supplemental plate accompanies the signal. A more serious error was committed by the 16.6 percent who believed that their turns are protected when they are facing either the green arrow or the green ball if this supplemental plate accompanies the signal. Language was the most significant variable associated with correctly identifying the meaning of this sign.

### Protected Left on Green Sign

The Protected Left on Green sign (R10-9a) is another sign that is in the Texas but not the national MUTCD. When participants were shown this sign, they were asked, "If you want to turn left at this intersection and the green light is on, what should you do?"

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| Yield to oncoming traffic. They will have a green light also. | 34.7              |
| Wait for a green arrow. Then turn left.                       | 47.5              |
| Turn left. Oncoming traffic will have a red light.            | *15.5             |
| Not sure.   | 2.3               |

The survey results indicate that this sign does not effectively communicate right-of-way assignment to a large majority of drivers. Only 15.5 percent recognized that a left turn would be protected, whereas 47.5 percent would wait for a green arrow to provide a protected left turn. Thirty-five percent thought oncoming traffic would have a green light also. These undesirable responses were fairly uniformly distributed across the survey population. However, respondents who had taken driver education within the past year performed significantly better on this question.

### Left Turn Yield on Green Ball Sign

Participants were shown a Left Turn Yield on Green Ball sign (R10-12) and asked, "If you have a green signal, what should you do to turn left?"

| <i>Answer Choice</i>                                | <i>Percentage</i> |
|---|-------------------|
| Stop and wait for a gap in traffic. Then turn left. | *74.5             |
| Wait for green arrow. Then turn left.               | 13.6              |
| Turn left. Oncoming traffic will have a red light.  | 4.3               |
| Not sure.   | 7.6               |

The Left Turn Yield on Green Ball sign does the best job of those signs in this survey of informing the driver of a permissive left turn condition: 74.5 percent chose the desirable response for this question. A certain percentage of respondents (13.6) would wait for a green arrow. Only 4.3 percent of the respondents made the more dangerous interpretation (interpreting a protected left turn). Those least apt to provide the correct interpretation were drivers over 65 years old, respondents with less than high school education, non-English-speaking respondents, unlicensed drivers, and drivers who had not taken driver education.

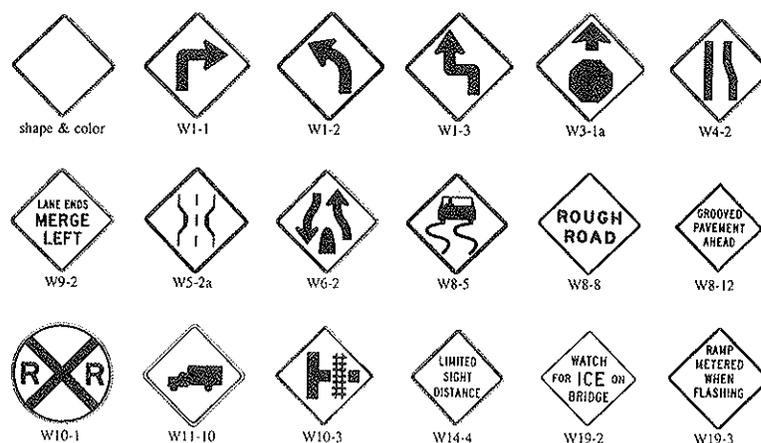


FIGURE 3 Warning signs included in survey.

### WARNING SIGN RESULTS

Approximately one-third of the survey (18 questions) dealt with the warning signs shown in Figure 3. A summary of the response rates for each of the warning signs is presented in Table 4. The survey results should be interpreted for each sign, giving consideration to the subject matter of the question and possible response choices. This section of the paper analyzes the results for each warning sign and includes the survey question for each sign and the possible response choices with

the percentages that selected each response. For each question, the correct response is indicated by an asterisk.

#### Warning Sign Shape and Color

One of the basic premises of a uniform signing system is that shape and color are standardized for a given category of signs. Therefore, the survey included one question that addressed the standard shape and color of a warning sign. In the next

TABLE 4 Survey Results for Warning Signs

| Warning Sign                         | Sign Label | Percent |           |          |
|--------------------------------------|------------|---------|-----------|----------|
|                                      |            | Correct | Incorrect | Not Sure |
| Warning Sign Shape & Color           | None       | 58.1    | 32.6      | 9.4      |
| Turn                                 | W1-1       | 31.9    | 55.9      | 12.2     |
| Curve                                | W1-2       | 32.4    | 66.7      | 0.9      |
| Reverse Turn                         | W1-3       | 66.5    | 30.8      | 2.7      |
| Stop Ahead                           | W3-1a      | 87.4    | 9.7       | 2.9      |
| Lane Reduction Transition            | W4-2       | 61.2    | 34.2      | 4.6      |
| LANE ENDS MERGE LEFT                 | W9-2       | 64.0    | 28.4      | 7.6      |
| Narrow Bridge                        | W5-2a      | 81.7    | 14.6      | 3.7      |
| Divided Highway Ends                 | W6-2       | 50.7    | 43.7      | 5.6      |
| Slow Down on Wet Road <sup>a</sup>   | W8-5       | 62.3    | 36.5      | 1.1      |
| ROUGH ROAD <sup>b</sup>              | W8-8       | 88.7    | 9.7       | 1.7      |
| GROOVED PAVEMENT AHEAD <sup>b</sup>  | W8-12      | 29.2    | 56.0      | 14.7     |
| Railroad Advance Warning             | W10-1      | 77.8    | 20.9      | 1.3      |
| Parallel Railroad Advance Warning    | W10-3      | 69.3    | 22.6      | 8.1      |
| Truck Crossing                       | W11-10     | 66.1    | 30.7      | 3.2      |
| LIMITED SIGHT DISTANCE <sup>c</sup>  | W14-4      | 44.9    | 40.3      | 14.8     |
| WATCH FOR ICE ON BRIDGE <sup>b</sup> | W19-2      | 84.0    | 13.9      | 2.1      |
| RAMP METERED WHEN FLASHING           | W19-3      | 45.7    | 27.5      | 26.8     |

<sup>a</sup>This sign is known as the Slippery When Wet sign in the National MUTCD.

<sup>b</sup>This sign is contained in the Texas MUTCD but does not appear in the National MUTCD.

<sup>c</sup>This sign was dropped from the National MUTCD, but is still contained in the Texas MUTCD.

to last question in the survey, a yellow diamond shape with a border but no legend was shown and the respondent was asked, "What does a sign this shape and color mean?"

| Answer Choice          | Percentage |
|------------------------|------------|
| Warning                | *58.1      |
| Directions or guidance | 19.7       |
| Construction area      | 12.9       |
| Not sure               | 9.4        |

Despite the fact that this question came after 16 other questions about a yellow diamond-shaped warning sign, only 58 percent were able to select the correct response. These responses indicate that drivers are not fully aware of the basic design premises of warning signs.

### Turn Sign

The Turn sign (W1-1) is used where the recommended speed on a turn is 30 mph or less and the recommended speed is equal to or less than the speed limit. This was the point emphasized in the correct response to the question. When asked to select the meaning of a Turn sign without an Advisory Speed plate (W13-1), survey participants gave the following responses:

| Answer Choice  | Percentage |
|--|------------|
| There is an intersecting road to the right ahead.      | 10.7       |
| You should drive 30 mph or less to make the next turn. | *31.9      |
| You should turn right at the next intersection.        | 45.2       |
| Not sure.  | 12.2       |

This question was a confusing one to many of the respondents, as indicated by the large percentage of "not sure" responses and by the number of comments made during the survey to the effect that there is more than one correct answer or that there is no correct answer. Those who did have a thorough understanding of the Turn sign were more often men and more often professional drivers. Misunderstanding was not significantly related to age, ethnicity, language, education, or driver education.

### Curve Sign

The Curve sign (W1-2) is used where the recommended speed is greater than 30 mph and equal to or less than the speed limit. This survey question presented the Curve sign without an Advisory Speed plate (W13-1) to see if drivers recognized the speed message of the sign. When drivers were asked what the sign meant, the following responses were selected:

| Answer Choice  | Percentage |
|--|------------|
| The road will curve to the left a short distance ahead and you should slow down before reaching the curve. | 65.0       |
| The road will curve to the left a short distance ahead, but you may drive the curve at the speed limit.    | *32.4      |
| The next mile of highway has several curves and you should slow down.                                      | 1.7        |
| Not sure.  | 0.9        |

The responses to this question indicate that drivers tend to believe that a Curve sign without an Advisory Speed plate implies the need for a speed reduction, as two-thirds of the drivers selected the "slow down" response. Although this is a safe response, it is nonetheless incorrect. The one-third of the drivers who knew the correct answer tended to be Anglos who had taken driver education.

### Reverse Turn Sign

The directional aspect of the Reverse Turn sign (W1-3) was the focus of this survey question. Drivers were asked what the sign meant and selected the following responses:

| Answer Choice   | Percentage |
|---|------------|
| Winding road ahead.   | 25.6       |
| You will make a turn to the right, then turn to the left ahead. | 5.3        |
| You will make a turn to the left, then turn to the right ahead. | *66.5      |
| Not sure.   | 2.7        |

The responses to this question indicate that there may be some confusion between the Reverse Turn sign and the Winding Road sign, as one-fourth selected the "winding road" response. The "winding road" response was more often a source of confusion for women and African-American respondents.

### Stop Ahead Sign

Comprehension of the Stop Ahead symbol sign (W3-1a) was a concern because of two potentially confusing symbols in the sign. The red octagon has the potential for being confused with a Stop sign and the upward pointing arrow might be misinterpreted as a directional indication. Drivers were asked what the sign told them to do, and the following responses were selected:

| Answer Choice  | Percentage |
|--|------------|
| Stop when you see this sign.                                 | 2.1        |
| Be prepared for a stop sign ahead.                           | *87.4      |
| At the next stop sign you should go straight after you stop. | 7.6        |
| Not sure.  | 2.9        |

This sign turned out to be the second best understood warning sign in the survey. Only 13 percent of the survey participants selected incorrect or not sure responses. The survey results indicate that the comprehension concerns about the octagon and arrow symbols were unfounded.

### Lane Reduction Transition Sign

The Lane Reduction Transition sign (W4-2) uses a symbol to indicate that there is a reduction in the number of traffic lanes. This sign was introduced in the 1961 edition of the MUTCD (11). Since then, there have been concerns about comprehension of the sign. Previous research studies have found that there are several common misinterpretations of this sign (5,7). Among the most common misinterpretations are that there

is a single lane ahead, the road changes from two-way to one-way, there are narrow lanes, and a there is shift in lane position. For this survey, drivers were placed in the left-hand lane and asked what the sign meant. The following responses were selected:

| <i>Answer Choice</i>   | <i>Percentage</i> |
|--|-------------------|
| There are fewer lanes ahead, and traffic on your right will move into your lane. | *61.2             |
| There is a one-lane road ahead.  | 22.8              |
| There are narrow lanes ahead.  | 11.3              |
| Not sure.  | 4.6               |

The response choices for this question require the driver to be knowledgeable of this warning sign because the symbol could conceivably describe any of the three choices. The difference between fewer lanes, one lane, and narrow lanes ahead was not apparent to 39 percent of the respondents. Language was a major factor in choosing the incorrect response, and driver education was a major factor in choosing the desirable response.

### Narrow Bridge Sign

The Narrow Bridge sign (W5-2a) is used to warn the driver of a bridge or culvert with a two-way width of 16 to 18 ft or a width that is less than the approach pavement. Drivers were asked the meaning of the sign and the following responses were selected:

| <i>Answer Choice</i>                        | <i>Percentage</i> |
|---|-------------------|
| Passing is not allowed on the bridge ahead. | 4.2               |
| A one-lane bridge is ahead.                 | 10.4              |
| A narrow bridge is ahead.                   | *81.7             |
| Not sure.                                   | 3.7               |

Given these options, respondents had little difficulty determining the intended message. However, since the word "bridge" was included in each response, the level of correct interpretation of the plan drawing of a bridge was not directly measured.

### Divided Highway Ends Sign

The Divided Highway Ends sign (W6-2) is used to indicate a change from a divided to an undivided cross section. This sign uses the same symbol as the Divided Highway sign (W6-1) except that it is rotated 180 degrees. Therefore, one of the reasons for including the Divided Highway Ends sign was to determine its interchangeability with the Divided Highway sign. Drivers were asked what the sign told them, and the following responses were selected:

| <i>Answer Choice</i>              | <i>Percentage</i> |
|-----------------------------------|-------------------|
| There is two-way traffic ahead.   | *50.7             |
| There is one-way traffic ahead.   | 6.0               |
| There is a divided highway ahead. | 37.8              |
| Not sure.                         | 5.6               |

Divided Highway Ends and Divided Highway signs are both commonly used, but the problem hypothesized was the interchangeability of these two signs in the minds of motorists. The 37.8 percent who thought that this sign meant there is a

divided highway ahead may have been responding to the "divided highway" phrase in the multiple-choice response and overlooking the implication for traffic directions. Men correctly answered this question significantly more often than women. Furthermore, the largest difference in correct responses between men and women was evidenced for this question.

### Slow Down on Wet Road Sign

Texas has renamed the Slippery When Wet sign to Slow Down on Wet Road (W8-5). The sign is used to warn drivers that the pavement surface may present a potentially hazardous condition when it is wet. The symbolic version of this sign was shown to drivers and they were asked what it meant.

| <i>Answer Choice</i>                | <i>Percentage</i> |
|-------------------------------------|-------------------|
| Be prepared for a winding road.     | 33.9              |
| Slow down when the pavement is wet. | *62.3             |
| Watch for out of control vehicles.  | 2.6               |
| Not sure.                           | 1.1               |

Almost two-thirds of the respondents were able to select the correct meaning of this sign, but the other third confused this sign with the Winding Road sign, an interpretation that has also been found in previous research on this sign (2,5).

Ethnic minorities were most inclined to give incorrect and "not sure" responses. However, correct answers were not associated with the language variable. Commercial drivers were significantly more knowledgeable of the meaning of this sign. Driver education was not significant for comprehension of this sign.

### Rough Road Sign

The Rough Road sign (W8-8) is included in the Texas MUTCD but not in the national MUTCD. The sign is used to warn of an extraordinarily rough pavement condition. Survey participants were shown the sign and asked what its purpose is. The responses to this question are as follows:

| <i>Answer Choice</i>                                     | <i>Percentage</i> |
|--|-------------------|
| To let motorcyclists know they should use caution.       | 7.2               |
| To let motorists know the road will be noisier ahead.    | 2.5               |
| To let motorists know the pavement is in poor condition. | *88.7             |
| Not sure.  | 1.7               |

The Rough Road sign had the highest desirable response rate of all the warning signs in the survey. It is worth noting that the first two incorrect responses contain some degree of truth. Almost everyone selected the correct response except respondents who classified themselves in the "other" ethnic group and who did not speak English as their primary language.

### Grooved Pavement Ahead Sign

The Grooved Pavement Ahead sign (W8-12) is primarily intended to warn motorcyclists that the pavement has been

grooved to improve its wet weather performance. Drivers were shown the sign and asked its purpose.

| <i>Answer Choice</i>                                      | <i>Percentage</i> |
|---|-------------------|
| To let motorists know the road will be slippery when wet. | 16.5              |
| To let motorists know the road will be noisier ahead.     | 39.5              |
| To let motorcyclists know they should use caution.        | *29.2             |
| Not sure.   | 14.7              |

Although the first and second responses may be true conditions, they do not accurately define the purpose of this sign. Drivers most frequently associated increased noise with grooved pavement. The 29 percent who did know the purpose of the Grooved Pavement Ahead sign more often were under 25 years old, classified in the ethnic group "other," spoke a language other than English as their primary language, had no operator license, but had a motorcycle license.

### Lane Ends Merge Left Sign

The Lane Ends Merge Left sign (W9-2) is intended to be used as a supplement to the Lane Reduction Transition sign. Drivers in the left lane were asked how they would respond to the sign, and the following responses were selected:

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| Be aware that traffic will be coming into your lane from the right. | *64.0             |
| Move to the right lane.   | 11.6              |
| Prepare to exit on the left.  | 16.8              |
| Not sure.   | 7.6               |

Although 64 percent selected the correct meaning of the sign, 12 percent of the drivers selected the meaning that is exactly the opposite of the desired maneuver. Another 17 percent thought the sign was related to an exit condition, which is completely different than the correct meaning. Drivers over 75 years of age and non-English-speaking drivers were particularly prone to select incorrect answers.

### Railroad Advance Warning Sign

The circular Railroad Advance Warning sign (W10-1) is placed upstream of a grade crossing to warn drivers that they are about to cross railroad tracks. This sign is one of only two signs that use the circular shape (the other is the civil defense evacuation route marker sign). Drivers taking the survey were asked to describe the purpose of this sign.

| <i>Answer Choice</i>                                  | <i>Percentage</i> |
|---|-------------------|
| To let you know you are at a railroad crossing.       | 17.4              |
| To let you know you will cross railroad tracks ahead. | *77.8             |
| To let you know there are two railroad tracks ahead.  | 3.5               |
| Not sure.   | 1.3               |

The responses to this question indicate that one of the problems associated with the Railroad Advance Warning sign is the failure to recognize the advance nature of the circular sign as compared with the railroad crossbuck, which is located

at the grade crossing. The advance nature of the Railroad Advance Warning sign was recognized by 78 percent of the respondents, although 17 percent thought that the Railroad Advance Warning sign is located at the grade crossing itself. Understanding of this sign was positively associated with driver education and negatively associated with age.

### Parallel Railroad Advance Warning Sign

Another type of advance railroad crossing sign is the Parallel Railroad Advance Warning sign (W10-3), which is used to warn drivers on a parallel highway that they will cross the railroad tracks if they turn. Although this sign provides an advance warning of a railroad-highway grade crossing in a manner similar to the circular sign, the Parallel Railroad Advance Warning sign is diamond-shaped. The survey question asked drivers what this sign means:

| <i>Answer Choice</i>   | <i>Percentage</i> |
|--|-------------------|
| If you turn onto the side road, you will cross a gravel road.        | 0.9               |
| You will cross a railroad track, then come to an intersection ahead. | 21.7              |
| If you turn onto the side road, you will cross a railroad track.     | *69.3             |
| Not sure.  | 8.1               |

Driver orientation was the confusing aspect of the Parallel Railroad Advance Warning sign for the 22 percent of the drivers who selected the second response. These individuals assumed that the driver facing this sign would be on the intersecting roadway. A relatively large number of drivers were not sure of the desirable response. Language and driver education were key variables associated with interpreting this symbol sign.

### Truck Crossing Sign

The symbolic Truck Crossing sign (W11-10) is used to warn drivers of locations where trucks may be entering, leaving, or crossing the highway. This sign was included in the survey to determine whether drivers associated the truck symbol with a crossing location or with truck use of the highway. Drivers were asked what the sign means:

| <i>Answer Choice</i>   | <i>Percentage</i> |
|--|-------------------|
| Be prepared for fire trucks entering or crossing the roadway in this area. | 2.0               |
| This is a warning that this road is heavily used by large trucks.          | 28.7              |
| Be prepared for trucks entering or crossing the roadway in this area.      | *66.1             |
| Not sure.  | 3.2               |

This warning sign was correctly understood by two-thirds of the survey respondents. However, 29 percent thought the sign indicated that the highway was heavily used by large trucks. Not surprisingly, a driver characteristic that was significantly associated with knowledge of this traffic control device was possession of a commercial driver license.

### Limited Sight Distance Sign

The Limited Sight Distance sign (W14-4) is used with an Advisory Speed plate to indicate the recommended speed on vertical curves where the sight distance is restricted. This sign was dropped from the national MUTCD in the 1988 edition (1), although it remains in the Texas MUTCD (10). Drivers were asked to identify the purpose of this sign.

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| To warn drivers that shadows make it difficult to see cars coming from the other direction. | 31.7              |
| To let drivers know they should be prepared to stop with little warning.                    | *44.9             |
| To let drivers with eyesight problems know they should use caution in this area.            | 8.6               |
| Not sure.   | 14.8              |

Fewer than half of the respondents correctly interpreted this warning. Almost one-third perceived the message as one of a temporary condition (i.e., the presence of shadows), and a relatively large percentage of the respondents (15 percent) were not sure of its meaning.

### Watch for Ice on Bridge Sign

Several signs are used in the United States to warn drivers that the road surface may be icy. In Texas the warning is provided with a fold-down sign with the legend Watch for Ice on Bridge (W19-2), which is displayed in advance of bridges during cold weather periods. In the survey, drivers were asked how they would respond to this sign and the following responses were selected:

| <i>Answer Choice</i>   | <i>Percentage</i> |
|--|-------------------|
| Don't drive on the bridge if there is ice on it.                       | 2.5               |
| Slow down and gently apply the brakes while you are on the bridge.     | 11.5              |
| Slow down, don't brake or make sudden turning movements on the bridge. | *84.0             |
| Not sure.  | 2.1               |

The message conveyed by the words on this sign appears obvious. However, other than watch for ice, what would motorists think is an appropriate driving response? Most (84 percent) did know the appropriate response, but 11.5 percent thought that brakes should be applied. The most significant effect on understanding this sign was language. Those that did not speak English as their primary language were most apt to misinterpret the sign.

### Ramp Metered When Flashing Sign

Although the Ramp Metered When Flashing sign (W19-3) is not in the national MUTCD, it does appear in the Texas MUTCD (10). When used, it is accompanied with one or two flashing beacons. Drivers were asked the meaning of this sign:

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| When the yellow lights are flashing, a traffic signal at the entrance to the freeway is in use. | *45.7             |
| Only a certain number of cars are allowed on the ramp when the yellow lights are flashing.      | 19.9              |
| You must pay a toll to use the freeway entrance ramp.   | 7.6               |
| Not sure.   | 26.8              |

A metered ramp is a relatively rare encounter for most drivers, particularly in the smaller cities where the survey was given. Therefore, many of the survey respondents based their responses solely on the sign comprehensibility instead of on previous driving experiences. Fewer than half of the respondents selected the correct meaning of this sign, although another 20 percent recognized the fact that ramp metering limits the use of the entrance ramp. The novelty of the sign as a traffic control device no doubt accounts for a portion of the 27 percent who selected the "not sure" response. This sign has a higher "not sure" response than any other warning sign in the survey. Drivers who knew the meaning of the sign tended to be from urban areas and had commercial or motorcycle driver licenses.

### PAVEMENT MARKING RESULTS

Seven of the survey questions addressed pavement markings. The response rates for each of the pavement marking questions are given in Table 5. These results should be interpreted carefully, as differences in questions and response choices may not allow for comparisons between question results. This section describes the results of the survey questions on pavement markings. Similar questions were asked in a study performed by the Texas Transportation Institute (TTI) in 1981 (5). The results of the two surveys that span 10 years are compared for many of the questions.

#### Single Broken Yellow Center Line

Two questions were asked in the 1981 survey (5) about a broken yellow center line separating two lanes. The first question asked if the road was one way or two way, and the second question asked if passing was permitted. Both questions had a correct response rate of 87 percent in the statewide survey. When shown the film of a broken yellow center line, 53 percent gave the correct open-ended response for both issues. Another 20 percent had one or the other issue correct, but not both. A total of 28 percent did not understand the meaning of the marking at all.

In the current survey, participants were asked, "Which one of the following statements is true about the dashed yellow center line?"

| <i>Answer Choice</i>  | <i>Percentage</i> |
|---|-------------------|
| This is a two-way road where you are allowed to pass.         | *76.8             |
| This is a two-way road where you are not allowed to pass.     | 12.2              |
| This is a one-way road where you are allowed to change lanes. | 8.2               |
| Not sure.   | 2.8               |

Approximately 77 percent of the respondents correctly identified the broken center line as a two-way road where passing is allowed. However, more 12 percent of the respondents thought that passing was not allowed. Although the passing distinction was not made by 12 percent of the drivers surveyed, 89 percent of the respondents recognized the two-way characteristic of the broken yellow line. A relatively small percentage was not sure of the correct response. The most

TABLE 5 Survey Results for Pavement Markings

| Pavement Marking                 | Percent |           |          |
|----------------------------------|---------|-----------|----------|
|                                  | Correct | Incorrect | Not Sure |
| Single Broken Yellow Center Line | 76.8    | 20.4      | 2.8      |
| Single Broken White Lane Line    | 50.3    | 46.4      | 3.3      |
| No-Passing Zone                  | 88.0    | 9.0       | 3.0      |
| Double Solid White Lane Line     | 61.0    | 29.0      | 10.0     |
| Solid White Edge Line            | 74.7    | 20.0      | 5.3      |
| Two-Way Left Turn Lane Marking   | 58.6    | 33.8      | 7.6      |
| Preferential Lane Marking        | 65.3    | 6.8       | 27.9     |

erroneous response choice was selected by more than 8 percent of the drivers surveyed. Respondents who had taken a driver education course were far more likely to answer this question correctly than respondents who had not taken a driver education course.

### Single Broken White Lane Line

Two questions were also asked in the 1981 survey (5) about a broken white lane line separating two lanes. The first question asked if the road was one or two way, and the second asked if passing was permitted. Only 47 percent selected the correct response of a one-way road. However, 93 percent chose the response that passing was permitted.

In this study drivers were to select one of three statements as being true about the dashed white line:

| Answer Choice   | Percentage |
|---|------------|
| This is a one-way road where you are allowed to change lanes.     | *50.3      |
| This is a one-way road where you are not allowed to change lanes. | 4.2        |
| This is a two-way road where you are allowed to pass.             | 42.2       |
| Not sure.   | 3.3        |

Just more than half of the respondents recognized the one-way designation of the white lane line. However, a large percentage (42 percent) responded that the white lane line indicated a two-way road. In this case the broken lane line effectively communicates the ability to change lanes or pass but does not effectively communicate directional information. An important variable associated with a correct response was driver education. Additionally, a linear relationship between age and correct responses was observed. Respondents under 25 answered this question correctly 65 percent of the time, and respondents over 75 answered correctly 10 percent of the time.

### No-Passing Zone Markings

No-passing zone markings were the most understood pavement markings surveyed. The 1981 survey found that 93 percent of drivers recognized that these markings would be found on a two-way road. Almost all of the interviewees (99 percent) knew that a no-passing situation was indicated. However,

when asked which direction of traffic was permitted to pass, only 69 percent identified the appropriate lane.

The current survey asked, "If you are traveling in the right lane, which of the following statements is true about the center line?"

| Answer Choice   | Percentage |
|---|------------|
| This is a two-way road where you are allowed to pass.         | 5.8        |
| This is a two-way road where you are not allowed to pass.     | *88.0      |
| This is a one-way road where you are allowed to change lanes. | 3.2        |
| Not sure.   | 3.0        |

Very few respondents (3.2 percent) confused the roadway with a one-way road, and very few (3.0 percent) were not sure of the meaning of this marking. These few were more likely to be older drivers, drivers with lower levels of education, non-Anglos, and drivers who had no driver education training.

### Double Solid White Lane Line

When asked about the double white lines on the pavement, participants chose the following responses:

| Answer Choice   | Percentage |
|---|------------|
| It is illegal to change lanes across these lines.                                       | *61.0      |
| You may change lanes across these lines with caution, if necessary.                     | 22.1       |
| You may change lanes across these lines from left to right, but not from right to left. | 6.9        |
| Not sure.   | 10.0       |

Thirty-nine percent of the drivers surveyed either considered it permissible, conditionally, to change lanes across double solid white lane lines (29 percent), or were not sure if changing lanes is permitted (10 percent). The fact that 61 percent of the respondents answered this question correctly is actually somewhat positive, given that the *Texas Drivers Handbook* (8) does not specifically address double solid white lines. The handbook illustrates the solid white line and describes its purpose to include channelizing, transitions, and lane use control. The handbook specifies that "crossing a solid white line should be avoided if possible." The in-context presentation used in the video survey portrayed a channelizing use of the double solid white lane lines. Therefore, some confusion may be explained by the similarity of use to the single solid white line and the lack of information available regarding double solid white lane lines. Respondents with college degrees were far more likely to choose the correct response. Driver education was not a significant variable for this pavement marking. With respect to age, the youngest drivers were most likely to select incorrect responses, and older drivers were more inclined to select the "not sure" response.

### Solid White Edge Line

Drivers selected the following responses when asked the purpose of the solid white line on the right side of the roadway:

| Answer Choice   | Percentage |
|---|------------|
| To let you know there is no curb on this road.                      | 9.6        |
| To let you know that you should not cross this line for any reason. | 10.4       |
| To let you know where the edge of your driving path is.             | *74.7      |
| Not sure.   | 5.3        |

The purpose of the question concerning the solid white edge line was to determine the number of drivers who mistakenly believe that it represents something other than the edge of the driving path—a belief held by 20 percent of those surveyed. The survey indicated that approximately 10 percent interpreted the edgeline as notice of the absence of a curb, which may be true in some cases, but not all. Another 10 percent viewed the solid white line as a prohibitive marking against crossing in all cases. A significantly correlated sociodemographic variable was language. To a driver whose primary language is not English the responses provided may seem similar or at least in some ways redundant. Age was not a significant factor in response to this question. The solid white edge line was not included in the 1981 survey (5).

### Two-Way Left-Turn Markings

The Texas MUTCD states that the two-way left-turn center lane is “for exclusive use of left turn vehicles and shall not be used for passing and overtaking or travel by a driver except to make a left turn.” The *Texas Driver Handbook* specifies that the center lane should not be used as a travel or passing lane but also says “the only time a vehicle should enter the center lane is at a point where the vehicle will have time to slow down or stop in order to make a safe left turn.” When asked how they would use the center lane, participants responded as follows:

| Answer Choice  | Percentage |
|--|------------|
| Get into this lane at the point where you are ready to turn left.                    | 26.2       |
| Get into this lane when you need to slow down in order to turn left.                 | *58.6      |
| Get into this lane when you need to speed up in order to move into the traffic lane. | 7.6        |
| Not sure.  | 7.6        |

Technically, the first two responses could be considered appropriate, because of the slight difference between the statements of the Texas MUTCD and the driver handbook. For survey tabulation purposes, the second response (given by 58.6 percent of the respondents) was considered the preferred response, and the first response (given by 26.2 percent of the respondents) was considered second best. Since the question asked was “How do you use the center lane?” the respondents were told (if they asked) that there was no incorrect response, but that the second response was a desirable response.

Of interest was the percentage of drivers who use the center turn lane as an acceleration lane. This response, the least desirable driving response, was given by 7.6 percent of the survey respondents. Another 7.6 percent were not sure how the lane should be used. None of the driving or demographic

characteristics were found to have a significant relationship to responses for this question.

The 1981 TTI survey included a multiple-choice question regarding two-way left-turn markings with the following choices and corresponding percentage of responses: (a) left turn lane, 59 percent; (b) passing lane, 5 percent; (c) emergency stopping area, 21 percent; and (d) don't know, 13 percent. Although the two questions are not comparable, the responses to each illustrate that 5 to 8 percent of drivers interpret these markings as acceleration or passing lanes and that a sizable percentage of drivers are not sure of the meaning of the markings.

The ambiguity surrounding this question (and the fact that 59 percent of drivers would use this lane to decelerate) points to a need for clarification. According to state trooper representatives on the current TTI study advisory panel, driving violations with respect to two-way left turn lane markings are apt to be enforced according to varying interpretations.

### Preferential Lane Marking (Diamond)

The diamond preferential lane marking was included in the survey to determine the familiarity and comprehension level of Texas motorists statewide with a marking used only on select freeways in the state. When asked why the white diamond is painted on the pavement, respondents selected these responses:

| Answer Choice                                     | Percentage |
|---|------------|
| This is a symbol used for aircraft speed control. | 4.3        |
| This lane is to be used only by certain vehicles. | *65.3      |
| This is a two-way road.                           | 2.5        |
| Not sure.   | 27.9       |

A large percentage (28 percent) of respondents were not sure of the meaning of this marker. Incorrect and “not sure” responses were given more often by respondents living in the smaller cities of the sample. Many commented that they had never seen this marking. Correct responses were given more often by drivers in Houston, Dallas, and San Antonio. Other driver characteristics that were associated with knowledge of the diamond preferential lane marking were those with high levels of education, men, and those who had taken driver education. Unfamiliarity with this traffic control device was more prevalent among drivers over age 55 and those with lower levels of driving exposure: those who drove fewer miles per year, made fewer long distance trips per year, and had no license. This pavement marking was not in use in Texas in 1981.

### SUMMARY

This paper has described the results of a survey assessing driver comprehension of traffic control devices. The survey, which included 13 questions on regulatory signs, 18 questions on warning signs, and 7 questions on pavement markings, was given to 1,745 drivers in Texas. These summary results should be used with caution, as the correct response rate by itself

does not provide a true indication of the effectiveness of a regulatory sign. Instead, the survey results should be interpreted for each individual sign, giving consideration to the subject matter of the question and possible response choices. The correct response rate for a given question should not be equated with the effectiveness of the traffic control device.

### Regulatory Signs

Comprehension levels for the regulatory signs ranged between 15 and 93 percent. The survey results for the regulatory signs revealed that the Reduced Speed Ahead sign more effectively conveys the upcoming lower speed limit than Speed Zone Ahead. Almost 80 percent of the respondents selected desirable driving responses to the Yield and Mandatory Movement word message signs. The Slower Traffic Keep Right, Do Not Cross Double White Line, and Keep Right signs were each indicated to be understood on the basis of correct responses by 70 percent of the drivers surveyed. Messages that involve a decision using choices of left and right or choices of contingency appear to be more complicated to drivers. The desirable response rate was only 65 percent for the Double Turn sign and 45 percent for the Two-Way Left Turn Only sign. These lower percentages may be a function of the measurement format, as evidenced by correlations between education, language, and desirable responses. The HOV Restriction sign was not interpreted correctly on the basis of responses from the majority of the drivers surveyed.

### Warning Signs

Comprehension levels for the 18 warning signs ranged between 29 and 89 percent. However, the specific aspect of the warning sign being tested and the possible response choices to a specific question have an impact on the correct response rate. These results indicate that there are several warning signs that the driving public does not fully understand. Some of the more significant areas of misunderstanding include the following: many drivers are not aware of the basic color and shape premises associated with warning signs, drivers do not associate a speed with the Turn and Curve signs, drivers are not familiar with the concept behind the Ramp Metered When Flashing sign, the Divided Highway Ends and the Divided Highway signs are sometimes confused with each other, drivers confuse the Slow Down on Wet Road sign with the Wind-ing Road sign, drivers do not recognize that the Grooved Pavement Ahead sign is intended for motorcyclists, and drivers associate Railroad Advance Warning signs with the crossing location itself and not an advance notice of the crossing.

### Pavement Markings

In the 1981 TTI survey, the findings showed that those drivers with the highest level of knowledge of pavement markings were those who had taken a driver education course. This

characteristic was the most important to overall understanding of the road marking code system. Drivers in the 1981 sample who took driver education tended to be young men who drove fewer miles per year than older drivers and had taken the driver education course within the previous 2 years.

Examination of comparable questions in the 1981 and 1991 surveys does not indicate much improvement in pavement marking comprehension. In 1981 two-way traffic and permissive passing was associated with the broken yellow center line by 87 percent of drivers. In 1991 the corresponding percentage was 77. Although 88 percent of the 1991 survey respondents correctly responded to a single question concerning no-passing zone markings, 93 and 99 percent of the 1981 respondents knew the two-way and no-passing indications, respectively. Forty-seven percent in 1981 recognized white pavement markings as applicable to one-way roads, compared with 50 percent in 1991. The two-way left-turn marking question was answered correctly by 59 percent of Texas drivers in both surveys.

These results suggest that, in general, the comprehension level of pavement markings has not improved in 10 years. A key avenue for improvement among younger drivers is driver education. Among drivers over 55, other methods such as public information efforts and message reinforcement through signing would probably be more effective. As the driving population ages in conjunction with the current pavement marking system, continuity may bring about greater understanding of traffic control devices.

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