

# Use of Supplemental Plaques To Improve Effectiveness of Warning Signs

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The use of sign plaques to supplement the message of a standard sign is a well-established practice. Guide signs make wide use of this practice through the use of cardinal direction and arrow markers. However, the use of supplemental plaques with warning signs is primarily limited to the Advisory Speed Plate and a few miscellaneous plaques. The described research evaluates the effectiveness of using supplemental plaques with standard warning signs to improve driver comprehension of the warning message. Driver comprehension of railroad and pedestrian crossing signs is evaluated with the standard sign alone and with supplemental plaques with arrow and distance markers. The results of driver surveys indicate that supplemental plaques improve driver understanding of the warning message. The research results include recommendations for using supplemental plaques with warning signs to indicate the distance to a hazard, the length of the hazard area, the location of the hazard, recommended driving responses for the hazard, and miscellaneous information. Other recommendations are suggested for the use of warning signs related to railroad and pedestrian crossings.

Standard highway signs do not always contain all the information that needs to be communicated to drivers, especially at night and during inclement weather. In these cases the information presented in a sign may be supplemented by plaques placed above and below the sign, or both. The use of supplemental plaques with standard highway signs is a well-established practice. However, except for the Advisory Speed Plate, supplemental plaques are not widely used with warning signs. Recent research (1) identified the type of hazard information needed by drivers and the extent to which the existing system of warning signs meets those needs. One finding of this research was that supplemental plaques could be used to provide drivers with additional information about potential hazards.

## TYPICAL USES OF SUPPLEMENTAL PLAQUES

The *Manual on Uniform Traffic Control Devices for Streets and Highways* (the manual or MUTCD) (2) contains the principles that govern the design, application, and placement of traffic control devices. MUTCD describes several different types of supplemental plaques for use with regulatory, warning, and guide signs. The most familiar forms of supplemental plaques are the cardinal direction and arrow markers used with guide signs. Educational plaques have also been widely used to help drivers learn the meanings of new symbol signs.

Supplemental plaques are not used with warning signs to the extent that they are used with guide signs. The most common form of supplemental plaque used with warning signs is the Advisory Speed Plate (W13-1), which is most commonly used with the Turn and

Curve warning signs. Although MUTCD states that the Advisory Speed Plate "is intended for use to supplement warning signs," the only warning signs that specifically indicate that an Advisory Speed Plate may be used with them are the Turn/Curve sign series and the BUMP/DIP signs. MUTCD also describes the use of distance plaques and miscellaneous plaques with warning signs. Almost all references to supplemental plaques are contained in the Hill sign section, although two other sections contain brief descriptions of supplemental distance plaques.

Several state MUTCDs contain detailed descriptions of supplemental plaques beyond that found in the national MUTCD (2). The South Carolina (3), Ohio (4), Minnesota (5), and New York (6) MUTCDs contain sections describing the use of distance plaques with warning signs. These supplemental distance plaques include legends such as 750 FEET, 1 MI, 1½ MI AHEAD, and NEXT ½ MILE. State MUTCDs also describe the use of supplemental plaques with school warning signs (Ohio), below Crossroad and Signal Ahead signs (Alabama), and containing diagonal arrows (Minnesota).

## PURPOSE OF STUDY

This paper describes a portion of the findings that resulted from research (1) on driver comprehension of warning signs. The research emphasized the system-wide consistency of the warning sign system and the information needs of drivers. It was intended to evaluate the basic principles on which the current system of warning signs are based and to determine whether any of these principles should be changed to improve driver comprehension of warning signs. The research was intended as a preliminary step toward determining the need to make some fundamental changes in the content and organization of the warning sign chapter of MUTCD (2). As such the research was intended to suggest some concepts and ideas for future discussion and research. Furthermore, the research focused solely on driver comprehension and did not include evaluations of legibility, learnability, driver response, reaction time, conspicuity, cost, or other factors.

The research found that hazard location and driving response information are important and that standard warning signs do not always provide drivers with this information. The information may not be necessary in all situations, because the driver can often determine the location of or response to a potential hazard from information in the visual field. In other situations, however, the information necessary to make the appropriate driving decision may not be visible to the driver (a situation that supports the need for a warning sign). Supplemental plaques can be used to provide site-specific information that is not typically contained in standard warning signs, including

- Distance to the potential hazard,
- Length of the potential hazard,
- Direction to or location of the potential hazard,
- Recommended speed for the potential hazard, or
- Miscellaneous identification or response information.

Most of the previous research on driver comprehension of warning signs has concentrated on comprehension of the sign legend alone, without supplemental information. When supplemental information has been evaluated, it has typically been limited to the Advisory Speed Plate. The research described in this paper was conducted to evaluate the effectiveness of using supplemental plaques with standard warning signs to improve driver comprehension of a potentially hazardous situation.

**STUDY METHODOLOGY**

The effectiveness of supplemental plaques was evaluated through two separate survey efforts. The initial survey evaluated the 11 signs shown in Figure 1. These 11 signs include four standard warning signs and seven alternative designs. All but one alternative design was created by adding a supplemental plaque below a standard warning sign.

Multiple-choice questionnaires were used to measure driver understanding of each sign. The responses for each question included one correct, two incorrect, and one not-sure answer. This evaluation format has been used in other studies of sign comprehension and provides a good starting point in assessing the effectiveness of a given sign. An attempt was made to select incorrect responses that were possible for the particular sign alternative. The incorrect responses were usually developed from common misinterpretations identified in previous research. The questions within a sign category were identical except for the sign image shown with the question. Each set of signs (A, B, or C) was given to a separate sample of drivers. The sample size for each set in the initial survey was approximately 195 drivers. After the results of the initial survey had been analyzed, a follow-up survey was developed. The follow-up survey evaluated the two alternative designs for the Advance Pedestrian Crossing sign (Sets A and C). The sample size of the follow-

up survey was approximately 125 drivers for each set. In both surveys U.S. customary units were used in the supplemental plaques to avoid driver confusion over the meaning of the units.

The initial survey was administered at an automobile show in Houston, Tex., and at a boat show in Bryan/College, Tex. The follow-up survey was administered at the same automobile show as the initial survey week after the initial survey. Participants were recruited from traffic passing by the show booth. There were no qualifications or requirements for participating in the survey except that only licensed drivers were asked to participate. The questions in both surveys were self-administered by the survey participants. As a result, participants were given unlimited time to consider the question and select a response. The survey administrator observed participants to ensure that participants did not consult with another person in answering the questions. The warning signs in all of the surveys were represented by a black-and-white image of the sign.

**SURVEY SAMPLE CHARACTERISTICS**

The characteristics of the subjects in the five survey sets were determined by questions at the end of each survey instrument. Table 1 summarizes these characteristics for each set and compares these characteristics with those of the Texas population as a whole and the Texas driving population. The two surveys were administered at locations that attracted a cross section of people who were not completely representative of the general population. Therefore, it was assumed before the surveys were given that the samples would not accurately reflect the general population. This assumption turned out to be true. The samples tended to have more males who were younger and more educated than the Texas population. The samples also had higher proportions of drivers who spoke English as the primary language.

**SURVEY FINDINGS**

The survey findings have been organized into three basic groups: advance warning of railroad-highway grade crossings, pedestrian crossings, and a generic supplemental distance plaque. In the tables summarizing the results, the correct response is shown in italics and is highlighted with an asterisk. The accuracies of the responses range between  $\pm 2.7$  and  $\pm 5.8$  percent with a 90 percent confidence interval. A z-test was used to conduct a statistical comparison of the results for alternatives. The equations used for the statistical analysis follow:

Null hypothesis,  $H_0: \pi_1 - \pi_2 = 0$

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

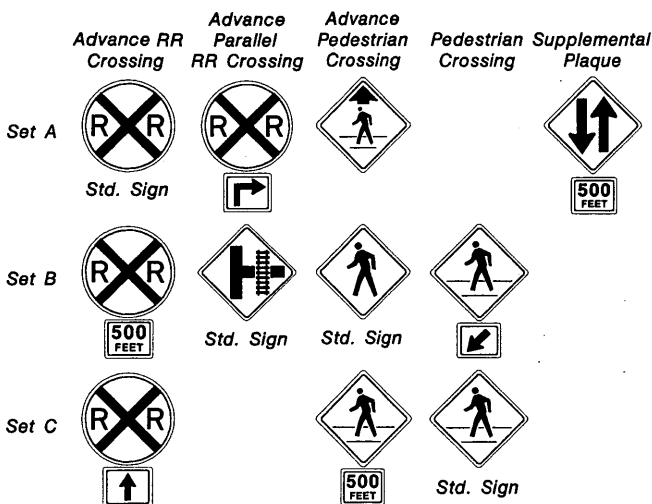
Test statistic:  $z = \frac{\hat{\pi}_1 - \hat{\pi}_2}{\sigma_{\hat{\pi}_1 - \hat{\pi}_2}}$

where

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

and  $\pi$  is approximated by

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



**FIGURE 1** Standard and alternative warning signs evaluated in the initial survey.

TABLE 1 Survey Sample Characteristics (Percent)<sup>1</sup>

Characteristic	Initial Survey			Follow-Up Survey		All Sets	Texas Population	Texas Drivers	
	Set A	Set B	Set C	Set A	Set C				
Gender	Male	65.6	66.2	64.9	75.2	70.7	67.8	49.3	51.5
	Female	34.4	33.8	35.1	24.8	29.3	32.2	50.7	48.5
Age	16 - 24	18.5	19.8	23.0	26.6	29.5	22.7	18.9	15.2
	25 - 34	25.3	24.5	17.4	21.7	27.9	23.1	24.4	25.0
	35 - 44	29.9	30.7	21.0	25.8	20.5	26.0	20.1	22.8
	45 - 54	14.4	14.6	18.5	17.5	13.9	15.4	12.9	14.6
	55 - 64	6.7	8.3	10.3	4.2	3.3	7.0	10.2	10.4
	65 +	5.2	3.6	9.7	4.2	4.9	5.7	13.6	12.0
Family Background	African Amer.	3.7	3.6	5.7	8.5	5.8	5.1	11.6	---
	Anglo	76.4	70.5	74.7	76.9	78.5	75.0	60.6	---
	Asian	3.7	6.7	3.1	6.8	3.3	4.7	N/A <sup>2</sup>	---
	Hispanic	9.4	7.8	8.8	6.8	9.1	8.5	25.6	---
	Other	6.8	11.4	7.7	0.9	3.3	6.7	2.2	---
Primary Language	Asian	2.1	3.6	1.5	1.7	0.8	2.1	---	---
	English	96.4	92.2	97.0	97.5	95.0	95.5	---	---
	Spanish	1.5	3.6	0.5	0.0	3.4	1.8	---	---
	Other	0.0	0.5	1.0	0.8	0.8	0.6	---	---
Years of Education	< High School	7.9	8.5	9.9	11.2	11.5	9.5	28.1	---
	High School Grad	23.2	15.9	20.3	14.7	15.6	18.4	25.9	---
	Tech/Trade School	7.9	4.8	5.2	5.2	7.4	6.1	N/A <sup>3</sup>	---
	Some College	24.7	31.7	26.6	33.6	28.7	28.7	27.8	---
	College Graduate	21.1	25.9	22.9	23.3	32.0	24.6	12.6	---
	Graduate School	15.3	13.2	15.1	12.1	4.9	12.7	5.5	---
Type of License	Operator	78.8	83.9	81.7	82.4	77.7	81.0	---	89.1
	Commercial	6.7	8.8	9.6	6.7	9.1	8.3	---	10.9
	Motorcycle only	0.0	0.0	0.5	0.0	0.8	0.2	---	< 0.1
	Oper and MC	11.4	6.2	7.1	8.4	8.3	8.3	---	N/A
	Comm and MC	3.1	1.0	1.0	2.5	4.1	2.2	---	N/A
Years Since Driver Education	None	16.1	23.3	16.5	19.3	23.1	19.4	---	---
	< 2	10.9	18.1	17.5	12.3	11.1	14.4	---	---
	3-10	30.2	27.5	27.3	26.3	35.9	29.1	---	---
Years Since Defensive Driving	> 10	42.7	31.1	38.7	42.1	29.9	37.0	---	---
	None	33.7	39.7	40.2	34.8	33.6	36.9	---	---
	< 2	26.3	26.3	20.1	24.1	29.2	24.9	---	---
Sample Size <sup>4</sup>	3-10	32.1	27.3	28.9	31.3	31.9	30.0	---	---
	> 10	7.9	6.7	10.8	9.8	5.3	8.2	---	---
Sample Size <sup>4</sup>		195	195	198	124	125	837	---	---

Notes: --- Data not applicable

<sup>1</sup>Percentages represent percent of the sample for each question and not a percentage of the total sample.

<sup>2</sup>For the statewide proportion, Asians are included in the other category.

<sup>3</sup>Statewide proportion not available.

<sup>4</sup>Not all background questions were answered by all respondents.

Rejection region: For a given value of  $\alpha$ , reject  $H_0$  if  $|z| > z_{\alpha/2}$

The  $\alpha$  value, or probability of a Type I error, is 0.10 throughout the analysis.

### Advance Warning Signs for Railroad-Highway Grade Crossings

The placement differences between the circular Railroad Advance Warning sign (W10-1) and the Crossbuck sign (R15-1) have not always been recognized by drivers. Several previous research studies (7-10) identified this type of confusion among drivers. The initial survey contained two questions that were intended to determine whether supplemental plaques would improve driver comprehension of the advance warning message. The questions evaluated the circular Railroad Advance Warning sign (W10-1) and the diamond Parallel Railroad Advance Warning sign (W10-3).

#### Railroad Advance Warning Sign (W10-1)

One question in the initial survey evaluated driver interpretation of the advance warning aspect of the standard circular sign and two

alternative designs, as shown in Figure 1. The alternative signs used supplemental plaques below the standard sign. The supplemental plaque in one alternative design displayed a distance, and the supplemental plaque in the other displayed an up arrow. The results of the survey question are given in Table 2.

The results for the standard sign indicate the same type of comprehension difficulties found in previous studies (7-10). More drivers (54 percent) thought that the standard sign was used at the crossing instead of ahead of it (44 percent). Driver interpretation of the advance warning improved with the alternative signs. The addition of a supplemental distance plaque increased the correct comprehension from 44 to 92 percent. The use of a supplemental arrow plaque increased the correct comprehension rate to 77 percent. It is important to note that the survey responses did not include a nonrailroad response.

These survey results indicate that a supplemental plaque improves comprehension of the advance nature of the standard sign. The supplemental plaque indicating the distance to the crossing appears to be better understood than an arrow supplemental plaque. However, the arrow supplemental plaque is better understood than the standard sign alone. In situations in which the driver may be uncertain about the actual location of the crossing or the crossing is

TABLE 2 Survey Results for Advance Railroad Warning Signs

Set A	Set B	Set C	What does this sign mean?
Standard	Distance Plaque	Arrow Plaque	
53.6%	6.7%	15.2%	You are at a railroad crossing.
2.6%	1.5%	5.1%	You must stop your car at the railroad tracks.
43.8%	91.8%	77.3%	*There is a railroad crossing ahead.
0.0%	0.0%	2.5%	I'm not sure what it means.

obscured from view, a supplemental plaque may help the driver identify the location of the crossing.

#### Parallel Railroad Advance Warning Sign (W10-3)

The diamond railroad sign provides advance warning of a railroad crossing on an intersecting road. This sign uses neither the circular shape nor the diagonal cross used to indicate a railroad crossing in other signs. Therefore, drivers may fail to associate this sign with a railroad crossing. Furthermore, there have been few evaluations of driver comprehension of this sign. Therefore, one question in the initial survey was developed for two purposes: (a) to measure comprehension of the standard diamond sign, and (b) to determine whether comprehension could be improved by the use of a circular railroad sign with a supplemental plaque. The alternative design used the standard circular Railroad Advance Warning sign (W10-1) with a supplemental bent arrow plaque below it, as shown in Figure 1. Only one alternative design was tested; therefore, the question appeared in only two questionnaires in the initial survey.

The survey results, summarized in Table 3, indicate that both signs are equally well understood. In fact, the response percentages are statistically equivalent (at  $\alpha = 0.01$ ). Driver understanding of both signs appears to be very high (approximately 94 percent). Drivers understand the intended message of both signs, even though the signs use different communication techniques.

The comprehension levels of these two signs are so similar that it is not appropriate to recommend the use of one over the other solely on the basis of driver comprehension. However, use of the circular sign with the supplemental bent arrow plaque has other advantages that may lead to it being the preferred choice. The circular alternative design is an enhancement of the standard Railroad Advance Warning sign (W10-1). As such it does not require drivers to understand another unique symbol. The alternative design maintains the use of a circle for advance warning of a railroad crossing that improves the consistency of the warning sign system. Finally, if the alternative design were to be established as the standard, the total number of different warning signs could be reduced.

#### Pedestrian Crossing Signs

Driver confusion in comprehending between the Advance Pedestrian Crossing sign (W11-2) and the Pedestrian Crossing sign (W11A-2) has been cited as a notable difficulty for these signs (11). The inability of drivers to distinguish between these two signs is because the only difference between them is the presence on the W11A-2 sign of two lines that are used to symbolize the crosswalk. Both signs were included in the evaluation to determine whether supplemental plaques could improve driver comprehension of the advance warning message in the W11-2 sign and the crossing message of the W11A-2 sign.

TABLE 3 Survey Results for Parallel Railroad Warning Signs

Set A		Set B		What does this sign mean?
Bent Arrow	Plaque	Standard	Standard	
0.0%	0.0%	0.0%	0.0%	You will come to a fence if you turn right.
93.3%	94.4%	94.4%	94.4%	*You will cross a railroad track if you turn right.
1.0%	1.0%	1.0%	1.0%	You will cross a rural road if you turn right.
5.7%	4.6%	4.6%	4.6%	I'm not sure what it means.

#### Advance Pedestrian Crossing Sign (W11-2)

The initial and follow-up surveys contained a question about the Advance Pedestrian Crossing sign and alternative designs. Both alternative designs used the Pedestrian Crossing sign (W11A-2) as the basis of their design, as shown in Figure 1. One alternative used an arrow at the top of the sign in a manner similar to that of the Stop Ahead (W3-1a) and Yield Ahead (W3-2a) signs. Although this alternative design departs from the use of supplemental plaques, it was selected to test the effectiveness of placing the arrow in the sign instead of using a supplemental plaque with an up arrow below the sign (which had already been evaluated with the Advance Railroad Crossing sign). The other alternative used a supplemental distance plaque containing the legend 500 FEET below the standard sign.

The initial survey results show that the arrow alternative had the highest comprehension level (85 percent) of the three signs. The results confirmed that many drivers do not understand the advance warning message indicated by the standard Advance Pedestrian Crossing sign. Although 63 percent correctly selected the advance warning response for the standard sign, 28 percent thought the sign marked the location of the crosswalk. Only 10 percent of the drivers interpreted the arrow alternative design as indicating the crosswalk location.

Most respondents (57 percent) to the supplemental distance plaque thought that the sign indicated a pedestrian zone of the length shown in the plaque. The large percentage selecting this response might be because it was the only answer that included "500 feet" in the response. The supplemental distance plaque performed well on other signs in the survey. It is possible that the lower level of comprehension for this sign was because of the wording of the survey responses instead of the effectiveness of the sign. This source of potential confusion led to the alternative signs being included in the follow-up survey.

The follow-up survey evaluated only the alternative designs. The response choices were similar to those of the initial survey, but they were worded to match the particular sign being evaluated. Responses to the distance alternative design included "500 feet" in two responses. Specific distances were not included in the responses to the arrow alternative design. The results of the follow-up survey for the arrow alternative design were almost identical to those of the initial survey. Driver comprehension of the supplemental distance plaque improved from that of the initial survey, but a substantial number (30 percent) continued to interpret the sign as indicating a 500-ft-long pedestrian zone. The results of the initial and follow-up surveys are given in Table 4.

The results indicate that comprehension of the Advance Pedestrian Crossing sign can be improved by adding an arrow to the top of a standard Pedestrian Crossing sign. Only 10 percent of the respondents associated the arrow alternative sign with crosswalk location. The alternative design with the supplemental

TABLE 4 Survey Results for Advance Pedestrian Crossing Signs

Initial Survey			Follow-Up Survey		What does this sign mean?
Set A	Set B	Set C	Set A	Set C	
Arrow Alt.	Standard	Distance Plaque	Arrow Alt.	Distance Plaque	
3.1%	9.2%	57.4%	8.1%	30.4%	The next 500 feet is a pedestrian zone. It marks the beginning of a pedestrian zone.
85.1%	62.6%	37.1%	80.5%	57.6%	*There is a pedestrian crossing 500 feet past this sign. *There is a pedestrian crossing ahead.
10.3%	27.7%	3.6%	8.1%	10.4%	It marks the location of a pedestrian crosswalk. There is a pedestrian crosswalk at this sign.
1.5%	0.5%	2.0%	3.3%	1.6%	I'm not sure what it means.

distance plaque reduced confusion with the Pedestrian Crossing sign less than the arrow alternative, but it was still better than the standard sign at conveying the advance nature of the warning sign. However, the distance plaque introduced a new type of misunderstanding. Many drivers thought this sign indicated a pedestrian zone of the indicated length. The survey results indicate that the Pedestrian Crossing sign with an arrow at the top of the sign is understood better than the standard Advance Pedestrian Crossing sign. Although it was not specifically tested with this sign, an up arrow plaque would probably provide a similar improvement in comprehension.

#### Pedestrian Crossing Sign (W11A-2)

In addition to addressing the advance warning of a pedestrian crosswalk, the initial survey also evaluated whether the crosswalk location itself could be more clearly indicated to the driver by use of a supplemental plaque. Only the standard Pedestrian Crossing sign and one alternative design were tested. The alternative sign added a supplemental arrow plaque below the standard Pedestrian Crossing sign, as shown in Figure 1, in the same manner that it is described in the Minnesota MUTCD (5). The supplemental plaque contained a diagonal arrow pointing down and to the left. The responses for this question were identical to those used in the Advance Pedestrian Crossing sign question in the initial survey. The response percentages are given in Table 5.

The results of the initial survey demonstrate that driver comprehension can be improved by adding the supplemental plaque. The supplemental plaque increased comprehension from 45 to 74 percent. The supplemental plaque also reduced confusion with the advance warning sign by more than half. These results indicate that adding a supplemental arrow plaque below the standard Pedestrian Crossing sign appears to increase significantly driver comprehension of the sign. Therefore, a supplemental diagonal arrow plaque used below the standard Pedestrian Crossing sign demonstrates the potential for improving driver understanding of the location of a pedestrian crossing.

#### Supplemental Distance Plaque

Warning signs are typically located according to the placement criteria contained in Section 2C-3 of the MUTCD (2). The distance between the warning sign and the potential hazard of which it warns is a function of the operating speed, the speed of the desired re-

sponse, and the complexity of the response. As a result a warning sign can be located as close as 30 m (100 ft) from a potential hazard or as far away as 260 m (850 ft). These placement criteria are engineering guidelines that the typical driver is not expected to know. Therefore, in some cases it may be appropriate to inform the driver of the distance from the warning sign to the potential hazard.

A question related to using a supplemental distance plaque is how a driver will interpret the plaque that indicates the distance to a potential hazard point. There are two possible interpretations: the distance to the potential hazard or the length of the potential hazard. One question in the initial survey was intended to evaluate this question.

One question in Set A used a supplemental distance plaque with the legend 500 FEET below a standard Two-Way Traffic sign (W6-3), as shown in Figure 1. The Two-Way Traffic sign was selected because both interpretations of the supplemental distance plaque are possible. Only the two choices plus a "not sure" response were provided. The response percentages to the question are given in Table 6. These responses indicate that a majority (89 percent) of the respondents were able to correctly interpret the intended meaning of the supplemental plaque.

A key factor in the effectiveness of a supplemental distance plaque is the ability of drivers to relate the distance shown in the plaque to a driving response. A driver may recognize that a plaque with the legend 150 METERS (500 FEET) indicates that the potential hazard is 150 m (500 ft) ahead. The question that needs to be explored is whether the driver can relate that distance to the

TABLE 5 Survey Results for Pedestrian Crossing Signs

Set B	Set C	What does this sign mean?
Arrow Plaque	Standard	
2.6%	5.6%	The next 500 feet is a pedestrian zone.
21.5%	49.2%	There is a pedestrian crossing ahead.
74.4%	45.2%	*It marks the location of a crosswalk.
1.5%	0.0%	I'm not sure what it means.

TABLE 6 Initial Survey Results for Supplemental Distance Plaque

Set A	What does this sign mean?
Percent	
88.7%	*Two-way traffic begins 500 feet past this sign.
10.8%	The section of two-way traffic is 500 feet long.
0.5%	I'm not sure what it means.

location of the potential hazard and the appropriate driving response. It may be necessary to show distances using tenths of a kilometer (mile) so that drivers can relate the distance to their odometers. Another point to be considered is that driver interpretation of the supplemental distance plaque may depend on the warning sign with which it is displayed.

## RECOMMENDATIONS

Standard warning signs can be very useful for indicating a potential hazard to a driver. However, a standard sign cannot easily provide information that is specific to a given location. The results of these evaluations indicate that supplemental plaques may provide effective means of conveying unique and site-specific information about a potential hazard. When a supplemental plaque was displayed with a standard sign, driver comprehension was generally higher than that for the standard sign alone. Therefore, the use of supplemental plaques with warning signs should be described in more detail in MUTCD. The following recommendations provide a means of better integrating supplemental plaques into the warning sign chapter of the MUTCD.

- Expand the MUTCD to include sections describing the use of supplemental plaques with warning signs. The present research indicates that supplemental plaques can provide useful information to drivers about potential hazards. Therefore, the MUTCD should be revised to include individual sections describing the use of supplemental plaques with warning signs. This practice has already been adopted in several state MUTCDs (3-6, 12, 13), which contain one or more sections describing the use of supplemental plaques with warning signs.

- There should be four series of supplemental plaques for warning signs. Supplemental plaques should be described according to the messages they convey. Figure 2 illustrates the four series of plaques. Some of these plaques are already described in the MUTCD, and others were evaluated in the research described. Some of these plaques are not currently used and were not evaluated in the present research. However, they are included in the recommended organization of these plaques to provide a system through which these plaques can function.

- Supplemental plaques for warning signs should be rectangular and have a black legend on a yellow border. The colors of supplemental plaques should be consistent with the colors of the warning signs with which they are used. The shapes of supplemental plaques should be consistent with the shapes of supplemental plaques used with other types of signs.

- The word "plaque" should be used to describe a supplemental sign located below a warning sign. The MUTCD uses "plaque," "plate," and "marker" to describe a supplemental sign. The word "panel" has also been used. One term should be selected for consistency and to eliminate the potential for confusion over the use of these supplemental devices.

- Where appropriate, MUTCD descriptions of warning signs should identify the supplemental plaques that can be used with the signs. The sections of the MUTCD that describe warning signs contain little mention of supplemental plaques. This can lead to some uncertainty whether it is appropriate to use a given supplemental plaque with a specific warning sign. Providing this information for each warning sign would reduce uncertainty and lead to greater use of supplemental plaques.

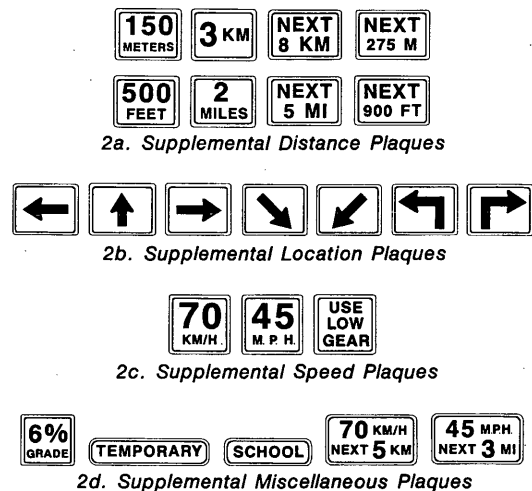


FIGURE 2 Supplemental plaques for warning signs.

The following recommendations describe the organization of supplemental plaques into four series of warning signs that could be added to MUTCD and the manner in which the plaques could be used. Some of these recommendations are not directly supported by the research described herein. When this is the case the recommendations indicate the need for additional research.

- The Supplemental Distance Plaque series consists of the plaques shown in Figure 2(a). Only the NEXT XX MILES plaque is shown in the MUTCD, although the use of supplemental distance plaques is described in several other sections.

- The XX METERS or XX KM (XX FEET or XX MILES) Supplemental Distance Plaques should be used to indicate the distance to a potential hazard itself or the beginning of a potential hazard extending over a length of roadway. These plaques are to inform the driver of the distance from a warning sign to the location of the potential hazard.

- The NEXT XX M or NEXT XX KM (NEXT XX FT or NEXT XX MI) Supplemental Distance Plaques should be used to indicate the length of road over which a potential hazard is located. These plaques are to inform the driver of the distance over which a potential hazard may be encountered.

- Further evaluations of Supplemental Distance Plaques should be conducted. These evaluations should evaluate the most effective manner of providing distance information to drivers. At a minimum these evaluations should cover two issues: (a) driver interpretation of the message conveyed by Supplemental Distance Plaques indicating the distance to a potential hazard or the length of the potential hazard area, and (b) the ability of drivers to translate distances shown in the plaques to their driving responses.

- The Supplemental Arrow Plaque series consists of the plaques shown in Figure 2(b). The use of these plaques with warning signs is new, although they are widely used with guide signs. These supplemental plaques should be used to identify the direction to or location of a potential hazard. In most cases, a warning sign indicates a potential hazard directly ahead. This situation is so common that an up arrow would not normally be needed. However, there are some instances in which the potential hazard is located on a cross

street and a horizontal arrow or bent arrow may be appropriate for those conditions. Other warning signs are actually used at the point of the potential hazard. In these cases, the downward diagonal arrow can be used to indicate that the potentially hazardous condition exists at that specific location. They should be used in a manner similar to their use with guide signs to achieve maximum uniformity in signing.

- The Supplemental Speed Plaques series consists of the plaques shown in Figure 2(c). These two plaques are based on existing warning sign plaques and are used to indicate a recommended speed for a potential hazard. The legend of the existing TRUCKS USE LOW GEAR sign should not refer to trucks. The legend can be shortened to USE LOW GEAR so that the sign will apply equally to trucks and automobiles.

- The Supplemental Miscellaneous Plaques series consists of the plaques shown in Figure 2(d). These plaques provide various types of information related to warning signs. They were not specifically evaluated in the research; therefore, additional evaluations should be conducted before they are used.

–The use of a Supplemental Combination Plaque that provides two types of information should be evaluated. For some potential hazards more than one supplemental plaque may be appropriate. Instead of mounting two separate plaques below a standard warning sign, various types of Supplemental Combination Plaques may be used. The effectiveness of these plaques should be evaluated before they are implemented. Figure 2(d) includes an example of a Supplemental Combination Plaque containing speed and distance information.

–The Supplementary Temporary Plaque should be evaluated for use with warning signs that will not be in place for an extended period of time. In some cases it may be desirable to indicate that a potential hazard may not be a permanent condition. This plaque can be used to indicate these situations.

–The Supplemental School Plaque should be evaluated for use with school warning signs. Research (11) has shown that many drivers do not recognize the message provided by school warning signs. Adding the Supplemental SCHOOL Plaque below these signs will help drivers associate them with the presence of schoolchildren.

The research results also identified methods of improving driver comprehension of signs used at railroad crossings and pedestrian crossings. These recommendations are described.

- Signs providing advance warning of a specific crossing location should use an arrow at the top of the sign, a supplemental up arrow plaque below the sign, or a supplemental distance plaque below the sign to indicate the advance warning of the crossing. Previous research and the survey results indicate that drivers do not distinguish between the advance warning sign for a crossing and the crossing sign itself. The surveys found that a distance plaque or arrow can significantly reduce confusion with the crossing signs. Warning signs with which the arrow should be used include Advance Pedestrian Crossing, Advance Bicycle Crossing, Advance School Crossing, and Railroad Advance Warning signs.

- Warning signs indicating the location of a crossing should use a Supplemental Diagonal Arrow Plaque to identify the location of the crossing. The survey results indicated that a diagonal down arrow under the standard warning sign improves driver comprehension of the crossing location.

## CONCLUSIONS

The uses of supplemental plaques with warning signs are already described in several sections of MUTCD, and they are also used in actual practice. However, MUTCD descriptions are somewhat limited, which tends to restrict the overall use of supplemental plaques. As the research described in this paper indicates, supplemental plaques demonstrate a potential for improving driver understanding of potential road hazards by providing drivers with site-specific information not normally contained in standard warning signs. Therefore, supplemental plaques for warning signs should be described as individual sign series in MUTCD so that practitioners can be informed of the many useful ways in which supplemental plaques can be used with warning signs.

The recommendations resulting from the research described here should be viewed as a starting point toward the wider use of supplemental plaques with warning signs. Many of the recommendations described in this paper are consistent with existing MUTCD principles and can be immediately implemented. Other uses of supplemental plaques should be further evaluated in field experiments to consider factors beyond driver comprehension. At a minimum these field experiments should evaluate legibility, driver response, and the costs of using supplemental plaques with warning signs.

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