Comprehension and Legibility of Selected Symbol Signs Phase IV

PUBLICATION NO. FHWA-HRT-22-088

SEPTEMBER 2022

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

The objective of the Transportation Pooled Fund Program's Traffic Control Device (TCD) Consortium is to assemble regional, State, and local entities, appropriate organizations, and the Federal Highway Administration (FHWA) to establish a systematic procedure to select, test, and evaluate existing and new TCDs that will support changes to the *Manual on Uniform Traffic Control Devices* and interim approvals.

This report documents an FHWA project examining the comprehension and legibility of existing and new signs. In 2016, the TCD Pooled Fund Study panel selected the following sign messages for symbol development and evaluation: Toll Plaza Electronic Toll Interoperability, Lane Reduction Treatment, Temporary Traffic Control Bicycle/Pedestrian Access, Flashing Yellow Arrow, Blind Hill Warning, Rail/Flangeway Gap Bicycle Warning, Vehicle Prohibition, Bicycle Passing Law, Passenger Ferry, Midblock Hybrid Beacon Pedestrian Crossings (Driver), Alternative Fuels, and Recreational and Cultural Interest.

This report is of interest to engineers, planners, and other researchers and practitioners concerned with road users' ability to see and understand signs. Information on the comprehension of Recreational and Cultural Interest signs may be of interest to local, regional, State, and park authorities as they evaluate their existing and planned public information strategies.

Brian P. Cronin, P.E.
Director, Office of Safety and Operations
Research and Development

Recommended citation: Federal Highway Administration, *Comprehension and Legibility of Selected Symbol Signs Phase IV* (Washington, DC: 2022) https://doi.org/10.21949/1521917.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-HRT-22-088	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Comprehension and Legibility of Selected Symbol Signs Phase IV		5. Report Date September 2022
		6. Performing Organization Code:
7. Author(s) Stacy A. Balk (ORCID: 0000-0003-3886-5117), Erin Kissner, and Bryan Katz (ORCID: 0000-0003-2813-8098)		8. Performing Organization Report No.
9. Performing Organization Name and Address Leidos, Inc. 6300 Georgetown Pike McLean, VA 22101		10. Work Unit No.
		11. Contract or Grant No. DTFH61-13-D-00024
12. Sponsoring Agency Name and Address Office of Safety and Research Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered March 2016–December 2017
		14. Sponsoring Agency Code HRDS-30

15. Supplementary Notes
The Contracting Officer's Representative and Human Factors Team Leader was Brian Phillips (HRDS-30; ORCID: 0000-0002-8426-0867).

16. Abstract
The traffic control device (TCD) pooled fund study (PFS) addresses human factors and operations issues through the systematic evaluation of existing and new TCDs. As a part of this effort, the Federal Highway Administration Human Factors Team evaluated sets of existing and proposed traffic signs for driver comprehension and legibility. The TCD PFS panel selected the following sign messages for evaluation: Lane Reduction Treatment, Temporary Traffic Control Bicycle/Pedestrian Access, Flashing Yellow Arrow, Alternative Fuels, Midblock Hybrid Beacon Pedestrian Crossings, Passenger Ferry, Bicycle Passing Law, Vehicle Prohibition, Rail/Flangeway Gap Bicycle Warning, Blind Hill Warning, Toll Plaza Electronic Toll Interoperability, and Recreation and Cultural Interest. The research team used open-ended responses, multiple-choice responses, and subjective rankings to assess sign comprehension and then tested the legibility of each sign. The study provides recommendations on the specific signs road users are most able to understand, as well as sign groups for which additional public education and sign testing would be recommended.

17. Key Words Traffic control devices, symbol sign, human factors, safety, transportation	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161. http://www.ntis.gov

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 65	22. Price N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1,000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Alt.	alternative
ANSI	American National Standard Institute
ATV	all-terrain vehicle
DOT	department of transportation
FHWA	Federal Highway Administration
MSe	mean squared error
MUTCD	*Manual on Uniform Traffic Control Devices*
PFS	pooled fund study
TCD	traffic control device

CHAPTER 1. INTRODUCTION

Traffic signs are an important communication tool that convey regulatory, warning, and guidance information to road users. The process of understanding user requirements for new signs is particularly important for symbol signs, which rely on a common nonverbal interpretation by a large and diverse population of drivers.

The traffic control device (TCD) pooled fund study (PFS) focuses on a systematic evaluation of new TCDs, employing a process that addresses human factors and operations issues for each TCD idea. As part of the TCD PFS effort, the Federal Highway Administration (FHWA) Human Factors Team evaluated driver comprehension and legibility for sets of sign alternatives for both existing and proposed traffic signs. For some sets, participants were also asked to rank the effectiveness of the alternatives.

By pooling resources and expertise, rather than performing several independent research studies across the country, the TCD PFS provides local and State agencies faster responses to their needs and new technologies using effective assessment skills and tools that enable consistent TCD idea identification and evaluation. The TCD PFS efforts address TCD issues identified by local and State jurisdictions, industries, and organizations and aid in the compliance to the *Manual on Uniform Traffic Control Devices* (MUTCD) rulemaking process and incorporation of novel TCDs into the MUTCD.[1]

TCD PFS members have selected various sign concepts to include as phase IV of a study to evaluate the effectiveness of concepts for new signs, most of which contain symbols. The remainder of this report describes the study effort.

LITERATURE REVIEW

Traffic symbol signs communicate important messages to the driver or road user using an icon or graphical representation rather than words. A well-designed symbol can communicate instructions to the driver quickly and accurately, but ambiguous designs may be misunderstood and have potentially dangerous consequences. The current review examines a brief history of symbol signs, the advantages of well-designed symbol signs, and criteria for evaluating the effectiveness of a symbol sign. The evaluation criteria presented in this report informed the dependent measures that were assessed in this study.

The concept of symbol signs has its early origins in Paris with the Convention on the International Circulation of Motor Vehicles held in 1909.[2] Because of this meeting, several European countries recommended adoption of four road sign warnings (hump, curve, road crossing, and railroad crossing). In 1949, the United Nations developed a new protocol on road signs in which 50 signs were specified and adopted by 30 countries.[2] This protocol was revised in 1953 and 1968 and adopted by more European, Asian, and South American countries. Although the United States had primarily used word signs, by 1970 the United States began the use of symbol signs, many of which came from the 1968 United Nations standards.[2]

The advantages to a well-designed symbol, in lieu of text, are numerous. Symbol signs can be identified at greater distances, providing drivers with important information from further away

and thus giving them more time to react to changing situations. Additionally, these signs can be identified quickly and more accurately at a glance, which is critical given the dynamic nature of the driving environment and the oftentimes cluttered visual scene. Symbol signs are better identified in adverse weather conditions (e.g., fog), where, due to the degraded visual conditions, focal vision (or recognition vision)—which is required to discern fine detail like text—would be impaired. Importantly, given the increasingly diverse makeup of nonnative drivers on the roadway, symbol signs have the advantage of being understood even by drivers who do not understand the language of the country.

However, symbol signs may be rendered ineffective and potentially dangerous when the meaning of the sign is not adequately conveyed by the selected symbol. In a study by Ogden, Womack, and Mounce, motorists were surveyed regarding their understanding of work zone signing.[3] The researchers found that these motorists had some difficulty interpreting both word and symbol messages on signs. Dewar, Kline, and Swanson found that at the time of their study, only 16 out of 85 of the standard traffic symbols used in the United States were understood by more than 95 percent of the drivers in their sample.[4] Additionally, for 10 of the signs they examined, comprehension was less than 40 percent. In another study, several motorists interpreted the No Entry For Motorcycles sign and the End Speed Limit sign exactly opposite of the intended meaning for these signs.[5] A sign that is not comprehended or interpreted with the intended meaning can create a hazard for road users.

Despite the importance of well-designed symbol signs, there is no universally accepted standard for evaluating the effectiveness of a design, nor a consistently applied comprehension accuracy criteria. Although there is not a definitive list of requirements for evaluating symbol signs, several researchers have proposed factors critical to the design and evaluation of symbol signs. Dewar proposed six criteria important to the design and evaluation of symbol signs listed and defined in this report:[6]

- Understandability: The ease with which the symbol can be understood.
- Legibility distance: The greatest distance at which the symbol can be clearly read.
- Conspicuity: The extent to which a sign can be easily detected or seen in a visually complex environment.
- Learnability: The extent to which the meaning of a symbol can be learned and remembered.
- Glance legibility: The ease with which the symbol can be read when it is seen for only a fraction of a second.
- Reaction time: How quickly the meaning of the sign can be identified.

Additionally, Dewar, Kline, and Swanson had transportation experts rate the relative importance of these six criteria.[4] In their study, comprehension was prioritized as the most important criteria, followed closely by conspicuity. Reaction time and legibility distance were rated as equally important, and learnability was rated as least important. Indeed, this prioritization makes

logical sense in that a symbol that is both easy to understand and conspicuous should allow drivers to respond from greater distances and with faster reaction times. Previous symbol sign studies conducted for the TCD PFS have used Dewar's list as guidance for symbol sign evaluation (e.g., the study by Katz, Dagnall, and O'Donnell).[7]

In addition to standards for sign evaluation, examining criteria for sign design is also important. Several symbol sign alternatives will be designed in the current study, and looking at human factors principles for sign design will be useful. Sanders and McCormick proposed five ergonomic principles for the design of symbol signs, which are highlighted as follows:[8]

- Spatial compatibility: The physical arrangement in space, relative to the position of information and directions.
- Conceptual compatibility: The extent to which symbols and codes conform to people's association.
- Physical representation: The similarity between the content of the sign and the reality it represents.
- Familiarity: The extent to which the driver is familiar with the sign from his/her driving experience.
- Standardization: The extent to which the codes used for different dimensions, such as color and shape, are consistent for all signs.

Both Shinar et al.[9] and Ben-Bassatt and Shinar[5] examined the topic of sign comprehension as it relates to the ergonomic principles listed in the preceding bulleted list. In both studies, there were high and significant correlations between the probability of sign comprehension and the extent to which the sign complied with the ergonomic principles of compatibility, familiarity, and standardization. Signs designed according to these principles should be easier for drivers to understand and make an appropriate response.

RESEARCH GOALS AND SELECTED SIGNS

The FHWA Human Factors Team conducted phase IV of the symbol signs study series to develop and evaluate proposed alternatives for new traffic signs. The goals of this study were as follows:

- Evaluate driver comprehension of selected signs.
- Measure the legibility distance of selected signs.
- Provide recommendations on signs that merit consideration for addition to the MUTCD.[1]

The TCD PFS panel selected the following sign messages for symbol development and evaluation (see section, Sign Categories, for detailed descriptions of each sign type):

- Lane Reduction Treatment.
- Temporary Traffic Control Bicycle/Pedestrian Access.
- Flashing Yellow Arrow.
- Alternative Fuels.
- Midblock Hybrid Beacon Pedestrian Crossings (Driver).
- Passenger Ferry.
- Bicycle Passing Law.
- Vehicle Prohibition.
- Rail/Flangeway Gap Bicycle Warning.
- Blind Hill Warning.
- Recreational and Cultural Interest.
- Toll Plaza Electronic Toll Interoperability.

RESEARCH APPROACH

The TCD PFS focuses on the systematic evaluation of new TCDs and employs a consistent process to research and address human factors and operations issues for these TCDs. As part of this effort, the FHWA Human Factors Team evaluated a selection of proposed symbols to ensure their effectiveness for driver comprehension and legibility distance. The research objectives of this study were to:

- Perform a literature review examining the current state of practice for effective symbol sign design.

- Develop a set of symbol sign alternatives.

- Perform a laboratory test to determine driver comprehension and legibility distance of the experimental symbol signs.

- Provide recommendations on the symbol signs alternatives that should be considered for inclusion in the next edition of the MUTCD.

SIGN CATEGORIES

The following sign categories for symbol development and evaluation were selected by the PFS panel. Images of each of the sign alternatives are presented in chapter 3, Results.

Lane Reduction Treatment

The current study results will be used in a future investigation of both the signing and lane markings best suited for lane reduction treatments or situations where one lane is ending.

Temporary Traffic Control Bicycle/Pedestrian Access

Growing interest in pedestrian and bicycle safety has made bicycle and/or pedestrian pathways more common. As large public works projects displace paths and routes, special detour routes for bicycles and/or pedestrians will become more prevalent. The team assessed bicyclist and

pedestrian comprehension of such signs based on how users perceive the route use and choose a route appropriate for their mode of travel.

Flashing Yellow Arrow

The Flashing Yellow Arrow sign informs drivers that they are expected to yield at a flashing yellow traffic signal. Adequately conveying dynamic "flashing" in a static symbol is a challenge. This study investigated the most appropriate symbol to portray a flashing yellow arrow.

Alternative Fuels

New alternative fuels (specifically hydrogen, liquid propane gas, biodiesel, and fast charging/slow charging electric vehicle stations) may require signing, alerting drivers to the location where these fuels can be obtained.

Midblock Hybrid Beacon Pedestrian Crossings (Driver)

Drivers may not understand what action to take when encountering hybrid beacon pedestrian crosswalks. Signs instructing drivers of the appropriate action to take at this type of crosswalk were investigated by the team.

Passenger Ferry

The MUTCD has an approved sign to indicate a vehicle ferry.[1] However, simply removing the vehicle symbol from this sign to indicate a passenger ferry would not be in conformance with the MUTCD standard. A symbol sign that indicates a passenger ferry was developed and evaluated by the team.

Bicycle Passing Law

More than 20 States have passed legislation requiring motorists to provide a minimum of 3 ft of clearance when passing bicyclists on the roadway.[10] However, there is not currently a standard sign that alerts motorists of this law. Many States and local highway agencies have developed their own signs to convey this message. These existing signs and several alternatives were tested for comprehension and legibility.

Vehicle Prohibition

Vehicle Prohibition signs indicate that certain vehicles (e.g., golf carts, motorcycles, jet skis, or all-terrain vehicles [ATVs]) are not permitted on bicycle or pedestrian pathways or trails. Some current symbols used by State and local highway agencies do not match existing symbols on signs compliant with the MUTCD. Additionally, some entities have expressed interest in combining several symbols into a single sign.

Rail/Flangeway Gap Bicycle Warning

Given the expansion of fixed guideway transit networks throughout the country and an increase in bicycle travel, rails have been embedded into the roadway, creating a flush surface allowing

roadway users other than motor vehicles to share this same space. This design, although fine for motor vehicle traffic, is problematic for bicyclists, as bicycle tires can drop into the flangeway gap if the bicyclist does not cross the gap at an appropriate angle, creating a dangerous situation for the bicyclist. Additionally, the top of the rail can become slippery in wet conditions. There is currently no MUTCD-approved sign to warn bicyclists about this potential hazard, although some States and local highway agencies have developed signs for this purpose. Some of the signs display a regulatory or guidance-related message on a diamond-shaped warning sign. This usage is inappropriate, as the diamond shape and yellow color are reserved for warning signs.

Blind Hill Warning

Vertical curves can obscure key roadway features or activity that might lie ahead of an unaware driver and therefore represent a critical safety event. There is no well-accepted TCD for warning drivers of vertical curvature. The Hill Blocks View sign and Limited Sight Distance sign have demonstrated limited success in conveying messages related to limited sight distance. A test of signs for blind hill warning will evaluate user understanding of the specific hazard indicated by the sign and may produce an output that can also be applied to the limited sight distance applications as well.

Recreational and Cultural Interest

These signs direct road users to general areas of interest or to specific facilities or activities within these areas. These signs may be used to alert the road user to the attraction from the roadway or may guide users once already inside a park or other recreational or cultural area. The team investigated the understandability of specific signs in this category.

Toll Plaza Electronic Toll Interoperability

To meet Moving Ahead for Progress in the 21st Century (MAP-21) requirements for federally funded facilities, the International Bridge, Tunnel and Turnpike Association began efforts toward designing technologies and business practices to implement national electronic toll interoperability within the United States.[(11)] Symbol signs to communicate that a specific toll has national interoperability capabilities were evaluated by the team.

CHAPTER 2. METHOD

Data were collected both at the Turner-Fairbank Highway Research Center and in a mobile laboratory. The use of the mobile laboratory allowed the team to collect data from participants from outside of the Washington, DC, metropolitan area. Participants sat approximately 5 ft from a 60-inch LCD display. Signs were evaluated for comprehension and legibility.

COMPREHENSION

The first portion of the study evaluated driver comprehension of each sign alternative in the different sign categories. This process consisted of multiple stages in which participants provided open-ended responses, multiple-choice responses, and subjective rankings of the signs. The open-ended and multiple-choice sections were between-subject factors, in which participants saw only one sign alternative from each sign category. Participants were shown one sign at a time in an appropriate and relevant context. Larger, physical print versions of each sign were provided to participants to allow for more detailed inspection. Specific questions were tailored for each sign type, which are detailed in chapter 3, Results.

Some, but not all, sign sets were ranked by perceived effectiveness. In the ranking section, participants were shown all sign alternatives for a given category and then ranked each sign on how well each alternative would work to show the intended meaning of the sign. Participants completed all comprehension questions before completing the ranking questions to ensure that the exposure to alternatives did not influence their response.

LEGIBILITY

Next, legibility distance (the maximum distance at which the participant can read text or decipher the elements of the sign) was assessed. For the legibility distance evaluation, eight participants viewed the same individual signs and answered comprehension questions for each sign.

For the test, each sign was shown one at a time and on a black background. The sign presentation began at a simulated distance of 1,000 ft (304.8 m). The sign expanded in size to simulate an approach speed of 45 mph. Participants were instructed to keep their eyes on the sign and to press a button on the table in front of them as soon as the sign became legible (i.e., as soon as they could identify the elements of the sign). When the button was pressed, the sign disappeared, and the distance was recorded. The participant then described the sign aloud. If the participant was correct, the researcher began a new trial with a different sign. If the participant was incorrect, the same sign reappeared and continued to increase in size, giving the participant another opportunity to press the button when the sign became legible.

Correctness was deemed as anything that confirmed that the sign was legible to the participant. If the sign size reached the full screen without a correct response, the trial was terminated, and the next trial began.

PARTICIPANTS

Two hundred people participated. Half of these participants were recruited from the Washington, DC, metropolitan area and completed the experiment at the Turner-Fairbank Highway Research Center. The remaining 100 participants completed participation in the mobile lab (which traveled to locations in central and coastal Virginia and an area near Orlando, FL). In all cases, no differences in responses were found based on data collection location. As a result, all data were combined. Participants were at least 18 yr of age, possessed a valid U.S. driver's license, and passed a visual acuity test with a minimum of 20/40 binocular vision, corrected if necessary. Before the start of the experiment, participants were asked to read and sign the informed consent form. Participants were paid $40 for their time.

CHAPTER 3. RESULTS

This section describes the results for each of the sign types tested. The information provided in this section is specific to the context of this research study. Tested signs and sign assemblies do not necessarily comply with MUTCD provisions. State departments of transportation (DOTs) and local jurisdictions are required to use MUTCD-compliant signs and sign assemblies. If a State DOT and/or local jurisdiction is interested in using a new TCD or a different application of an existing device, it must receive approval to experiment from FHWA using the MUTCD experimentation process.[1]

LANE REDUCTION TREATMENT

Table 1 presents all alternatives for Lane Reduction signs. Sign alternative (Alt.) 1, Alt. 2, and Alt. 3 are not in the MUTCD, whereas Alt. 4, Alt. 5, and Alt. 6 are already included in the MUTCD.[1] The results of the comprehension, ranking, and legibility tasks are presented in the following subsections.

Table 1. Lane Reduction Treatment sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
					

All photos source: FHWA.[1]

Comprehension

Participants were presented with an image of a lane reduction roadway with a sign placed in the appropriate context location. Participants were only exposed to a single lane reduction sign and were asked, “Imagine you are driving along the roadway and encounter this sign. What does this sign mean?” Open-ended responses were coded based on participants’ response of lane ending, merge, lane ends and merge combined, lane narrowing, or some other response.

Table 2 gives the percentage of participant responses in each coded category by sign alternative. For example, 46.7 percent of the responses to Alt. 1 were coded as lane ending. Nonparametric analyses were performed to determine whether differences in responses varied by sign alternative. Statistically significant differences are noted by a p value of 0.05 (i.e., less than 5 percent chance that the results would occur by chance) and are presented in bold font with an asterisk in the tables. Here, the percentage of participants who mentioned the lane was ending only (no mention of the need to merge) was significantly influenced by sign alternative. The percentage of participants who mentioned the need to merge (without mentioning that the lane was ending) also varied significantly as a function of sign alternative. No significant difference was found across sign alternatives in the percentage of participants who mentioned both the lane ending and the need to merge, the percentage of participants who indicated that the lane was narrowing, or the percentage of participants who gave incorrect responses.

Table 2 Percentage of participant responses within each coded category for each Lane Reduction Treatment sign alternative.

Sign Alternative	Lane Ending Only (Percent)	Merge Only (Percent)	Lane Ending and Merge (Percent)	Lane Narrowing (Percent)	Other/ Incorrect (Percent)
Alt. 1	46.7	3.3	40.0	0.0	10.0
Alt. 2	40.0	12.5	45.0	2.5	0.0
Alt. 3	13.3	40.0	36.7	0.0	10.0
Alt. 4	40.0	10.0	36.7	6.7	6.7
Alt. 5	16.7	10.0	70.0	0.0	3.3
Alt. 6	12.5	20.0	62.5	0.0	5.0
***p* Value**	**0.011***	**0.009***	>0.05	>0.05	>0.05

*Statistically significant difference.

To better capture their understanding of the sign, participants were then asked to mark checkboxes to indicate what they felt the sign meant. Results are presented in table 3. Participants could select more than one response (the total for each row will sum to more than 100 percent). Nonparametric tests were performed to determine whether responses differed based on sign alternative.

Table 3. Percentage of participants responding to each Lane Reduction Treatment sign category.

Sign Alternative	Right Lane Closed (Percent)	Left Lane Closed (Percent)	Right Lane Ends (Percent)	Left Lane Ends (Percent)	Traffic Merging Ahead (Percent)
Alt. 1	6.7	3.3	73.3	26.7	70.0
Alt. 2	10.0	0.0	67.5	25.0	62.5
Alt. 3	36.7	13.3	83.3	13.3	83.3
Alt. 4	13.3	0.0	83.3	0.0	86.7
Alt. 5	23.3	0.0	93.3	0.0	73.3
Alt. 6	27.5	0.0	90.0	5.0	77.5
***p* Value**	**0.018***	**0.003***	**0.045***	**<0.001***	0.206

*Statistically significant difference.

Paired comparison tests were performed to determine where differences existed. Significantly more people responded that Alt. 3 meant that the right lane was closed than Alt. 1 ($p = 0.003$), Alt. 2 ($p = 0.005$), and Alt. 4 ($p = 0.021$). Similarly, significantly more people responded that Alt. 6 meant that the right lane was closed than Alt. 1 ($p = 0.027$) and Alt. 2 ($p = 0.045$). No other statistically significant differences between signs believed to indicate that the right lane was closed were found. Those who saw Alt. 3 were more likely to respond that the sign meant the left lane was closed than any other sign alternative ($p < 0.05$). No other significant differences were found for this response.

Those who saw Alt. 2 were significantly less likely to indicate that the sign meant that the right lane ends than those who saw signs Alt. 5 ($p = 0.006$) and Alt. 6 ($p = 0.009$). Those who saw

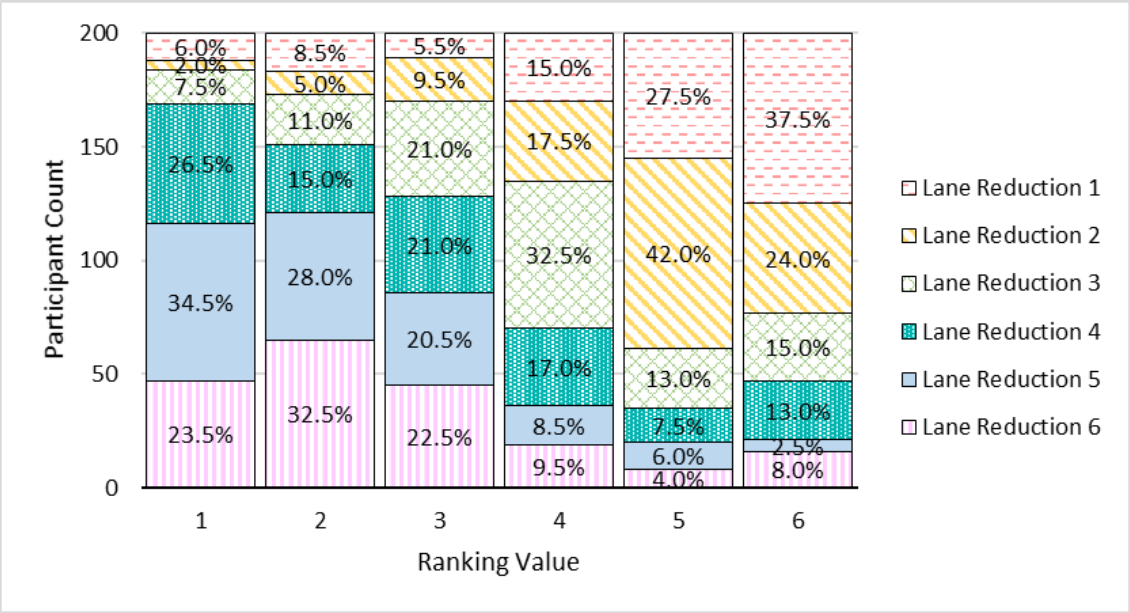
Alt. 1 were significantly less likely than those who saw Alt. 5 ($p = 0.044$) to indicate that the sign meant that the right lane was ending. Those who saw signs Alt. 1, Alt. 2, and Alt. 3 were significantly more likely than those who saw signs Alt. 4, Alt. 5, or Alt. 6 to believe that the left lane was ending ($p < 0.01$). No differences were found between responses to signs Alt. 1, Alt. 2, and Alt. 3. This finding could have notable implications for driver behavior.

Next, participants were asked about their actions/behaviors in the presence of the sign. They were asked, "Assume that you are traveling in the rightmost lane. When should you move out of the lane that is ending?" Table 4 presents the percentage of participants selecting each response by sign alternative. No statistically significant differences between sign alternatives were found.

Table 4. Percentage of responses to when participants stated they would begin to merge/switch lanes.

Sign Alternative	As Soon As Possible (Percent)	Somewhere Between Seeing the Sign and Where the Lane Begins to Taper (Narrow) (Percent)	When the Lane Begins to Taper (Narrow) (Percent)	Follow the Lane Until It Ends and Transitions into a Single Lane (i.e., Follow the White Line) (Percent)
Alt. 1	66.7	23.3	0.0	10.0
Alt. 2	62.5	35.0	2.5	0.0
Alt. 3	73.3	16.7	10.0	0.0
Alt. 4	66.7	16.7	10.0	6.7
Alt. 5	76.7	10.0	3.3	10.0
Alt. 6	72.5	22.5	2.5	2.5
p Value	0.771	0.057	0.615	0.748

Finally, participants were told the intended meaning of the Lane Reduction sign. All alternatives were presented, and participants were asked to rank them in terms of perceived effectiveness (figure 1). When only the top choice indicated by the participants was considered (ranking = 1), Alt. 5 was selected as the top choice by 34.5 percent (69/200) of the participants, and Alt. 4 was selected as the top choice by 26.5 percent (53/200) of the participants. There was a statistically significant difference in the rankings of each alternative, $\chi^2(25) = 484.38$, $p < 0.001$.



Source: FHWA.
Lane reductions 1–6 = Alt. 1–6, respectively.

Figure 1. Graph. Percentage of participants selecting each Lane Reduction Treatment sign alternative at each ranking value.

Legibility

Participants were presented with the same single Lane Reduction sign as they had previously seen. The sign slowly became larger on a television screen to simulate approaching a sign along the roadway. The sign was presented in isolation. Participants pressed a button to indicate that they could determine the content of the sign. A verbal response confirmed that the participant did indeed determine the sign content. Table 5 presents the mean simulated response distances for each of the signs. Mean response distance varied significantly by sign alternative, $F(5) = 16.76$, mean squared error (MSe) = 6,576.25, $p < 0.001$.

Table 5. Mean response distance by Lane Reduction Treatment sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	446.97
Alt. 2	432.78
Alt. 3	459.10
Alt. 4	551.81
Alt. 5	408.81
Alt. 6	379.58

Pairwise comparison follow-up testing revealed Alt. 4 was recognized at a distance significantly greater than those for all other alternatives ($p < 0.05$). Alt. 6 was recognized at a distance significantly shorter than those for all other signs ($p < 0.05$). These results are not surprising, given that symbol signs generally contain more robust and less fine detail than worded signs.

The finer the detail, the more challenging it is to determine content at a distance.

TEMPORARY TRAFFIC CONTROL BICYCLE/PEDESTRIAN ACCESS

Table 6 presents all alternatives for Temporary Traffic Control signs. All sign alternatives are already included in the MUTCD.[1] The results of the comprehension and legibility tasks are presented in the following subsections.

Table 6. Temporary Traffic Control Bicycle/Pedestrian Access sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3
		

All photos source: FHWA.[1]

Comprehension

Participants were only exposed to a single temporary TCD sign and were asked, "Imagine you are driving and encounter this sign. What does this sign mean?" The sign was placed in context in a location that was ambiguous as to whether it pertained to a bicycle/pedestrian path or the main roadway. Open-ended responses were coded based on responses of a detour plus the person or persons toward which the sign is directed (e.g., pedestrians, cyclists, vehicles).

The sign alternative significantly affected participant response, $\chi^2(10) = 96.30$, $p < 0.001$. Table 7 presents the percentage of participant responses coded to each category. Given the ambiguity of the sign placement, paired comparisons for this question were not performed. Notably, however, some of the responses did not fall into a category specifically related to a detour: e.g., "Construction ahead proceed with caution," or "Drive through there with caution in case someone is walking. You could park there and walk if you wanted to."

Table 7. Percentage of participant responses within each coded category for each Temporary Traffic Control Bicycle/Pedestrian Access sign alternative.

Sign Alternative	Detour Plus Specific Vehicle Types (Percent)	Detour Only (Percent)	Pedestrian Only, No Detour (Percent)	Bike Only, No Detour (Percent)	Vehicle Only, No Detour (Percent)	Other Response (Percent)
Alt. 1	0.0	84.3	0.0	0.0	2.9	12.9
Alt. 2	54.3	11.4	1.4	11.4	2.9	18.6
Alt. 3	41.7	33.3	1.7	1.7	0.0	21.7

The same question was asked again, but this time participants were asked to imagine that they were a bicyclist: "Imagine you are bicycling and encounter this sign. What does this sign mean?" Once again, sign alternative significantly affected participant response, $\chi^2(10) = 41.32$, $p < 0.001$. Table 8 presents the percentage of participant responses coded to each category.

Table 8. Percentage of participant responses when participants imagined they were a bicyclist within each coded category for each Temporary Traffic Control Bicycle/Pedestrian Access sign alternative.

Sign Alternative	Detour Plus Specific Vehicle Types (Percent)	Detour Only (Percent)	Pedestrian Only, No Detour (Percent)	Bike Only, No Detour (Percent)	Vehicle Only, No Detour (Percent)	Other Response (Percent)
Alt. 1	8.6	57.1	0.0	10.0	11.4	12.9
Alt. 2	17.1	31.4	0.0	21.4	1.4	28.6
Alt. 3	31.7	30.0	1.7	5.0	1.7	30.0

Finally, to assess more clearly their understanding of which road users should use an alternate route, participants were asked, "Imagine traveling along the roadway and encounter this sign. Which of these statements is true? (check all that apply)." Options were: "Motorists should use an alternate route," "Bicyclists should use an alternate route," and "Pedestrians should use an alternate route."

Table 9 presents the percentage of participants who selected each mode that must use an alternate route by sign alternative. Nonparametric tests revealed that for each mode of transportation, sign type significantly influenced response: motorists, $\chi^2(2) = 119.50$, $p < 0.001$; bicyclists, $\chi^2(2) = 64.62$, $p < 0.001$; and pedestrians, $\chi^2(2) = 54.33$, $p < 0.001$.

Table 9. Percentage of participants who selected each mode of transportation, divided by alternative.

Sign Alternative	Motorists (Percent)	Bicyclists (Percent)	Pedestrians (Percent)
Alt. 1	94.3	71.4	47.1
Alt. 2	10.0	97.1	94.3
Alt. 3	20.0	31.7	91.7
***p* Value**	**<0.001***	**<0.001***	**<0.001***

*Statistically significant difference.

Supplemental pairwise comparisons revealed that significantly more participants responded that the motorists should use an alternate route with Alt. 1 than with the other two alternatives ($p < 0.001$). When asked about bicyclists, all three alternatives performed significantly differently from one another ($p < 0.001$). When asked about pedestrians, significantly fewer participants responded that pedestrians should use an alternate route with Alt. 1 than with the other two alternatives ($p < 0.001$).

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 10. Mean response distance varied significantly by sign alternative, $F(2) = 21.69$, MSe = 7,856.06, $p < 0.001$. Pairwise comparison follow-up testing revealed that Alt. 1 generated significantly greater recognition distances than Alt. 2 and Alt. 3 ($p < 0.05$). No significant difference between Alt. 2 and Alt. 3 was found ($p > 0.05$).

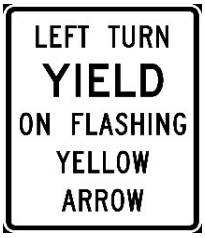
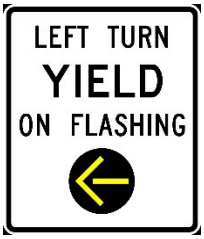
Table 10. Mean response distance by Temporary Traffic Control Bicycle/Pedestrian Access sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	574.50
Alt. 2	480.20
Alt. 3	499.50

FLASHING YELLOW ARROW

Table 11 presents all alternatives for Flashing Yellow Arrow signs. Alt. 1 is compliant with the MUTCD, as creation of word message-only signs is allowed to address traffic situations not addressed by other standard signs.[(1)] Alt. 2 and Alt. 3 are not compliant with the MUTCD as they include a symbol. A condition in which no sign was placed next to the signal mast was also included. This option was designed to provide insight as to whether the sign is necessary to properly interpret the signal. The results of the comprehension, ranking, and legibility tasks are presented in the following subsections.

Table 11. Flashing Yellow Arrow sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4
			(no sign)

All photos source: FHWA.

Comprehension

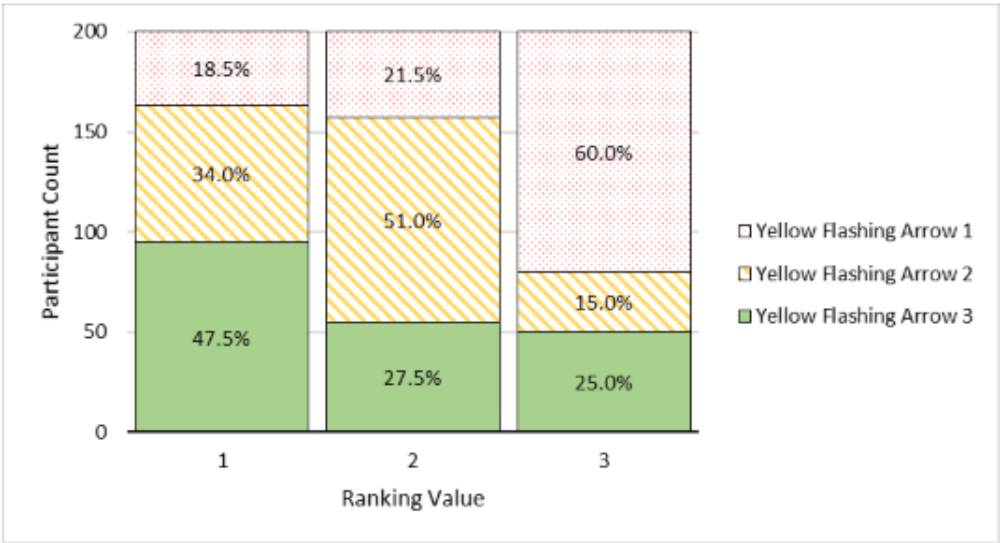
Participants were only exposed to a single Flashing Yellow Arrow sign and were asked, "Imagine you are driving and encounter this sign. You want to make a left turn and are positioned in the proper lane. How would you proceed?" The sign was placed in context next to the signal face on the mast arm. The yellow arrow was presented as animated (i.e., flashing), on, (i.e., steady and not flashing), and off (blank). Open-ended responses were coded based on the following responses: acknowledgment that the driver did not have the right of way and needed to watch for oncoming traffic, driver needed to use caution only, or some other response.

Participant responses as percentages are presented in table 12. When all data were explored, no statistically significant differences between sign alternatives were found, nor was there a significant interaction between the flashing state of the signal mast and the sign alternative ($p > 0.05$). However, the flashing state of the signal was found to significantly affect response. Significantly more people who saw the animated flashing yellow arrow verbally indicated that they did not have the right of way and needed to yield to oncoming traffic ($p < 0.05$). This result suggests the flashing of the light itself is meaningful to drivers.

Table 12. Percentage of participant responses within each coded category for each Flashing Yellow Arrow sign alternative, by flashing state.

Flashing State	Sign Alternative	Yield to Oncoming Traffic (Percent)	Use Caution Only (Percent)	Other (Percent)
Off	Alt. 1	80.0	0.0	20.0
	Alt. 2	65.0	10.0	25.0
	Alt. 3	75.0	5.0	25.0
	Alt. 4	65.0	20.0	15.0
On (steady)	Alt. 1	65.0	20.0	15.0
	Alt. 2	75.0	5.0	20.0
	Alt. 3	60.0	20.0	20.0
	Alt. 4	45.0	30.0	25.0
Animated (flashing)	Alt. 1	70.0	30.0	0.0
	Alt. 2	100.0	0.0	0.0
	Alt. 3	85.0	5.0	10.0
	Alt. 4	70.0	30.0	0.0

Next, participants were told the intended meaning of the Flashing Yellow Arrow sign. The three sign alternatives were presented (i.e., no blank sign was shown for ranking). Participants were asked to rank the signs in terms of perceived effectiveness (figure 2). When only the top choice indicated by the participants was considered (ranking = 1), Alt. 3 was selected as the top choice by 47.5 percent (95/200) of the participants, and Alt. 2 was selected as the top choice by 34.0 percent (68/200) of the participants. There was a statistically significant difference in the rankings of each alternative, $\chi^2(4) = 121.44$, $p < 0.001$. Alt. 1 (all text) was consistently rated the least effective sign ($p < 0.05$).



Source: FHWA.
Yellow flashing arrows 1–3 = Alt. 1–3, respectively.

Figure 2. Graph. Percentage of participants selecting each Flashing Yellow Arrow sign alternative at each ranking value.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 13. Mean response distance did not vary significantly by sign alternative, $F(2) = 0.80$, MSe = 3,455.212, $p > 0.05$. In other words, all signs were read at a similar distance.

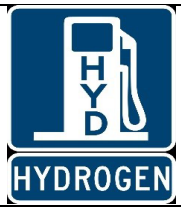
Table 13. Mean response distance by Flashing Yellow Arrow sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	376.07
Alt. 2	379.38
Alt. 3	389.97

ALTERNATIVE FUELS

Table 14 presents all alternatives for Alternative Fuels signs. Alt. 7 is already included in the MUTCD.[1] All other sign alternatives are not MUTCD compliant. The results of the comprehension and legibility tasks are presented in the following subsections.

Table 14. Alternative Fuels sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
					
Alt. 7	**Alt. 8**	**Alt. 9**	**Alt. 10**	**Alt. 11**	**Alt. 12**
					

All photos source: FHWA.[1]
BD = biodiesel; LNG = liquefied natural gas; M = methanol; HYD = hydrogen; H2 = hydrogen; CNG = compressed natural gas.

Comprehension

Participants were only exposed to a single alternative fuel sign and were asked, "Imagine you are driving along the roadway and encounter this sign. What service is available at this exit?" Open-ended responses were coded as correct, partially correct, or incorrect/some other response. For example, for Alt. 3, a response of "fuel" would be considered partially correct because biodiesel is a type of fuel, but the response does not specify which specific type of fuel. The percentage of responses coded as correct, partially correct, and incorrect are displayed in

table 15. Note that *p* values are not available for Alt. 3 and Alt. 6, as all participants gave partially correct responses for these signs.

Table 15. Percentage of participant responses within each coded category for each Alternative Fuels sign alternative.

Sign Alternative	Correct (Percent)	Partially Correct (Percent)	Incorrect/Other Response (Percent)	*p* Value
Alt. 1	25.0	75.0	0.0	**0.025***
Alt. 2 (supplemental placard)	60.0	40.0	0.0	0.527
Alt. 3	0.0	100.0	0.0	+
Alt. 4 (supplemental placard)	40.0	60.0	0.0	0.527
Alt. 5	0.0	100.0	0.0	+
Alt. 6 (supplemental placard)	40.0	55.0	5.0	**0.019***
Alt. 7	5.0	95.0	0.0	**< 0.001***
Alt. 8 (supplemental placard)	50.0	45.0	5.0	**0.026***
Alt. 9	20.0	80.0	0.0	0.058
Alt. 10 (supplemental placard)	50.0	50.0	0.0	1.0
Alt. 11	10.0	35.0	55.0	**0.047***
Alt. 12	10.0	20.0	70.0	**0.045***

*Statistically significant difference.
+*p* Values not available.

Each alternative was evaluated with and without the supplemental placard. Overall, alternatives with the supplemental placard resulted in significantly more completely correct responses than those without ($p < 0.001$). Follow-up paired comparison analyses were performed, and summary results are presented in table 16.

Table 16. Paired comparison results examining Alternative Fuels signs with versus without supplemental placards.

No Placard	Supplemental Placard	*p* Value
Alt. 1	Alt. 2	0.061
Alt. 3	Alt. 4	**0.002***
Alt. 5	Alt. 6	**0.003***
Alt. 7	Alt. 8	**0.003***
Alt. 9	Alt. 10	0.114

*Statistically significant difference.

Participants were also asked questions to assess more clearly their interpretation and understanding of the signs. Participant responses to the question, "I would expect this service to be provided at a traditional fueling station," are found in table 17. Participant responses to the question, "If I were looking for typical unleaded fuel, I would be able to find it at this service station," are found in table 18. Participant responses to the question, "At this service station, what else might you expect to find?" are presented in table 19.

Table 17. Percentage of participant responses by sign alternative to the statement, "I would expect this service to be provided at a traditional fueling station."

Sign Alternative	Yes (Percent)	No (Percent)
Alt. 1	70.0	30.0
Alt. 2 (supplemental placard)	50.0	50.0
Alt. 3	18.0	82.0
Alt. 4 (supplemental placard)	50.0	50.0
Alt. 5	85.0	15.0
Alt. 6 (supplemental placard)	45.0	55.0
Alt. 7	60.0	40.0
Alt. 8 (supplemental placard)	25.0	75.0
Alt. 9	70.0	30.0
Alt. 10 (supplemental placard)	55.0	45.0
Alt. 11	35.0	65.0
Alt. 12	30.0	70.0

Table 18. Percentage of participant responses by sign alternative to the statement, "If I were looking for typical unleaded fuel, I would be able to find it at this service station."

Sign Alternative	Yes (Percent)	No (Percent)
Alt. 1	80.0	20.0
Alt. 2 (supplemental placard)	60.0	40.0
Alt. 3	90.0	10.0
Alt. 4 (supplemental placard)	20.0	80.0
Alt. 5	95.0	5.0
Alt. 6 (supplemental placard)	40.0	60.0
Alt. 7	70.0	30.0
Alt. 8 (supplemental placard)	40.0	60.0
Alt. 9	70.0	30.0
Alt. 10 (supplemental placard)	40.0	60.0
Alt. 11	50.0	50.0
Alt. 12	30.0	70.0

Table 19. Percentage of participant responses by sign alternative to the question, "At this service station, what else might you expect to find?"

Sign Alternative	An Attendant (Percent Response of Yes)	Public Restroom (Percent Response of Yes)	Concessions (Percent Response of Yes)
Alt. 1	35.0	45.0	45.0
Alt. 2 (supplemental placard)	20.0	70.0	50.0
Alt. 3	60.0	75.0	35.0
Alt. 4 (supplemental placard)	60.0	50.0	30.0
Alt. 5	70.0	65.0	70.0
Alt. 6 (supplemental placard)	65.0	70.0	50.0
Alt. 7	45.0	6.0	55.0
Alt. 8 (supplemental placard)	75.0	70.0	55.0
Alt. 9	70.0	60.0	50.0
Alt. 10 (supplemental placard)	55.0	65.0	50.0
Alt. 11	30.0	50.0	35.0
Alt. 12	50.0	70.0	30.0

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 20. Mean response distance varied significantly by sign alternative, $F(11) = 6.12$, MSe = 32,579.22, $p < 0.001$. Pairwise comparison follow-up testing revealed a multitude of differences. Those differences are summarized in table 21.

Table 20. Mean response distance by Alternative Fuels sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	478.55
Alt. 2 (supplemental placard)	350.7
Alt. 3	479.08
Alt. 4 (supplemental placard)	433.74
Alt. 5	479.91
Alt. 6 (supplemental placard)	407.02
Alt. 7	478.84
Alt. 8 (supplemental placard)	392.13
Alt. 9	489.05
Alt. 10 (supplemental placard)	389.57
Alt. 11	457.06
Alt. 12	407.91

Table 21. Summary of paired comparison differences by Alternative Fuels sign alternative.

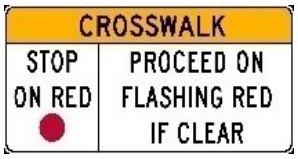
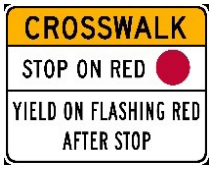
Sign Alternative	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11	Alt. 12
Alt. 9	–	*	–	–	–	*	–	*	–	*	–	*
Alt. 5	–	*	–	–	–	*	–	*	–	*	–	*
Alt. 3	–	*	–	–	–	*	–	*	–	*	–	*
Alt. 7	–	*	–	–	–	*	–	*	–	*	–	*
Alt. 1	–	*	–	–	–	*	–	*	–	*	–	*
Alt. 11	–	*	–	–	–	*	–	*	–	*	–	–
Alt. 4	–	*	–	–	–	–	–	–	–	–	–	–
Alt. 12	*	–	*	–	*	–	*	–	*	–	–	–

*Statistically significant difference.
–No difference.

MIDBLOCK HYBRID BEACON PEDESTRIAN CROSSING

Table 22 presents all alternatives for Hybrid Beacon Crossing signs. None of the signs are compliant with the MUTCD. A condition in which no sign was placed next to the signal mast was also included. This action was designed to provide insight as to whether the sign is necessary to properly interpret the signal. The results of the comprehension and legibility tasks are presented in the following subsections.

Table 22. Midblock Hybrid Beacon Pedestrian Crossings sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
				(no sign)

All photos source: FHWA

Comprehension

Participants were only exposed to a single Hybrid Beacon Pedestrian Crossing sign and were asked, “Imagine you are driving and encounter this signal. What does this sign mean?” The sign was placed in context next to the signal face on the mast arm. The signal was presented as off, flashing red, solid/steady red, or flashing yellow. In an additional condition, each of the signal statuses were shown without any sign. Participant responses are summarized in table 23. Responses were coded as correct based on the signal that was shown to each participant (e.g., a flashing red means stop, then proceed according to the rules applicable at a stop sign). As can be seen in the table, there were also people who provided a response that was not incorrect but did not address the question at hand (e.g., “It is a pedestrian crossing.”).

Table 23. Percentage of participant responses within each coded category for each Midblock Hybrid Beacon Pedestrian Crossings sign alternative, by flashing state.

Flashing State	Sign Alternative	Correct Response (Percent)	Stop Only (Percent)	Emergency Signal (Percent)	Responded to a Different Question (Percent)	Caution (Percent)	Other Incorrect (Percent)
Off	Alt. 1	10.0	10.0	0.0	70.0	10.0	0.0
	Alt. 2	10.0	20.0	0.0	70.0	0.0	0.0
	Alt. 3	0.0	20.0	0.0	70.0	10.0	0.0
	Alt. 4	10.0	30.0	0.0	50.0	0.0	10.0
	Alt. 5	20.0	0.0	10.0	40.0	10.0	20.0
Flashing red	Alt. 1	30.0	50.0	0.0	20.0	0.0	0.0
	Alt. 2	20.0	60.0	0.0	0.0	0.0	20.0
	Alt. 3	60.0	20.0	0.0	10.0	0.0	10.0
	Alt. 4	20.0	50.0	0.0	20.0	0.0	10.0
	Alt. 5	0.0	90.0	10.0	0.0	0.0	0.0
Steady red	Alt. 1	90.0	10.0	0.0	0.0	0.0	0.0
	Alt. 2	90.0	10.0	0.0	0.0	0.0	0.0
	Alt. 3	70.0	30.0	0.0	0.0	0.0	0.0
	Alt. 4	90.0	10.0	0.0	0.0	0.0	0.0
	Alt. 5	90.0	0.0	10.0	0.0	0.0	0.0
Flashing yellow	Alt. 1	0.0	40.0	20.0	10.0	0.0	30.0
	Alt. 2	0.0	0.0	40.0	10.0	0.0	50.0
	Alt. 3	40.0	0.0	60.0	0.0	0.0	0.0
	Alt. 4	10.0	10.0	30.0	0.0	0.0	50.0
	Alt. 5	0.0	0.0	90.0	0.0	10.0	0.0

When all data are explored, no statistically significant differences between sign alternatives were found, $\chi^2(20) = 28.80$, $p > 0.05$. However, the light state of the signal was found to significantly affect response, $\chi^2(15) = 210.78$, $p < 0.001$. Given the large number of participants who did not provide a response and who answered the question presented, this result was not explored further. Next, participants were asked, "Imagine you are driving and encounter this signal. There is a pedestrian waiting to cross the street. How would you proceed?" Participant responses were coded as one of three responses: yield/stop for pedestrian, no indication of yielding/stopping, or other (table 24).

Table 24. Percentage of participant responses within each coded category for each Midblock Hybrid Beacon Pedestrian Crossings sign alternative when a pedestrian was waiting to cross the street, by flashing state.

Flashing State	Sign Alternative	Yield/Stop (Percent)	No Yield/Stop (Percent)	Other (Percent)
Off	Alt. 1	90.0	10.0	0.0
	Alt. 2	60.0	20.0	20.0
	Alt. 3	70.0	10.0	20.0
	Alt. 4	90.0	10.0	0.0
	Alt. 5	70.0	30.0	0.0
Flashing red	Alt. 1	90.0	10.0	0.0
	Alt. 2	100.0	0.0	0.0
	Alt. 3	90.0	10.0	0.0
	Alt. 4	100.0	0.0	0.0
	Alt. 5	90.0	10.0	0.0
Steady red	Alt. 1	100.0	0.0	0.0
	Alt. 2	100.0	0.0	0.0
	Alt. 3	80.0	20.0	0.0
	Alt. 4	90.0	0.0	10.0
	Alt. 5	100.0	0.0	0.0
Flashing yellow	Alt. 1	80.0	20.0	0.0
	Alt. 2	80.0	20.0	0.0
	Alt. 3	80.0	20.0	0.0
	Alt. 4	80.0	20.0	0.0
	Alt. 5	90.0	10.0	0.0

When all data were explored, no statistically significant differences between sign alternatives were found, $\chi^2(8) = 7.05$, $p > 0.05$. However, the light state of the signal was found to affect response significantly, $\chi^2(6) = 17.45$, $p = 0.008$.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 25. Mean response distance varied significantly by sign alternative, $F(3) = 10.16$, MSe = 45,907.07, $p < 0.001$. Pairwise comparison follow-up testing revealed that Alt. 3 was recognized at a significantly shorter distance than

Alt. 1 and Alt. 2 ($p < 0.05$). Alt. 2 was recognized at a significantly longer distance than Alt. 3 and Alt. 4 ($p < 0.05$).

Table 25. Mean response distance by Midblock Hybrid Beacon Pedestrian Crossings sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	399.72
Alt. 2	408.08
Alt. 3	340.89
Alt. 4	371.96

PASSENGER FERRY

Table 26 presents all alternatives for the Passenger Ferry signs. None of the alternatives are MUTCD compliant. The results of the comprehension and legibility tasks are presented in the following subsections.

Table 26. Passenger Ferry sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
				

All photos source: FHWA.

Comprehension

Participants were asked to "Imagine you are driving and encounter this sign. What does this sign mean?" Participant responses were coded by response category: ferry, other recreational boat, and other. Responses by sign alternative are summarized in table 27. Nonparametric tests revealed that sign alternative significantly affected participant response, $\chi^2(8) = 57.45$, $p < 0.001$.

Table 27. Percentage of participant responses within each coded category for each Passenger Ferry sign alternative.

Sign Alternative	Ferry (Percent)	Other Recreational Vehicle (Percent)	Other (Percent)
Alt. 1	77.5	7.5	15.0
Alt. 2	50.0	37.5	12.5
Alt. 3	30.0	55.0	15.0
Alt. 4	72.5	2.5	25.0
Alt. 5	85.0	10.0	5.0

Next, participants were asked to specify who could ride the ferry (check all that apply). A summary of these results is presented in table 28. Significant differences were found across sign alternatives in the percentage of people who indicated passenger vehicles, pedestrians, bicyclists, motorcyclists, freight vehicles, and transit vehicles were allowed on the ferry.

Table 28. Percentage of participant responses by sign alternative to the question, "Who can ride this ferry?"

Sign Alternative	Passenger Vehicle (Percent Response of Yes)	Pedestrians (Percent Response of Yes)	Bicyclists (Percent Response of Yes)	Motorcyclists (Percent Response of Yes)	Freight Vehicles (Percent Response of Yes)	Transit Vehicles (Percent Response of Yes)
Alt. 1	95.0	32.5	27.5	40.0	95.0	27.5
Alt. 2	7.5	95.0	97.5	7.5	0.0	0.0
Alt. 3	5.0	100.0	2.5	0.0	0.0	0.0
Alt. 4	25.0	15.0	15.0	15.0	95.0	12.5
Alt. 5	97.5	42.5	35.0	52.5	7.5	5.0
p Value	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**<0.001***	**<0.001***

*Statistically significant difference.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 29. Mean response distance did not significantly vary by sign alternative, $F(4) = 1.71$, MSe = 12,166.63, $p > 0.05$.

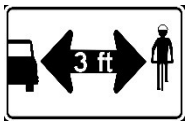
Table 29. Mean response distance by Passenger Ferry sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	432.89
Alt. 2	417.51
Alt. 3	458.90
Alt. 4	457.03
Alt. 5	434.44

BICYCLE PASSING LAW

Table 30 presents all alternatives for Bicycle Passing Law signs. None of the alternatives are in the MUTCD. The results of the comprehension, ranking, and legibility tasks are presented in the following subsections.

Table 30. Bicycle Passing Law sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
					

All photos source: FHWA.

Comprehension

Comprehension questions were presented in the context of a participant imagining himself/herself as both a motorist and a bicyclist. These questions were presented in a randomized order. Results as the motorist are presented first. Participants were asked, "Imagine you are driving along the roadway and encounter this sign near a bicyclist. What does this sign mean?" Responses were coded based on who participants reported should leave space while passing laterally, or if the sign was interpreted as a rule for longitudinal passing. Nonparametric tests revealed that sign alternative significantly affected participant response, $\chi^2(25) = 41.35$, $p = 0.021$. A summary of the percentage of each response type by sign alternative is presented in table 31.

Table 31. Percentage of participant responses, from the perspective of a motorist, within each coded category for each Bicycle Passing Law sign alternative.

Sign Alternative	Car Leaves Space, Lateral (Percent)	Bike Leaves Space, Lateral (Percent)	No Indicator of Who Leaves Space, Lateral (Percent)	Bike Passing Bike (Percent)	Longitudinal Space, Following (Percent)	Other (Percent)
Alt. 1	53.3	0.0	10.0	3.3	3.3	30.0
Alt. 2	70.0	0.0	0.0	0.0	0.0	30.0
Alt. 3	90.0	3.3	0.0	0.0	0.0	3.3
Alt. 4	76.6	3.3	3.3	0.0	0.0	16.7
Alt. 5	65.0	5.0	10.0	0.0	0.0	20.0
Alt. 6	56.7	0.0	3.3	0.0	0.0	40.0

The same question was posed to participants from the perspective of a bicyclist: "Imagine you are bicycling along the roadway and encounter this sign near a motorist. What does this sign mean?" Responses were coded similarly. Nonparametric tests revealed that sign alternative significantly affected participant response, $\chi^2(25) = 64.46$, $p < 0.001$. A summary of the percentage of each response type by sign alternative is presented in table 32.

Table 32. Percentage of participant responses, from the perspective of a bicyclist, within each coded category for each Bicycle Passing Law sign alternative.

Sign Alternative	Car Leaves Space, Lateral (Percent)	Bike Leaves Space, Lateral (Percent)	No Indicator of Who Leaves Space, Lateral (Percent)	Bike Passing Bike (Percent)	Longitudinal Space, Following (Percent)	Other (Percent)
Alt. 1	50.0	6.7	0.0.	6.7	3.3	33.3
Alt. 2	47.5	17.5	0.0	0.0	0.0	35.0
Alt. 3	86.7	3.3	0.0	0.0	3.3	6.7
Alt. 4	50.0	16.7	3.3	0.0	0.0	30.0
Alt. 5	37.5	17.5	17.5	0.0	0.0	27.5
Alt. 6	26.7	16.7	0.0	0.0	0.0	56.7

Next, to capture participant understanding of the sign more clearly, a multiple-choice question was presented: "Imagine traveling along the roadway and you encounter this sign. Which of these statements is true? (check all that apply)."

A. As a motorist, I should provide at least 3 ft of space for bicyclists while passing.
B. As a bicyclist, I should provide at least 3 ft of space for motorists to pass.
C. As a motorist, I could receive a ticket for not providing 3 ft of space while passing a bicyclist.
D. As a bicyclist, I could receive a ticket for not providing 3 ft of space for motorists to pass.

A summary of responses, including significant differences between sign alternatives, are presented in table 33.

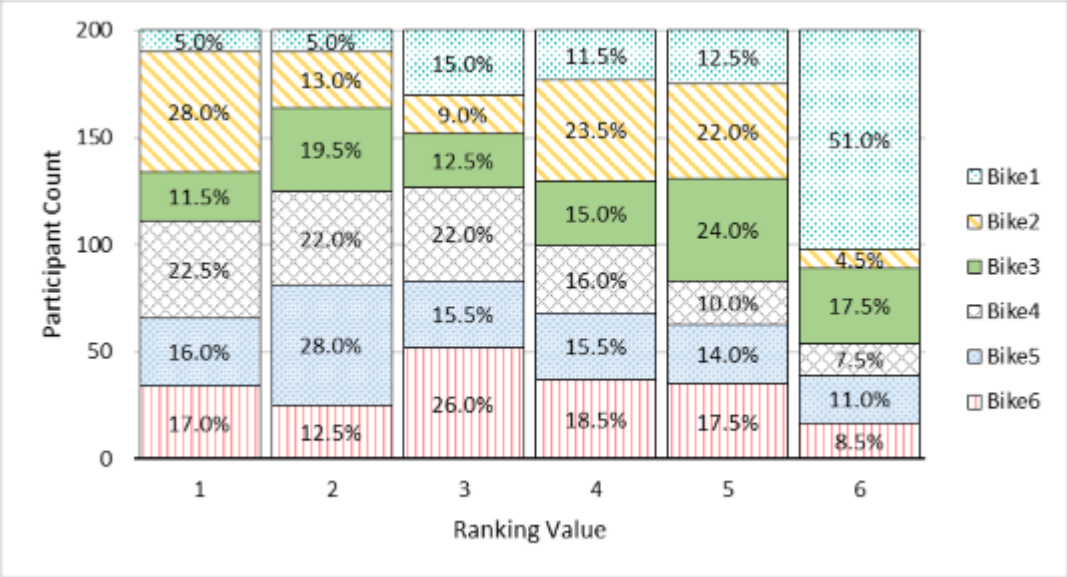
Table 33. Percentage of participant responses by sign alternative to the question, "Which of these statements is true?"

Sign Alternative	A. Motorist Leaves Space (Percent Response of Yes)	B. Bicyclist Leaves Space (Percent Response of Yes)	C. Motorist Receives Ticket (Percent Response of Yes)	D. Bicyclist Receives Ticket (Percent Response of Yes)
Alt. 1	96.7	33.3	43.3	13.3
Alt. 2	97.5	25.0	75.0	12.5
Alt. 3	96.7	20.0	70.0	16.7
Alt. 4	93.3	80.0	70.0	43.3
Alt. 5	97.5	72.5	62.5	32.5
Alt. 6	93.3	66.7	50.0	30.0
p Value	0.908	**<0.001***	0.056	**0.017***

*Statistically significant difference.

Next, participants were told the intended meaning of the Bicycle Passing sign. The six sign alternatives were presented, and participants were asked to rank them in terms of perceived effectiveness. When only the top choice indicated by the participants was considered (ranking = 1), Alt. 2 was selected as the top choice by 28.0 percent (56/200) of the participants,

and Alt. 4 was selected as the top choice by 22.5 percent (45/200) of the participants. There was a statistically significant difference in the rankings of each alternative, $\chi^2(25) = 311.64$, $p < 0.001$. Alt. 1 was consistently rated the least effective sign ($p < 0.05$). In general, data show that the bike signs were usually preferred by the participants in the following order: Alt. 4 or Alt. 2 or Alt. 5, Alt. 6 or Alt. 3, and Alt. 1. Figure 3 summarizes the percentage of time participants selected each of the sign alternatives at each ranking level.



Source: FHWA.
Bikes 1–6 = Alt. 1–6, respectively.

Figure 3. Graph. Percentage of participants selecting each Bicycle Passing Law sign alternative at each ranking value.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 34. Mean response distance significantly varied by sign alternative, $F(5) = 20.77$, MSe = 5,433.43, $p < 0.001$. Follow-up paired comparisons show that Alt. 1, Alt. 5, and Alt. 4 did not result in statistically significantly different legibility distances ($p > 0.05$). However, all three (Alt. 1, Alt. 5, and Alt. 4) were read at a distance significantly greater than that for Alt. 3, Alt. 2, and Alt. 6. Alt. 6 was more legible than Alt. 3 ($p < 0.05$). No difference between Alt. 2 and Alt. 3 was found ($p > 0.05$).

Table 34. Mean response distance by Bicycle Passing Law sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	452.73
Alt. 2	376.15
Alt. 3	328.11
Alt. 4	470.49
Alt. 5	470.25
Alt. 6	385.23

VEHICLE PROHIBITION

Table 35 presents all alternatives for Vehicle Prohibition signs that were evaluated. None of the alternatives are included in the MUTCD. The results of the comprehension and legibility tasks are presented in the following subsections.

Table 35. Vehicle Prohibition sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3
		

All photos source: FHWA.

Comprehension

Participants were only exposed to a single Vehicle Prohibition sign and were asked, "Imagine you encounter this sign. What does this sign mean?" The sign was placed in context, near an entrance to a trail from a parking lot. Participant responses were coded into several categories: prohibition plus the specific pictured mode, prohibition plus an adjacent but not pictured category, prohibition plus general motorized vehicle, or other. A common response for an adjacent but not pictured category was "no jet skis." Participant responses are summarized in table 36. Nonparametric analyses revealed that sign alternative influenced participant response, $\chi^2(6) = 24.53$, $p < 0.001$.

Table 36. Percentage of participant responses within each coded category for each Vehicle Prohibition sign alternative.

Sign Alternative	No Pictured Mode (Percent)	No Nonpictured Mode (Percent)	No Motorized Vehicles (Percent)	Other (Percent)
Alt. 1	61.7	20.0	15.0	3.3
Alt. 2	55.7	15.7	21.4	7.1
Alt. 3	47.1	42.9	2.9	7.1

Next, to capture participant understanding of the sign more clearly, a multiple-choice question was presented: "Imagine you encounter this sign. Which types of transportation are prohibited (not allowed on trail)? (check all that apply)." Table 37 shows the percentage of participants who responded that bicyclists, motorcycles, ATVs, and snowmobiles were prohibited for each sign type. Significant differences were found between sign types for all response types.

Table 37. Percentage of participant responses by sign alternative to the question, "Which types of transportation are prohibited?"

Sign Alternative	Bicyclists (Percent Response of Yes)	Motorcycles (Percent Response of Yes)	ATVs (Percent Response of Yes)	Snowmobiles (Percent Response of Yes)
Alt. 1	21.7	100.0	58.3	43.3
Alt. 2	2.9	71.4	90.0	44.3
Alt. 3	0.0	11.4	24.3	97.1
p Value	**<0.001***	**<0.001***	**<0.001***	**<0.001***

*Statistically significant difference.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 38. Mean response distance did not significantly vary by sign alternative, $F(2) = 1.49$, MSe = 7,117.44, $p > 0.05$.

Table 38. Mean response distance by Vehicle Prohibition sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	442.31
Alt. 2	451.78
Alt. 3	462.62

RAIL/FLANGEWAY GAP BICYCLE WARNING

Table 39 presents all alternatives For Rail Flangeway Gap signs that were evaluated. None of the alternatives are in the MUTCD. The results of the comprehension, ranking, and legibility tasks are presented in the following subsections.

Table 39. Rail/Flangeway Gap Bicycle Warning sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4
			

All photos source: FHWA.

Comprehension

Participants were only exposed to a single Rail Flangeway sign and were asked, "What does this sign mean?" The sign was placed in context, near a rail crossing. Participant responses fell into multiple categories:

A. Use caution/care when crossings plus tracks plus bicycles.
B. Use caution/care when crossings plus tracks plus bicycles plus need to cross tracks perpendicularly.
C. Bike hazard or some other unspecified issue.
D. Tracks ahead.
E. Other.

Participant responses are summarized in table 40. Nonparametric analyses revealed that sign alternative influenced participant response, $\chi^2(12) = 79.11$, $p < 0.001$.

Table 40. Percentage of participant responses within each coded category for each Rail/Flangeway Gap Bicycle Warning sign alternative.

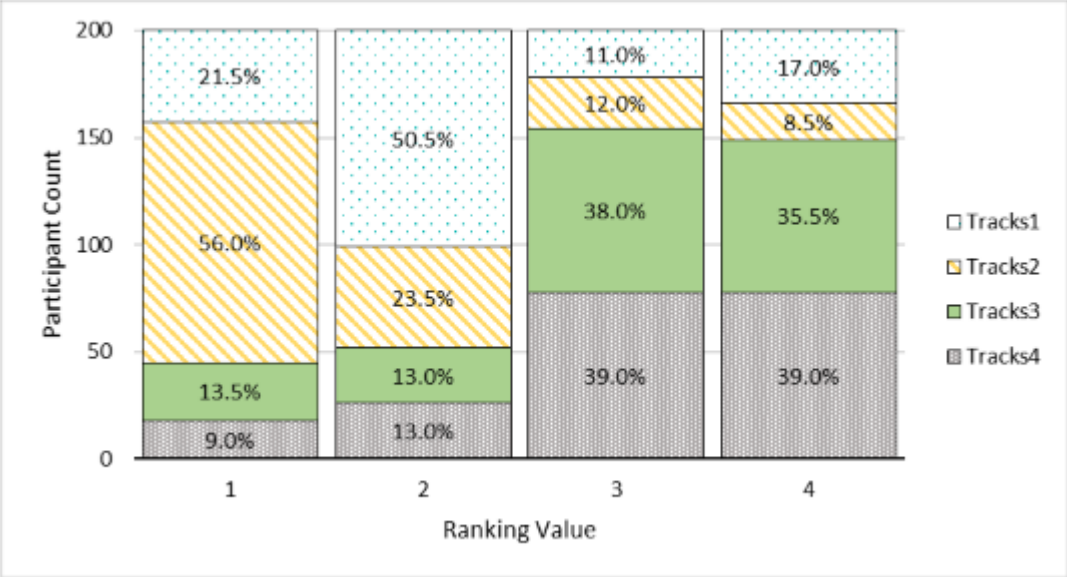
Sign Alternative	A. Bikes Use Caution When Crossing (Percent)	B. Bikes Use Caution When Crossing Plus Need to Cross Perpendicularly (Percent)	C. Bike Hazard or Some Other Unspecified Issue (Percent)	D. Tracks Ahead (Percent)	E. Other (Percent)
Alt. 1	22.0	8.0	8.0	54.0	8.0
Alt. 2	66.0	2.0	4.0	4.0	24.0
Alt. 3	22.0	12.0	2.0	18.0	46.0
Alt. 4	24.0	8.0	0.0	16.0	52.0

To gain better insight into participant understanding of the sign, each was asked, "Imagine that you are traveling by bicycle and encounter this sign. Would you dismount your bike before crossing the tracks?" Participant responses are summarized in table 41. Nonparametric analyses revealed that sign alternative did not influence participant response, $\chi^2(3) = 4.27$, $p > 0.05$.

Table 41. Participant responses to the question, "Would you dismount your bike before crossing the tracks?"

Sign Alternative	Yes (Percent)	No (Percent)
Alt. 1	36.0	64.0
Alt. 2	50.0	50.0
Alt. 3	56.0	44.0
Alt. 4	48.0	52.0

Next, participants were told the intended meaning of the Rail Flangeway sign. The four sign alternatives were presented, and participants were asked to rank them in terms of perceived effectiveness. Sign alternative significantly affected ranking, $\chi^2(9) = 293.96$, $p < 0.001$. When only the top choice indicated by the participants was considered (ranking = 1), Alt. 2 was selected as the top choice by a majority of the participants. The data suggests that the tracks signs were usually preferred by the participants in the following order: Alt. 2, Alt. 1, Alt. 3 or Alt. 4. Figure 4 summarizes the percentage of time participants selected each of the sign alternatives at each ranking level.



Source: FHWA.
Tracks 1–4 = Alt. 1–4, respectively.

Figure 4. Graph. Percentage of participants selecting each Rail/Flangeway Gap Bicycle Warning sign alternative at each ranking value.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 42. Mean response distance significantly varied by sign alternative, $F(3) = 16.23$, MSe = 3,114.21, $p < 0.001$. Follow-up paired comparisons revealed that Alt. 1 was recognized at a distance significantly shorter than

that for Alt. 2, Alt. 3, and Alt. 4 ($p < 0.001$). No differences between Alt. 2, Alt. 3, and Alt. 4 were found ($p > 0.05$).

Table 42. Mean response distance by Rail/Flangeway Gap Bicycle Warning sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	320.91
Alt. 2	375.86
Alt. 3	389.67
Alt. 4	386.31

BLIND HILL WARNING

Table 43 presents the alternative Blind Hill Warning signs that were evaluated. Alt. 1 is already included in the MUTCD.[1] All other signs are not MUTCD compliant. The results of the comprehension, ranking, and legibility tasks are presented in the following subsections.

Table 43. Blind Hill Warning sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4
			

All photos source: FHWA.[1]

Comprehension

Participants were posed an open-ended question to assess comprehension of the Blind Hill Warning sign. The sign was placed in-context near the crest of a hill. The first question was, "Imagine you are driving and encounter this sign. What does this sign mean?" Participant responses were coded based on the following:

A. Mention of a sight obstruction and a hill/mountain/similar.
B. Mention of a hill (but no sight obstruction).
C. Mention of a sight obstruction (but no hill).
D. Use caution (but no specifics as to why).
E. Other.

Nonparametric analyses revealed that sign alternative influenced participant response, $\chi^2(12) = 113.75$, $p < 0.001$. A summary of responses is presented in table 44.

Table 44. Percentage of participant responses within each coded category for each Blind Hill Warning sign alternative.

Sign Alternative	A. Sight Obstruction Plus Hill (Percent)	B. Hill (Percent)	C. Sight Obstruction (Percent)	D. Use Caution (Percent)	E. Other (Percent)
Alt. 1	58.0	2.0	28.0	8.0	4.0
Alt. 2	14.0	84.0	0.0	0.0	2.0
Alt. 3	50.0	16.0	12.0	18.0	4.0
Alt. 4	34.0	38.0	6.0	10.0	12.0

Next, participants were told the intended meaning of the Blind Hill Warning sign. The four sign alternatives were presented, and participants were asked to rank them in terms of perceived effectiveness (figure 5). Sign alternative significantly affected ranking, $\chi^2(9) = 323.52$, $p < 0.001$. When only the top choice indicated by the participants was considered (ranking = 1), Alt. 1 was selected as the top choice by the majority of participants 65.5 percent (131/200). The data show that the Blind Hill Warning signs were usually preferred by the participants in the following order: Alt. 1, Alt. 3, Alt. 2, and Alt. 4.

Source: FHWA.
Hills 1–4 = Alt. 1–4, respectively.

Figure 5. Graph. Percentage of participants selecting each Blind Hill Warning sign alternative at each ranking value.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 45. Mean response distance significantly varied by sign alternative, $F(3) = 14.88$, MSe = 4,445.71, $p < 0.001$. Follow-up paired comparisons revealed that Alt. 1 and Alt. 2 were recognized at a distance significantly

greater than that for Alt. 3 and Alt. 4 ($p < 0.01$). No other statistically significant differences were found ($p > 0.05$).

Table 45. Mean response distance by Blind Hill Warning sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	439.14
Alt. 2	424.89
Alt. 3	371.71
Alt. 4	367.29

RECREATION AND CULTURAL INTEREST

Table 46 presents all alternative Recreation and Cultural Interest signs that were evaluated. All signs are already included it the MUTCD, except for Alt. 11, which includes the trailer camping symbol from D9-3a (a General Service sign) on the brown background of a Recreation and Cultural Interest sign.[1] The results of the comprehension and legibility tasks are presented in the following subsections.

Table 46. Recreation and Cultural Interest sign alternatives selected for evaluation, and response percentages.

Sign Alternative	Alternative Image	Response	Coded Response (Percent)
Alt. 1		Camping	32.7
		Camping plus trailer	17.3
		Other	50.0
Alt. 2		Camping	25.0
		Camping plus recreational vehicle	23.1
		Other	51.9
Alt. 3		Parking	86.0
		Police station	12.0
		Other	2.0
Alt. 4		Lighthouse	91.7
		Other	8.3
Alt. 5		First aid	66.7
		Hospital	29.2
		Urgent care	2.1
		Other	2.1

Sign Alternative	Alternative Image	Response	Coded Response (Percent)
Alt. 6		Boat ramp	58.0
		Boating activity	24.0
		Other	18.0
Alt. 7		Marina	24.0
		Anchor	58.0
		Other	18.0
Alt. 8		Winter recreation area	10.0
		Specific winter recreation area	54.0
		Snow area	12.0
		Other	24.0
Alt. 9		Sanitary waste disposal for recreational vehicle	8.0
		Camping	64.0
		Other	28.0
Alt. 10		Picnic area	94.0
		Snack bar/food area	2.0
		Other	4.0
Alt. 11		Camping	18.0
		Specific type of camping	48.0
		Other	34.0
Alt. 12		Camping	46.0
		Specific type of camping	46.0
		Other	8.0

All photos source: FHWA.[1]

Comprehension

Participants were presented with an in-context interest sign for Lincoln State Park positioned along the side of the roadway and were asked, "What amenities are available at Lincoln State Park?" Responses were coded and are presented in table 46.

Legibility

The same legibility procedure was used as described in the Lane Reduction Treatment, Legibility subsection. Mean response distances are presented in table 47. Mean response distance significantly varied by sign alternative, $F(3) = 14.88$, MSe = 4,445.71, $p < 0.001$.

Table 47. Mean response distance by Recreation and Cultural Interest sign alternative.

Sign Alternative	Mean Distance (ft)
Alt. 1	420.76
Alt. 2	434.09
Alt. 3	564.60
Alt. 4	437.04
Alt. 5	535.74
Alt. 6	421.22
Alt. 7	480.11
Alt. 8	517.28
Alt. 9	430.89
Alt. 10	518.73
Alt. 11	471.97
Alt. 12	528.13

Comprehension of Additional Recreation Signs

Seventy-two additional Recreation signs were also evaluated for comprehension as part of a separate task. These additional signs were those that may not be commonly used or seen as appropriate for highway signing, but rather would likely be used in parks or recreation areas. Participants were told that they would be presented with a series of signs that they might see in or near a park or recreation area. They were shown one sign at a time on a plain black background and were instructed to indicate the meaning of each sign or what service the sign was telling them was available. The responses were coded and are presented in the appendix.

TOLL PLAZA ELECTRONIC TOLL INTEROPERABILITY

Table 48 presents all alternatives for Toll Interoperability signs that were evaluated. None of these alternatives are compliant with the MUTCD. The results of the comprehension tasks are presented in the following subsections.

Table 48. Toll Interoperability sign alternatives selected for evaluation.

Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
					

All photos source: FHWA.

Comprehension

Participants were presented with an in-context photo (see figure 6 as an example). Each participant was only shown one of the Interoperability signs and was asked, “Imagine you are driving on a toll road and encounter this sign. What does this sign mean?” Participants were

directed to the individual Interoperability sign as the focus of their response. Participant responses were coded as one of four major responses: transponder, a multistate transponder (or acknowledgment that the transponder could be used at any toll plaza), or don't know/other. Participant responses are summarized in table 49. Nonparametric statistics revealed that sign alternative did not affect participant responses, $\chi^2(10) = 16.25$, $p > 0.05$.

Source: FHWA.

Figure 6. Screenshot. Example of an in-context photo displaying a toll interoperability sign.

Table 49. Percentage of participant responses within each coded category for each Toll Plaza Electronic Toll Interoperability sign alternative.

Sign Alternative	Transponder (Percent)	Multistate Transponder (Percent)	Don't Know/Other (Percent)
Alt. 1	75.0	0.0	25.0
Alt. 2	56.7	0.0	43.3
Alt. 3	83.3	3.3	13.3
Alt. 4	36.0	0.0	35.0
Alt. 5	63.3	0.0	36.7
Alt. 6	86.7	0.0	13.3

Next the potential effects of education about interoperability were explored. One-third of the participants were told, "You've recently received a letter in the mail stating that there is a new effort to allow interoperability between different toll roads and toll transponder brands. This interoperability will allow you to pay tolls on any compatible toll road with any transponder brand. This special symbol will indicate toll road compatibility." The remaining participants did not receive this education.

Participants were then asked, “Imagine you are driving on a toll road and encounter this sign. You have an E-ZPass® brand toll transponder. Which lane(s) can you use to pay the toll? (select all that apply).” A summary of responses is presented in table 50. See figure 6 for an example of lane labeling. For this section only, a seventh alternative was included that did not have an Interoperability sign. Overall (independent of education), the Interoperability sign that participants saw did not influence their lane choices ($p > 0.05$). The education itself, however, did influence participant response. Participants who received the education were significantly more likely to select lane 1 than those who did not receive the education ($p = 0.016$). No other comparisons were statistically significant.

Table 50. Percentage of participants responding that they could pay the toll using a toll transponder for each lane.

Education	Sign Alternative	Lane 1 (Percent)	Lane 2 (Percent)	Lane 3 (Percent)
No education	Alt. 1	100.0	0.0	0.0
	Alt. 2	80.0	10.0	10.0
	Alt. 3	100.0	0.0	0.0
	Alt. 4	90.0	30.0	30.0
	Alt. 5	100.0	30.0	20.0
	Alt. 6	100.0	40.0	30.0
	Alt. 7	80.0	20.0	10.0
Education	Alt. 1	100.0	0.0	0.0
	Alt. 2	100.0	20.0	20.0
	Alt. 3	100.0	20.0	20.0
	Alt. 4	100.0	0.0	0.0
	Alt. 5	100.0	10.0	0.0
	Alt. 6	100.0	0.0	0.0
	Alt. 7	100.0	40.0	20.0

Finally, the participants’ general understanding of toll transponder use was explored. One-third of the participants were asked, “Imagine you are driving on a toll road and encounter this sign. You do not have a toll transponder. Which lane(s) can you use to pay the toll? (select all that apply).” As expected, the Interoperability sign did not significantly affect lane choice across all three lanes ($p > 0.05$). As can be seen in table 51, participants clearly understood that they could not travel in lane 1 without a transponder.

Table 51. Percentage of participants responding that they could pay a toll without a toll transponder for each lane.

Sign Alternative	Lane 1 (Percent)	Lane 2 (Percent)	Lane 3 (Percent)
Alt. 1	0.0	100.0	100.0
Alt. 2	0.0	100.0	90.0
Alt. 3	0.0	100.0	100.0
Alt. 4	0.0	100.0	100.0
Alt. 5	0.0	100.0	90.
Alt. 6	0.0	100.0	100.0

CHAPTER 4. RECOMMENDATIONS, DISCUSSION, AND CONCLUSIONS

This section summarizes the results for each of the tested sign types and provides recommendations based on those results. The tested signs and sign assemblies do not necessarily comply with MUTCD provisions. As noted in chapter 3, State DOTs and local jurisdictions are required to use MUTCD-compliant signs and sign assemblies. If a State DOT and/or local jurisdiction is interested in using a new TCD or a different application of an existing device, they must receive approval from FHWA to experiment using the MUTCD experimentation process.[1]

LANE REDUCTION TREATMENT

According to the open-ended responses, between 86.7 and 97.5 percent of participants in each signing category responded that a lane was ending and/or there would be merging traffic ahead. However, when the researchers looked at the responses for the multiple-choice question, the participants seemed to be confused about which lane was ending, depending on the signing alternative that they viewed. Even though all sign alternatives were intended to indicate that the right lane was ending, participants who viewed Alt. 1, Alt. 2, and Alt. 3 were significantly more likely than those who saw Alt. 4, Alt. 5, or Alt. 6 to believe that the left lane was ending. Therefore, the use of arrows could possibly be contributing to this confusion regarding which lane is ending.

The signing alternatives also influenced whether participants were likely to indicate that a lane was closed (rather than ending). Participants who viewed Alt. 3 were more likely to indicate that the sign meant that the left lane was closed than those who viewed any other sign alternative. Participants who viewed Alt. 3 were also more likely than those who viewed Alt. 1, Alt. 2, or Alt. 4 to report that the right lane was closed. Participants who viewed Alt. 6 were more likely than those who viewed Alt. 1 or Alt. 2 to report that the right lane was closed.

Based on these responses, it is evident that Alt. 4 and Alt. 5 performed the best in terms of conveying the intended meaning (right lane ends) and not conveying unintended meaning (e.g., right lane closed, left lane closed, left lane ends). More participants reported that the right lane ends when viewing Alt. 5 (93.3 percent) than when viewing Alt. 4 (83.3 percent), and Alt. 5 was selected as the top choice by more participants (34.5 percent) than Alt. 4 (26.5 percent). Alt. 6 also performed well in terms of comprehension; however, it had a significantly shorter legibility distance than all other alternatives.

Recommendations for Lane Reduction Treatment

Although Alt. 5 may be slightly easier for participants to understand than Alt. 4, they both had high comprehension, and both are currently allowed in the MUTCD. Furthermore, Alt. 4 was recognized at a legibility distance significantly greater than all other alternatives. This result is not surprising, as symbol signs tend to have longer legibility distances than text signs. Therefore, either Alt. 4 or Alt. 5 would be acceptable for use. Alt. 6 also performed well in terms of comprehension and is currently allowed in the MUTCD; however, it had significantly shorter legibility distances than all other alternatives.

TEMPORARY TRAFFIC CONTROL BICYCLE/PEDESTRIAN ACCESS

As shown in table 6, the primary difference between the three sign alternatives is whether, and what, specific mode(s) of transportation are shown on the sign. The results shown in table 9 indicate that if a specific mode of transportation is not shown on the sign (Alt. 1), the majority of participants (94.3 percent) believed that motorists should use an alternative route. Participants generally assumed (71.4 percent) that bicyclists would also follow the detour. Only 47.1 percent of participants believed that pedestrians should follow the detour as well. When both pedestrians and bicycles are shown on the sign (Alt. 2), 94.3 percent of participants indicated that pedestrians should use an alternate route, and 97.1 percent indicated that bicyclists should use an alternate route. When only a pedestrian is shown on the sign (Alt. 3), 91.7 percent of participants believed pedestrians should use an alternate route, and only 31.7 percent of participants believed bicyclists should use an alternate route. However, when participants are shown the bicycle and/or pedestrian symbols, motorists may still interpret the sign as applicable to them as well. For example, Alt. 3 shows a pedestrian on the sign, but 20.0 percent of participants who viewed this sign still responded that motorists should take the detour.

Recommendations for Temporary Traffic Control Bicycle/Pedestrian Access

In general, participants tended to indicate that the detour applies to the transportation mode(s) shown on the sign. However, motorists may still believe the sign applies to them, even when the sign does not indicate it (table 9, Alt. 3 example). Therefore, although the signs appear to be generally effective, this type of sign may not be completely clear as evaluated. The contextual placement of the sign for this study was intentionally ambiguous. However, this ambiguous placement could be representative of some real-world situations where a path cannot be seen from the location of the sign. Therefore, the sign should ideally be placed and angled in such a way that it is clear that the sign is directed only toward pedestrians and bicyclists. Additionally, although Alt. 1 had significantly higher legibility distances than Alt. 2 and Alt. 3, including the pedestrian and bicycle symbols is likely acceptable, as pedestrians and bicyclists are generally traveling at lower speeds on sidewalks or trails.

FLASHING YELLOW ARROW

As indicated in the results, there were no significant differences between sign alternatives, nor was there a significant interaction between the flashing state of the signal mast and sign alternative. Regardless of sign alternative or flashing state, between 75.0 and100.0 percent of participants reported that the driver needed to yield to oncoming traffic or use caution. This outcome was also true for participants who viewed Alt. 4 (no sign), signifying that even with no sign at all, people would choose to either yield to oncoming traffic or use caution. The results also indicated that significantly more people who saw the animated flashing yellow arrow verbally indicated that they did not have the right of way and needed to yield to oncoming traffic. This result is important because it suggests that the flashing light carries meaning to drivers.

When the participant rankings of the signs are considered, participants generally preferred Alt. 3 and Alt. 2 over Alt. 1. All three signs had similar legibility distances. Although there were no statistically significant differences, more participants selected Alt. 3 as their top choice than

Alt. 2. Alt. 3 also had a slightly longer legibility distance (although, again, the difference was not significant).

Recommendations for Flashing Yellow Arrow

With only 70.0 percent of participants reporting that they need to yield to oncoming traffic when viewing the animated flashing yellow arrow with no sign, not using a sign at all may be premature. However, in the future, signs may not be needed or may be able to be removed after a certain period of time. Alt. 3 or Alt. 2 are both acceptable signs to use.

ALTERNATIVE FUELS

As indicated in table 15, participants were, in general, more likely to be partially correct (e.g., indicating "fuel" without specifying what type of fuel) than fully correct (i.e., indicating the correct type of fuel that was available). Keep in mind, however, that, depending on the goals of the driver (i.e., the specificity of the type of fuel the driver is trying to find), a partially correct response could mislead the driver to make an incorrect decision. As such, these results should be interpreted with caution. Additionally, participants were more likely to be fully correct (i.e., understand what type of fuel is available) when viewing signs with the supplemental placards than when viewing signs without the supplemental placards. Participants viewing the signs with the supplemental placards were also less likely to expect the service to be provided at a traditional fueling station and/or expect that they would also be able to find unleaded fuel at that service station. Although the signs without the placards tended to have higher legibility distances than the signs with the placards, the placards are necessary for comprehension of the signs.

Participants had particular difficulty partially understanding Alt. 11 and Alt. 12, presumably because these signs include only the abbreviations and do not include the gas pump symbol. This result suggests that the gas pump symbol is helpful.

Participants were not asked if they use any of these types of alternative fuels. Presumably, people who use such alternative fuels may be more familiar with the abbreviations for these fuels, and thus results may have been varied if alternative fuel users, specifically, were included in the study.

Recommendations for Alternative Fuels

Alternative Fuels signs should include the gas pump symbol and a supplemental placard indicating the type of alternative fuel that is offered.

MIDBLOCK HYBRID BEACON PEDESTRIAN CROSSINGS

When told that there was a pedestrian waiting to cross the street and asked how they would proceed, the majority of participants said that they would yield or stop for pedestrians (table 24). There were no significant differences between sign alternatives. However, the state of the signal (off, flashing red, steady red, or flashing yellow) was found to significantly affect responses. Participants who experienced the off or flashing yellow signals were generally likely to report that they would stop or yield, but slightly less so than those who saw the flashing red or steady red signals.

Although responses did not differ significantly by sign alternative (including Alt. 5, for which no sign was presented at all), some interesting findings are presented in table 23. For example, when the flashing red state in table 23 is considered, Alt. 3 seems to do the best job conveying to drivers that they can proceed after stopping when the crosswalk is clear. All other sign alternatives seem to tell participants that they must stop on flashing red, regardless of whether there is a pedestrian present or not, with 90.0 percent of participants who viewed Alt. 5 (no sign) reporting only that they should stop (table 23). Additionally, 90.0 percent of participants who saw Alt. 5 (no sign) with a flashing yellow signal indicated it was an emergency signal. Participants indicating that the flashing yellow indicates an emergency signal does not necessarily present a safety hazard, as they would likely proceed with caution and/or check for approaching vehicles. These examples do highlight the need for a sign, at least initially, while people are learning what the different flashing states mean.

Although Alt. 3 resulted in a higher correct response rate for the flashing red and flashing yellow states, it resulted in a slightly lower correct response rate for the off and steady red states compared with other signing alternatives (table 23). Furthermore, the legibility testing indicated that Alt. 3 was recognized at significantly shorter (worse) distances than Alt. 1 and Alt. 2, and that Alt. 2 was recognized a significantly longer distance than Alt. 3 and Alt. 4.

Recommendations for Midblock Hybrid Beacon Pedestrian Crossings

Since there is no statistical difference between signing alternatives in terms of decision to yield and stop, any of the alternatives would be adequate. However, Alt. 1 and Alt. 2 had higher legibility distances.

PASSENGER FERRY

The results of the open-ended questions (table 27) indicate that, in general, participants understand any of the sign alternatives to indicate the presence of a ferry. However, the alternatives that included the image of a motorized vehicle (Alt. 1, Alt. 4, and Alt. 5) resulted in higher percentages of participants indicating that a ferry was present than alternatives that only included the images of pedestrians or pedestrians and bicycles on the ferry (Alt. 2 and Alt. 3).

When participants were asked to select all who could ride the ferry (table 28), they generally tended to respond that only the modes of transportation shown in the sign were able to use the ferry. For example, for Alt. 4, 95.0 percent of participants reported that freight vehicles were allowed; however, only 25.0 percent reported that passenger vehicles were allowed and 15.0 percent reported that motorcyclists were allowed. Although it may be assumed that participants understand that the sign would show the largest type of vehicle allowed on the ferry (thus implying that smaller motorized vehicles are also allowed), participant responses indicate that confusion exists concerning who can ride the ferry, unless the information is explicitly shown on the sign.

Recommendations for Passenger Ferry

If the intent of the sign is to convey that multiple user types can use the ferry, then the sign should include each user type so people understand who can use the ferry.

BICYCLE PASSING LAW

When the first open-ended question (from the perspective of the driver) is considered, Alt. 3, Alt. 4, and Alt. 2 had the highest comprehension with 90.0, 76.6, and 70.0 percent, respectively, indicating that the car should leave lateral space (table 31). When the second open-ended question (from the perspective of the bicyclist) is considered, Alt. 3, Alt. 4, Alt. 1, and Alt. 2 had the highest comprehension with 86.7, 50.0, 50.0, and 47.5 percent, respectively, indicating that the car should leave lateral space (table 32). Once participants received the multiple-choice question (table 33), nearly all participants (between 93.3 and 97.5 percent) reported that the motorist should leave lateral space. However, many people also reported that the bicyclist should leave space and/or could receive a ticket. In this question, more people who viewed Alt. 4, Alt. 5, and Alt. 6 reported that the bicyclist should leave space and/or could receive a ticket than those who viewed Alt. 1, Alt. 2, and Alt. 3. Therefore, the use of the arrows in Alt. 4, Alt. 5, and Alt. 6 might be leading participants to believe that the bicyclists should also leave space.

When the results of both the open-ended and multiple-choice questions are considered, Alt. 2 and Alt. 3 would be considered the best in terms of comprehension, followed by Alt. 1 or Alt. 4. However, Alt. 1 was consistently ranked as the least effective sign by participants, while most participants (28.0 percent) selected Alt. 2 as their top choice, followed by 22.5 percent of participants who selected Alt. 4 as their top choice.

Somewhat contrary to the comprehension results, the mean legibility distances for Alt. 1, Alt. 5, and Alt. 4 were significantly greater than those for Alt. 3, Alt. 2, and Alt. 6.

Recommendations for Bicycle Passing Law

When comprehension, legibility, and ranking are considered, Alt. 3 is the most effective.

VEHICLE PROHIBITION

Participants generally understood that the mode of transportation that was presented on the sign was prohibited, with 61.7, 55.7, and 47.1 percent of participants viewing Alt. 1, Alt. 2, and Alt. 3, respectively, indicating that the pictured modes were prohibited in their open-ended responses. However, participants are less likely to assume that these signs mean that other modes of transportation not depicted on the sign are prohibited as well (table 36 and table 37). For example, as shown in the multiple-choice results in table 37, between 90.0 and 100.0 percent of participants selected that the mode of transportation shown on the sign was prohibited. Fewer participants, ranging from 0.0 percent to 58.3 percent, indicated that modes other than the one shown on the sign were also prohibited. The only exception to this finding is that for Alt. 2, 71.4 percent of participants indicated that motorcycles were prohibited (when the sign shows an ATV). However, the symbol in Alt. 3 may have simply been mistaken for a motorcycle.

Recommendations for Vehicle Prohibition

As stated previously, between 47.1 and 61.7 percent of participants indicated in their open-ended responses that the pictured mode of transportation was prohibited. This level of comprehension indicates that the symbols may not accurately indicate what the purpose of the sign might be. Although participants tended to understand more that the pictured mode was prohibited in the

multiple-choice question, they were less likely to say that other modes were also prohibited. Therefore, text signs may be better for these types of signs. Or, if a symbol is used, text should also be included to clarifying the intent.

RAIL/FLANGEWAY GAP BICYCLE WARNING

As shown in table 40, the sign alternative had a significant influence on participant response. Only 30.0, 34.0, and 32.0 percent of participants who viewed Alt. 1, Alt. 3, and Alt. 4, respectively, reported that bicyclists should use caution when crossing tracks, or that they should cross perpendicularly, whereas 68.0 percent of participants who viewed Alt. 2 indicated that bicyclists should use caution when crossing tracks or should cross perpendicularly. When providing subjective rankings of the signs' effectiveness, Alt. 2 was also selected as the top choice by the majority (56.0 percent) of participants, followed by Alt. 1, Alt. 3, and Alt. 4. Sign alternative had no significant difference on whether participants reported that they would dismount their bike before crossing the tracks. Alt. 3 and Alt. 4 were presumably confusing for participants, as 46.0 percent and 52.0 percent, respectively, of their responses fell into the "other" category.

Alt. 1 was recognized at a significantly shorter (worse) legibility distance than Alt. 2, Alt. 3, and Alt. 4. However, there were no significant differences between the legibility distances of Alt. 2, Alt. 3, and Alt. 4.

Recommendations for Rail/Flangeway Gap Bicycle Warning

Of the signs tested, Alt. 2 is the best option for signing for a rail/flangeway gap bicycle warning.

BLIND HILL WARNING

Although it is important that motorists understand that this sign is conveying the presence of a hill, it is more important that they understand that the hill is causing a sight obstruction, or that they simply recognize that there may be a sight obstruction. When participants who at least mentioned that there was a sight obstruction (may or may not have also mentioned a hill) are considered, Alt. 1 had the highest comprehension (86.0 percent) followed by Alt. 3 (62.0 percent). Alt. 4 and Alt. 2 had relatively low comprehension (40.0 and 14.0 percent, respectively). When the participants who mentioned a sight obstruction and a hill in their responses are considered, Alt. 1 had the highest comprehension (58.0 percent) followed by Alt. 3 (50.0 percent). The ranking data show that participants usually preferred the signs in the following order: Alt. 1, Alt. 3, Alt. 2, and Alt. 4. Alt. 1 was selected as the top choice by the majority (65.5 percent) of participants.

One of the primary reasons to use a symbol sign instead of a text sign is that symbols typically result in better legibility (longer distances). Interestingly, Alt. 1 (the text sign) had the highest mean legibility distances of all four alternatives. The results indicated that Alt. 1 and Alt. 2 were recognized at significantly greater distances than Alt. 3 and Alt. 4.

Recommendations for Blind Hill Warning

Alt. 1 had the highest comprehension, legibility distance, and subjective ranking of effectiveness. Therefore, the researchers recommended that Alt. 1 (which is currently in the MUTCD) continue to be used.

RECREATIONAL AND CULTURAL INTEREST

Although there are varying criterion for determining appropriate sign comprehension, the American National Standards Institute (ANSI) develops standards for the design, application, and use of signs, colors, and symbols and suggests a strict criteria of 85.0 percent comprehension. The results presented in table 46 indicate that Alt. 3, Alt. 4, and Alt. 10 are easily understood by participants and are acceptable for continued use. Alt. 12 was also deemed acceptable for continued use in that the participants who answered "camping" were assumed to imply camping in a tent or other nonvehicular means. On the other hand, there was some confusion about Alt. 1, Alt. 2, Alt. 6, Alt. 7, Alt. 8, Alt. 9, and Alt. 11. Therefore, it is recommended that these signs be evaluated to determine the most appropriate symbol to convey the intended meaning of each sign.

The results presented in the appendix are ordered from the signs that received the highest percentage of completely correct responses to the signs with the lowest percentage of completely correct responses. As these signs were not meant to be compared with each other, the recommendations were based on the comprehension scores of each individual sign.

Using the ANSI criteria, the following signs had at least 85.0 percent complete comprehension and, thus, are recommended for continued use:

- Golfing.
- Restrooms.
- Tennis.
- Trash Dumpster.
- Swimming.
- Motor Boating.
- Archery.
- Horse Trail.
- Picnic Shelter.
- Fishing Area.
- Tunnel.
- Baseball.
- Falling Rocks.
- Hiking Trail.
- Viewing Area.
- Chair Lift or Ski Lift.
- Cross-Country Skiing.
- Sleeping Shelter.
- Post Office.

- Dog Sledding.
- Nature Study Area.
- Scuba Diving.
- Bus Stop.

Recommendations for Recreational and Cultural Interest

For all additional signs, it is recommended that further testing be conducted to determine the best symbol for conveying each intended message.

TOLL PLAZA ELECTRONIC TOLL INTEROPERABILITY

When viewing the different sign alternatives, participants generally understood that the symbols meant a toll transponder, but they did not understand that the transponder could be used in multiple States, or that it could be used at any toll plaza (table 49). Sign alternative did not significantly affect participant responses.

Even with no education on the toll transponder interoperability, participants tended to understand that if they had an E-ZPass transponder, then they could use lane 1. However, the participants who received the education were significantly more likely to select lane 1 than those who did not receive the education. Additionally, the sign alternative viewed by participants did not influence lane choices, and participants clearly understood that they could not travel in lane 1 without a transponder, regardless of which sign alternative was used. Therefore, it is presumed that education, rather than the actual symbol or sign that is used, is the more important component in conveying interoperability.

Recommendations for Toll Plaza Electronic Toll Interoperability

Regardless of which symbol is selected, education will be key in ensuring that road users understand the concept of interoperability. Based on the results, no symbol is recommended over another, since none was statistically significant. However, should some symbols be considered, Alt. 1, Alt. 3, and Alt. 6 did have slightly higher comprehension than the other alternatives for the open-ended question (table 49) and for the lane-choice question when no education was given (table 50).

APPENDIX. ADDITIONAL RECREATION SIGNS RESULTS

Table 52 give the results for the 72 additional recreation signs that were evaluated for comprehension. Participants were instructed to indicate the meaning of each sign or what service the sign was telling them was available.

Table 52. Recreation sign results.

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Golfing		100.0	0.0	0.0
Restrooms		100.0	0.0	0.0
Tennis		99.0	0.0	1.0
Trash dumpster		98.0	2.0	0.0
Swimming		98.0	0.0	2.0
Motor boating		98.0	1.0	1.0
Archery		98.0	0.0	2.0
Horse trail		96.0	3.0	1.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Picnic shelter		95.0	0.0	5.0
Fishing area		95.0	0.0	5.0
Tunnel		93.0	0.0	7.0
Baseball		93.0	6.0	1.0
Falling rocks		93.0	5.0	2.0
Hiking trail		91.0	1.0	8.0
Viewing area		90.0	0.0	10.0
Chair lift or ski lift		90.0	5.0	5.0
Cross-country skiing		89.0	1.0	10.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Sleeping shelter		88.0	4.0	8.0
Post office		87.0	0.0	13.0
Dog sledding		87.0	4.0	9.0
Nature study area		86.0	5.0	9.0
Scuba diving		86.0	0.0	14.0
Bus stop		85.0	6.0	9.0
Waterskiing		84.0	7.0	9.0
Theater		84.0	1.0	15.0
Wildlife viewing		84.0	0.0	16.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Tramway		83.0	0.0	17.0
Hand launch or small boat launch		82.0	2.0	16.0
Recycling		81.0	0.0	19.0
Snow tubing		79.0	1.0	20.0
Whale viewing		77.0	15.0	8.0
Climbing		77.0	22.0	1.0
Beach		77.0	14.0	9.0
Sledding		76.0	3.0	21.0
All-terrain trail		76.0	10.0	14.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Jet ski or personal watercraft		76.0	7.0	17.0
Snowshoeing		75.0	1.0	24.0
Canoeing		74.0	22.0	4.0
Deer viewing area		72.0	23.0	5.0
Seal viewing		71.0	15.0	14.0
Sailing		67.0	30.0	3.0
Stable		66.0	2.0	32.0
Surfing		64.0	0.0	36.0
Grocery store		64.0	6.0	30.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Mechanic		63.0	4.0	33.0
Ice skating		62.0	14.0	24.0
Snowmobiling		61.0	1.0	38.0
Diving		60.0	39.0	1.0
Hang gliding		59.0	7.0	34.0
Kennel		59.0	1.0	40.0
Kayaking		55.0	28.0	17.0
Row boating		51.0	47.0	2.0
Off-road vehicle trail		51.0	9.0	40.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Snowboarding		51.0	0.0	49.0
Fishing pier		48.0	51.0	1.0
Wind surfing		48.0	51.0	1.0
Tour boat		47.0	3.0	50.0
Downhill skiing		38.0	56.0	6.0
Corral		34.0	65.0	1.0
Ski jumping		31.0	47.0	23.0
Ranger station		30.0	12.0	58.0
Dam		26.0	2.0	72.0

Sign Name	Sign Image	Completely Correct (Percent)	Partially Correct (Percent)	Incorrect (Percent)
Radiator water		26.0	33.0	42.0
Ice fishing		17.0	77.0	6.0
Rafting		16.0	78.0	6.0
Amphitheater		10.0	2.0	88.0
Fish ladder		5.0	3.0	92.0
Fish hatchery		3.0	6.0	91.0
Driving tour		0.0	1.0	99.0
Cultural interest area		0.0	0.0	100.0
Point of interest		0.0	0.0	100.0

All photos source: FHWA.[1]

REFERENCES

1. FHWA. 2009. *Manual of Uniform Traffic Control Devices for Streets and Highways*. Washington, DC: Federal Highway Administration.

2. Dewar, R., D. Kline, F. Scheiber, and A. Swanson. 1997. *Symbol Signing Design for Older Drivers*. Report No. FHWA-RD-94-069. Washington, DC: Federal Highway Administration.

3. Ogden, M. A., K. N. Womack, and J. M. Mounce. 1990. "Motorist Comprehension of Signing Applied in Urban Arterial Work Zones." *Transportation Research Record: The Journal of the Transportation Research Board* 1281: 127–135.

4. Dewar, R., D. Kline, and H. Swanson. 2001. "Age differences in comprehension of traffic symbols." *Accident Reconstruction Journal* 12, no. 1: 37–41.

5. Ben-Bassat, T., and D. Shinar. 2006. "Ergonomic Guidelines for Traffic Sign Design Increase Sign Comprehension." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 48, no. 1: 182–195.

6. Dewar, R. E. 1988. "Criteria for the Design and Evaluation of Traffic Sign Symbols." *Transportation Research Record: The Journal of the Transportation Research Board* 1160: 1–6.

7. Katz, B. J., E. E. Dagnall, and C. C. O'Donnell. 2012. "Evaluation of Comprehension and Legibility of International and Domestic Nonstandard Symbol Signs." *Transportation Research Record: The Journal of the Transportation Research Board* 2298, no. 1: 46–60.

8. Sanders, M. S., and E. J. McCormick. 1993. *Human Factors in Engineering and Design*, 7th ed. New York: McGraw Hill.

9. Shinar, D., R. E. Dewar, H. Summala, and L. Zakowska. 2003. "Traffic sign symbol comprehension: a cross-cultural study." *Ergonomics* 46: 1549–1565.

10. Barnett, J., N. Gizinski, E. Mondragon-Parra, J. E. Siegel, D. Morris, T. Gates, and P. Savolainen. 2020. "Automated Vehicles Sharing the Road: Surveying Detection and Localization of Pedalcyclists." *IEEE Transactions on Intelligent Vehicles* 6, no. 4: 649-664. https://doi.org/10.1109/TIV.2020.3046859, last accessed April 8, 2022.

11. Office of the Federal Register, National Archives and Records Administration. "Public Law 112-141—Moving Ahead for Progress in the 21st Century Act." Government. U.S. Government Printing Office, July 5, 2012. https://www.govinfo.gov/app/details/PLAW-112publ141, last accessed March 9, 2022.

Recommended citation: Federal Highway Administration,
Comprehension and Legibility of Selected Symbol Signs Phase IV
(Washington, DC: 2022) https://doi.org/10.21949/1521917.

HRSO-30/09-22(WEB)E