Traffic Control Devices Pooled Fund Study

Comprehension and Legibility of Selected Symbol Signs Phase IV

Final Report

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INTRODUCTION

Traffic signs are an important communication tool that is used to 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 non-verbal interpretation by a large and diverse population of drivers.

The Traffic Control Devices Pooled Fund Study (TCD PFS) focuses on a systematic evaluation of novel traffic control devices (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 both existing and proposed traffic signs. Sets of sign alternatives were evaluated for driver comprehension and legibility. 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 which enable consistent TCD idea identification and evaluation. The TCD PFS efforts address TCD issues identified by local and state jurisdictions, industry, and organizations and aid in the compliance to the MUTCD rule-making process and incorporation of novel TCDs into the MUTCD.

The TCD PFS members have selected various sign concepts to include as Phase IV of a study to evaluate the effectiveness of concepts for new symbol signs. 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 having 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 here will inform the dependent measures that will be assessed in the current 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, four road sign warnings (hump, curve, road crossing, and railroad crossing) were recommended for adoption by several European countries. 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. Though the United States had used primarily word signs, by 1970 the U.S. began the use of symbol signs many of which came from the 1968 U.N. 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 oftentimes cluttered visual scene. Symbol signs are better identified in adverse weather conditions (i.e. fog) where due to the degraded visual conditions, focal vision (or recognition vison), which is required to discern fine detail like text, would be impaired. Importantly, given the increasingly diverse make-up of drivers on the roadway, symbol signs have the advantage of being understood even by those drivers who do not understand the language of the country.

Yet, 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. The researchers found that these motorists had some difficulty interpreting both word and symbol messages on signs.[3] Dewar, Kline, and Swanson found that only 16 out of 85 of the standard traffic symbols used in the United States at the time were understood by more than 95 percent of the drivers in their sample. Additionally, for 10 of the signs they examined, comprehension was less than 40 percent.[4] 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. Though 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[6] proposed 6 criteria important to the design and evaluation of symbol signs listed and defined here:

- *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[4] had transportation experts rate the relative importance of these six criteria. In this 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 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., Katz, Dagnall, & O'Donnell[7]).

In addition to standards for sign evaluation, it is important to examine criteria for sign design. Several symbol sign alternatives will be designed in the current study and it is useful to look at human factors principles for sign design. Sanders and McCormick[8] proposed five ergonomic principles for the design of symbol signs highlighted below:

- *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 or 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 Bassatt and Shinar[5] examined the topic of sign comprehension as it relates to the above ergonomic principles. 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.

The TCD PFS panel selected the following sign messages for symbol development and evaluation (Detailed descriptions of each sign type are included in the next section of the document.):

- 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 Signs

- Bicycle Passing Law
- Passenger Ferry
- Regulatory Signs for Midblock, Hybrid Beacon Pedestrian Crossings (Driver)
- Alternative Fuels
- Recreational and Cultural Interest

RESEARCH APPROACH

The TCD PFS focuses on the systematic evaluation of novel 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 that the symbols are effective with regards to 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 Pooled Fund Study Panel. Images of each of the sign alternatives are presented in the results section of this report.

Lane Reduction Treatment

The results of this study will be used in a future investigation of both the signing and lane markings best suited for lane reduction treatment.

Temporary Traffic Control Bicycle/Pedestrian Access

As work on bicycle and/or pedestrian pathways becomes more common and large public works projects displace paths and routes, special detour routes for bicycles and/or pedestrians will become more common. The comprehension of such signs by both bicyclists and pedestrians will be considered based on how users perceive the use of the route and choose a route appropriate for their mode of travel.

Flashing Yellow Arrow

A traffic sign is used to inform drivers that they are expected to yield at a flashing yellow traffic signal. Yet, it is challenging to adequately convey dynamic “flashing” in a static symbol. This study investigated the most appropriate symbol to portray a flashing yellow arrow.

Alternative Fuels

There are new alternative fuels (specifically hydrogen, liquid propane gas, biodiesel, and fast charging / slow charging electric vehicle stations) for which signing may be required.

Regulatory Signs for Midblock, Hybrid Beacon Pedestrian Crossings (Driver)

It may not always be clear what action a driver should take when encountering hybrid beacon pedestrian crosswalks. Signs that instruct the driver as to the appropriate action to take at the crosswalk were investigated.

Passenger Ferry

An MUTCD approved sign exists to indicate a vehicle ferry, but 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.

Bicycle Passing Law

Over 20 states have passed legislation requiring motorists to provide a minimum of 3 feet of clearance when passing bicyclists on the roadway. Yet, there is not currently a standard sign that provides motorists with notice of this law. Many states and local highway agencies have developed their own signs to convey this message. These signs and alternatives to these were tested to ensure comprehension and legibility.

Vehicle Prohibition Signs

These signs would be used to indicate that certain vehicles (e.g., golf carts, motorcycles, jet skis, or ATVs) are not permitted on bicycle or pedestrian pathways or trails. Some current symbols do not match existing symbols for highway use; additionally, there is 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 other roadway users to share this same space. This design, though fine for motor vehicle traffic, is problematic for bicyclists as bicycle tires can drop into the flangeway gap if not crossed 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 though 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, an inappropriate use of the shape and color reserved for warning signs.

Blind Hill Warning

Though 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 traffic control device 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 are used to 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 understandability of specific signs in this category will be investigated.

Toll Plaza Electronic Toll Interoperability

The International Bridge, Tunnel and Turnpike Association (IBTTA), in order to meet MAP-21 requirements for federally funded facilities, has begun efforts towards technologies and business practices to implement national electronic toll interoperability within the United States. Symbol signs to communicate that a specific toll has national interoperability capabilities were evaluated.

METHOD

Data were collected both at the Turner-Fairbank Highway Research Center and in a mobile laboratory. The use of the mobile laboratory provided the opportunity to collect data from participants of diverse background who regularly drive outside of the Washington, DC, metropolitan area. Participants sat approximately 5 feet from a 60” 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 was a multiple stage process 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 in order to allow for more detailed inspection. Specific questions were tailored for each sign type which are detailed in the results section.

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 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,

participants viewed the same individual signs for which comprehension questions were answered.

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 1000 feet (304.8 meters). The sign expanded in size to simulate an approach speed of 45 mi/h. 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 they were incorrect, the same sign reappeared and continued to increase in size so the participant had 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

A total of 200 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 travelled 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 years 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. Prior to the start of the experiment, participants were asked to read and sign the Informed Consent form. Participants were paid $40 for their time.

RESULTS

LANE REDUCTION

Table 1 presents all alternatives for lane reduction signs. The results of the comprehension, ranking, and legibility tasks are presented here.

Table 1. Lane Reduction Treatment Sign Alternatives Selected for Evaluation

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

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 placard 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 response of lane ending, merge, lane ends & merge combined, lane narrowing, or some other response.

Table 2 presents the percentage of participant responses in each coded category by sign alternative. For example, 46.7 percent of the responses to sign alternative 1, were coded as lane ending. Non-parametric analyses were performed to determine if differences in responses varied by sign alternative. Significant differences are noted by a *p* value of .05 (i.e., less than 5 percent chance that the results would occur by chance) and are presented in bold font with an *. Here, participants that mentioned the lane was ending only (no mention of the need to merge), was significantly influenced by sign alternative.

Table 2. Percentage of participant responses within each coded category for each alternative.

Alternative	% Lane Ending only	% Merge only	% Lane ending, Merge	% Lane Narrowing	% Other/ incorrect
Alt. 1	46.7	3.3	40.0	0	10
Alt. 2	40	12.5	45	2.5	0
Alt. 3	13.3	40	36.7	0	10
Alt. 4	40	10	36.7	6.7	6.7
Alt. 5	16.7	10	70	0	3.3
Alt. 6	12.5	20	62.5	0	5
p value	**.011***	**.009***	>.05	>.05	>.05

*indicates a significant difference

To better capture participants' understanding of the sign, people 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). Non-parametric tests were performed to determine if responses differed based on sign alternative.

Paired comparison tests were performed to determine where differences existed. Significantly more people responded that sign alternative 3 meant that the right lane was closed than alternative 1 ($p = .003$), alternative 2 ($p = .005$), and alternative 4 ($p = .021$). Similarly, significantly more people responded that sign alternative 6 meant that the right lane was closed than alternative 1 ($p = .027$) and sign alternative 2 ($p = .045$). No other significant differences between signs believed to indicate that the right lane was closed were found.

Those that saw sign alternative 3 were more likely to respond that the sign meant left lane closed than any other sign alternative ($p < .05$). No other significant differences were found for this response.

Those that saw sign alternative 2 were significantly less likely to indicate that the sign meant that the right lane ends than those that saw alternative 5 ($p = .006$) and alternative 6 ($p = .009$). Those

that saw sign alternative 1 were significantly less like than those that saw sign alternative 5 (p = .044) to indicate that the sign meant that the right lane was ending.

Those that saw sign alternatives 1, 2, and 3 were significantly more likely than those that saw alternatives 4, 5, or 6 to believe that the left lane was ending ($p < .01$). No differences were found between responses to sign alternatives 1, 2, and 3. This finding could have significant implications for driver behavior.

Table 3. Percentage of participants responding to each category.

Alternative	Right Lane Closed %	Left Lane Closed %	Right Lane Ends %	Left Lane Ends %	Traffic Merging ahead %
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	**.018***	**.003***	**.045***	**<.001***	.206

*indicates a significant difference

Next participants were asked about their actions/behaviors in the presence of the sign. “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 significant differences between sign alternatives were found.

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

Alternative	As soon as possible %	Somewhere between seeing the sign and where the lane begins to taper (narrow) %	When the lane begins to taper (narrow) %	Follow the lane until it ends and transitions into a single lane (i.e., follow the white line) %
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**	.771	.057	.615	.748

*indicates a significant difference

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. When considering only the top choice indicated by the participants (Ranking = 1), alternative 5 was selected as the top choice by 34.5 percent (69/200) of the participants and alternative 4 was selected as the top choice by 26.5 percent (53/200) of the participants. There was a significant difference in the rankings of each alternative χ^2 (25) = 484.38, $p < .001$.

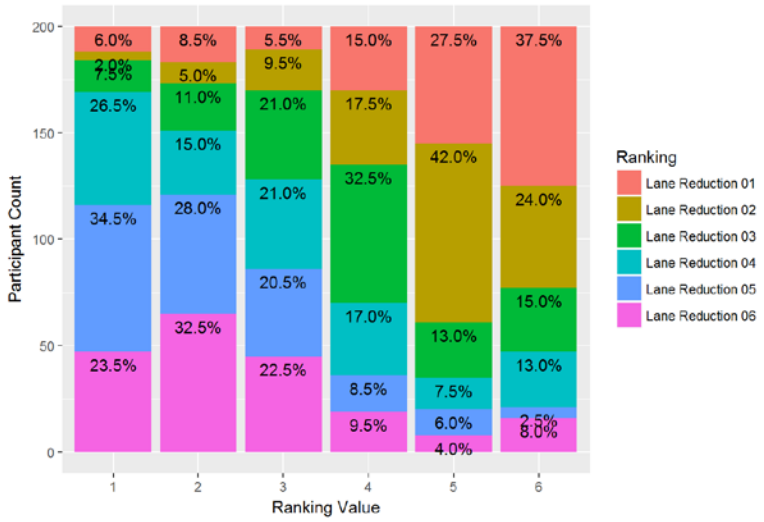


Figure 1. The percentage of participants selecting each sign alternative at each ranking value.

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 was used to confirm 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, MSe = 6576.25, $p <.001$.

Pairwise comparison follow up testing revealed sign alternative 4 was recognized at a distance significantly greater than all other alternatives ($p < .05$). Sign alternative 6 was recognized at a distance significantly shorter than all other signs ($p < .05$). These results are not surprising given that symbol signs generally contain more robust and contain less fine detail than worded signs. The finer the detail, the more challenging it is to determine content at a distance.

Table 5. Mean response distance by sign alternative.

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

TEMPORARY TRAFFIC CONTROL BICYCLE/PEDESTRIAN ACCESS

Table 6 presents all alternatives for temporary traffic control signs. The results of the comprehension and legibility tasks are presented here.

Table 6. Temporary Traffic Control Bicycle/Pedestrian Access Sign Alternatives Selected for Evaluation

Alt. 1	Alt. 2	Alt. 3

Comprehension

Participants were only exposed to a single Temporary Traffic Control Device 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 + the person or persons the sign is directed toward (e.g., pedestrians, cyclists, vehicles).

The sign alternative significantly affected participant response $\chi^2(10) = 96.30$, $p < .001$. Table 7 presents the percentage of participant responses coded to each category. Given the ambiguity of the placement of the signs, paired comparisons for this question were not performed. Of note, however are some of the responses that did not fall into a category specifically related to a detour. For example, "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. The percentage of participant responses within each coded category for each alternative.

Alternative	Detour + specific vehicle types %	Detour Only %	Pedestrian Only (no detour) %	Bike Only (no detour) %	Vehicle Only (no detour) %	Other Response %
Alt. 1	0	84.3	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	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 $\chi^2(10) = 41.32$, $p < .001$. Table 8 presents the percentage of participant responses coded to each category.

Table 8. The percentage of participant responses within each coded category for each alternative.

Alternative	Detour + specific vehicle types %	Detour Only %	Pedestrian Only (no detour) %	Bike Only (no detour) %	Vehicle Only (no detour) %	Other Response%
Alt. 1	8.6	57.1	0	10	11.4	12.9
Alt. 2	17.1	31.4	0	21.4	1.4	28.6
Alt. 3	31.7	30.0	1.7	5.0	1.7	30.0

Finally, to more clearly assess participants’ understanding 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 that selected each mode that must use an alternate route by sign alternative. Non-parametric tests revealed that for each mode of transportation, sign type significantly influenced response; motorists, $\chi^2(2) = 119.50$, $p < .001$; bicyclists, $\chi^2(2) = 64.62$, $p < .001$; pedestrians, $\chi^2(2) = 54.33$, $p < .001$.

Table 9. The percentage of participants that selected each mode of transportation that selected each mode of transportation, divided by alternative.

Alternative	Motorists %	Bicyclists %	Pedestrians %
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**	**<.001***	**<.001***	**<.001***

*indicates a significant difference

Supplemental pairwise comparisons revealed that significantly more participants responded that the motorists should use an alternate route with alternative 1, than the other two alternatives ($p <. 001$). When asked about bicyclists, all three alternatives performed significantly different from one another ($p <. 001$). When asked about pedestrians, significantly fewer participants responded that pedestrians should use an alternate route with alternative 1, than the other two alternatives ($p <. 001$).

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 10. Mean response distance varied significantly by sign alternative $F(2) = 21.69$, $MS_e = 7856.06$, $p <.001$. Pairwise comparison follow up testing revealed that sign alternative 1 generated

significantly greater recognition distances than alternatives 2 and 3 ($p < .05$). No significant difference between sign alternative 2 and 3 was found ($p > .05$).

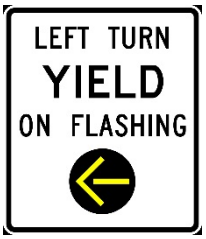
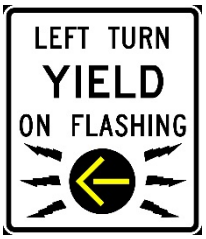
Table 10. Mean response distance by sign alternative.

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. A condition in which no sign was placed next to the signal mast was also included. This was designed to provide insight as to whether or not the sign is necessary to properly interpret the signal. The results of the comprehension, ranking, and legibility tasks are presented here.

Table 11. Flashing Yellow Arrow Sign Alternatives Selected for Evaluation

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

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 flashing, on a solid state, and blank. Open ended responses were coded as a response including the acknowledgement that the driver did not have the right of way and needed to watch for oncoming traffic, as a need to use caution only, or some other response.

Participant responses as percentages are presented in Table 12. When exploring all data, no 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 ($p > .05$). 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 ($p < .05$). This result lends one to believe that the flashing of the light itself carries meaning to drivers.

Table 12. The percentage of participant responses within each coded category for each alternative, by flashing state.

Flashing state	Sign Alternative	Yield to oncoming traffic %	Use Caution Only %	Other %
Off	Alt. 1	80	0	20
	Alt. 2	65	10	25
	Alt. 3	75	5	25
	Alt. 4	65	20	15
On (steady)	Alt. 1	65	20	15
	Alt. 2	75	5	20
	Alt. 3	60	20	20
	Alt. 4	45	30	25
Animated (flashing)	Alt. 1	70	30	0
	Alt. 2	100	0	0
	Alt. 3	85	5	10
	Alt. 4	70	30	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) and participants were asked to rank them in terms of perceived effectiveness. When considering only the top choice indicated by the participants (Ranking = 1), alternative 3 was selected as the top choice by 47.5 percent (95/200) of the participants and alternative 2 was selected as the top choice by 34 percent (68/200) of the participants. There was a significant difference in the rankings of each alternative χ^2 (4) = 121.44, $p < .001$. Alternative 1 (all text) was consistently rated the least effective sign ($p < .05$)

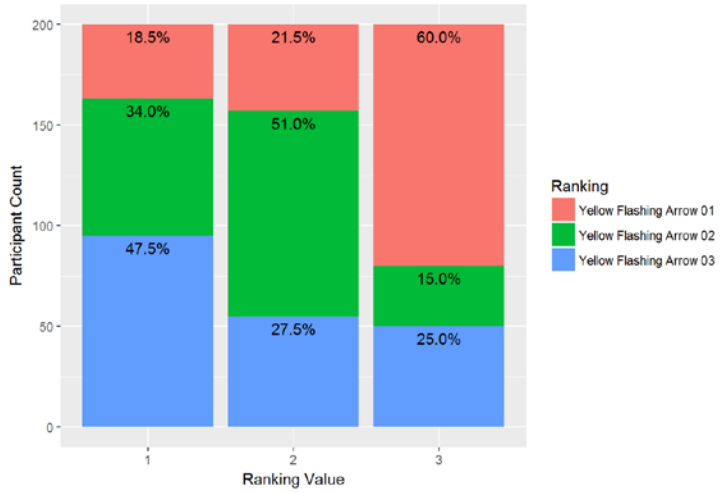


Figure 2. The percentage of participants selecting each sign alternative at each ranking value.

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 13. Mean response distance did not vary significantly by sign alternative $F(2) = .80$, $MS_e = 3455.212$, $p > .05$. In other words, all signs were read at a similar distance.

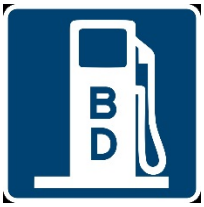
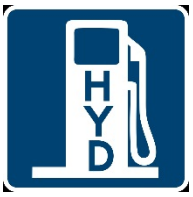
Table 13. Mean response distance by sign alternative.

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 fuel signs. The results of the comprehension and legibility tasks are presented here.

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**
					

Comprehension

Participants were only exposed to a single alternative fuel placard 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 alternative #3, a response of "fuel" would be considered partially correct because biodiesel is a type of fuel, but the response doesn't specify which specific type of fuel.

Table 15. The percentage of participant responses within each coded category for each alternative.

Alternative	% correct	% Partially correct	% Incorrect/other response	P value
Alt. 1	25	75	0	**.025***
Alt. 2 (Supplemental Placard)	60	40	0	.527
Alt. 3	0	100	0	*
Alt. 4 (Supplemental Placard)	40	60	0	.527
Alt. 5	0	100	0	*
Alt. 6 (Supplemental Placard)	40	55	5	**.019***
Alt. 7	5	95	0	**.000***
Alt. 8 (Supplemental Placard)	50	45	5	**.026***
Alt. 9	20	80	0	.058
Alt. 10 (Supplemental Placard)	50	50	0	1.0
Alt. 11	10	35	55	**.047***
Alt. 12	10	20	70	**.045***

*indicates a significant difference

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 <.001). Follow-up paired comparison analyses were performed, summary results are presented in Table 16.

Table 16. Paired comparison results examining signs with supplemental placards compared to those without.

No Placards	Supplemental Placard	*p* value
Alt. 1	Alt. 2	.061
Alt. 3	Alt. 4	**.002***
Alt. 5	Alt. 6	**.003***
Alt. 7	Alt. 8	**.003***
Alt. 9	Alt. 10	.114

*indicates a significant difference

Participants were also asked questions to more clearly assess participants' 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. The percentage of participant responses by sign alternative to the question "I would expect this service to be provided at a traditional fueling station"

Alternative	Yes (%)	No (%)
Alt. 1	70	30
Alt. 2 (Supplemental Placard)	50	50
Alt. 3	18	82
Alt. 4 (Supplemental Placard)	50	50
Alt. 5	85	15
Alt. 6 (Supplemental Placard)	45	55
Alt. 7	60	40
Alt. 8 (Supplemental Placard)	25	75
Alt. 9	70	30
Alt. 10 (Supplemental Placard)	55	45
Alt. 11	35	65
Alt. 12	30	70

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

Alternative	Yes (%)	No (%)
Alt. 1	80	20
Alt. 2 (Supplemental Placard)	60	40
Alt. 3	90	10

Alt. 4 (Supplemental Placard)	20	80
Alt. 5	95	5
Alt. 6 (Supplemental Placard)	40	60
Alt. 7	70	30
Alt. 8 (Supplemental Placard)	40	60
Alt. 9	70	30
Alt. 10 (Supplemental Placard)	40	60
Alt. 11	50	50
Alt. 12	30	70

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

Alternative	An Attendant (% yes)	Public Restroom (% yes)	Concessions (% yes)
Alt. 1	35	45	45
Alt. 2 (Supplemental Placard)	20	70	50
Alt. 3	60	75	35
Alt. 4 (Supplemental Placard)	60	50	30
Alt. 5	70	65	70
Alt. 6 (Supplemental Placard)	65	70	50
Alt. 7	45	60	55
Alt. 8 (Supplemental Placard)	75	70	55
Alt. 9	70	60	50
Alt. 10 (Supplemental Placard)	55	65	50
Alt. 11	30	50	35
Alt. 12	50	70	30

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 20. Mean response distance varied significantly by sign alternative $F(11) = 6.12$, $MS_e = 32579.22$, $p < .001$. Pairwise comparison follow up testing revealed a multitude of differences. Those differences are summarized in Table 21.

Table 20. Mean response distance by sign alternative.

Alternative	Mean Distance
Alt. 1	478.55
Alt. 2 (Supplemental Placard)	350.73
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 sign alternative.

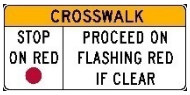
	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11	Alt. 12
Alt. 9		*				*		*		*		*
Alt. 5		*				*		*		*		*
Alt. 3		*				*		*		*		*
Alt. 7		*				*		*		*		*
Alt. 1		*				*		*		*		*
Alt. 11		*				*		*		*		
Alt. 4		*										
Alt. 12	*		*		*		*		*			
Alt. 6	*	*	*	*	*		*		*		*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

***indicates a significant difference**

MIDBLOCK HYBRID BEACON PEDESTRIAN CROSSING

Table 22 presents all alternatives for hybrid beacon crossing signs. A condition in which no sign was placed next to the signal mast was also included. This was designed to provide insight as to whether or not the sign is necessary to properly interpret the signal. The results of the comprehension and legibility tasks are presented here.

Table 22. Midblock Hybrid Beacon Pedestrian Crossings Sign Alternatives Selected for Evaluation.

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

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 dark, flashing red, solid/steady red, or as 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 upon 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 that provided a response that was not incorrect, but did not address the question at hand (e.g., “it is a pedestrian crossing”).

Table 23. The percentage of participant responses within each coded category for each alternative, by flashing state.

Flashing state	Sign Alternative	Correct response %	Stop only %	Emergency Signal %	Responded to a different question %	Caution %	Other incorrect %
Dark	Alt. 1	10	10	0	70	10	0
	Alt. 2	10	20	0	70	0	0
	Alt. 3	0	20	0	70	10	0
	Alt. 4	10	30	0	50	0	10
	Alt. 5	20	0	10	40	10	20
Flashing Red	Alt. 1	30	50	0	20	0	0
	Alt. 2	20	60	0	0	0	20
	Alt. 3	60	20	0	10	0	10
	Alt. 4	20	50	0	20	0	10
	Alt. 5	0	90	10	0	0	0
Steady Red	Alt. 1	90	10	0	0	0	0
	Alt. 2	90	10	0	0	0	0
	Alt. 3	70	30	0	0	0	0
	Alt. 4	90	10	0	0	0	0
	Alt. 5	90	0	10	0	0	0
Flashing Yellow	Alt. 1	0	40	20	10	0	30
	Alt. 2	0	0	40	10	0	50
	Alt. 3	40	0	60	0	0	0
	Alt. 4	10	10	30	0	0	50
	Alt. 5	0	0	90	0	10	0

When exploring all data, no significant differences between sign alternatives were found, χ^2 (20) = 28.80, p >.05. However, the light state of the signal was found to significantly affect response, χ^2 (15) = 210.78, p <.001. Given the large number of participants that did not provide a response and that answered the question presented, this result was not explored further.

Next participants were asked to “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. The percentage of participant responses within each coded category for each alternative, by flashing state.

Flashing state	Sign Alternative	Yield/stop %	No Yield/stop %	Other %
Dark	Alt. 1	90	10	0
	Alt. 2	60	20	20
	Alt. 3	70	10	20
	Alt. 4	90	10	0
	Alt. 5	70	30	0
Flashing Red	Alt. 1	90	10	0
	Alt. 2	100	0	0
	Alt. 3	90	10	0
	Alt. 4	100	0	0
	Alt. 5	90	10	0
Steady Red	Alt. 1	100	0	0
	Alt. 2	100	0	0
	Alt. 3	80	20	0
	Alt. 4	90	0	10
	Alt. 5	100	0	0
Flashing Yellow	Alt. 1	80	20	0
	Alt. 2	80	20	0
	Alt. 3	80	20	0
	Alt. 4	80	20	0
	Alt. 5	90	10	0

When exploring all data, no significant differences between sign alternatives were found, X^2 (8) = 7.05, p >.05. However, the light state of the signal was found to significantly affect response, X^2 (6) = 17.45, p =.008.

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 25. Mean response distance varied significantly by sign alternative F(3) = 10.16, MS_e = 45907.07, p <.001. Pairwise comparison follow up testing revealed that alternative 3 was recognized at a

significantly shorter distance than alternatives 1 and 2 ($p <. 05$). Sign alternative 2 was recognized a significantly longer distance than signs 3 and 4. ($p <. 05$)

Table 25. Mean response distance by sign alternative.

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. The results of the comprehension, and legibility tasks are presented here.

Table 26. Passenger Ferry Sign Alternatives Selected for Evaluation

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

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, other. Responses by sign alternative are summarized in Table 27. Non-parametric tests revealed that sign alternative significantly affected participant response, X^2 (8) = 57.45, $p <.001$.

Table 27. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	Ferry %	Other Recreational Vehicle %	Other %
Alt. 1	77.5	7.5	15
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). Summary of these results is presented in Table 28.

Table 28. The percentage of participant responses by sign alternative to the question "Who can ride this Ferry?"

Alternative	Passenger Vehicle (% yes)	Pedestrians (% yes)	Bicyclists (% yes)	Motorcyclists (% yes)	Freight Vehicles (% yes)	Transit Vehicles (% 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
Alt. 3	5.0	100.0	2.5	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	**<.001***	**<.001***	**<.001***	**<.001***	**<.001***	**<.001***

***Indicates significant difference**

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 29. Mean response distance did not significantly vary by sign alternative $F(4) = 1.71$, $MS_e = 12166.63$, $p > .05$.

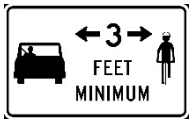
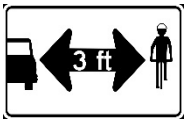
Table 29. Mean response distance by sign alternative.

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. The results of the comprehension, ranking, and legibility tasks are presented here.

Table 30. Bicycle Passing Law Sign Alternatives Selected for Evaluation

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

Comprehension

Comprehension questions were presented both in the context of a participant imagining him/herself as a motorist and a bicyclist. The order in which these were presented was randomized. 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. Non-parametric tests revealed that sign alternative significantly affected participant response, X^2 (25) = 41.35, *p* =.021. A summary of the percentage of each response type by sign alternative is presented in Table 31.

Table 31. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	Car leaves space (lateral) %	Bike leaves space (lateral) %	No indicator of who leaves space (lateral) %	Bike passing bike%	Longitudinal space (following) %	Other %
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. Non-parametric tests revealed that sign alternative significantly affected participant response, X^2 (25) = 64.46, *p* <.001. A summary of the percentage of each response type by sign alternative is presented in Table 32.

Table 32. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	Car leaves space (lateral) %	Bike leaves space (lateral) %	No indicator of who leaves space (lateral) %	Bike passing bike%	Longitudinal space (following) %	Other %
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 more clearly capture participant understanding of the sign, 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 are presented in Table 33.

Table 33. The percentage of participant responses by sign alternative to the question "Which of these statements are true"

Alternative	A. Motorist leave space. (% yes)	B. Bicyclist leave space. (% yes)	C. Motorist receive ticket. (% yes)	D. Bicyclist receive ticket. (% 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	.908	**<.001***	.056	**.017***

***indicates a 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 considering only the top choice indicated by the participants (Ranking = 1), alternative 2 was selected as the top choice by 28 percent (56/200) of the participants and alternative 4 was selected as the top choice by 22.5 percent (45/200) of the participants. There was a significant difference in the rankings of each alternative χ^2 (25) = 311.64, $p < .001$. alternative 1 was consistently rated the least effective sign ($p < .05$). In general, data helps support that the Bikes signs were usually preferred by the participants in the following order: alternative 4 or alternative 2 or alternative 5, alternative 6 or alternative 3, alternative 1. Figure 3 summarizes the percent of time that each of the sign alternatives was selected at each ranking level.

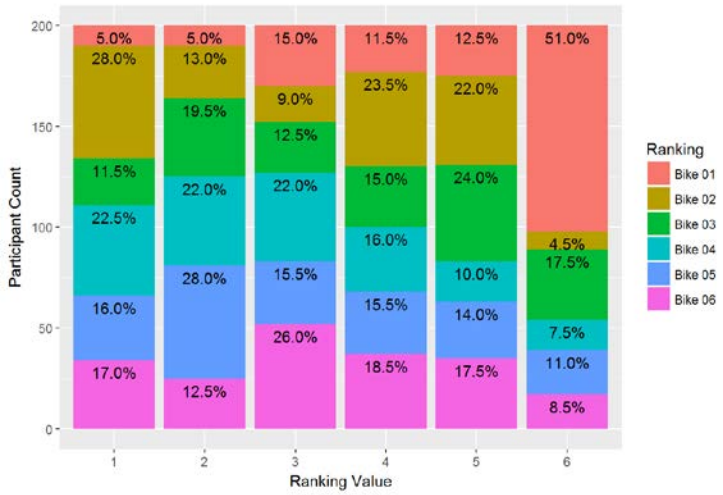


Figure 3. The percentage of participants selecting each sign alternative at each ranking value.

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 34. Mean response distance significantly varied by sign alternative F(5) = 20.77, MS_e = 5433.43, p <.001. Follow-up paired comparisons show that alternatives 1, 5, and 4 did not result in significantly different legibility distances (p >.05). However, all three (alternatives 1, 5, and 4) where read at a distance significantly greater than alternatives 3, 2, and 6. Alternative 6 was more legible than alternative 3 ($p < .05$). No difference between alternatives 2 and 3 were found (p >.05).

Table 34. Mean response distance by sign alternative.

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. The results of the comprehension and legibility tasks are presented here.

Table 35. Vehicle Prohibition Sign Alternatives Selected for Evaluation.

Alt. 1	Alt. 2	Alt. 3

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 + the specific pictured mode, prohibition + an adjacent but not pictured category, prohibition + 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. Non-parametric analyses revealed that sign alternative influenced participant response χ^2 (6) = 24.53, $p < .001$.

Table 36. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	No pictured mode %	No non-pictured mode %	No motorized vehicles %	Other %
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 more clearly capture participant understanding of the sign, 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. The percentage of participant responses by sign alternative to the question "Which types of transportation are prohibited"

Alternative	Pedestrians (% yes)	Bicyclists (% yes)	Motorcycles (% yes)	ATVs (% yes)	Snowmobiles (% yes)
Alt. 1	0.0	21.7	100.0	58.3	43.3
Alt. 2	0.0	2.9	71.4	90.0	44.3
Alt. 3	0.0	0.0	11.4	24.3	97.1
P value	n/a	**< .001***	**< .001***	**< .001***	**< .001***

***indicates a significant difference**

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 38. Mean response distance did not significantly vary by sign alternative $F(2) = 1.49$, $MS_e = 7117.44$, $p > .05$.

Table 38. Mean response distance by sign alternative.

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. The results of the comprehension, ranking, and legibility tasks are presented here.

Table 39. Rail/Flangeway Gap Bicycle Warning Sign Alternatives Selected for Evaluation.

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

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 + tracks + bicycles
B. Use caution/care when crossings + tracks + bicycles + 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. Non-parametric analyses revealed that sign alternative influenced participant response χ^2 (12) = 79.11, $p < .001$.

Table 40. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	A. bikes use caution when crossing %	B. bikes use caution when crossing + need to cross perpendicularly %	C. Bike hazard or some other unspecified issue %	D. Tracks ahead %	E. Other %
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?" Non-parametric analyses revealed that sign alternative did not influenced participant response χ^2 (3) = 4.27, $p > .05$.

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

Sign Alternative	Yes %	No %
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, χ^2 (9) = 293.96, p <001. When considering only the top choice indicated by the participants (Ranking = 1), alternative 2 was selected as the top choice by a majority of the participants. The data helps support that the Tracks signs were usually preferred by the participants in the following order: Tracks Sign 2, Tracks Sign 1 , Tracks Sign 3 or 4. Figure 4 summarizes the percent of time that each of the sign alternatives was selected at each ranking level.

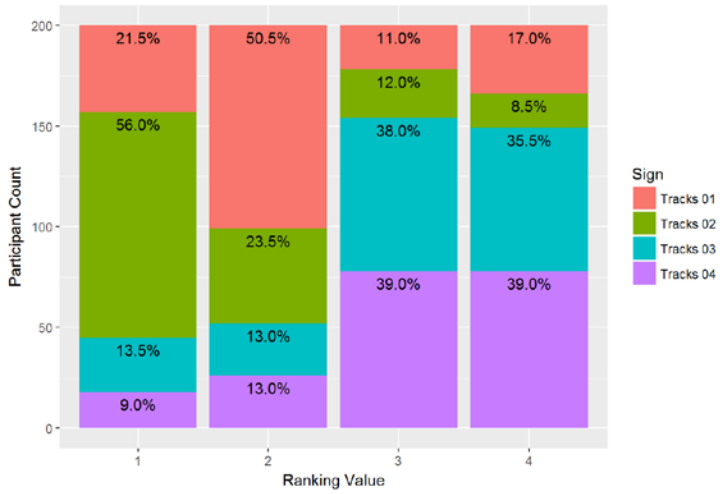


Figure 4. The percentage of participants selecting each sign alternative at each ranking value.

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 42. Mean response distance significantly varied by sign alternative $F(3) = 16.23$, $MS_e = 3114.21$, $p < .001$. Follow-up paired comparisons revealed that alternative 1 was recognized at a distance significantly shorter than alternatives 2, 3, and 4 ($p < .001$). No differences between alternatives 2, 3, and 4 were found ($p > .05$).

Table 42. Mean response distance by sign alternative.

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. The results of the comprehension, ranking, and legibility tasks are presented here.

Table 43. Blind Hill Warning Sign Alternatives Selected for Evaluation

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

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 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

Non-parametric analyses revealed that sign alternative influenced participant response χ^2 (12) = 113.75, $p < .001$. A summary of responses are presented in Table 44

Table 44. The percentage of participant responses within each coded category for each alternative.

Sign Alternative	A. sight obstruction + hill %	B. Hill %	C. Sight obstruction %	D. Use Caution %	E. Other %
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. Sign alternative significantly affected ranking, χ^2 (9) = 323.52, p <001. When considering only the top choice indicated by the participants (Ranking = 1), alternative 1 was selected as the top choice by the majority of participants 65.5 percent (131/200). The data helps support that the blind hill warning signs were usually preferred by the participants in the following order: alternative 1, alternative 3, alternative 2, alternative 4.

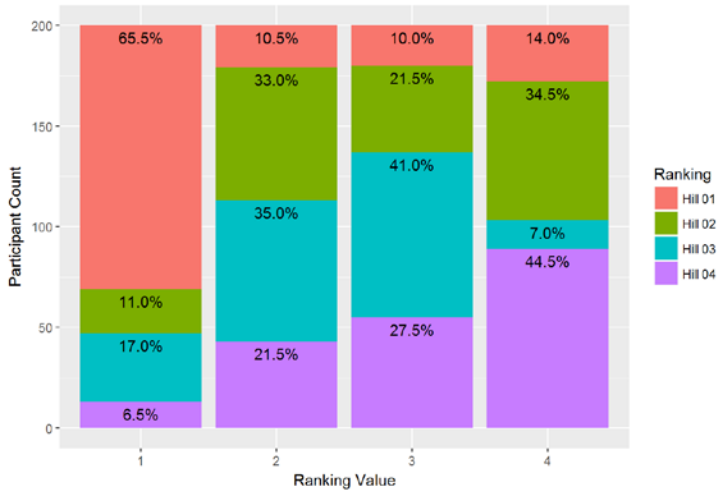


Figure 5. The percentage of participants selecting each sign alternative at each ranking value.

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 45. Mean response distance significantly varied by sign alternative $F(3) = 14.88$, $MS_e = 4445.71$, $p < .001$. Follow-up paired comparisons revealed that alternatives 1 and 2 were recognized at a distance significantly greater than alternatives 3 and 4 ($p < .01$). No other significant differences were found ($p > .05$).

Table 45. Mean response distance by sign alternative.

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

RECREATION AND CULTURAL INTEREST

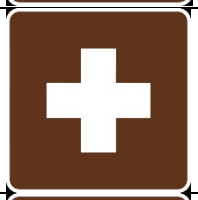
Table 46 presents all alternative recreation and cultural interest signs that were evaluated. The results of the comprehension and legibility tasks are presented here.

Comprehension

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

Table 46. Recreation and Cultural Interest Sign Alternatives Selected for Evaluation, and response percentages

Alternative	Alternative image	Response	Percent coded response
Alt. 1		Camping	32.7
		Camping + trailer	17.3
		Other	50
Alt. 2		Camping	25.0
		Camping + RV	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
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 rec area	10.0
		Specific winter rec area	54.0
		Snow area	12.0
		Other	24.0
Alt. 9		Sanitary waste disposal for RV	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

Legibility

The same legibility procedure was used. Mean response distances are presented in Table 47. Mean response distance significantly varied by sign alternative $F(3) = 14.88$, $MS_e = 4445.71$, $p < .001$.

Table 47. Mean response distance by sign alternative.

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 were recreation signs that may not be commonly used or seen as appropriate for use on highway signs, 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 Appendix A.

TOLL INTEROPERABILITY

Table 48 presents all alternatives for toll interoperability signs that were evaluated. The results of the comprehension tasks are presented here.

Table 48. Toll Interoperability Sign Alternatives Selected for Evaluation

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

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 multi-state transponder (or acknowledgement that it 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, χ^2 (10) = 16.25, $p > .05$.

Figure 6. Example of an in-context photo that displayed a toll interoperability placard.

Table 49. Percentage of participant responses within each coded category for each alternative.

Alternative	% Transponder	% Multistate transponder	% Don't know/Other
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 will allow you to pay tolls on any compatible toll road with any transponder brand. This special symbol will be used to 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)?" See Figure 6 for example of lane labeling. For this section only, a seventh alternative was included in which no interoperability sign was included. Overall, (independent of education) the interoperability sign that participants saw did not influence lane choices ($p > .05$). The education itself, however, did influence participant response. Participants that received the education were significantly more likely to select Lane 1 than those that did not receive the education ($p = .016$). No other comparisons were significant.

Table 50. Percentage of participants responding to each an affirmative for each lane.

Education	Alternative	% Lane 1	% Lane 2	% Lane 3
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, participant general understanding of toll transponder use was explored. A 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, interoperability sign did not significantly affect lane choice across all three lanes ($p > .05$). 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 to each an affirmative for each lane.

Alternative	% Lane 1	% Lane 2	% Lane 3
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	90.0
Alt. 6	0.0	100.0	100.0

RECOMMENDATIONS, DISCUSSION AND CONCLUSIONS

LANE REDUCTION

Summary Findings for Lane Reduction

According to the open-ended responses, between 86.7 percent 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 looking at the responses for the multiple-choice question, there seemed to be confusion about which lane was ending depending on the signing alternative that was viewed. Even though all sign alternatives were intended to indicate that the right lane was ending, participants who viewed alternatives 1, 2, and 3 were significantly more likely than those who saw alternatives 4, 5, or 6 to believe that the left lane was ending. Therefore, it is possible that the use of arrows could 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 alternative 3 were more likely to indicate that the sign meant that the left lane was closed than any other sign alternative. Participants who viewed alternative 3 were also more likely than those who viewed alternatives 1, 2, or 4 to report that the right lane was closed. Participants who viewed alternative 6 were more likely than those who viewed alternatives 1 or 2 to report that the right lane was closed.

Based on these responses, it is evident that alternative 4 and alternative 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 (see Table 3) when viewing alternative 5 (93.3 percent) than when viewing alternative 4 (83.3 percent), and alternative 5 was selected as the top choice by more participants (34.5 percent) than who selected alternative 4 as their top choice (26.5 percent). Alternative 6

also performed well in terms of comprehension; however, it had a significantly shorter legibility distance than all other alternatives.

Recommendations for Lane Reduction

Although alternative 5 may be slightly easier for participants to understand than alternative 4, they both had high comprehension and both are currently allowed in the MUTCD. Furthermore, alternative 4 was recognized at a legibility distance significantly greater than all other alternatives, which is not surprising as symbol signs tend to have longer legibility distances than text signs. Therefore, either alternative 4 or alternative 5 would be acceptable for use.

Alternative 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

Summary Findings for 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 (alternative 1), the majority of participants (94.3 percent) believed that motorists should use an alternative route and it was generally assumed (71.4 percent) that bicyclists would also follow the detour, with only 47.1 percent of participants who believed that pedestrians should follow the detour as well. When both pedestrians and bicycles are shown on the sign (alternative 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 (alternative 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 shown the bicycle and/or pedestrian symbols, there is still some chance that motorists may interpret the sign as applicable to them as well. For example, alternative 3 shows a pedestrian on the sign, but 20 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 there is still a chance that motorists may believe the sign applies to them even when that is not indicated by the sign (see above example with alternative 3). Therefore, although the signs appear to be generally effective, this type of sign may not be completely clear as evaluated. It should be noted that the contextual placement of the sign for this study was intentionally ambiguous, however this could be representative of some real-world situations where a path cannot be seen from the location of the sign. Therefore, it is ideal if the sign is placed and angled in such a way that it is clear that the sign is directed only toward pedestrians and bicyclists. Additionally, although alternative 1 had significantly higher legibility distances than alternatives 2 and 3, it is likely okay to include the pedestrian and bicycle symbols as pedestrians and bicyclists are generally traveling at lower speeds on sidewalks or trails.

FLASHING YELLOW ARROW

Summary Findings for 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 75-100 percent of participants reported that the driver needed to yield to oncoming traffic or use caution; this was also true for participants who viewed alternative 4 (no sign), signifying that even with no sign at all, people would either choose to 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 is important because it suggests that the flashing light carries meaning to drivers.

When considering the participant rankings of the signs, participants generally preferred alternative 3 and alternative 2 over alternative 1. All three signs had similar legibility distances. Although there were no statistically significant differences, more participants selected alternative 3 as their top choice than those who selected alternative 2, and alternative 3 also had a slightly longer legibility distance (though, again, not significant).

Recommendations for Flashing Yellow Arrow

With only 70 percent of participants reporting that they need to yield to oncoming traffic when viewing the animated flashing yellow arrow with no sign, it may be premature to not use a sign at all. However, there may be a point in the future where the signs will not be needed, or can be removed after a certain period of time. Alternative 3 or alternative 2 are both acceptable signs to use.

ALTERNATIVE FUELS

Summary Findings for 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 they were to be 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 – a partially correct response could mislead the driver to make and 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 alternatives 11 and 12, presumably because these signs include only the abbreviations and do not include the gas pump symbol. This would lead one to believe that the gas pump symbol is helpful.

It should be noted that 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 used in the study.

Recommendations for Alternative Fuels

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

MIDBLOCK HYBRID BEACON PEDESTRIAN CROSSINGS

Summary Findings for Regulatory Signs for 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 (see Table 24). There were no significant differences between sign alternatives, however the state of the signal (dark, flashing red, steady red, or flashing yellow) was found to significantly affect responses. Participants who experienced the dark 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 alternative 5, for which no sign was presented at all), there are still some interesting findings presented in Table 23. For example, when considering the flashing red state in Table 23, alternative 3 seems to do the best job in 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 percent of participants who viewed alternative 5 (no sign) reporting only that they should stop (see Table 23). Additionally, 90 percent of participants who saw alternative 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 to see if anything was coming. These examples do highlight the need for a sign, at least initially, while people are learning what the different flashing states mean.

Although alternative 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 dark and steady red states when compared to other signing alternatives (see Table 23). Furthermore, the legibility testing indicated that alternative 3 was recognized at significantly shorter (worse) distances than alternatives 1 and 2, and that alternative 2 was recognized a significantly longer distance than signs 3 and 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, alternatives 1 and 2 had higher legibility distances.

PASSENGER FERRY

Summary Findings for Passenger Ferry

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

When participants were asked to select all who could ride the ferry (see Table 28), people generally tend to respond that only the modes of transportation shown in the sign are the ones who are able to use the ferry. For example, for alternative 4, 95 percent of participants reported that freight vehicles were allowed, however only 25 percent reported that passenger vehicles were allowed and 15 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), it is evident by participant responses that there is confusion about who can ride the ferry unless it 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

Summary Findings for Bicycle Passing Law

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

When considering the results of both the open-ended and multiple choice questions, alternative 2 and alternative 3 would be considered the best in terms of comprehension, followed by

alternative 1 or alternative 4. However, alternative 1 was consistently ranked as the least effective sign by participants, while most participants (28 percent) selected alternative 2 as their top choice, followed by 22.5 percent of participants who selected alternative 4 as their top choice.

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

Recommendations for Bicycle Passing Law
When considering comprehension, legibility, and ranking, alternative 3 is the most effective.

VEHICLE PROHIBITION

Summary Findings for Vehicle Prohibition
Participants generally understood that the mode of transportation that was presented on the sign was prohibited, with 61.7 percent, 55.7 percent and 47.1 percent of participants viewing alternatives 1, 2, and 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 that are not depicted on the sign are prohibited as well (see Tables 36 and 37). For example, as shown in the multiple choice results in Table 37, between 90.0 percent 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 is that for alternative 2, 71.4 percent of participants indicated that motorcycles were prohibited (when the sign shows an ATV), however it's possible that the symbol in alternative 3 was simply mistaken for a motorcycle.

Recommendations for Vehicle Prohibition
As stated previously, between 47.1 percent 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 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, there should also be text to go along with them clarifying the intent.

RAIL/FLANGEWAY GAP BICYCLE WARNING

Summary Findings for Rail/Flangeway Gap Bicycle Warning
As shown in Table 40, the sign alternative had a significant influence on participant response. Only 30.0 percent, 34.0 percent and 32.0 percent of participants who viewed alternatives 1, 3, and 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 alternative 2 indicated that bicyclists should use caution when crossing tracks or should cross perpendicularly. When providing subjective rankings of the signs' effectiveness, alternative 2 was also selected as the top choice by the majority (56.0 percent) of participants, followed by alternative 1, alternative 3, and alternative 4. Sign alternative had no significant difference on whether

participants reported that they would dismount their bike before crossing the tracks. Alternatives 3 and 4 were presumably confusing for participants, as 46.0 percent and 52.0 percent, respectively, of their responses fell into the "other" category.

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

Recommendations for Rail/Flangeway Gap Bicycle Warning
Of the signs tested, alternative 2 is the best option for signing for a rail/flangeway gap bicycle warning.

BLIND HILL WARNING

Summary Findings for 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 considering participants who at least mentioned that there was a sight obstruction (may or may not have also mentioned a hill), alternative 1 had the highest comprehension (86.0 percent) followed by alternative 3 (62.0 percent); alternative 4 and alternative 2 had relatively low comprehension (40.0 percent and 14.0 percent, respectively). When considering the participants who mentioned a sight obstruction AND a hill in their responses, alternative 1 had the highest comprehension (58.0 percent) followed by alternative 3 (50.0 percent). The ranking data shows that participants usually preferred the signs in the following order: alternative 1, alternative 3, alternative 2, and alternative 4. Alternative 1 was selected by 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, alternative 1 (the text sign) had the highest mean legibility distances of all four alternatives. The results indicated that alternatives 1 and 2 were recognized at significantly greater distances than alternatives 3 and 4.

Recommendations for Blind Hill Warning
Alternative 1 had the highest comprehension, legibility distance, and subjective ranking of effectiveness. Therefore, it is recommended that alternative 1 (which is currently in the MUTCD) continue to be used.

TOLL PLAZA ELECTRONIC TOLL INTEROPERABILITY

Summary Findings for 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 it is a multi-state transponder or that it could be used at any toll plaza (see Table 49); sign alternative did not significantly affect participant responses.

Even with no education on interoperability of the toll transponder, participants tended to understand that if they had an EZPass transponder, then they could use lane 1. However, the participants that 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, there is no reason to recommend one symbol over another since none were statistically significant, but should some symbols be considered, alternatives 1, 3 and 6 did have slightly higher comprehension than the other alternatives for the open-ended question (see Table 49) and for the lane-choice question when no education was given (see Table 50).

RECREATIONAL AND CULTURAL INTEREST

Recommendations for Recreational and Cultural Interest

Although there are varying criterion used for determining appropriate sign comprehension, the American National Standard Institute (ANSI) develops standards for the design, application and use of signs, colors and symbols and suggests a strict criteria of 85 percent comprehension. The results presented in Table 46 indicate that alternatives 3, 4, and 10 are easily understood by participants and are acceptable for continued use. Alternative 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 non-vehicular means. On the other hand, there was some confusion about alternatives 1, 2, 6, 7, 8, 9 and 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 Appendix A 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 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

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

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APPENDIX A. ADDITIONAL RECREATION SIGNS RESULTS

Sign Name	Sign Image	Completely Correct	Partially Correct	Incorrect
Golfing		100%	0%	0%
Restrooms		100%	0%	0%
Tennis		99%	0%	1%
Trash Dumpster		98%	2%	0%
Swimming		98%	0%	2%
Motor Boating		98%	1%	1%
Archery		98%	0%	2%

Horse Trail		96%	3%	1%
Picnic Shelter		95%	0%	5%
Fishing Area		95%	0%	5%
Tunnel		93%	0%	7%
Baseball		93%	6%	1%
Falling Rocks		93%	5%	2%
Hiking Trail		91%	1%	8%
Viewing Area		90%	0%	10%

Chair Lift or Ski Lift		90%	5%	5%
Cross Country Skiing		89%	1%	10%
Sleeping Shelter		88%	4%	8%
Post Office		87%	0%	13%
Dog Sledding		87%	4%	9%
Nature Study Area		86%	5%	9%
Scuba Diving		86%	0%	14%
Bus Stop		85%	6%	9%

Waterskiing		84%	7%	9%
Theater		84%	1%	15%
Wildlife viewing		84%	0%	16%
Tramway		83%	0%	17%
Hand Launch or Small Boat Launch		82%	2%	16%
Recycling		81%	0%	19%
Snow tubing		79%	1%	20%
Whale Viewing		77%	15%	8%

Climbing		77%	22%	1%
Beach		77%	14%	9%
Sledding		76%	3%	21%
All-Terrain Trail		76%	10%	14%
Jet Ski or Personal Watercraft		76%	7%	17%
Snowshoeing		75%	1%	24%
Canoeing		74%	22%	4%
Deer Viewing Area		72%	23%	5%

Seal viewing		71%	15%	14%
Sailing		67%	30%	3%
Stable		66%	2%	32%
Surfing		64%	0%	36%
Grocery Store		64%	6%	30%
Mechanic		63%	4%	33%
Ice skating		62%	14%	24%
Snowmobiling		61%	1%	38%

Diving		60%	39%	1%
Hang gliding		59%	7%	34%
Kennel		59%	1%	40%
Kayaking		55%	28%	17%
Row Boating		51%	47%	2%
Off-Road Vehicle Trail		51%	9%	40%
Snowboarding		51%	0%	49%
Fishing pier		48%	51%	1%

Wind surfing		48%	51%	1%
Tour boat		47%	3%	50%
Downhill Skiing		38%	56%	6%
Corral		34%	65%	1%
Ski Jumping		31%	47%	23%
Ranger Station		30%	12%	58%
Dam		26%	2%	72%
Radiator Water		26%	33%	42%

Ice fishing		17%	77%	6%
Rafting		16%	78%	6%
Amphitheater		10%	2%	88%
Fish Ladder		5%	3%	92%
Fish Hatchery		3%	6%	91%
Driving Tour		0%	1%	99%
Cultural Interest Area		0%	0%	100%
Point of Interest		0%	0%	100%