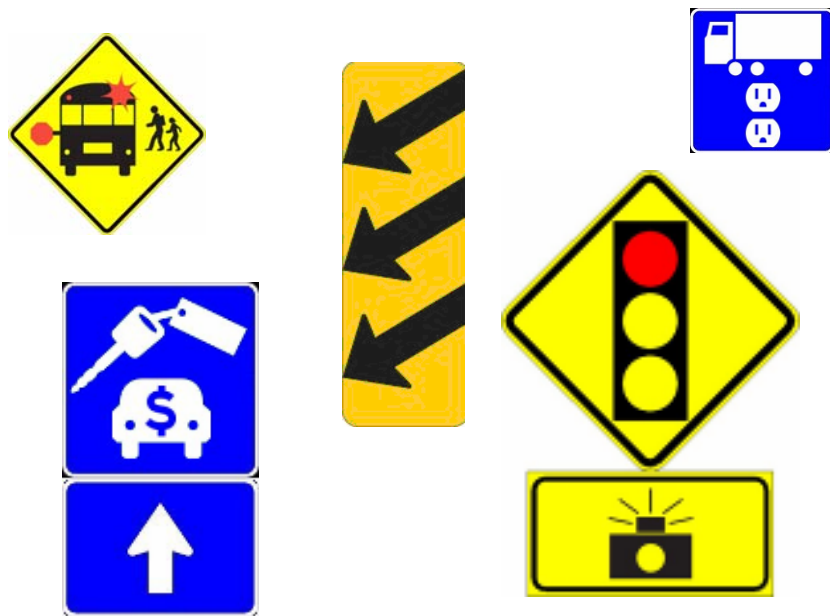


Traffic Control Devices Pooled Fund Study

Design and Evaluation of Selected Symbol Signs

Final Report

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The objective of the Traffic Control Devices Pooled Fund Study (TCD PFS) is to assemble a group composed of State and local agencies, appropriate organizations and the FHWA to 1) establish a systematic procedure to select, test and evaluate approaches to novel TCD concepts as well as incorporation of results into the MUTCD; 2) select novel TCD approaches to test and evaluate; 3) determine methods of evaluation for novel TCD approaches; 4) initiate and monitor projects intended to address evaluation of the novel TCDs; 5) disseminate results; and 6) assist MUTCD incorporation and implementation of results.

To join the TCD PFS, or for more information about the TCD PFS

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EXECUTIVE SUMMARY

The Traffic Control Devices Pooled Fund Study (TCD PFS) focuses on a systematic evaluation of novel TCDs, employing a consistent process that addresses human factors and operations issues for each TCD idea. As part of the PFS effort, the FHWA Human Centered Systems Team evaluated proposed symbols for new traffic signs in order to ensure that the symbols were effective when taking driver comprehension and legibility requirements into consideration. The ten (10) symbols evaluated were:

- Wireless Internet
- Rental Car
- Ferry
- Information
- Automated/Photo Enforcement
- School Bus Stop Ahead
- Motorcycle Warning
- Truck Parking
- Truck Electrification
- Object Marker

The goals of this study were to develop alternative symbol sign designs and then test them to determine driver comprehension and legibility distance of the experimental symbols. Prior to developing alternative sign designs, the research team conducted four (4) focus groups with the general driving population as well as ten (10) focused interviews with truck drivers. Multiple alternatives for each sign were developed based on input from drivers about the critical factors of each symbol. Critical factors of a symbol include features such as a side view versus a front view, traditional versus modern, etc.

The team then conducted 174 surveys to determine driver comprehension for each sign alternative. The surveys were administered to the general driving public, but drivers with Commercial Driver's Licenses (CDLs) were specifically targeted for the truck parking and truck electrification signs. The survey was designed to gauge if participants understood a sign's meaning or whether the sign was confusing. The alternatives were then evaluated in the SignSim Laboratory to determine at what distance they become legible.

Based on driver input and the results of the comprehension and legibility testing, the research team provided recommendations on symbols that should be included in the next edition of the Manual on Uniform Traffic Control Devices (MUTCD). For some signs, the team was able to clearly recommend a new symbol. The team determined that for other signs, like rental car and truck electrification, there was too much driver confusion and as a result symbols were not recommended. The team's final recommendations also suggested continued use of the object marker sign currently in the MUTCD.

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INTRODUCTION

Traffic signs provide an important communication tool that is used to convey regulatory, warning, and guidance information to road users. There are many different traffic signs in use and there is always research underway to evaluate the potential effectiveness of new sign designs. The process of evaluating a new sign is particularly important for symbol signs, as they may be confusing to road users if not properly designed and evaluated. In the study described in this report, researchers evaluated driver understanding and legibility for a series of potential new symbol signs.

BACKGROUND

The *Manual on Uniform Traffic Control Devices* (MUTCD) is the national standard for traffic control devices.¹ It contains the basic principles that govern the selection, design, installation, operation, and maintenance of traffic control devices. According to the MUTCD, traffic control devices “*notify road users of regulations and provide warning and guidance needed for the safe, uniform, and efficient operation of all elements of the traffic stream.*”¹ The MUTCD also states that for a traffic control device to be effective it should:

1. Fulfill a need;
2. Command attention;
3. Convey a clear, simple meaning;
4. Command respect from road users; and
5. Give adequate time for proper response.

A device cannot command attention if it is not conspicuous. Additionally, a device cannot convey a clear and simple meaning if the device is not comprehended. If a device is not understood, then the sign will not command respect from road users. If any of the three major driver-related properties are inadequate, then the traffic control device will not provide an adequate time for a proper response. Providing adequate time for a proper response is the most critical, because without proper response time, drivers will not be able to perceive problems and react to them in an adequate amount of time to maneuver their vehicles, which may ultimately lead to crashes.

The MUTCD also gives guidance for the design of traffic control devices. The MUTCD states in Section 1A.03:¹

“Devices should be designed so that size, shape, and color, composition, lighting or retroreflection, and contrast are combined to draw attention to the devices; that size, shape, color, and simplicity of the message combine to produce a clear meaning; that legibility and size combine with placement to permit adequate time for response; and that uniformity, size, legibility, and reasonableness of the message combine to command respect.”

Regarding symbols signs, the MUTCD states the following in Section 2A.13:¹

“Symbol designs shall in all cases be unmistakably similar to those shown in this Manual and in the “Standard Highway Signs” book. New symbol designs shall be adopted by the Federal Highway Administration based on research evaluations to determine road user comprehension, sign conspicuity, and sign legibility.”

From this language, it is apparent that new sign symbols can be introduced only after being evaluated through research and formal adoption in the MUTCD by the Federal Highway Administration (FHWA). Although it is not difficult to design a sign that “seems” to be effective, it is important for transportation engineers to recognize that the driver might perceive the sign to mean something completely different, and may not act in the manner that is intended by the engineer. Therefore, it is essential to research the driver-related issues that exist when new traffic signs are introduced to the roadway environment, which is the focus of the effort documented in this report.

RESEARCH GOALS

The Traffic Control Devices Pooled Fund Study (TCD PFS) focuses on systematic evaluation of novel TCDs, employing a consistent process that addresses human factors and operations issues for each TCD idea. The PFS provides local and state agencies quicker response to their needs and quicker response to new technologies with the right assessment skills and tools will enable consistent TCD idea identification and evaluation. The 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.

As part of the PFS effort, the FHWA Human Centered Systems Team evaluated proposed symbols for new traffic signs in order to ensure that the symbols were effective when taking driver comprehension and legibility requirements into consideration. The goals of this study were to:

- perform a literature review to determine design elements for effective symbol signs,
- conduct focus groups and focus interviews to obtain driver input on symbol design,
- develop alternative symbol sign designs through an expert panel review,
- obtain driver input on experimental sign designs,
- perform a laboratory test to determine legibility distance and driver comprehension of the experimental symbols, and
- provide recommendations on symbols that should be included in the next edition of the MUTCD.

The Pooled Fund Study Panel selected the following sign messages for symbol development and evaluation.

- **Wireless Internet** - The intended purpose of the wireless Internet sign is to inform road users that a rest stop or other roadside facility provides wireless Internet access. A proposed sign/symbol would be new and is not currently in the MUTCD although a variety of symbols are used in non-roadway signs to convey a similar message.

- Rental Car - The rental car symbol was added to the research study to provide agencies with a sign symbol that could be used to direct road users to a generic rental car facility. The symbol is not intended to provide information about a specific rental car company. The symbol is not currently in the MUTCD although there are several different symbols that are used around the world to indicate rental car locations.
- Ferry - The ferry symbol sign is potentially intended as a general information sign that would be used to trailblaze road users to a ferry landing. The symbol is not currently in the MUTCD, but there are other symbols for airports and train stations (I series signs) that are used for a similar purpose.
- Information - The information sign is used to indicate a location where road users can get tourist information. There is a symbol sign currently specified in the MUTCD, a “question mark.” Concerns have been raised that road user comprehension of this symbol may be low and some other symbol or word message could potentially serve as a replacement.
- Automated/Photo Enforcement - The use of automated enforcement for red-light running is increasing. It is used in many jurisdictions to increase compliance with signal indication and increases safety. Some of these jurisdictions require that a sign inform road users where automated enforcement is used. A variety of signs are currently used for this purpose and the MUTCD does not have a symbol to convey the use of automated or photo enforcement. The sign that is currently used by practitioners would be the standard Signal Ahead sign (with red, yellow, and green indications shown) combined with the Photo Enforced supplemental plaque.
- School Bus Stop Ahead - The School Bus Stop Ahead sign warns road users that they may encounter a stopped school bus on the roadway. The word message sign is currently in the MUTCD and the research team was investigating whether a symbol sign could be more effective.
- Motorcycle Warning - Since they have only two wheels, some roadway conditions may be more hazardous to motorcycles than four wheeled vehicles. The purpose of the evaluation for this sign was to identify a symbol that could be used with a variety of warning signs to indicate that the warning is intended for motorcyclists. There is no such symbol or message in the current MUTCD.
- Truck Parking - The truck parking service sign is intended to be used to direct large trucks to an area that is specifically designed for accommodating the parking needs of large trucks. Although an existing symbol is provided for certain regulatory truck signs (such as truck prohibition and weight restrictions), the intent of the evaluation was to develop a symbol sign that would be used to provide guidance information. There is no such sign in the current MUTCD.

- Truck Electrification - Some jurisdictions have situations where stopped trucks have created a noise pollution situation due to running engines. Truckers that have stopped overnight leave the diesel engine running so that the trucker can have electricity to run the air conditioning and other appliances in the truck's sleeper cab. At some locations, jurisdictions have provided electrical power for trucks to address the noise and air pollution issues associated with engines idling for long periods. There is no such sign in the current MUTCD. A symbol sign message for indicating the availability of electrical plug-ins for trucks is desired.
- Object Marker - The type III object marker is used to warn road users of a hazard in or near the roadway. The diagonal stripes on the type III object marker are sloped downward to the side on which traffic is supposed to pass. The research team evaluated the standard object marker and other alternative designs to determine whether understanding of the critical message could be improved.

RESEARCH APPROACH

The basic research approach used by the team consisted of five major elements: gathering information to develop alternatives, developing the alternatives, evaluate understanding of the alternatives, evaluate legibility of the best performing alternatives, and developing recommendations on use. The specific activities conducted by the research team included the following:

- Develop Alternatives for Comprehension Evaluation
 - ♦ Conduct a state-of-practice survey to see what various state agencies around the United States are using as well as international agencies to convey the information.
 - ♦ Investigate sign symbols used in non-roadway situations, such as airports and transit facilities to identify common characteristics.
 - ♦ Conduct focus groups of road users to generate potential alternatives and identify critical sign symbol characteristics.
 - ♦ Utilize a working group of transportation professionals (traffic engineers, human factors professionals, and other transportation specialists) to refine the focus group alternatives for the formal evaluation portion of the study.
- Conduct Comprehension Evaluation
 - ♦ Prepare a driver survey to evaluate comprehension of the meaning or intended response of the symbol alternatives
 - ♦ Conduct the comprehension surveys. Most of the surveys were conducted at a local shopping mall.
- Conduct Legibility Evaluation
 - ♦ Determine the recognition distance of the proposed symbol signs using a laboratory simulator consisting of a projector with a zoom lens.
- Develop Recommendations
 - ♦ Use the results of the comprehension and recognition distance evaluations to compare the performance of the various symbol signs and develop the study recommendations.

LITERATURE REVIEW

There are many different research studies on the effectiveness of traffic signs, including evaluations of comprehension, legibility, and driver response. This chapter describes the research methods that were used in previous studies to evaluate traffic control devices to shed light on how the symbol sign evaluation should be conducted.

One of the critical factors to consider in an evaluation of symbol signs is that there is not a recommended methodology for conducting such an evaluation. Dewar and Ells identified the need for evaluating various methods that can be used, since there is no information as to which methods provide the best information.² Dewar and Ells also explained that there are several factors dealing with traffic control devices that should be investigated, including meaning, attention value, legibility, processing time, learnability, and influence on driver behavior. In a later paper on symbol signing, Dewar described six criteria as being important in the evaluation and design of symbol signs including legibility distance, understandability, conspicuity, learnability, glance legibility, and reaction time.³

COMPREHENSION EVALUATIONS

Comprehension has been measured a number of different ways by different researchers. Alicandri and Wochinger asked research participants to write their interpretation of the sign meanings and indicate what action they would take if the signs were seen on the roadway.⁴ Katz et al. used a similar procedure except that multiple-choice questions were asked after the initial interpretation of sign meanings.⁵ The multiple-choice test was used to examine whether participants made problematic inferences about different signs (e.g., that an animal presence sign with a flashing beacon turned off meant that no deer were present). In both cases, images of the signs were used without a background or roadway scene. Picha et al. showed participants a picture of the sign in-context where the roadway background was included in the picture with graphics software to superimpose the sign.⁶ Next to this picture, a close-up view of the device was provided along with multiple-choice questions about each sign type.

FIELD EVALUATIONS

Dewar and Ells indicated that “before-and-after” studies are one of the most frequently used methods for evaluating signs; however, they also pointed out that there are several problems with this method.² Dewar and Ells suggest that three possible methods of evaluating signs include a field study under normal driving conditions, a modified field study using scaled down signs, and a laboratory experiment to determine reaction time. Reaction time was taken to be the amount of time between the onset of the stimulus and the activation of a voice-operated instrument that was triggered when the correct meaning of the sign was spoken. The three techniques were compared and it was determined that the overall trends and relationships were similar; however, the actual distances obtained in the simulator were less than in the field. The concept of “optimal index” is also described by Dewar and Ells and is stated as “*the degree to which [a sign] conveys the intended message to a driver operating a vehicle in an actual driving situation.*”¹ The

authors suggest that the optimal index can be evaluated in the laboratory with less money and less time required than a field study.

LABORATORY EVALUATIONS

Desrosiers performed field and laboratory investigations to determine the effectiveness of traffic signs.⁷ The author stated that laboratory studies eliminate problems dealing with environmental variables (weather, light, and traffic conditions) as well as reduce the time required to gather data and provide researchers with additional control over the experiment. The author used 16mm color film using a motion picture technique to simulate the signs to research participants. The author also stated that laboratory tests can replace field tests but for absolute values, a correction factor must be used to represent field conditions.

Some studies have shown that there are several reasons that legibility distances are underestimated in a simulator. Zwahlen et al. pointed out that factors contributing to the underestimate of legibility distances include insufficient display resolution, insufficient luminance and contrast representation, no change in depth perception, small image vibrations, or non-uniform and less sharp symbol or legend contours.⁸

Sign research for both comprehension as well as recognition distances have been performed at Turner-Fairbank Highway Research Center (TFHRC) in the past as shown in Philips et al.⁹, Alicandri and Wochinger⁴, and Mahach et al.¹⁰ The Philips et al. study dealt solely with the use of the SignSim laboratory for determining comprehension and recognition distances. It was determined that relative recognition distances could be found in the simulator but actual recognition distances could not be obtained without further validation. It was determined that signs could be compared against each other for relative recognition; however the actual recognition distances could not be calculated.

The Mahach et al. study hoped to test the significance of the differences in recognition distance between the SignSim and the natural environment by using actual scaled signs in TFHRC's Photometric and Visibility Laboratory (PVL).¹⁰ The study pointed out that the effect of the light on signs in a natural environment is different from the SignSim because in the SignSim, the light is diffused as a sign approaches. The result turned out to be that there was a significant difference between the recognition distances obtained in the SignSim from the PVL for almost all signs.

SUMMARY

For comprehension testing, previous researchers looked at both open ended as well as multiple choice responses to obtain information about various sign alternatives. This study will incorporate similar methods so that first, it can be determined if participants understand the general meaning of the signs and second, to determine whether or not participants understand certain specific characteristics of the signs.

The research indicates that TFHRC's SignSim laboratory will provide acceptable data for relative recognition distances; however, scale factors will be required to provide actual recognition distances. Additionally, from the previous research, it is important for the brightness capabilities of the Sign Simulator to be adjusted in order to simulate the natural environment and thus these issues were incorporated into the current study.

A field study would be required to effectively determine the scale factors required to relate the Sign Simulator to field results, but this topic will be investigated in a future study. For comparing alternatives, the Sign Simulator is expected to provide the information required.

























STUDY APPROACH

The engineers and other professionals that are responsible for evaluating and approving symbol signs do not have the same perspective of these symbols as the typical road users. As transportation professionals, engineers are intimately familiar with the design and use of traffic control devices. Therefore, it can be difficult for these professionals to place themselves in the mindset of an uninformed driver. To address this, the research team utilized focus groups of typical drivers and interviews with professional truck drivers to help the team identify the critical characteristics for the symbol signs.

DOMESTIC AND INTERNATIONAL STATE-OF-PRACTICE SURVEY

Examples of various domestic and international symbol signs were gathered and studied prior to the development of new symbol sign designs for this study. Images of signs were collected from around the United States as well as several countries in Europe, Asia, and other parts of the world. Table 1 provides several examples of symbol signs from a sample of the locales and sources considered.

Table 1: Assortment of Domestic and International Symbol Signs

Symbol Sign Category	Symbol Sign and Locale / Source		
Wireless Internet	 World Wide Web	 University of California-Riverside, USA	
Rental Car	 Seattle-Tacoma International Airport, USA	 Car hire Iceland	
Ferry	 Finland	 China	 Mexico
Tourist Information	 France	 USA (FHWA)	 New Zealand
Automated/ Photo Enforcement	 New York, USA	 Hong Kong	
School Bus Stop Ahead	 Québec, Canada	 USA (FHWA)	
Motorcycle Warning	 British Columbia, Canada	 Italy	 South Africa
Truck Parking	 Belgium	 Hong Kong	
Vehicle Electrification	 France	 USA (FHWA)	
Object Marker	 France	 USA (FHWA)	 South Africa

FOCUS GROUPS AND FOCUSED INTERVIEWS

Focus groups were conducted involving roadway users to determine symbol alternatives for each sign. A focus group is an interactive discussion between a small number of participants that allows for the development of qualitative data. Researchers often use focus groups to generate ideas and creativity among the participants about a particular item of interest. Focus groups may be useful during any stage of a research project, but are particularly useful for exploratory purposes where little is known about the topic of interest.

General Driver Focus Groups

Four focus groups of licensed drivers were conducted to generate driver opinions on what the symbols under evaluation should look like. Site selection for the focus groups was based on two factors; proximity to research team member locations and area characteristics. Selecting cities that were familiar to team members was a critical factor. To maximize attendance at the focus group sessions, it was important that the meeting location was well known, easy to get to and accessible by mass transportation. By selecting cities that team members were familiar with, the amount of time scouting for a prime meeting location was significantly reduced. It also allowed team members to more easily recruit participants by posting flyers and spreading the word through meetings at community centers, educational facilities, etc. Team members were also knowledgeable about the road system and mass transportation alternatives so that they could better assist participants with directions to the meeting location.

It was additionally important to ensure that a wide array of roadway users with different driving experiences were included in the focus group phase of the study. To assure diversity among the focus groups, it was crucial to select cities with differing demographics and highway systems. The team decided that one site should be a metropolitan area with a high population and an expansive highway system that included multiple Interstates. The second site should be the opposite with a much lower population whose drivers rely mostly on rural highways. Recruiting focus group participants with driving experiences on both rural and urban highways would help ensure that the symbols developed would be recognizable by a more diverse group of drivers.

Since a majority of the symbol sign research team is located at the FHWA Turner-Fairbank Highway Research Center, the team selected the center's home area of Fairfax County, Virginia as the first focus group site. Fairfax County is part of the Northern Virginia area and is located just outside of Washington, DC. The area is served by several Interstates, including I-495 (the Capital Beltway) and I-66, as well as the George Washington Memorial Parkway, State Route (S.R.) 7, S.R. 267, S.R. 123 and S.R. 193. Northern Virginia has a population of two (2) million people, 30 percent of the state's total population (www.factfinder.census.gov).

The Fairfax County focus group sessions were held at the Virginia Tech Northern Virginia Center, which is located off of S.R. 7 and easily accessible by I-495 and I-66. There was ample parking for participants using their personal vehicles to attend, and the Center was located directly across the street from a Metrorail station as well as stops for the Metrobus and Fairfax Connector bus.

College Station, Texas was selected as the second site since the focus group moderator is a professor at Texas A&M University. College Station is located in Brazos County in Central Texas and is considerably more rural than Fairfax County. It is situated 100 miles from Houston and Austin and 160 miles from Dallas and San Antonio. College Station, along with the city of Bryan, has a combined population of 133,550 people (www.factfinder.census.gov). Major travel routes include State Highway 6 and State Highway 30. Numerous Farm to Market Roads also make up the network of highways that serve the area.

The College Station focus groups were held in a rented meeting room at a hotel. The hotel was well known by area residents and located directly off of a major highway serving the area, the Earl Rudder Freeway.

To ensure that all age groups would be represented in the focus groups, two sessions were scheduled in both cities. One session was held in the morning or middle of the day when it might be more convenient for older drivers to attend, and one session was held in the evening when students and workers would be able to attend. Table 2 shows the focus group schedule for all four sessions.

Table 2: Focus Group Schedule

Focus Group Session	Location	Date	Time
1	Fairfax County, VA	Thursday, January 26, 2006	Early afternoon
2	Fairfax County, VA	Thursday, January 26, 2006	Evening
3	College Station, TX	Wednesday, February 15, 2006	Evening
4	College Station, TX	Thursday, February 16, 2006	Late morning

Participant Recruiting

To recruit participants for the focus group sessions, the team developed and posted flyers at the meeting locations, local community centers, libraries, businesses (i.e. grocery stores), and city halls. In addition to general drivers, the team wanted to specifically ensure that motorcyclists would also be present for the focus groups. Therefore, the flyers were distributed to motorcycle shops and local motorcycle clubs who were asked to disseminate the information to their members.

To supplement the flyers, the research team also recruited participants in Fairfax County utilizing a database of subjects who had previously participated in research studies at the FHWA Turner Fairbank Highway Research Center. Previous research subjects who had indicated a desire to participate in additional research studies were contacted directly by phone about the focus groups. In College Station, newspaper advertisements recruiting participants were placed in The Bryan-College Station Eagle. The advertisement provided details about the focus groups along with a toll free number for individuals to call if they were interested.

Demographic information that was captured included the individual’s age, gender, confirmation of a valid driver’s license and whether s/he had a motorcycle or commercial endorsement on his/her license. This information assisted the team with evenly distributing participants across the focus group sessions so that a representative mix was present at each session. If one particular age or gender category had been filled, then the prospective participant was asked if s/he would be willing to serve as an alternate. This system allowed the team to have at least one alternate for each session. Some alternates were called upon due to scheduled participants dropping out for various reasons.

Ten participants were recruited for each focus group session. Average attendance at the focus group sessions was eight participants.

Table 3 summarizes the participant gender mix for each session.

Table 3: Focus Group Participant Characteristics

Focus Group Session	Total Participants	Non-Motorcyclist		Motorcyclist	
		Male	Female	Male	Female
Focus Group 1 Fairfax County Early afternoon	6	2	3	0	1
Focus Group 2 Fairfax County Evening	8	4	3	1	0
Focus Group 3 College Station Evening	9	5	4	0	0
Focus Group 4 College Station Late morning	9	3	6	0	0

Focus Group Methodology and Structure

To ensure consistency between all focus groups, a moderator script was developed and the same format was used for each session. At each session, the moderator described basic roadway signing principles (such as legibility requirements, shape, and color), the general concept/message that needed to be conveyed, and let the focus group participants generate their own ideas on what the symbols should look like. The moderator then led a general group discussion on the symbols that the participants generated to identify common characteristics that are worth communicating. Where appropriate, the moderator also discussed existing signing principles that may be closely related to the subject.

At the beginning of each focus group session, the moderator would explain the purpose of the session and how the information obtained from participants would assist with the goals of the Symbol Sign Study. The moderator emphasized that all participant information, as well as their input, would be kept confidential, and that at any point during the session, the participants could end their involvement. A second member of the research team was present at each session to take notes of the group's discussion and was introduced by the moderator. Participants were paid \$20 for their time at the end of each session, which lasted 90 minutes. Fairfax County participants who drove to the meeting location and parked in a paid parking lot were also reimbursed for parking expenses.

The moderator initiated general discussion with the focus groups by asking participants about the elements of a good sign. This general discussion was used to break the ice with the group and to get participants thinking about what makes a sign a good sign. Comments from the group about beneficial sign elements included:

- Visibility
- Clear and unambiguous
- Color
- Consistent design
- Clear sight lines
- Size
- Can be understood by non-English speaking drivers
- Well maintained
- Message clarity
- Consistency
- Noticeable/conspicuous
- Placement
- Considers driver expectancy
- Repetition, use of multiple signs
- Shape
- Size and style (font) of letters

The moderator then asked if the group had opinions on text vs. symbols on signs. This discussion helped identify situations that were, or were not, appropriate for using symbols. Generally, participants thought the use of symbols was a good idea since they are faster to "read" and take less time to convey a message or direction. However, group members expressed concern that symbols can also be confusing and misleading. Unless the symbol conveys a clear message, participants considered text to be a better choice. Comments from focus group members during this discussion included:

- It's complicated if there are too many words.
- Symbols are sometimes more confusing than words.
- Sometimes symbols are wrong.
- Symbols are quicker to understand if you're familiar with them. This is especially true for motorcyclists who have limited time to look at signs because they are watching for other hazards.
- Symbols are universal.
- Symbols are good if they are tied to an international standard.
- Symbols are easier and faster to read as opposed to words.
- Symbols are great if they are obvious.
- Combine words and symbols on one sign.

After this general discussion, the moderator began obtaining specific input for selected symbols. On average, each focus group was asked about seven different symbols during a session. Each group discussed at least six of the nine symbols and each symbol was discussed by at least two focus groups. Table 4 summarizes the symbol set that each focus group discussed.

Table 4: Symbols Discussed at Each Focus Group

Focus Group Session	Symbols Discussed
Focus Group 1: Fairfax County, VA	School Bus Stop Ahead Automated Enforcement Object Marker Motorcycle Warning Wireless Internet Ferry
Focus Group 2: Fairfax County, VA	Automated Enforcement Information Area Rental Car Motorcycle Warning Ferry Object Marker School Bus Stop Ahead
Focus Group 3: College Station, TX	Object Marker Automated Enforcement Wireless Internet Information Area Rental Car Motorcycle Warning Truck Parking
Focus Group 4: College Station, TX	Object Marker School Bus Stop Ahead Information Area Wireless Internet Rental Car Ferry Truck Parking

Focus Group Results

The moderator first presented a photograph, similar to Figure 1 that depicted a scenario that group members might encounter on the highway. The picture would show where a sign would be placed in relation to the scenario. Appendix A includes pictures of the scenarios that were presented during the focus groups. The moderator would give a brief narrative about the driving situation and then ask the participants to draw the type of symbol that they expected to see on a sign in the scenario depicted on a sheet of paper. The moderator would then ask each participant to share his/her design and give an explanation for the elements included.

Table 5 and Table 6 summarize the design elements included in participant drawings and discussed during the roundtable descriptions.



Figure 1: Example Scenario Presented to Focus Group Participants

Table 5: Symbol Sign Concepts Discussed by Focus Groups

Symbol	Focus Group Design Elements for Symbols	
Wireless Internet	<ul style="list-style-type: none"> • Mix of words and symbols • Moving signal [i.e. ●)))] • Computer (laptop view) • Radio tower emitting waves • Laptop emitting waves • Lightning bolt signal with laptop 	<ul style="list-style-type: none"> • Computer with lightning bolt symbol and CONNECT • Computer with WIRELESS on screen • WWW • “WiFi”
Rental Car	<ul style="list-style-type: none"> • Side view of car • People at a booth, exchanging money/keys • Car with trunk open with luggage • Key • Money • \$ • Rental car booth 	<ul style="list-style-type: none"> • Rental car company logos on sign • Car with R • Car with RENTAL CAR • RENTAL • Include distance to rental car location • Directional arrow
Ferry	<ul style="list-style-type: none"> • Side and rear views of ferry • Flat surface on ferry • Car ramp • Side, front and rear views of cars on ferry • Person and car on the ferry • Water • Directional arrow with distance 	<ul style="list-style-type: none"> • Ferry with water line with a person, car and truck with slash-through-circle symbol to indicate if people, cars and trucks are allowed • Ferry on water between 2 roads • FERRY
Information	<ul style="list-style-type: none"> • ? • INFORMATION • INFO • T I • i • I • TRAVEL INFORMATION • VISITOR INFORMATION • LOCAL / TOURIST INFORMATION 	<ul style="list-style-type: none"> • 2 people facing each other with INFORMATION • Trifold brochures • Picture of concierge (person at a desk/booth) • Fold out map with a ? • Light bulb • Picture of an eyeball to represent I • i within a house or building
Automated Enforcement	<ul style="list-style-type: none"> • Front and side views of camera • Modern and antique camera styles used • Policeman holding a camera 	<ul style="list-style-type: none"> • Law enforcement badge • Traffic signal with red light emphasized • SMILE

Table 6: Symbol Sign Concepts Discussed by Focus Groups (continued)

Symbol	Focus Group Design Elements for Symbols	
School Bus Stop Ahead	<ul style="list-style-type: none"> • Side, back, rear and top views of school bus • Emphasize red lights and make one look like it's flashing • Stop sign on side or rear of bus • Children • Child crossing street • Bus shelter 	<ul style="list-style-type: none"> • Use of pentagon shape to indicate school • CAUTION with distance • WATCH FOR STOPPED SCHOOL BUS • SCHOOL BUS LOADING AHEAD • SCHOOL BUS CAUTION • BE PREPARED TO STOP • WATCH FOR SCHOOL BUS STOPPED AHEAD
Motorcycle Warning	<ul style="list-style-type: none"> • Side and oblique views of motorcycle • Motorcycle helmet • Motorcycle skidding, tilting, wrecking • M with view of motorcycle • Upside down motorcycle with "!" • Driver being thrown from motorcycle 	<ul style="list-style-type: none"> • Include symbol of the hazard • Squiggly lines • Gravel • Batman "kapow" outline • CAUTION
Truck Parking	<ul style="list-style-type: none"> • Side view of truck • Vehicle weight inside truck symbol • Truck with P • Trucks with directional arrows • Car, truck and bus with arrows • Truck with smoke stack • Truck symbol with OK or slash-thru-circle 	<ul style="list-style-type: none"> • RESTRICTED AREA ONLY • OVER 30 MINUTES / UNDER 30 MINUTES with directional arrows • Long parking lines • Side views of large class vehicles (bus, box truck, big rig) • Use of X to restrict vehicle types
Object Marker	<ul style="list-style-type: none"> • Use of red and white color scheme • TAKE CARE • CAUTION / DANGER with symbol of hazard and distance 	<ul style="list-style-type: none"> • REDUCE SPEED • SLOW DOWN • CLOSE

After reviewing all participant symbol designs, the moderator would explain the type of sign that would be posted for the situation. If available, the current sign design would be shown and participants were given an opportunity to comment on elements that were helpful or confusing. Sometimes, international symbols for the depicted scenario were available, and these too would be shown to the group for comment. Appendix B includes the current and international symbol designs that were presented to the focus groups.

Object Marker. One of the most challenging symbols for the focus groups was the object marker. When given the driving situation, a majority of participants could not independently recall the current sign in use to warn drivers of roadside hazards. When the groups were presented with the current sign, many recognized it, but were not aware that the diagonal striping had any meaning. Some participants commented that it might not be possible to develop a universal symbol for all hazards. Other participants commented that the symbol should be more specific about the type of hazard the object markers intend to identify. When reviewing various international symbols, the group preferred the use of arrows to the use of striping. Some also preferred the red and white color scheme as opposed to the current standard of yellow and black since red to them indicated danger. However, some participants preferred the yellow and black colors since yellow to them indicated caution. A few participants commented that the current sign is adequate and that driver confusion is an educational issue and not a design issue. One participant suggested notching a top corner of the current sign to help indicate the direction people should travel.

Motorcycle Warning. During the discussion about the motorcycle warning symbol, the moderator asked participants with motorcycle endorsements about hazards they encounter that would not necessarily be hazards for other vehicles. Many reported that any situation where traction is reduced (i.e. gravel, open bridge joints, grates and grooved pavement) is a hazard since motorcycles only have two points of contact. Potholes and dips are also especially hazardous for motorcycles. A few participants suggested that the hazard should be identified, but that a motorcycle symbol might not necessarily need to be attached because motorcyclists will know if the hazard applies to them. Several participants commented that other drivers might misinterpret the motorcycle symbol as a warning that they should be watching for motorcycles in the area. A motorcycle participant did emphasize that the use of symbols is important because there is not enough time to read text because motorcyclists must consistently watch for hazards that do not affect other drivers.

Truck Driver Interviews

The one symbol under evaluation that was not discussed in the focus groups was the truck electrification symbol. It was important to obtain comments directly from truck drivers for the two truck symbols in the study: truck parking and truck electrification. Therefore, team members conducted interviews with truck drivers at a truck stop located at Exit 104 on Interstate 95 in Carmel Church, Virginia.

Interview Methodology and Structure

With management permission, team members set up an interview station at a Flying J Travel Plaza in between the truck parking area and the plaza building entrance. As truck drivers approached the entrance, they were asked to participate in a 15 minute interview about new symbols under evaluation that would be for truck drivers. Ten truck drivers were recruited onsite to participate and they were paid \$20 for their involvement. All participants operated 18 wheeler trucks and had CDL endorsements on their licenses. Ages ranged from 30-68 years and experience ranged from 1.5-38 years as a truck driver. All participants indicated that driving trucks was their primary occupation and several drove in all 48 continental states.

The format used for the focus groups was also used for the interviews. The truck drivers were presented with a picture of a scenario and a team member would give a verbal explanation of the situation. The drivers were then asked to draw the type of symbol that they expected to see on a sign in the scenario depicted. The truck drivers used the same type of form drawing sheets that were used in the focus groups. When their drawings were complete, the drivers were offered an opportunity to explain the design elements they included in the symbol design. Table 7 summarizes the design elements from the truck driver drawings.

Focused Interview Results

Overall, drivers like symbols if they are clear and are on large enough signs and placed well enough in advance. Many believe the best way to depict truck parking and truck electrification is through a combination of text messages and symbols. A common comment by the truck drivers was that the truck symbol should be representative of and contain elements of 18-wheeler tractor trailers. Drivers mentioned that they sometimes couldn't tell if a truck symbol is for a box truck or a tractor trailer. This is especially important when signs are being placed in areas where a tractor trailer cannot maneuver as well as a box truck because of its wider turn radius. Drivers also commented that recreational vehicles, cars pulling trailers, and buses will park in truck parking areas. Many drivers remarked that it is necessary to differentiate between the various vehicle types for designated parking areas.

Table 7: Truck Driver Design Elements for Symbols

Symbol	Truck Driver Design Elements for Symbols
Truck Parking	<ul style="list-style-type: none"> • Cab and trailer (with space in between the 2 components) • Cab should depict the “condo” type and not the flat cab • Majority prefer side view of truck • 2 participants prefer front view of truck • 6 wheels (when viewed from side) • Smoke stacks / pipes • Trailer should be long so truck is not confused with a box truck • Front grill and dual pipes (if front view) • Depict 3 – 4 trucks in a parking lot • Directional arrows
Truck Electrification	<ul style="list-style-type: none"> • Lightning bolt • Circular outlet (symbolizes what the outlet looks like on the truck) • Hose / power cord into the cab • Satellite • Box type device hanging over the truck • Electrical outlet with a power cord • Truck symbol with circular outlet

After drawing their own symbols, drivers were shown samples of truck parking and truck electrification symbols and asked to comment on them. Appendix C includes pictures of the sample symbols shown to the truck drivers. For the truck parking symbol, a majority of the drivers liked the “P” with the truck symbol. When viewing the truck electrification symbols, most drivers did not like the example with just an electrical outlet and cord. They commented that it did not give enough information and they prefer some type of truck symbol with the electrification symbol so they knew it is meant for them. Most truck drivers were familiar with the services provided by a company known as IdleAire[®] and thus drivers preferred the IdleAire[®] symbol because they knew what IdleAire[®] meant. One driver commented that the symbol would still be acceptable even if the “IdleAire[®]” was removed.

Focus Group Summary

After conducting the four focus groups and ten truck driver interviews, the research team compiled a list of similar design elements from the participants’ drawings for each symbol. These elements were shared with graphic artists to begin the process of developing alternative symbols to be used for the subsequent comprehension and legibility distance tests.

EXPERT PANEL

Team members met with graphic artists to review basic roadway signing principles and to share input from the focus groups and interviews. The graphic artists then developed 4 – 5 alternatives for each symbol that were reviewed by the research team. After some adjustments to the alternatives, a second set of alternatives was developed for presentation to the TCD PFS panel. After incorporating TCD PFS comments into the symbol alternatives, a third set was developed for review by an expert panel.

Input from the expert panel meeting was used to develop a fourth and final set of alternative symbols that would be used in the comprehension and legibility distance tests. Figure 2 includes the final symbol alternatives that were developed for subsequent testing.

Sign/Symbol	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Wireless Internet					None	None
Rental Car	 	 	 	None	None	None
Ferry	 	 	 	None	None	None
Tourist Information				None	None	None
Automated/Photo Enforcement	 	 		None	None	None
School Bus Stop Ahead						None
Motorcycle Warning	 	 	 	 	None	None
Truck Parking				None	None	None
Truck Electrification			None	None	None	None
Object Marker						

Figure 2: Sign Alternatives Selected for Evaluation

SURVEY DESIGN AND ADMINISTRATION

For the surveys, there were 174 participants recruited primarily in Virginia at a local shopping mall, a rest area with truck traffic, and at a community center. Of these, 82 were female and 92 were male. By age group, 47 participants were between 18 and 25 years of age, 93 were between 26 and 64 years of age, and 34 were 65 years of age and older. Of the 174 participants, 21 held a commercial driver's license (CDL).

Each participant was surveyed concerning either five or six of the ten sign categories. For each category each participant was given a series of three or four pages on which they were to respond. On the first page of the series was one of the symbol sign alternatives embedded within an appropriate context in a digital photograph. Figure 3 shows a photograph with one of the object marker alternatives.



Figure 3: Example of an Object Marker Alternative as Shown in the Comprehension Survey.

Below the photograph were blank spaces where the participant was asked to write (1) what the sign meant, and (2) what action the sign indicated that a driver should take. On the next page of each series, the same photograph as on the previous page was shown and the participant was asked to place an *X* next to the one of five choices that best represents the meaning of the sign. For some categories an additional page was included that showed the same symbol sign again accompanied by some text that explained the use of the sign. Below the symbol and text was another set of multiple options with instructions for the participant to place an *X* next to the option that was most correct. For instance, for the *school bus stop ahead* category, participants were asked to indicate where the bus stop would be located from among the options: “Next to the sign”; “Up to 500 feet away from the sign”; and “In a location that is not immediately visible to drivers”. The final page for each category showed all alternative signs for that category, and the participant was asked to indicate on 7 point scales how well he or she thought each sign would

work. The anchors for the scale were 1, “would not work at all”; 4, “might work”; and 7, “would work very well”.

LABORATORY ASSESSMENT OF LEGIBILITY DISTANCE

The third and final phase of the symbol sign evaluation was the legibility distance test. The legibility distance testing component of the symbol sign study was performed in a controlled laboratory environment. This chapter describes the testing procedures and the results of the legibility distance for each of the symbols.

Apparatus

The symbol sign legibility distance laboratory test was conducted at the Federal Highway Administration’s Turner-Fairbank Highway Research Center (TFHRC) SignSim Laboratory in McLean, VA. In the SignSim, software is used to dynamically vary the size and brightness of signs that are back-projected onto a frosted glass screen. Sign images that are mounted on 35 mm slides are presented in a manner that simulates how the sign would appear as it is approached in a vehicle. That is, the sign is first presented as a small (zoomed out) and dim image that gradually grows in size and brightness. In this study, participants observed the “approaching” sign and pressed a response button when they could tell whether the sign on the screen was the same as a target sign. The simulated sign distance at the time the button was pressed was recorded.

Stimuli

Thirty-six (36) symbol signs alternatives were used for stimuli. There were ten categories of symbol signs with each category having between two and six alternatives. The images of the sign alternatives were mounted into 35mm slide frames and housed in a standard slide carousel mounted on top of the SignSim. Additional signs were tested during this study for two unrelated research studies. These additional signs were symbols signs but were not included in the following analyses.

Participants

Forty-eight (48) people were recruited from the Washington DC-area to participate in the study. All participants were legal adults (18 and older) and had a current driver’s license. Participants were also required to have a visual acuity of at least 20/40 (with correction) and were tested prior to participation. Half of the participants were seventy-five (75) years and older with genders represented equally. Table 8 shows the age and gender categories and Table 9 shows the median and mean age for the young and older participant groups. The same people participated in a separate research study in the SignSim laboratory immediately prior to the legibility distance testing study. The separate, unrelated 30-minute study was conducted under similar lighting conditions which allowed participants to become fully dark adapted.

Table 8: Research Participant Age and Gender

	Young (18-74)	Older (75+)
Male	12	12
Female	12	12

Table 9: Mean and Median Age by Age Group

	Mean	Median
Young (18-74)	33.04	23.5
Older (75+)	79.25	79

Procedure

Participants completed the informed consent form and were given a visual acuity test prior to starting the experiment. Upon entering the SignSim laboratory, participants were seated in a chair 7 feet (2.1 meters) from the screen. Instructions were read to the participant. The participant remained seated in the chair through the entire process. Figure 4 shows the experimental setup for the legibility distance assessment test.

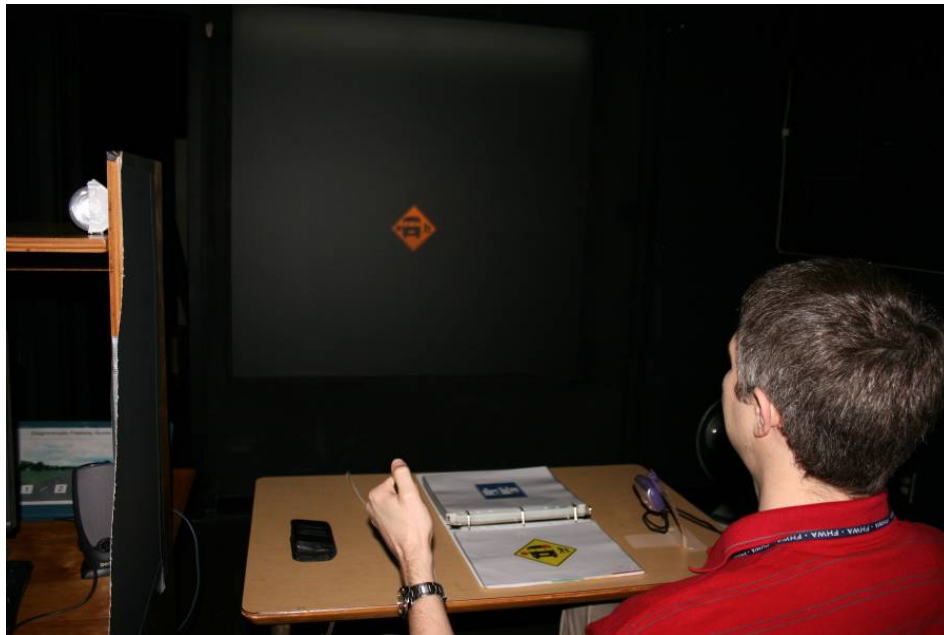


Figure 4: Legibility Distance Assessment Test Setup in the SignSim

The participants were given a three-ring notebook with images of various types of signs. Signs in the notebook included the thirty-six (36) test symbol sign alternatives, thirteen (13) distracter signs, and nine (9) signs used for two unrelated studies. Examples of the distracter signs include a Stop Sign, Yield Sign, Telephone Sign, and other signs currently in the MUTCD. There were two notebooks, each with a different order. Half of the participants viewed each notebook. The signs in the notebook were randomly ordered.

Participants were given several practice trials before starting the actual test to become familiar with the procedure. Each trial consisted of the participant viewing a sign in the notebook until

they were familiar with what it looked like. The participant pressed the response button to begin the zooming of an image on the screen. Participants looked at the sign on the screen and had to determine, with 100 percent confidence, if the sign was an exact match or not. Once participants made this determination, they were instructed to press the response button immediately. The sign then disappeared from the screen and the participant responded “Same” or “Different” depending on whether the sign on the screen matched the one in the notebook. The researcher recorded the participant’s response on the computer and instructed the participant to go to the next sign in the notebook to begin a new trial.

RESULTS

This chapter describes the results of the comprehension and legibility distance testing for each of the symbols. When comparing age categories (young versus old) in the legibility distance test there was a statistically significant difference in mean distances of sign alternatives averaged together for each sign category, with the exception of Truck Parking. This is likely a result of the fact that the older participants were 75 years or older and reduced vision levels and other factors such as task comprehension and reaction time may have been a factor. The results are not significant when comparing individual sign alternatives between age categories so therefore those results are not presented.





WIRELESS INTERNET

Comprehension Survey Results

Various locations offer wireless Internet. Typical wireless Internet locations include rest areas, hotels, restaurants/cafes, and airports. These locations may not be located adjacent to a major highway and a sign may be needed to direct people to the location where they can access wireless Internet. Even if wireless Internet is at a location on a highway, this will not be apparent without an identifying sign.

The research team evaluated four symbols that might be appropriate for use in a new sign that would indicate the availability of wireless Internet access. The four alternatives and the results of the comprehension evaluation are shown in Table 10. For the open-ended response question, all of the alternatives were fairly well understood except for alternative 4. Respondents were rated by the research team in terms of whether or not they seemed to understand the symbol. If a respondent's open-ended response indicated that they understood the symbol, it was categorized as "understood" and if the open-ended response did not seem to indicate that they understood the symbol, it was categorized as "not understood". Alternatives 1, 2, and 3 performed the best in the multiple choice questions, with very similar results that were not significant at the $\alpha = 0.05$ level ($z = 1.04$). The differences in overall ratings were not statistically significant, thus the ratings for all wireless internet symbol alternatives are indicated.

Table 10: Comprehension Results for Wireless Internet Symbol

Sign Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4		
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Understood	84%	84%	84%	16%		
Not Understood	16%	16%	16%	84%		
Meaning						
Reduce Radio Noise	0%	4%	0%	5%		
Fallout Shelter	0%	0%	0%	0%		
Radio Tower	4%	4%	0%	38%		
Wireless Internet	96%	88%	96%	43%		
Satellite Radio	0%	4%	4%	14%		
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
12%	12%	9%	17%	13%	13%	24%

Legibility Distance Results

There were four alternative signs tested for the wireless internet symbol. Table 10 shows the alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, $[F(3,117) = 20.67, p < 0.001]$. Alternative 4 had the highest mean legibility distance of 196 feet and was statistically different from the other three alternatives. There were no significant differences in the other alternatives. Figure 5 shows the mean distance and 2-standard errors for each sign alternative.

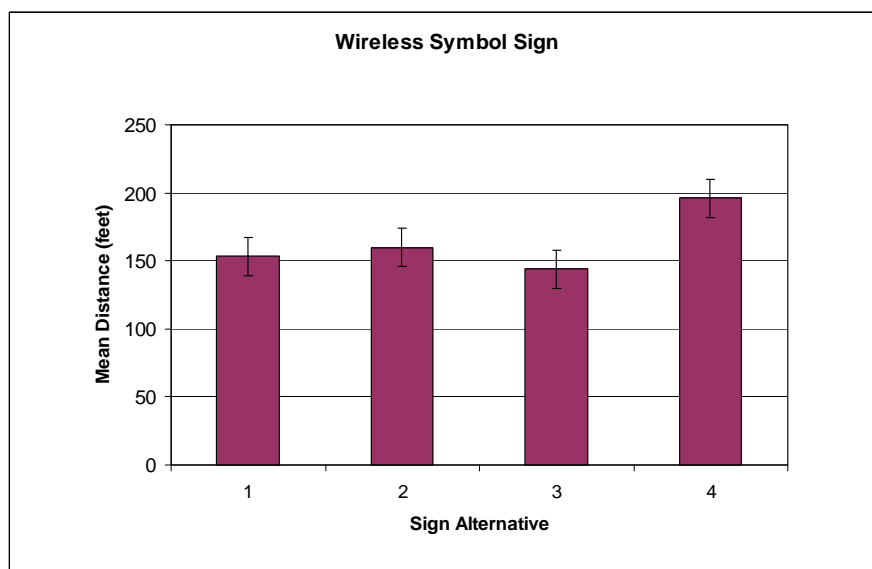


Figure 5: Mean Distances of Wireless Symbol Sign Alternatives




RENTAL CAR

Comprehension Survey Results

In addition to airports, rental car companies have established locations at non-traditional sites, such as in neighborhoods and strip malls. Usually, people renting cars are not familiar with the area. Local residents may also have trouble finding some car rental locations because they are located off of the major highway. A sign may be needed to direct drivers/travelers to the location where they can pick up or return a rental car.

The three alternatives and the results of the comprehension study are shown in Table 11. For the open response question, it was apparent that none of the symbols were well understood. For all three alternatives for the multiple choice response, no more than 45 percent of the participants knew that the symbol was for a rental car location. The differences in overall ratings were not statistically significant, thus the ratings for all rental car symbol alternatives are indicated.

Table 11: Comprehension Results for the Rental Car Symbol

Sign Alternative	Alternative 1	Alternative 2	Alternative 3			
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Understood	20%	16%	20%			
Not Understood	80%	84%	80%			
Meaning						
Parking Lot Ahead	29%	35%	23%			
Reminder to Lock Car	29%	30%	18%			
Valet Parking	8%	13%	14%			
Rental Car	21%	17%	45%			
Locksmith	13%	4%	0%			
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
25%	13%	10%	21%	10%	11%	10%

Legibility Distance Results

There were three alternative signs tested for the rental car symbol. Table 11 shows the three alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, $[F(2,82) = 18.39, p < 0.001]$. Alternative 3 had the lowest mean legibility distance of 161 feet and was statistically different from the other two alternatives. There was no statistically significant difference between alternatives 1 and 2. Figure 6 shows the mean distance and 2-standard errors for each sign alternative.

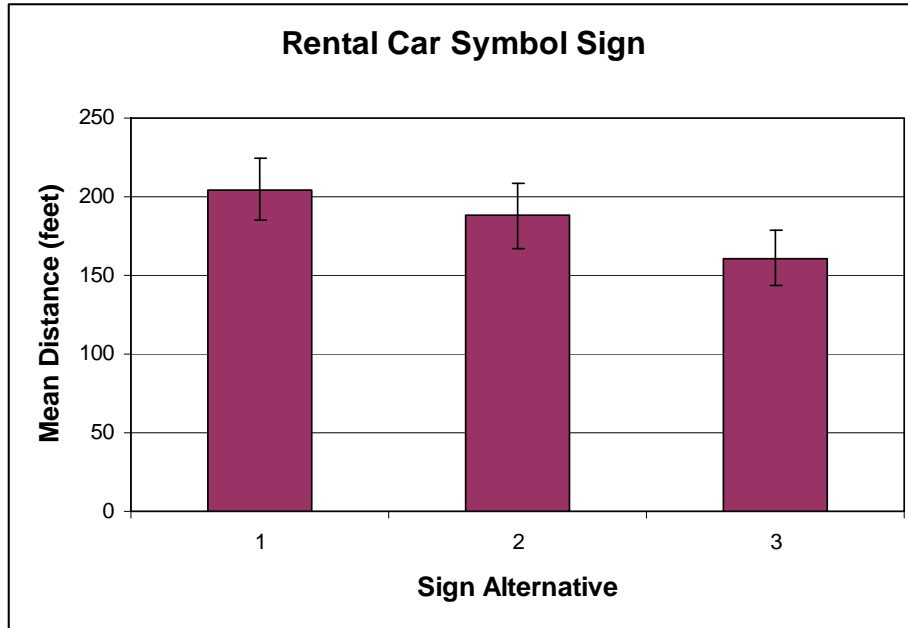


Figure 6: Mean Distances of Rental Car Symbol Sign Alternatives




FERRY

Comprehension Survey Results

Car ferries can be difficult to find because they are either located within busy ports or at the end of small beach or island roads. Since these locations may not be located adjacent to a major highway, signs may be needed to direct drivers to the ferry. In addition to identifying the ferry location, drivers might also need to know what vehicle types are permitted. For example, truck drivers might want to know if their vehicles are allowed.

The three alternatives and the results of the comprehension evaluation for the ferry symbols are shown in Table 12. For the open response question, 64 to 80 percent of the respondents had some understanding that the symbol was a ferry symbol, depending on the alternative. For all three alternatives in the multiple-choice assessment, 79 percent of participants knew the symbol was for a ferry. Once told the meaning of the sign, participants were asked which users were acceptable on the ferry. All alternatives assumed that cars could use the ferry, but other than alternative 3 for trucks, most respondents were unsure as to whether trucks, motorcycles, passengers, or bicycles could use the ferry. As in the previous symbols, the average user rating values had a large variance and thus there were no significant differences. The differences in overall ratings were not statistically significant, thus the ratings for all ferry symbol alternatives are indicated.

Table 12: Comprehension Results for the Ferry Symbol

Sign Alternative		Alternative 1	Alternative 2	Alternative 3		
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Understood		64%	80%	76%		
Not Understood		36%	20%	24%		
Meaning						
High Water		0%	0%	8%		
Ferry		79%	79%	79%		
Car Trailers		17%	8%	8%		
Cruise Ship		0%	4%	4%		
Cargo Ship		4%	8%	0%		
Acceptable Users						
Cars		100%	96%	92%		
Trucks		24%	28%	84%		
Motorcycles		56%	44%	48%		
Passengers		48%	48%	40%		
Bicycles		40%	40%	24%		
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
8%	4%	5%	14%	19%	19%	32%

Legibility Distance Results

Three alternatives were tested for the ferry symbol sign. Table 12 shows the three alternative designs. There was no statistically significant difference among the three ferry symbol signs and therefore the mean distances for each sign alternative are not presented. The overall mean for all the sign alternatives was 123 feet.

INFORMATION




Comprehension Survey Results

Various places have a central location where travelers can get information about an area. Often these are tourist information locations, but they do not have to be in tourist locations. These locations may not be next to the major highway and a sign may be needed to direct travelers to where they can get general information about an area. Even if the location is on a highway, it may not be apparent to a traveler. The sign will help the location to be readily identified as an information location.

The existing MUTCD sign is alternative 2, but practitioners generally believe that the “question mark” symbol is unclear. The three alternatives and the results of the comprehension study are shown in Table 13. In general, the text “INFO” performed much better than the other two

alternatives ($z = 2.6$ and 3.3 for alternatives 3 and 1, respectively). When looking at the multiple choice responses, 20 percent of the participants believed that the “i” in alternative 1 was for wireless internet access. Also, motorists seem to expect that Tourist Information would be available in the form of maps and brochures but it wasn’t necessarily expected that a manned booth be present. The differences in overall ratings were not statistically significant, thus the ratings for all information symbol alternatives are indicated.

Table 13: Comprehension Results for Information Symbol

Sign Alternative	Alternative 1	Alternative 2 Current Sign	Alternative 3			
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Understood	56%	68%	96%			
Not Understood	44%	32%	4%			
Meaning						
Use Caution	4%	0%	0%			
Wireless Internet Available	20%	0%	0%			
Medical Assistance	0%	8%	5%			
Traveler Information	76%	92%	95%			
Services Expected						
Maps Available	60%	84%	79%			
Brochures Available	80%	80%	75%			
Manned Booth During Business Hours	44%	64%	46%			
Manned Booth 24 Hours	28%	36%	25%			
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
19%	7%	4%	15%	9%	16%	30%

Legibility Distance Results

There were three alternative signs tested for the information symbol. Table 13 shows the alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, $[F(2,80) = 33.69, p < 0.001]$. Alternative 3 had the lowest mean legibility distance of 157 feet and was statistically different from the other two alternatives. There was no statistically significant difference between alternatives 1 and 2. Figure 7 shows the mean distance and 2-standard errors for each sign alternative.

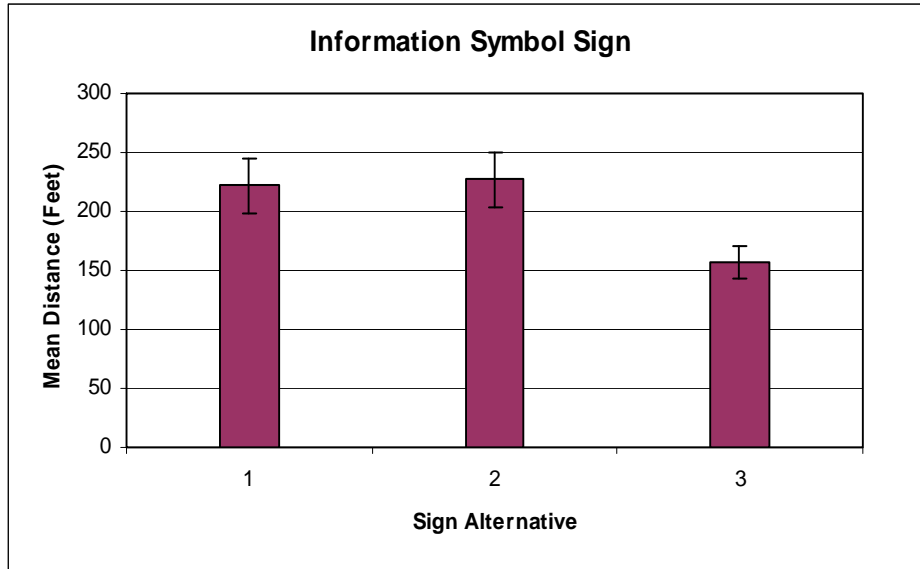


Figure 7: Mean Distances of Information Symbol Sign Alternatives




AUTOMATED/PHOTO ENFORCEMENT

Comprehension Survey Results

Automated enforcement involves the use of cameras and other remote sensing devices to identify traffic violations and the offending driver, and then mail a citation to the vehicle owner. Automated enforcement is designed to identify traffic law violators without depending on the presence of police officers. Devices may be used for red-light running or speeding, and while in limited use now, may become more common in the future. For the purposes of this study, the symbol evaluation was restricted to just automated enforcement for red-light running. These camera systems are connected to traffic signals and to sensors buried in the pavement at the crosswalk or stop line. The system continuously monitors the traffic signal and triggers the camera to photograph vehicles as they pass a certain point once the signal turns red. The date, time and location are recorded along with a photo. The purpose of an automated enforcement warning sign is to inform drivers that they are in an area where automated enforcement may be used to issue traffic violations.

The three alternatives and the results of the comprehension study are shown in Table 14. For the open response question, all of the alternatives were fairly well understood with no significant differences at the $\alpha = 0.05$ level. When focusing on the multiple choice responses, the symbols in both alternative 2 and 3 perform equally as well, but the overall rating for alternative 2 was higher, although not significant. The differences in overall ratings were not statistically significant, thus the ratings for all automated enforcement symbol alternatives are indicated.

Table 14: Comprehension Results for Automated/Photo Enforcement Symbol

Sign Alternative	Alternative 1	Alternative 2	Alternative 3			
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Understood	92%	88%	92%			
Not Understood	8%	12%	8%			
Meaning						
Red Light Enforcement Cameras	83%	96%	92%			
Sun Glare	0%	0%	0%			
Traffic Signal Ahead	0%	0%	0%			
Scenic View Ahead	0%	0%	0%			
Speed Limit Enforced by Radar	4%	0%	0%			
Speeding Enforcement Cameras	13%	4%	8%			
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
5%	5%	7%	17%	12%	22%	33%

Legibility Distance Results

There were three alternative signs tested for the automated/photo enforcement symbol. Table 14 shows the three alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, [F (2,78) = 24.48, $p < 0.001$]. Alternative 2 had the highest mean legibility distance of 223 feet and was statistically different from alternative 3, which had the lowest mean legibility distance of 165 feet. There was no statistically significant difference between alternative 1 and the other alternatives. Figure 8 shows the mean distance and 2-standard errors for each sign alternative.

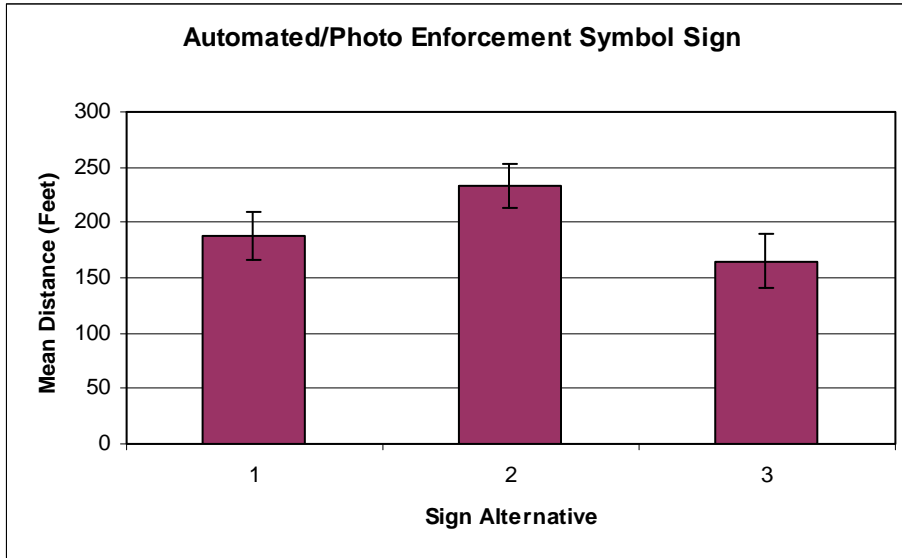


Figure 8: Mean Distances of Automated/Photo Enforcement Symbol Sign Alternatives






SCHOOL BUS STOP AHEAD

Comprehension Survey Results

The MUTCD designates warning signs for use when there is an unexpected condition on or adjacent to the highway and for situations that might not be readily apparent to road users. The current school bus stop ahead sign contains the word message “SCHOOL BUS STOP AHEAD”. It is used in locations where school buses stop to pickup or discharge passengers, the bus is not visible to drivers from at least 500 feet, and the stop cannot be moved to a location where the bus would be visible from 500 feet.

The School Bus Stop Ahead warning sign was evaluated to determine if a symbol could provide better understanding than the current word message sign. The five alternatives and the results of the comprehension study are shown in Table 15. For the open response question, all of the alternatives were fairly well understood with no significant differences. For the multiple choice response, alternatives 2, 3, and 5 all scored 95 percent. The differences in overall ratings were not statistically significant, thus the ratings for all school bus stop ahead alternatives are indicated.

Table 15: Comprehension Results for the School Bus Stop Ahead Symbol

Sign Alternative	Alternative 1 Current Sign	Alternative 2	Alternative 3	Alternative 4	Alternative 5	
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Clearly Understood	96%	92%	88%	80%	92%	
Not Understood	4%	8%	12%	20%	8%	
Meaning						
School Crosswalk	0%	0%	5%	15%	5%	
School Bus Stop	90%	95%	95%	85%	95%	
Children at Play	5%	0%	0%	0%	0%	
School Zone Ahead	5%	5%	0%	0%	0%	
Average Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
6%	5%	5%	15%	12%	17%	40%

Legibility Distance Results

There were five alternative signs tested for the school bus stop ahead symbol. Table 15 shows the five alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, [F (4,152) = 29.32, $p < 0.001$]. Alternatives 1, 3, and 4 were legible at mean distances of 209, 207, and 196 feet, respectively and were statistically different from alternatives 2 and 4. Alternatives 1, 3, and 4 had the three highest mean legibility distances. Figure 9 shows the mean distance and 2-standard errors for each sign alternative.

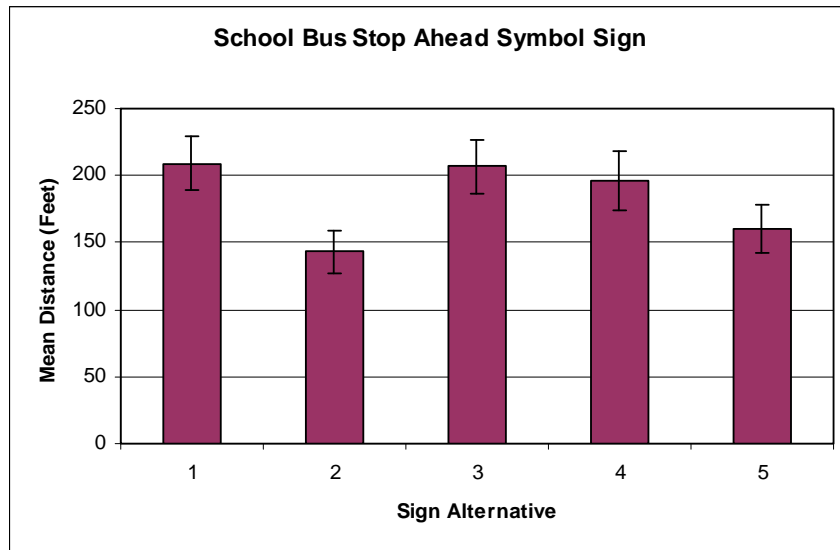


Figure 9: Mean Distances of School Bus Stop Ahead Symbol Sign Alternatives





MOTORCYCLE WARNING

Comprehension Survey Results

The motorcycle warning sign is meant to warn motorcyclists of road hazards that are unique to them. Examples of such hazards are open bridge joints and grooved pavement. A specialized warning sign can assist a motorcyclist with recognizing a hazard thus allowing him to take appropriate action. During research, the team discovered that general drivers sometimes believed the motorcycle symbol was a warning to them to be watchful for motorcycles. A successful symbol will be recognized by both general drivers and motorcyclists as specific to warning of a road hazard for motorcycles.

The four alternatives and the results of the comprehension study are shown in Table 16. For the open-ended response question, there were some differences between the results for a traditional style motorcycle versus a modern motorcycle symbol where the older style was more easily understood ($z = 1.88$ between alternatives 2 and 4). When analyzing the multiple choice responses, all four performed similarly in indicating that the sign was a motorcycle warning sign. The differences in overall ratings were not statistically significant, thus the ratings for all motorcycle warning symbol alternatives are indicated.

Table 16: Comprehension Results for Motorcycle Warning Symbol

Sign Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4		
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Clearly Understood	68%	60%	80%	84%		
Not Understood	32%	40%	20%	16%		
Meaning						
Wear Helmet for Safety	0%	8%	0%	4%		
Motorcycle Warning	84%	75%	83%	87%		
Motorcycles Permitted	4%	8%	9%	4%		
Watch for Motorcyclists	12%	8%	9%	4%		
Motorcycle Parking Ahead	0%	0%	0	0%		
Average Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
7%	3%	5%	19%	15%	20%	31%

Legibility Distance Results

There were four alternative signs tested for the motorcycle warning symbol. Table 16 shows the four alternative designs and the results from the legibility distance test. An overall within-

subjects analysis was conducted and there was a statistically significant effect for sign alternative, [F (3,123) = 3.94, $p = 0.010$]. Alternative 3 had the highest mean legibility distance of 205 feet and was statistically different from alternatives 2 and 4. There was no statistically significant difference between alternative 1 and the other alternatives. Figure 10 shows the mean distance and 2-standard errors for each sign alternative.

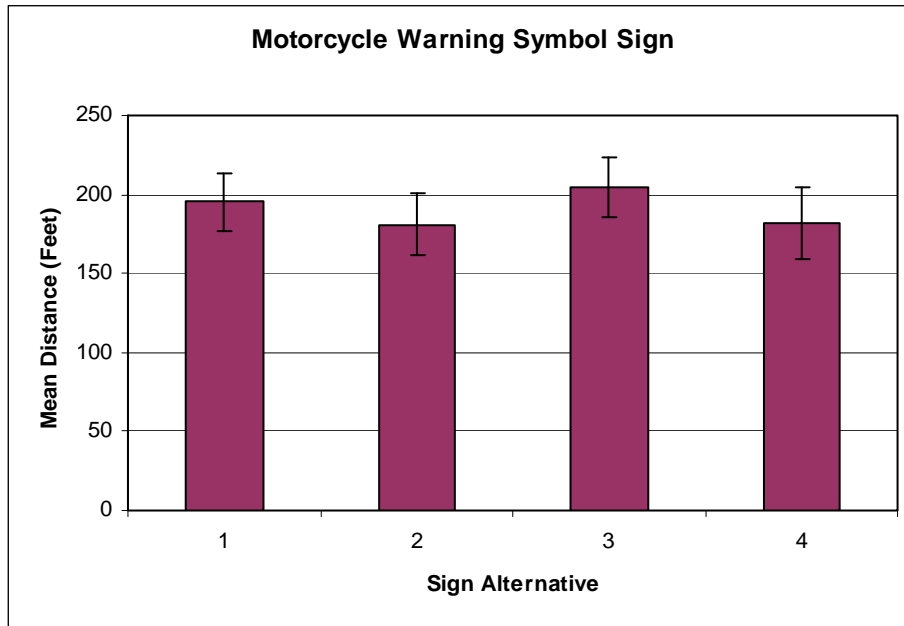


Figure 10: Mean Distances of Motorcycle Warning Symbol Sign Alternatives

TRUCK PARKING




Comprehension Survey Results

The purpose of the truck parking sign is to inform truck drivers of areas where they can park their trucks. This symbol is intended for use at locations like rest areas and service plazas where the parking lots have designated areas for truck parking. Many locations are currently using word messages with directional arrows to indicate truck parking areas. It is important that truck drivers are aware of truck parking locations as these areas take the length of their vehicles into account and allow extra room for their larger turning radius. The issue repeatedly raised by truck drivers is that other vehicles will utilize truck parking areas thereby reducing the number of spaces available for the trucks that need it. Truckers report that vehicles commonly utilizing truck parking areas include passenger cars, vehicles towing trailers, recreational vehicles, buses and box trucks.

In developing the questions and interpreting the results, the research team tried to determine the extent to which the alternatives identified a location where truck parking was available. The three alternatives and the results of the comprehension study are shown in Table 17. All alternatives were pretty well understood. Respondents were also asked what types of vehicles would be permitted to park in truck parking areas, and in general, small trucks and tractor trailer

trucks were perceived to be acceptable while buses and recreational vehicles were not. The differences in overall ratings were not statistically significant, thus the ratings for all truck parking symbol alternatives are indicated.

Table 17: Comprehension Results for Truck Parking Symbol

Sign Alternative	Alternative 1	Alternative 2	Alternative 3			
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Clearly Understood	92%	92%	92%			
Not Understood	8%	8%	8%			
Meaning						
Passing Trucks is Permitted	0%	4%	8%			
Heavy Truck Loads Permitted	0%	0%	4%			
Truck Parking	100%	96%	88%			
Weigh Station Ahead	0%	0%	0%			
Loading Zone	0%	0%	0%			
Vehicles Permitted						
Cars	4%	0%	13%			
Small Trucks	56%	64%	52%			
Tractor Trailers	76%	84%	96%			
Recreational Vehicles	32%	20%	24%			
Buses	40%	28%	32%			
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
11%	8%	7%	16%	10%	18%	29%

Legibility Distance Results

There were three alternative signs tested for the truck parking symbol. Table 17 shows the three alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, $[F(2,66) = 35.35, p < 0.000]$. All three alternatives were statistically different from each other. Alternatives 1, 2, and 3 were legible at mean distances of 147, 179, and 230 feet, respectively. Figure 11 shows the mean distance and 2-standard errors for each sign alternative.

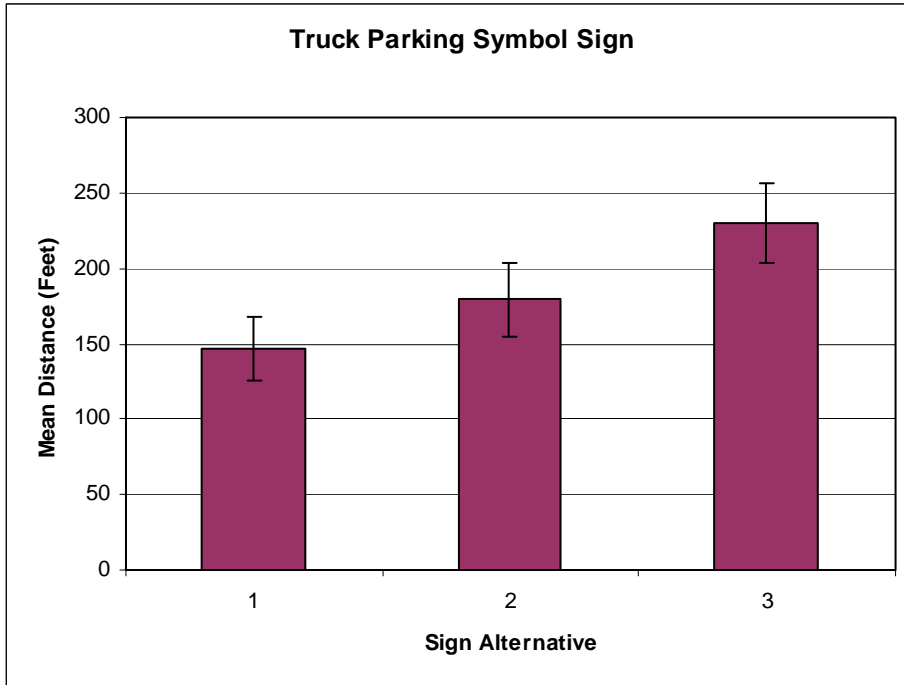




Figure 11: Mean Distances of Truck Parking Symbol Sign Alternatives

TRUCK ELECTRIFICATION

Comprehension Survey Results

The truck electrification sign is intended to inform truckers of locations where they can access electrical power so that they do not have to idle their engines to be able to use air conditioning and other appliances in the sleeping cab. This is an issue in some locations where truckers idle their engines while parked for long periods which creates air and noise pollution. In developing the questions and interpreting the results, the research team tried to determine the extent to which the alternatives identified a location where truck electricity was available. The two alternatives and the results of the comprehension study are shown in Table 18. In general, participants did not appear to be familiar with truck electrification and it was not widely chosen as an appropriate meaning. In fact, more people found the symbols to be more applicable to areas with both truck parking and electric vehicle charging. Even when only looking at the subpopulation of CDL drivers, only 22% understood that the symbol was intended for truck electrification. The differences in overall ratings were not statistically significant, thus the ratings for all truck electrification symbol alternatives are indicated.

Table 18: Comprehension Results for Truck Electrification Symbol

Sign Alternative				Alternative 1	Alternative 2	
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Clearly Understood				56%	60%	
Not Understood				44%	40%	
Meaning						
Truck Parking for Electric Powered Trucks				17%	25%	
Truck Electrification Available				39%	29%	
Beware of Wires				0%	0%	
Truck Stop Ahead				4%	0%	
Truck Parking and Electric Vehicle Charging				39%	46%	
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
1%	5%	5%	24%	20%	26%	19%

Legibility Distance Results

The truck electrification symbol had two alternative signs. Table 18 shows the two alternative designs. There was no statistically significant difference among the two truck parking symbol signs. The overall mean for the two sign alternatives was 194 feet.

OBJECT MARKER

Comprehension Survey Results







The Type 3 object marker is defined as an object marker, but it functions in the same way as a sign. The diagonal stripe sign is in the current MUTCD and is used to warn of a hazardous object within or adjacent to the roadway. An additional message is that the diagonal stripes indicate the side that vehicles are supposed to pass on (the stripes are sloped downward to the side that vehicles are supposed to pass). After they provided their own written definition of the meaning of the sign, participants were asked to choose the best definition of the meaning of the sign from among the following alternatives:

- The roadway ends ahead
- There is a hazardous object behind the sign.
- There is a curve to the left ahead.
- Construction ahead.
- There is a pothole in the road.

There were six alternatives to object marker designs. Alternative 2 is the current version in the MUTCD but many practitioners do not feel that the sign is clear. The six alternatives and the results of the comprehension study are shown in Table 19.

No alternative was well understood for the open-ended response question when provided multiple choices as to what the intended meanings were, no object marker scored higher than 30 percent correct. Alternatives 3 and 4 were most frequently identified as correctly indicating that drivers should pass to the left of the marker, with 72 and 79 percent of participants respectively correctly selecting this meaning. The differences in overall ratings were not statistically significant, thus the ratings for all object marker alternatives are indicated.

Table 19: Comprehension Results for Type 3 Object Marker Symbol

Sign Alternative	Alternative 1	Alternative 2 Current Sign	Alternative 3	Alternative 4	Alternative 5	Alternative 6
						
Open-Ended Response (What does this sign mean to you? What action should you take?)						
Clearly Understood	24%	24%	8%	4%	16%	4%
Not Understood	76%	76%	92%	96%	84%	96%
Meaning						
Roadway Ends Ahead	16%	21%	17%	0%	29%	13%
Hazardous Object	8%	25%	0%	0%	29%	8%
Left Hand Curve	72%	46%	71%	96%	33%	79%
Construction Ahead	4%	4%	0%	4%	4%	0%
Pothole in Road	0%	4%	13%	0%	4%	0%
Required Action						
Drive to the right of the sign	0%	4%	4%	0%	4%	8%
Drive to the left of the sign	29%	24%	72%	79%	8%	68%
Signs gives no direction	71%	72%	24%	21%	88%	24%
Overall Rating						
1 Would Not Work at All	2	3	4 Might Work	5	6	7 Would Work Very Well
35%	14%	9%	17%	8%	7%	9%

Legibility Distance Results

There were six alternatives tested for the object marker symbol sign. Table 19 shows the six alternative designs. An overall within-subjects analysis was conducted and there was a statistically significant effect for sign alternative, [$F(5,150) = 8.27, p < 0.001$]. Alternative 5 was legible at a mean distance of 171 feet and was statistically different than alternatives 1, 2, 3, and 6. Alternative 1, with the highest mean distance of 237 feet, was statistically different than alternative 4. There was also a statistically significant difference between alternative 4, with a mean distance of 202 feet, and alternative 6. Figure 12 shows the mean distance and 2-standard errors for each sign alternative.

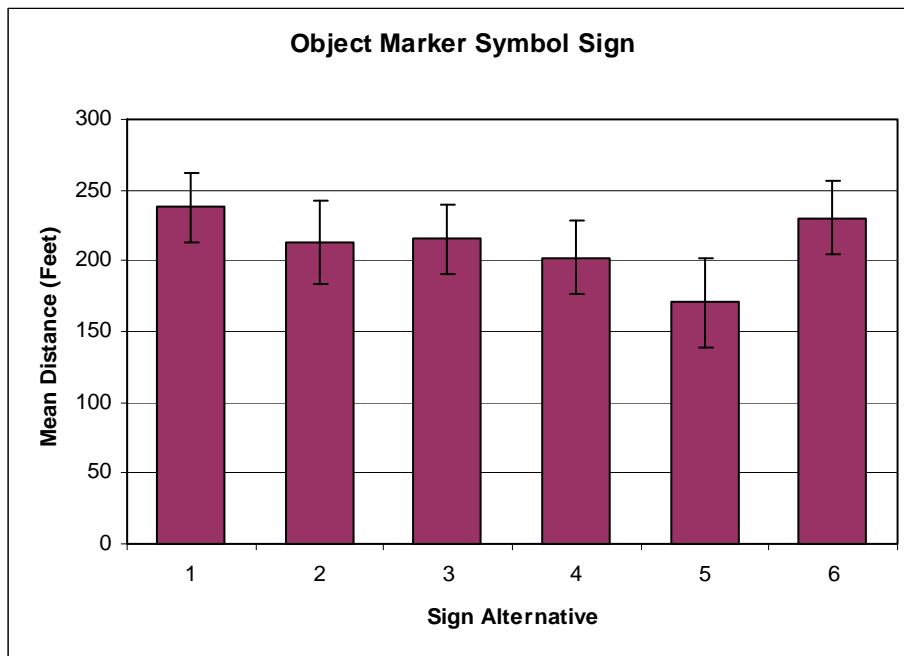




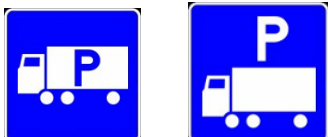


Figure 12: Mean Distances of Object Marker Symbol Sign Alternatives

SUMMARY OF COMPREHENSION RESULTS

In this phase of the study 174 drivers were surveyed to assess how well the sign alternatives were understood. Table 20 shows the alternatives for each category that achieved higher than 75 percent comprehension in the open-ended question assessment testing section.

Table 20: Alternative Symbols that Achieved Higher than 75% Comprehension

Sign/Symbol	Alternatives With Higher Than 75% Comprehension
Wireless Internet	
Rental Car	None
Ferry	None
Information	
Automated/Photo Enforcement	
School Bus Stop Ahead	
Motorcycle Warning	None
Truck Parking	
Truck Electrification	None
Object Marker	None

SUMMARY OF LEGIBILITY RESULTS

Overall, with the exception of the Ferry Symbol Sign, all of the sign categories had some statistically different sign alternatives for mean legibility distances. The Truck Parking sign category was the only category to have all sign alternatives have statistically significant differences from each other. Although the simulated distances cannot be compared to real world distances they are relative to each other and can be compared within sign categories and even across categories to identify the best candidates.

FINDINGS AND RECOMMENDATIONS

The research team is providing recommendations for symbol signs based on input from the general driving population and results of the comprehension and legibility testing. Based on the results of this study, the recommended symbols are effective when taking driver comprehension and legibility requirements into consideration and are suggested for inclusion in the next edition of the MUTCD.

WIRELESS INTERNET

The research team evaluated the four symbols shown in Figure 13 for this application; all were presented as white on blue service signs.

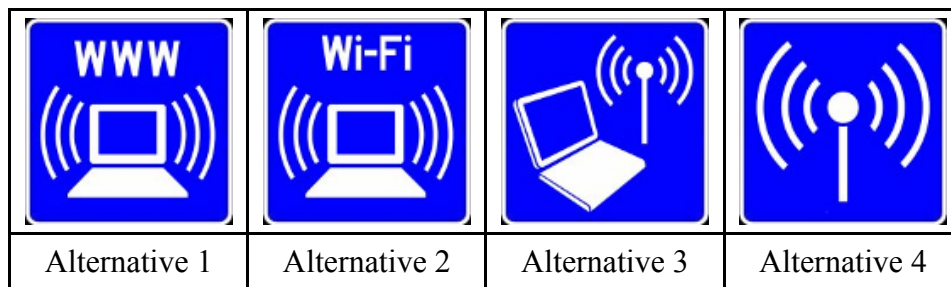


Figure 13: Wireless Internet Signs Evaluated in Study

Summary of Findings for Wireless Internet

In the comprehension evaluation, alternatives 1 and 3 had the highest levels of comprehension and were not significantly different. In the legibility evaluation, alternative 4 had the highest recognition distance, with alternatives 1, 2, and 3 producing similar recognition distances.

Recommendations for Wireless Internet

Since alternative 4 was not understood well, the overall results indicate that either alternative 1 or 3 should be recommended for potential implementation. Both the comprehension and legibility results for each alternative were essentially equal and do not clearly indicate that one symbol is better than the other.

RENTAL CAR

The research team evaluated the three symbols shown in Figure 14 for this application; all were presented as white on blue service signs.

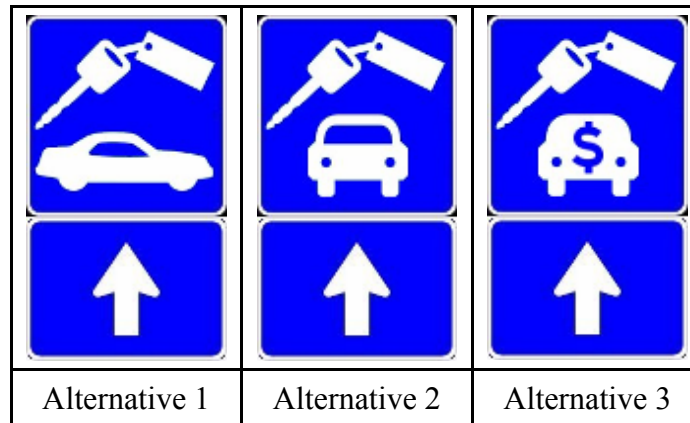


Figure 14: Rental Car Signs Evaluated in Study

Summary of Findings for Rental Car

The comprehension evaluation found that none of the evaluated symbols was understood well by the survey participants. For all three signs, the responses in the open-ended assessment that were classified as “not understood” were at least 80 percent. Even when “rental car” was provided as one of the multiple-choice responses, the best performing sign (Alternative 3) had the intended meaning selected by only 45 percent of the subjects. In the legibility evaluation, Alternative 3 was the worst performing of the three signs.

Recommendations for Rental Car

Since none of the symbols were understood well, the research team does not recommend any of the symbols for implementation.

FERRY

The research team evaluated the three symbols shown in Figure 15 for this application; all were presented as white on blue signs. It should be noted that the only difference between Alternatives 1 and 2 is the presence of the smokestack in Alternative 2.

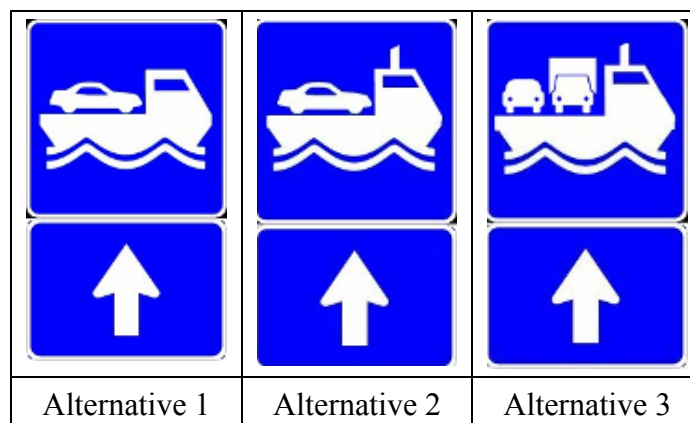


Figure 15: Ferry Signs Evaluated in Study

Summary of Findings for Ferry

The comprehension evaluation evaluated the ability of the symbol to indicate a ferry access point to road users as well as the types of vehicles the ferry accommodates. The open-ended assessment of the comprehension evaluation found that the percentage of subjects that did not clearly understand the alternatives ranged from 20 to 36 percent. In the multiple-choice assessment, the “ferry” response was selected by 79 percent of subjects for all three alternatives. All three also had high levels of understanding that cars were permitted on the ferry, but only Alternative 3 had a high understanding that trucks were also permitted, which is not surprising given it is the only alternative that has a truck in the symbol.. The legibility results for all three signs were similar, with no statistically significant differences in the legibility distances.

Recommendations for Ferry

Since the legibility results were the same for all three signs, the implementation recommendation is based on the comprehension results. Alternative 2 is recommended because it was well understood and best used to describe general ferry applications.

INFORMATION

The information sign is used to indicate a location where road users can get tourist information. Figure 16 illustrates the alternatives evaluated by the research team in the study. All were presented as white on blue signs. Alternative 2 is the sign currently specified in the MUTCD. Alternative 1 is similar to the type of symbol used in many international countries and Alternative 3 was identified in the focus groups as a desirable alternative.

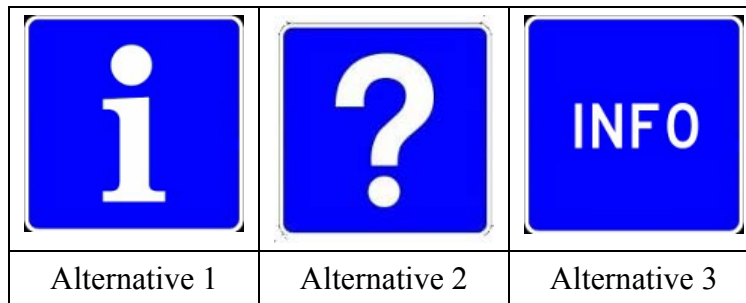


Figure 16: Information Signs Evaluated in Study

Summary of Findings for Information

The open-ended assessment of the comprehension evaluation clearly indicated that Alternative 3 was the best understood sign. In the multiple-choice assessment, Alternatives 2 and 3 had similar correct response percentages and much better than Alternative 1. Alternative 2 had slightly better understanding of the services that might be available. In the legibility evaluation, Alternative 2 provided the longest legibility distance and Alternative 3 had the shortest.

Recommendations for Information

In this case, the sign with the best performance in the comprehension evaluation (Alternative 3) had the lowest performance in the legibility evaluation. However, as presented in the legibility evaluation, Alternative 3 has the potential to improve legibility by increasing the letter height. As presented in the legibility evaluation, the letter height in Alternative 3 is 5 inches, resulting in a predicted legibility index of 31.4 ft/in. By increasing the letter height to 8 inches, the legibility performance can be expected to improve to 251 feet, which would be more consistent (and actually higher than) the mean values for the other alternatives. Therefore, Alternative 3 with 8 inch letters is recommended.

AUTOMATED/PHOTO ENFORCEMENT

Figure 17 illustrates the three alternatives evaluated in this study. In all three alternatives, only the red indication is shown, which distinguishes this warning sign from the Signal Ahead warning sign where all three indications (red, yellow, and green) are shown.

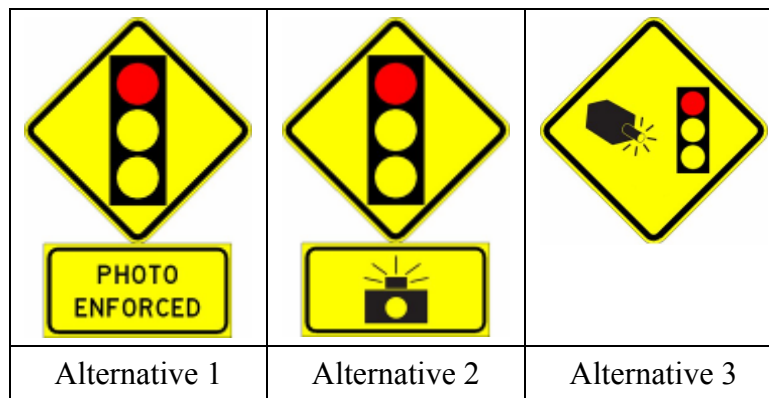


Figure 17: Automated/Photo Enforcement Signs Evaluated in Study

Summary of Findings for Automated/Photo Enforcement

In the open-ended assessment of the comprehension evaluation, there were no significant differences. In the legibility evaluation, the sign with the best legibility distance was Alternative 2. Alternative 3 has the lowest legibility distance and Alternative 1 was only slightly better.

Recommendations for Automated/Photo Enforcement

Based on the results of the two evaluations, the researchers recommend the addition of a new warning sign where only the red indication on a traffic signal is shown. The camera plaque (as shown in Alternative 2) should be the plaque used with this new warning sign. The width of this plaque can be reduced to a size smaller than was evaluated in this study. Although the legibility distance is less, the Photo Enforced plaque can be retained in the MUTCD and may be used as an alternative to the preferred sign. There is no evidence to indicate the standard Signal Ahead Sign (W3-3) would not perform better but it was not tested in this study.

SCHOOL BUS STOP AHEAD

The research team evaluated four symbols, in addition to the current word message sign. Figure 18 illustrates these alternatives. All alternatives were presented as warning signs.

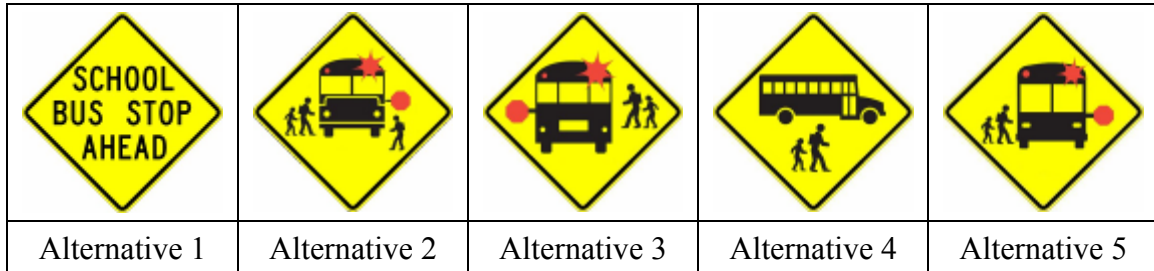


Figure 18: School Bus Stop Ahead Signs Evaluated in Study

Summary of Findings for School Bus Stop Ahead

The current word message sign (Alternative 1) did well in all of the comprehension evaluations. Alternatives 2, 3, and 5 had the highest percentage selecting the correct meaning in the multiple-choice assessment. Only Alternative 4, which showed the side view of a school bus, performed poorly with respect to the other alternatives. In the legibility evaluation, Alternative 1 had the highest legibility distance, with Alternatives 3 and 4 having legibility distances that were slightly less. There was no statistical difference in the legibility distance for these three alternatives.

Recommendations for School Bus Stop Ahead

Based on the comprehension and legibility results, Alternative 3 is the symbol sign that is recommended for implementation.

MOTORCYCLE WARNING

Figure 19 presents the four alternatives evaluated by the research team. From this figure, it is clear that there are two symbols evaluated in two contexts. The two symbols are different styles of motorcycles. In Alternatives 1 and 3, the symbol is presented in a plaque. In Alternatives 2 and 4, they are presented within the warning sign. For all four alternatives, grooved pavement was the warning message presented with the symbol, although many other warning messages could have been used.

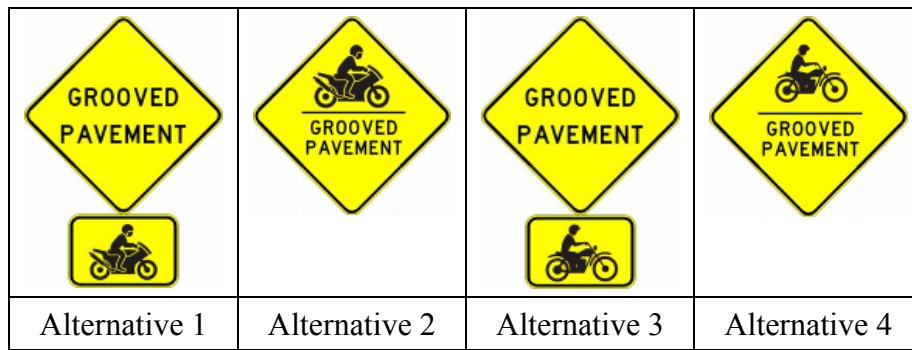


Figure 19: Motorcycle Warning Signs Evaluated in Study

Summary of Findings for Motorcycle Warning

The symbol used in Alternatives 1 and 2 was found to be less understandable than the symbol used in Alternatives 3 and 4. There was no statistically significant difference in the results of the legibility evaluation. No significant differences were found in the use of a separate plaque versus using the symbol embedded in the diamond warning sign.

Recommendations for Motorcycle Warning

The use of the motorcycle symbol in Alternatives 3 and 4 should be used.

TRUCK PARKING

Figure 20 illustrates the three alternatives evaluated in this study.

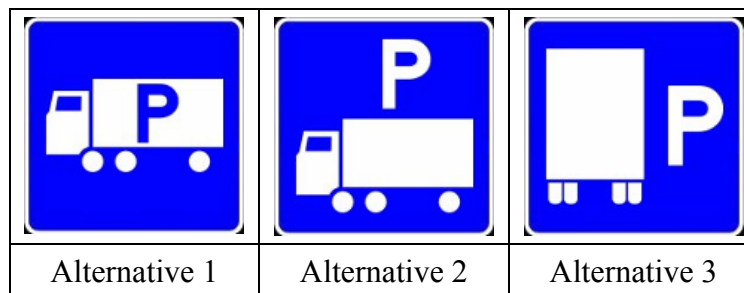


Figure 20: Truck Parking Signs Evaluated in Study

Summary of Findings for Truck Parking

There were no significant differences in the comprehension evaluation. The legibility evaluation indicated that Alternative 3 is the most legible, followed by Alternatives 1 and 2.

Recommendations for Truck Parking

Although Alternative 3 had the highest legibility distance, the research team recommends Alternative 2 for implementation. This sign is intended primarily for truck drivers and would

most likely be used within a rest area or other location where trucks and other vehicles have exited from a main road and are traveling at a lower speed.

TRUCK ELECTRIFICATION

The research team developed two alternatives for this sign as shown in Figure 21. They were presented as white-on-blue service signs.

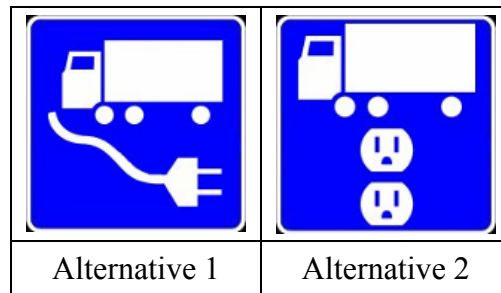


Figure 21: Truck Electrification Signs Evaluated in Study

Summary of Findings for Truck Electrification

Neither of the alternatives did well in the open-ended or multiple-choice assessments. Many drivers felt that the sign indicated that truck parking and electric vehicle charging is available at the facility. Assuming that electric vehicles will become more popular, it would not be appropriate to include a sign where the intended meaning might be for vehicle recharging. Alternative 1 had a longer legibility distance than Alternative 2, but the difference was not statistically significant.

Recommendations for Truck Electrification

Based on the comprehension results, the research team does not recommend either of these alternatives for implementation.

OBJECT MARKER

The research team evaluated the standard Object Marker and five alternative designs. Figure 22 illustrates the alternatives evaluated in the study.

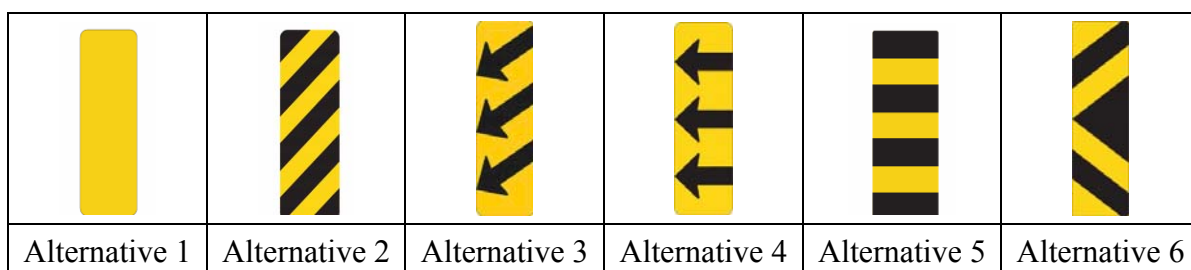


Figure 22: Object Markers Evaluated in Study

Summary of Findings for Object Marker

In the open-ended assessment, all of the alternatives had “not understood” percentages in the 76-92 percent range. Less than 30 percent selected the correct response in the multiple-choice version. When asked to rate the signs with respect to two messages (hazardous object and pass to the left), Alternative 4 had the highest rating. The comprehension results clearly indicate that none of the alternatives, including the current sign, had high comprehension levels. The legibility evaluations found that Alternatives 1, 2, 3, and 6 had the highest legibility distances and that there was no statistically significant difference between the four distances.

Recommendations for Object Marker




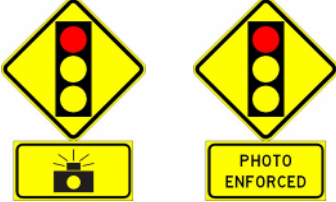

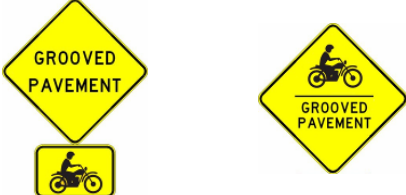

Based on the poor comprehension levels found in the comprehension evaluation, the researchers do not recommend any of the alternatives for implementation. For lack of a better alternative, the current object marker should continue to be used.

OVERALL COMMENTS

In this study, the research team developed numerous alternative symbols for ten traffic signs and evaluated the comprehension and legibility of each of the alternatives. Comprehension was evaluated through a driver survey that was administered to 174 subjects and legibility was evaluated in a simulator using 48 subjects. The research team reviewed the results of each evaluation and used those results to identify symbols that should be considered for implementation.

Table 21 shows the recommended alternative(s) for each of the symbols/signs evaluated in the study. In some cases, the research team is not recommending any of the symbols evaluated for implementation due to the poor comprehension levels found in the comprehension evaluation.

Table 21: Recommended Sign/Symbol Alternatives

Sign/Symbol	Recommended Alternative(s)
Wireless Internet	
Rental Car	No symbol recommended
Ferry	
Information	 (8-inch text)
Automated/Photo Enforcement	
School Bus Stop Ahead	
Motorcycle Warning	
Truck Parking	
Truck Electrification	No symbol recommended
Object Marker	No symbol recommended Continue to use current object marker

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5. Katz, B.J., Rousseau, G.K. & Warren, D.L. *Comprehension of Warning and Regulatory Signs for Speed*. Proceedings of the Institute of Transportation Engineers Annual Meeting. Seattle, WA, 2003.
6. Picha, D.L., H.G. Hawkins, and K.N. Womack. *Motorist Understanding of Alternative Designs for Traffic Signs*. Research Report 1261-5F. Texas Transportation Institute. College Station, TX, 1995.
7. Desrosiers, R.D. Moving Picture Technique for Highway Signing Studies – An Investigation of its Applicability. *Public Roads*, Vol. 33, No. 7, Bureau of Public Roads, Washington, DC, 1965, pp. 143-147.
8. Zwahlen, H.T., X. Hu, M. Sunkara, and L.M. Duffus. Recognition of Traffic Sign Symbols in the Field During Daytime and Nighttime. *Proceedings of the Human Factors Society 35th Annual Meeting*, Santa Monica, CA, 1991, pp. 1058-1062.
9. Philips, B.H., J.E. Fox, and R.D. Peters. *Computer-Aided Optimization and Evaluation of Selected Signs*. Presented at the Transportation Research Board 77th Annual Meeting, Washington, DC, 1998.
10. Mahach, K.R., K. Wochinger, R. Marshall, and D. Eppich. Sign Simulator Validated in FHWA Study. *Public Roads*, Federal Highway Administration, Washington, DC, July/August 1999.

APPENDIX A FOCUS GROUP SCENARIO PICTURES

The pictures shown below were presented to participants in the focus groups for the signs indicated with each photo. The participants were told that the sign would be located where the white cloud appeared in the photo, except for the automated enforcement situation where the photos illustrated what photo enforcement was.



Figure 23: Wireless Internet, Information, and Truck Electrification



Figure 24: Ferry and Rental Car



Figure 25: Automated/Photo Enforcement 1



Figure 26: Automated/Photo Enforcement 2



Figure 27: School Bus Stop Ahead and Motorcycle Warning



Figure 28: Truck Parking



Figure 29: Object Marker

APPENDIX B: CURRENT US AND INTERNATIONAL SYMBOL DESIGNS

The symbols presented in this appendix were presented to the focus group participants as part of the process of generating symbol alternatives. These symbols were not presented to focus group participants until after the participants had generated their own thoughts on what the symbols should look like. The researchers then asked the participants to comment on the symbols shown in this appendix.

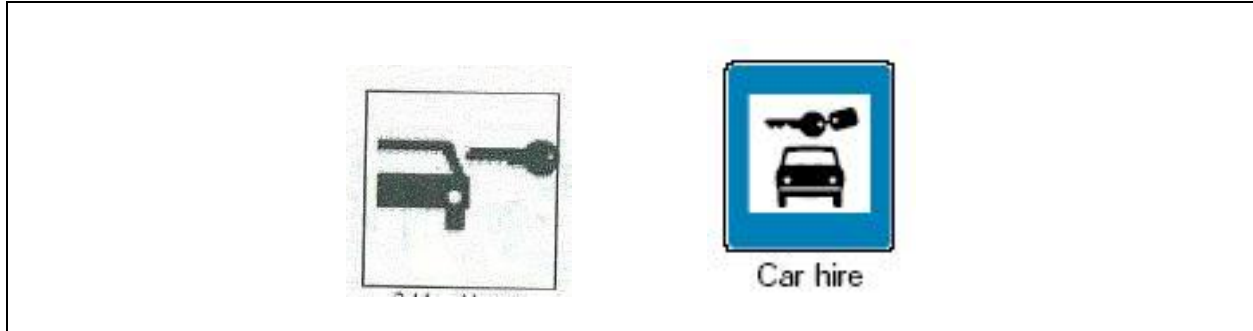


Figure 30: Symbols for Rental Car



Figure 31: Symbols for Ferry

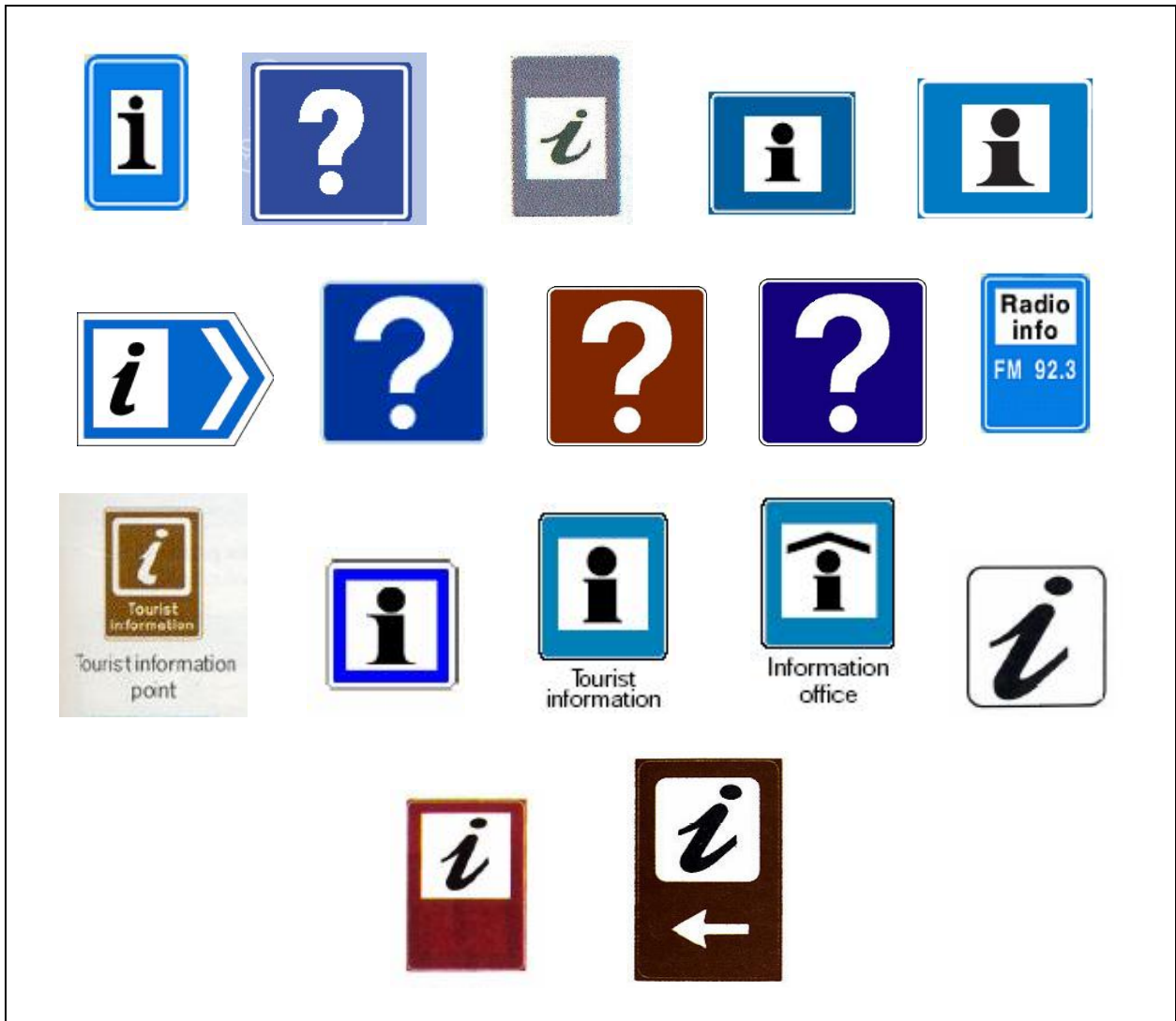


Figure 32: Symbols for Motorist Services Symbols for Information



Figure 33: Symbols for Red Light Photo Enforcement



Figure 34: Symbols for School Bus Stop Ahead



Figure 35: Symbols for Motorcycle Warning



Figure 36: Symbols for Truck Parking

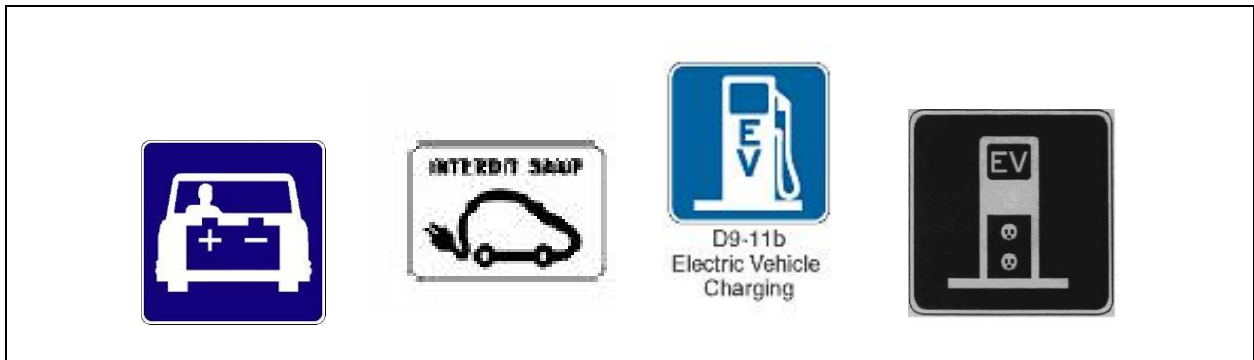


Figure 37: Symbols for Electric Vehicle Charging

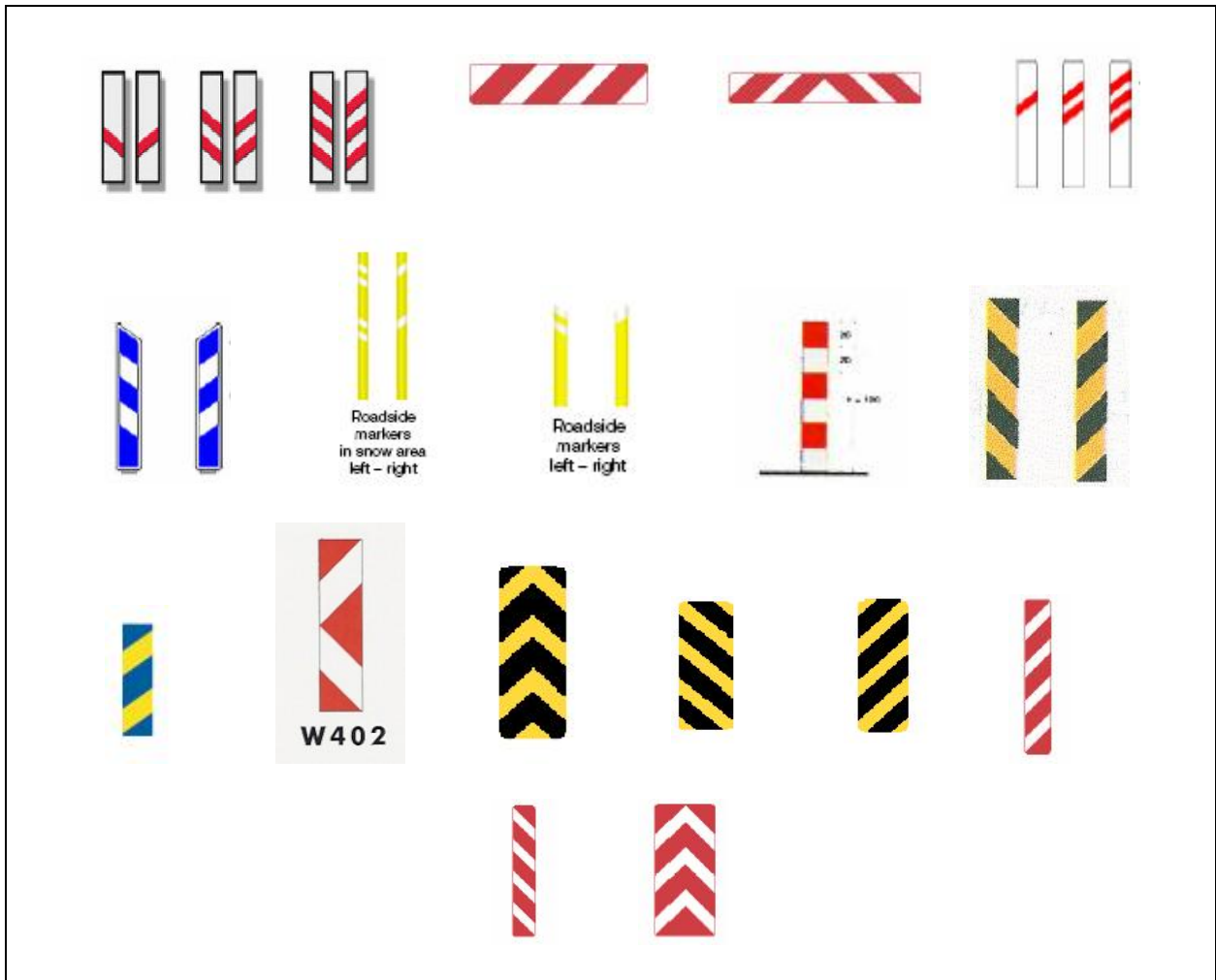


Figure 38: Symbols for Type 3 Object Marker



Figure 39: Symbols for Wireless Internet

**APPENDIX C:
SYMBOLS SHOWN TO TRUCK DRIVERS IN FOCUSED INTERVIEWS**



Figure 40: Symbols for Truck Parking

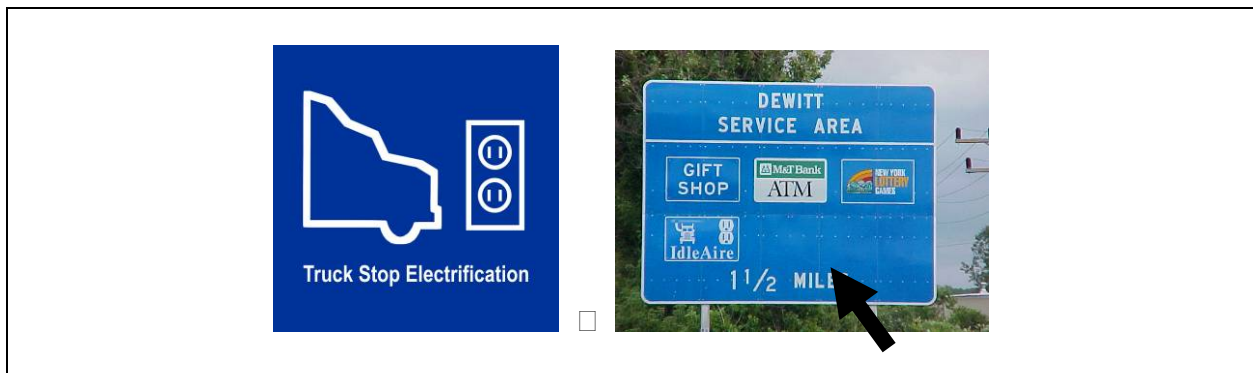


Figure 41: Symbols for Truck Electrification

APPENDIX D: EXAMPLES OF SURVEY INSTRUMENT

The following pages present the questions that were asked for each of the symbols signs evaluated in the study. All 36 symbol sign alternatives were evaluated in the survey activity. Each survey consisted of 5-6 symbol sign categories with each category having only one alternative. Individual survey instruments were prepared in such a way that the survey could be completed in 15 minutes.

For the overall survey activity each of the 36 symbol sign alternatives was seen by 25 people. Since the Type 3 Object Marker had the most alternatives (6), there were no less than 6 versions of the survey. There were many versions of the survey to ensure that all 36 signs alternatives were viewed equally by 25 people. 21 of the surveys were created specifically to include a Truck Electrification and Truck Parking alternative so they could be administered to truck drivers. All participants recorded their own responses to make the survey more efficient. However the participants were observed by the researchers at all times to reduce errors.

WIRELESS INTERNET

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

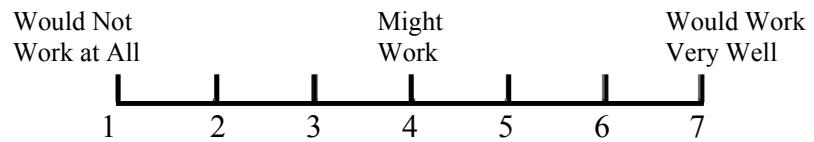
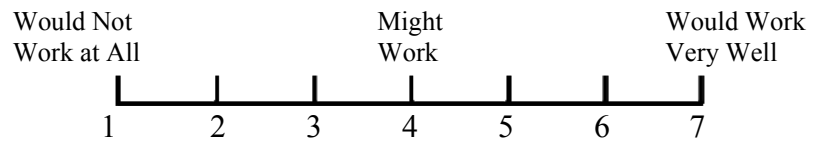
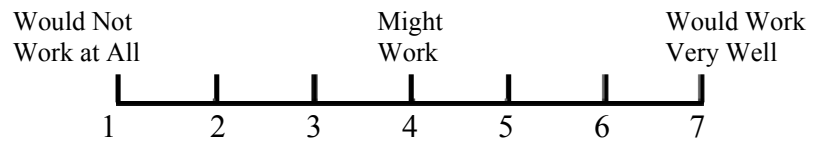
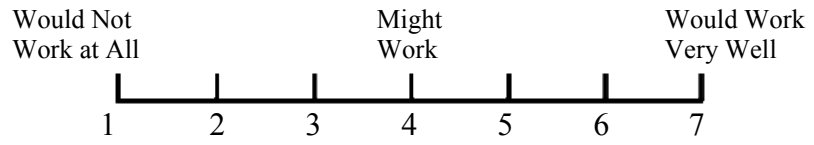
Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- Reduce radio noise at this rest area
- There is a fallout shelter at this rest area
- There is a radio tower at this rest area
- Wireless Internet is available at this rest area
- Satellite radio is available at this rest area

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that wireless Internet is available.



RENTAL CAR

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

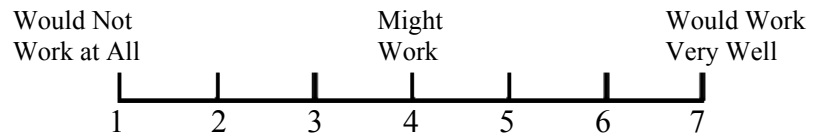
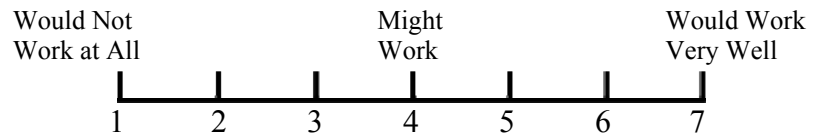
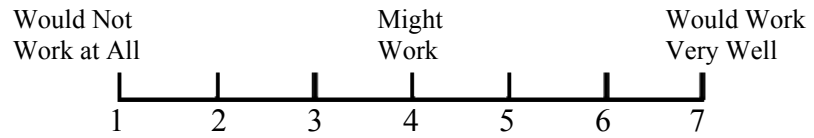
Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- There is a parking lot ahead
- Don't forget to lock your car when parking
- There is valet parking ahead
- There is a rental car facility ahead
- There is a locksmith ahead

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that there is a rental car facility ahead.



FERRY

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- _____ There is high water on the roadway ahead
- _____ There is a ferry access point ahead
- _____ There is a depot for trailers carrying cars ahead
- _____ There is a cruise ship access point ahead
- _____ There is a cargo ship access point ahead

Required Action Image and Question

This sign indicates there is a ferry access point ahead.

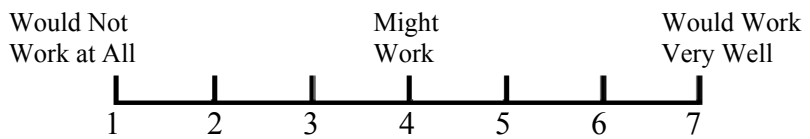
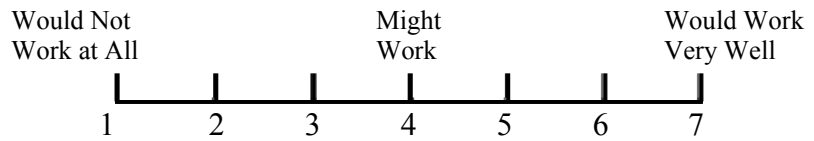
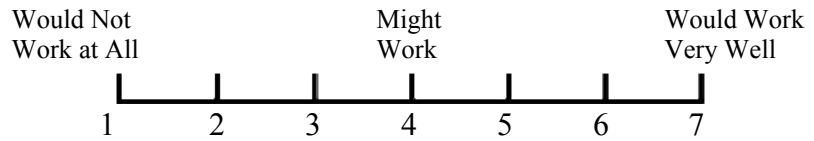


Place an "X" next to the appropriate users of the ferry. (Mark all that apply)

- _____ Cars
- _____ Trucks
- _____ Motorcycles
- _____ Passengers
- _____ Bicycles

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that there is a ferry access point ahead.



INFORMATION

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- Use caution at this rest area
- There is wireless Internet available at this rest area
- Medical assistance is available at this rest area
- There is traveler information available at this rest area

Required Action Image and Question

These signs indicate that information is available at a particular facility.

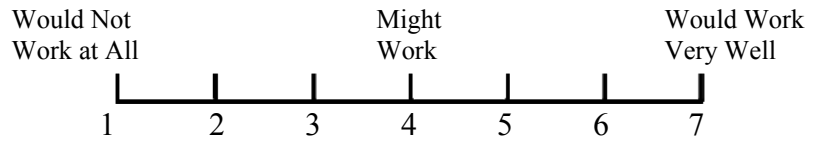
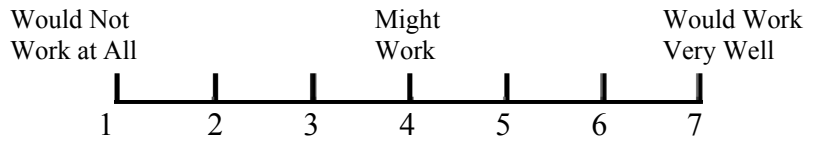
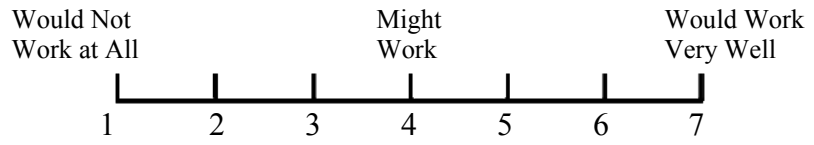


What types of information services do you expect the facility to provide? (Mark all that apply)

- Maps available
- Brochures available of local attractions
- Manned booth during normal business hours
- 24 hour manned booth

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that information is available.



AUTOMATED/PHOTO ENFORCEMENT

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

What action should you take?

Meaning Question

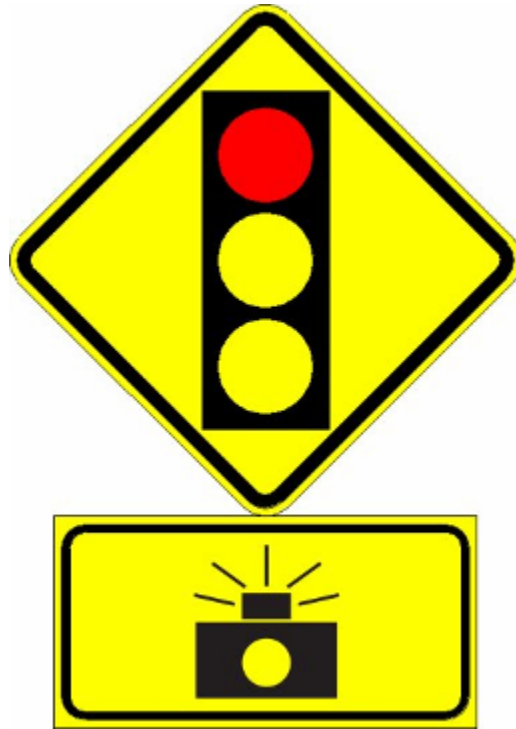
Place an X next to the one choice that best represents the meaning of this sign.

- There are traffic signals with red light enforcement cameras at the intersection
- There may be sun glare ahead
- There is a traffic signal ahead
- There is a scenic view ahead
- Speed limit enforced by radar
- There are speeding enforcement cameras ahead

Required Action Image and Question

This sign is used to indicate there are traffic signals with red light enforcement cameras at the intersection.

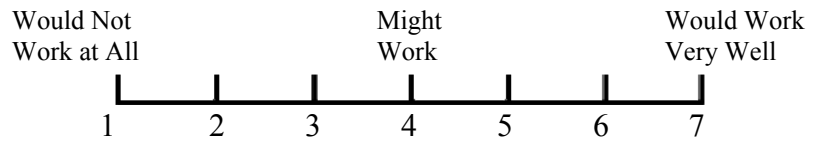
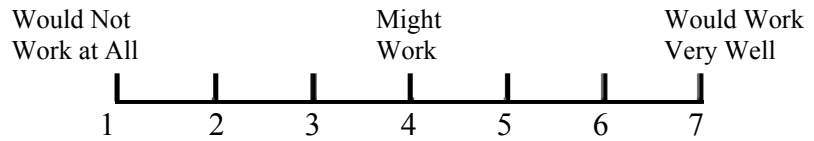
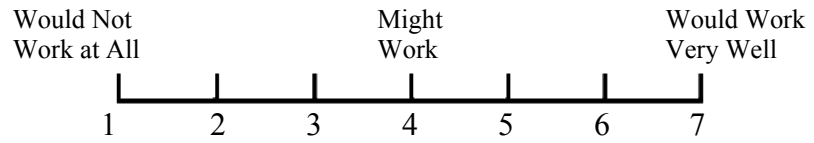
The symbol below can be used for other situations that can be photo enforced.



What other driving situations can be photo enforced?

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that red light photo enforcement cameras are in use.



SCHOOL BUS STOP AHEAD

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

What action should you take?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- There is a school crosswalk ahead
- There is a school bus stop ahead
- Children may be playing in the roadway ahead
- There is a school zone ahead

Required Action Image and Question

This sign indicates there is a school bus stop ahead.
Children might be crossing the street from both sides.



Place an "X" next to the choice that best represents where you expect the school bus stop to be located.

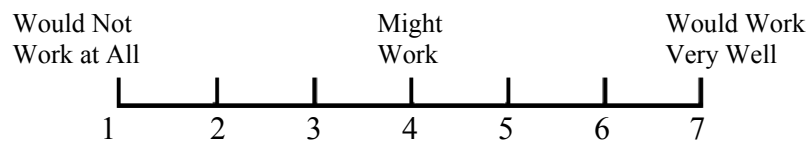
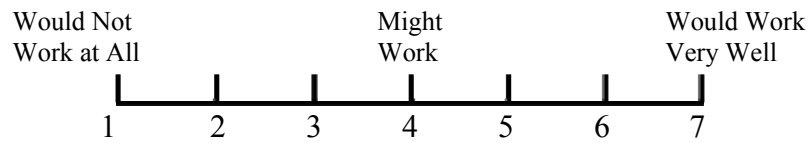
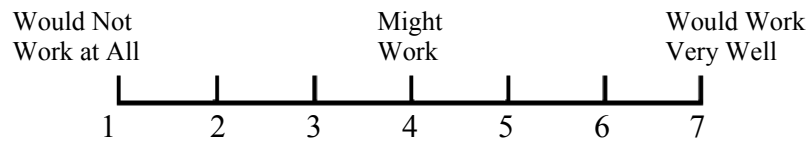
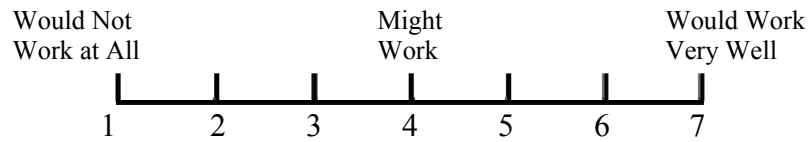
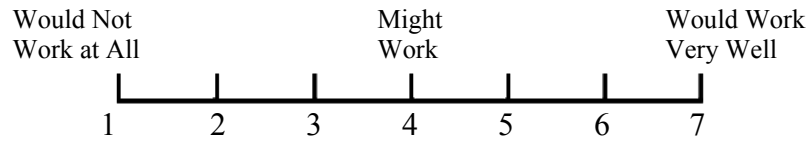
_____ Next to the sign

_____ Up to 500 feet away from the sign

_____ In a location that is not immediately visible to drivers

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that there is a school bus stop ahead.



MOTORCYCLE WARNING

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

What action should you take?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- Wear a helmet for safety
- There is a warning that motorcycles should pay attention to
- Motorcycles are permitted on the roadway
- Watch for motorcyclists
- Motorcycle parking ahead

Required Action Image and Question

This sign warns motorcyclists of grooved pavement.



Have you driven a motorcycle before?

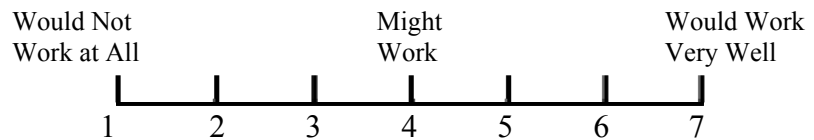
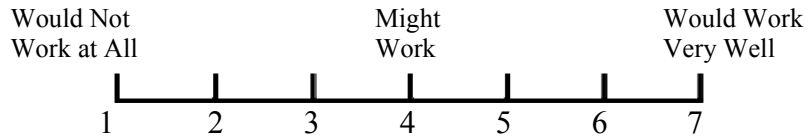
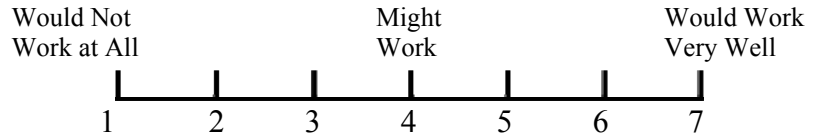
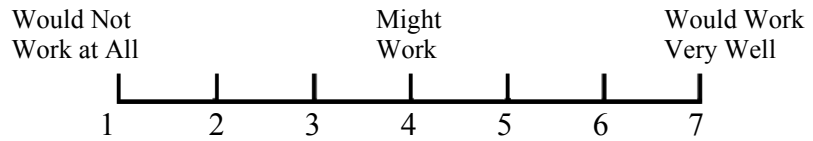
_____ Yes

_____ No

What other hazards do motorcyclists need to watch for?

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that there is a special warning for motorcyclists.



TRUCK PARKING

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- Passing trucks is permitted
- Heavy truck loads permitted
- Truck parking is provided
- Weigh station ahead

Required Action Image and Question

This sign indicates that truck parking is available at a particular facility.

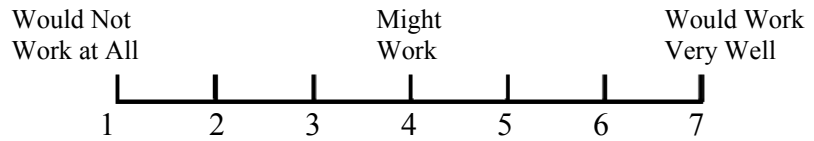
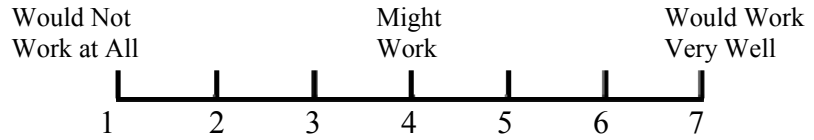
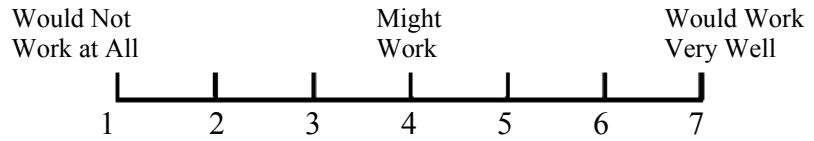


Which of the following vehicles should follow this sign to parking? (Mark all that apply)

- Cars
- Small moving trucks (like U-Haul, Ryder, etc.)
- Tractor trailers
- Recreational vehicles
- Buses

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that truck parking is available.



TRUCK ELECTRIFICATION

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

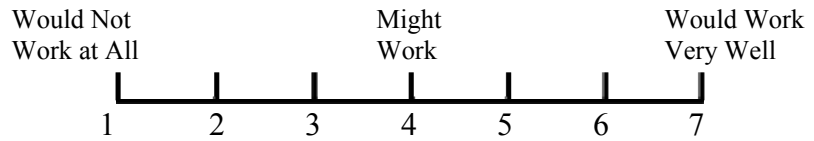
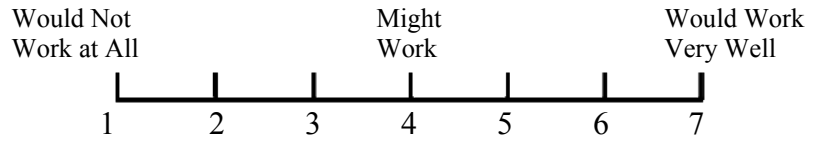
Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- There is truck parking available for electric-powered trucks
- Truck electrification is available at this rest area
- Be cautious of wires across the road
- There is a truck stop ahead
- Truck parking and electric vehicle recharging area

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that truck electrification is available.



OBJECT MARKER

Image Used with Open-Ended and Meaning Questions



Open-Ended Question

What does this sign mean to you?

What action should you take?

Meaning Question

Place an X next to the one choice that best represents the meaning of this sign.

- Roadway ends ahead
- There is a hazardous object behind this sign
- There is a curve to the left ahead
- Construction ahead
- There is a pothole in the road

Required Action Image and Question

This sign indicates there is a hazardous object behind it.



Place an "X" next to the choice that best represents what you should do when you see this sign.

_____ Drive to the right of the sign

_____ Drive to the left of the sign

_____ Sign gives no direction

Rating of Alternatives Question

For each sign below, circle the number on the scale that indicates how well you think the sign describes that there is a hazardous object and that the vehicle should stay left to avoid it.

