**Research Problem Statement**

**Research Problem Title:** Evaluation of Selected Symbol Signs

**Statement of Problem**

The goal of the Traffic Control Device (TCD) Consortium Pooled Fund Study (PFS) is to systematically evaluate traffic control devices with a consistent process that addresses both human factors and operations issues. Given the purpose of traffic signs, to communicate regulatory information, provide warnings, and give guidance to drivers, it is important to perform systematic evaluations of the effectiveness of both existing and new sign designs. (1) This evaluation process can be particularly important for signs containing symbols because they rely on a common non-verbal interpretation of the meaning of the sign by a large and diverse population of drivers.(2) Incorrect interpretations of signs can lead the signs to be ineffective and increase the likelihood of risky driving behaviors.(3) There have been four other symbol sign studies conducted under the TCD PFS.

The objective of this research is to evaluate the following for new and existing symbol and text-based signs and related plaques, as appropriate, to determine the sign that is best understood and most effective at conveying the meaning.

1. The possibility of creating a symbol where one does not exist.
2. Legibility.
3. Driver’ comprehension.

The signs studied may include regulatory, warning, temporary traffic control, or other.

The following sign categories will be included.

1. low bridge clearance,
2. no turn on red,
3. slippery surface,
4. national network,
5. cardinal directional arrow,
6. golf cart and all-terrain vehicle (ATV) warning,
7. frisbee (disc) golf recreation,
8. do not cross freeway,
9. school bus stop ahead,
10. two-way traffic,
11. electronic bicycle (e-bike),
12. vertical curve,
13. keep right,
14. dump truck bed down, and
15. commercial motor vehicles/trucks in multilane roundabouts.

**Summary of Relevant Literature**

Symbol signs, or signs that convey information using symbols rather than text, offer a number of important advantages. Symbol signs can generally be identified from greater distances than text-based signs, such that drivers have more time to react to the information a symbol sign provides.(4) Additionally, symbol signs are often identified more accurately at a glance and in conditions in which vision is significantly degraded (e.g., fog).(5) Importantly, symbol signs are not language dependent, so they may be understood by a diverse group of drivers.

However, the potential advantages associated with symbol signs can only occur if the signs are understood correctly. Several studies have noted the potential for drivers to misinterpret symbol signs.(2,4,6) For example, an assessment by Ben-Bassat and Shinar of 31 regulatory, warning, and information signs, found that driver comprehension was highly variable, with some signs being understood very well, some signs being only partially understood, and some signs being misinterpreted as meaning the opposite of its intended meaning by the majority of participants (e.g., interpreting a “no entry for motorcycles” sign as “motorcycles permitted”).(7) This type of sign misinterpretation can reduce traffic safety since it may produce unpredictable and even dangerous behavior.(3) Therefore, it is critical that symbol signs be properly evaluated to ensure their effectiveness.

**Descriptions of Sign Categories**

The following sections describe each of the sign categories proposed to be evaluated in this research. The specific sign alternatives to be tested in each sign category will be identified and developed as part of the research process if this project idea is selected.

***Low Bridge Clearance***

Over-height crashes occur when a vehicle that is taller than the clearance underneath a structure such as a bridge, tunnel, or overpass collides with that structure. Bridges sustain substantial damage as a result of repeated over-height crashes. In fact, over-height crashes have been sighted as the most common source of bridge damage and the third most common source of bridge failure in the U.S.(8) Over-height crashes also pose a substantial safety concern and disrupt roadway throughput.(9) Given their potential to disrupt roadways, damage infrastructure, and cause injury there is a strong desire to prevent over-height crashes.

The 2009 Manual on Uniform Traffic Control Devices (MUTCD) specifies two signs that can be used to warn drivers about low clearance, W12-2 and W12-2a.(1) Specifically, when clearance is less than 12” above a state’s maximum vehicle height, sign W12-2 or W12-2a should display the actual clearance height (or the clearance height minus up to 3 inches) to the nearest inch either on or in advance of the structure. In addition, if the clearance is less than the state’s maximum vehicle height, the W12-2 sign, with a supplemental distance plaque, should be placed at the nearest point at which an over-height vehicle could detour or turn around. Testing could evaluate the potential for a symbol sign to convey low bridge clearance information to drivers.

Commercial motor vehicle (CMV) drivers would be the primary road users who are affected by these signs, and therefore should be included as participants in the study. While testing the general driving public would be necessary to determine whether the symbol sign(s) could be mistakenly interpreted as applying to them, a subset of the participant population should likely be CMV drivers in order to adequately assess the signs.

***No Turn on Red***

Allowing drivers to turn right during a red signal can be an effective method of increasing throughput at an intersection. However, in some circumstances turning right on red can pose a threat to safety. For example, drivers may be at risk if their view of vehicles approaching from the left is limited by either the angle of the intersecting roadway, the geometry of the intersection, or physical barriers near the roadway.(1) Right turns on reds can also have implications for pedestrian safety. When turning right, drivers tend to focus their attention to the left, to watch for vehicular traffic. With their attention directed to the left, drivers often fail to account for pedestrians who are crossing directly in front of them.(10) Preventing right turns on red can also preserve the safety of a protected pedestrian phase, which can be particularly important at intersections where pedestrian traffic is high or when more vulnerable pedestrians, such as children, older adults, or persons with disabilities frequent a roadway.(1)

The 2009 MUTCD includes the R10-11 series of no turn on red signs, which include the text phrase “NO TURN ON RED.” The R10-11 sign includes a red dot symbol, while the R10-11a and R10-11b signs are completely text based. (1) Testing could assess the potential for a “NO TURN ON RED” sign that does not rely on text.

***Slippery Surface***

Risk of crash involvement is heightened under slippery conditions due to the reduced friction between the pavement surface and tires. When given adequate warning about the presence of a slippery road, drivers can make changes to their behavior that reduce crash risk such as reducing their speed, increasing their following distance, increasing their attention to the road, and reducing overtaking maneuvers.(11) Thus, TCDs that are effective at warning drivers about slippery conditions have the potential to reduce crash risk.

The 2009 MUTCD contains the Slippery When Wet (W8-5) sign which can be used to warn drivers about unexpected slippery conditions.(1) Supplementary plaques (W8-5p, W8-5aP, W8-5bP, W8-5cp) can be added to this sign as a way of indicating the reason that the road may be slippery (e.g., ice, excess oil). Testing could be done to determine (1) if symbols other than the W8-5 could more easily convey slippery surface information to drivers and (2) if the Slippery When Wet (W8-5) sign can be combined with different supplementary plaque messages. For example, there is interest in determining if supplementing the W8-5 with a plaque that reads “BRIDGE FREEZES FIRST” can be used and how sign comprehension and legibility would differ from the BRIDGE ICESE BEFORE ROAD (W8-13) sign.

***National Network***

The national network consists of approximately 200,000 miles of roadway designed to facilitate interstate commerce by linking principal cities and densely developed areas.(12) For areas within the national network, the 2009 MUTCD provides transportation agencies with the option of using national network signs R14-4 and R14-5 to identify routes and ramps along the national route where trucks are and are not allowed. (1) However, some agencies have used, or have interest in using, these signs in other applications (e.g., used as overhead or post-mounted signs in work zones to identify which lanes trucks can/cannot use, as opposed to using a text-only signs to convey this information). Testing could help determine how these signs are interpreted in different contexts and shed light into the potential use of national network signs outside of the national network.

***Cardinal Directional Arrow***

Route signs are used to specify an interstate or route to drivers.(1) Auxiliary signs can be added to the route sign to convey additional information about the route. Cardinal direction auxiliary signs consist of the words “NORTH” (M3-1), “SOUTH” (M3-2), “EAST” (M3-3) and “WEST” (M3-4) to indicate the direction of the route. The 2009 MUTD specifies that cardinal direction auxiliary signs are to be mounted above the route sign. Directional arrow auxiliary signs (M6-1 – M6-7) can also be added to point out the general direction that the route follows. When used, these signs are to be mounted below the route sign.

Auxiliary signs can be helpful in providing route information to drivers. However, in some cases the combination of cardinal direction, arrow, and other auxiliary signs can overwhelm the capacity of the sign assembly, especially for dual post assemblies that attempt to convey information about multiple routes. In these cases, some State DOTs have previously authorized the use of a sign that combines cardinal direction and arrows within the same sign.(13) Combining these two pieces of information within one sign reduced the cost of the route sign; however, it is unclear what effect the combination had on sign comprehension.

***Golf Cart and All-Terrain Vehicle (ATV)***

It is becoming increasingly common for golf carts to be used outside of golf courses. Similarly, ATVs and off highway vehicles have been approved on certain roadways in some States. Where golf cart and ATV traffic is expected it could be beneficial to use TCDs to alert drivers about locations where these types of vehicles may enter the roadway. The 2009 MUTCD includes sign W11-11, a symbol sign depicting a golf cart, for this purpose.(1) However, it is possible that modifications to the warning sign, to make it less golf-specific, may improve drivers’ comprehension of the sign in communities where golf cart traffic is not typically tied to a golf course. Testing could assess this hypothesis and whether a more generic symbol could also be used to warn drivers about ATV traffic.

***Frisbee (Disc) Golf***

The 2009 MUTCD includes recreational and cultural interest area signs (Chapter 2M) that are used to sign for attractions or traffic generators that “are open to the general public for the purpose of play, amusement, or relaxation.” (1) There is a need to identify an appropriate symbol for a frisbee (disc) golf recreation symbol sign to guide road users to frisbee golf facilities.

***Do Not Cross Freeway***

The 2009 MUTCD includes the No Pedestrian Crossing (R9-3) symbol sign to prohibit pedestrians from crossing a roadway at an undesirable location and the NO PEDESTRIAN CROSSING (R9-3a) word message sign that can be used in place of the symbol sign. However, some States continue to have issues with pedestrian deaths due to pedestrians attempting to cross at-grade freeways. In some cases, this may be due to pedestrians not being able to see at safer locations along the roadway (e.g., other cross streets or underpasses where crossing might be safer) and/or unfamiliar pedestrians who are unaware that there is a street crossing available down the road. These scenarios cannot be signed for at ramps where prohibition signs would typically be posted. Several States have developed potential text and/or symbol sign options to either indicate to pedestrians that they should not cross the freeway, or to warn drivers to watch out for crossing pedestrians. Research is needed to determine (1) if there is a symbol sign could be effective in warning pedestrians not to cross the freeway, (2) what combination of sign message and/or symbol would be most effective, and (3) whether the sign(s) should be directed at pedestrians, drivers, or both.

***School Bus Stop Ahead***

Child pedestrians can be at particular risk on the roadway. Their small size can make them difficult for drivers to see and their ability to interact safely with traffic is limited due to their underdeveloped cognitive and motor skills.(14,15) TCDs that warn drivers about locations where children board or exit a school bus are safety critical. The 2009 MUTCD provides S3-1 signs, to warn drivers about the presence of a school bus stop.(1) This yellow warning sign uses red to highlight certain areas of a black bus symbol. Of interest is the value of the inclusion of the red color to the comprehension and legibility of the sign.

***Two-Way Traffic***

The 2009 MUTCD contains the W6-3, Two-Way Traffic sign, which is used to warn drivers about a transition from a multi-lane divided section of roadway to a two-lane, two-way section of roadway.(1) However, it is unclear how this sign would perform in situations where roadwork temporarily creates two-way traffic on one side of the highway, or if alternative, work zone specific signing would be useful. Additional signing may be especially required in situations where drivers are approaching two-way traffic from a crossroad, as the W6-3 sign was intended for drivers who are already traveling in the direction of traffic the sign is referring to.

***E-Bike Signs***

As electronic bicycles become more popular it will be valuable to create TCDs that specify where riders are allowed to ride e-bikes and where e-bikes may be prohibited. The National Park Service has already began testing on symbol signs that may be used for this purpose. Additional comprehension and legibility testing of e-bike signing is needed.

***Vertical Curve***

Signing for horizontal curvature in roadways where drivers’ view is obstructed has been well researched and associated signing strategies are included in the 2009 MUTCD. However, similar research has yet to be conducted for vertical curves. The limited sight distance (W14-4) appeared in the MUTCD from 1978-1988 and the hill blocks view (W7-6) sign first appeared in the 2003 MUTCD.(1) There has been limited research on these signs, or other, limited visibility symbol signs. Furthermore, it would be beneficial to identify signs and/or supplemental plaques that provide clarity in the actual risks (e.g., increase traffic hazards especially when vertical curves are combined with downstream horizontal curvature, intersections, driveways, or other unexpected roadway features) for when there is need to provide warning of a specific hazard. Sign comprehension testing would be helpful in determining (1) what sign legend(s) or symbol(s) would most effectively convey the meaning of the sign and/or specific hazards, (2) if supplemental plaques (e.g., conveying advisory speeds or clarifying messages) help to increase driver comprehension of the hazard and what action they should take, and (3) which legends, symbols, and supplemental plaques are most effective in conveying the need to slow down.

***Keep Right***

The 2009 MUTCD has four options for “Keep Right” signs at median noses (R4-7, R4-7a, R4-7b, and R4-7c); however, the MUTCD does not specify how to select between the R4-7, R4-7a or R4-7b signs or when R4-7a or R4-7b may be more appropriate than the R4-7 sign. Although the R4-7 seems to be commonly used, there still seems to be variation in the use of these signing alternatives. The Notice of Proposed Amendments for the 11th Edition of the MUTCD, includes language stating that the R4-7a or R4-7b sign should be used instead of the R4-7 sign “*where the approach end of the island channelizes traffic away from the approach road, such as at a loop ramp*”, as well as a new standard statement “*If Keep Right signs are installed, they shall be placed as close as practical to the approach ends of the medians and shall be visible to traffic on the divided highway and angled toward the applicable crossroad approach as shown in Figure 2B-18*”. (17)

Research is need to determine (1) which sign alternatives are best understood and deter wrong-way entry (onto typical divided non-limited access highway and specific to median-nose applications), (2) whether mounting a warning or object marker (e.g., OM3L) below the sign improves driver ability to determine where to turn, and (3) in urban settings with constrained space, how do different arrows perform (consider both regulatory and warning options).

***Dump Truck Bed Down***

Dump trucks striking overpasses or overhead sign structures on highways after leaving an active working area (unloading) poses high risk of injury or fatality to the truck driver, operational delays of hours or days while the incident is cleared, significant cost impacts to the structure owner, and potentially catastrophic consequences should the structure fail. It could be beneficial to develop a sign that could be permanently mounted in the right-of-way in locations where these types of dump truck strikes are common (e.g., on public roads outside of permanent industrial land uses that generate high dump truck volumes and/or on freeway on-ramps with high dump truck volumes). Research is needed to determine (1) if it is possible to create a symbol or word message for this situation that could be used as a warning/regulatory/temporary traffic control device, (2) comprehension of various sign alternatives and (3) what type of sign (regulatory, warning, or temporary traffic control) is most appropriate and effective.

While testing with the general driving public would be necessary to determine whether non-truck drivers could mistakenly interpret the sign as applying to them, research would also need to be conducted with dump truck drivers specifically.

***Commercial Motor Vehicles/Trucks in Multilane Roundabouts***

Note: This sign category captures the same concept as the *Use of Signing for* *Safe Operation of Passenger Vehicles and Commercial Motor Vehicles in a Multilane Roundabout* problem statement. The scope in this Symbol Signs problem statement is focused on laboratory sign testing only.

Commercial Motor Vehicles (CMVs), and particularly longer and wider trucks, traversing multiple lane roundabouts can commonly track over lane lines for various reasons including:

* smaller multi-lane roundabouts which encourage straddling of lanes to protect trucks from tapping vehicles in their blind spots,
* trucks desiring the fastest path through the roundabout to keep their momentum, and
* trucks shying away from contacting vertical faced curbs on splitter island and outside edge curbs.

CMVs often have difficulty maneuvering through roundabouts due to the higher turning radius. Depending upon the circumstance, trucks or other CMVs may take multiple lanes and encroach upon vehicle space that might be used by passenger vehicles. This can relate to low-speed sideswipe crashes, contributing to motor carrier dislike for roundabouts. While the 2009 MUTCD addresses traffic control devices within roundabouts, it does not address how to inform drivers about potential conflicts with CMVs within roundabouts. On routes where large vehicles are common (more than one per hour for eight hours in a day, including peak periods) there is a need for a warning sign to help motorist understand the complexities of traversing a roundabout at the same time as large trucks.

**Research Approach**

The objective of this research is to produce data on sign comprehension and legibility of symbol signs on select topics or categories. The assessment would compare existing and new symbol and text signs and supplemental plaques, as necessary, as directed by the TCD PFS members. While a State DOT and/or local jurisdiction interested in using new TCDs or different applications of existing devices would still be required to go through the MUTCD experimentation process, this study could provide an important first step in determining sign designs that would be good candidates for additional testing and implementation.

*Task 1 – Kick-off Meeting and Project Management*

Researchers would attend a kickoff meeting with FHWA and the TCD PFS panel. The researchers would work closely with the project TOCOR and TCD PFS project champions to determine the nature of testing that will be needed for each sign category. In addition to discussing the evaluation approach(es) that would be appropriate for each sign category, the research team will also consider any relevant criteria for research participants involved in the study. For example, some sign categories, such as low bridge clearance and dump truck bed down, may benefit from or require the inclusion of a specific subset of drivers (e.g., CMV or dump truck drivers) to thoroughly address the research questions.

*Task 2 –* *Information Gathering and Sign Development/Selection*

The research team will scan relevant literature and will work with the TOCOR, TCD PFS, MUTCD team, and other stakeholders to identifying potential sign designs and/or sign messages for each sign category. The research team will then work with the TCD PFS to select the sign designs, i.e., sign alternatives, to be evaluated in each sign category.

For sign categories that do not have any existing sign designs, the research team will gather input from the TCD PFS on what people might expect to see on such signs, and may also conduct brief focus groups with the general driving public for additional insight, if needed. Any sign concepts that are developed will be discussed with FHWA and the TCD PFS members to determine which sign alternatives should be evaluated in the study. The research team will then develop the selected sign alternatives for each of the sign categories.

*Task 3 –* *Research Plan Development*

Based on inputs from the kickoff meeting and stakeholder coordination, the research team will develop and submit a research plan that summarizes past research and specifies the signs and methodology that will be used for conducting the study.

*Task 4 – Stimulus Preparation, Data Collection, & Data Analysis*

The research team will develop any needed stimulus and/or visualizations and conduct the laboratory evaluations based on the final research plan. Assessments of sign comprehension will be conducted. Participants may view virtual versions of the signing options and report their understanding of the signs’ intended message. Assessments of sign legibility will also be conducted as appropriate. Participants may view a sign, which expands in size, to simulate driving toward the sign at an appropriate approach speed, and participants would indicate when they can read the sign. Appropriate data analyses will then be performed.

*Task 5 – Final Report and Presentation*

The research team will develop a final report that describes the research approach and results and provides a discussion of the findings. The team will present their findings to the TCD PFS members.

**Chance of Successful Evaluation:**

High

Once TCD comprehension is assessed, a subsequent field study may be needed to examine how drivers respond to signs within a real-world context.

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