TECHBRIEF

Novel Highway Signs to Support Infrastructure-Based Motorcycle-Crash Countermeasures: Phase II

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This document is a technical summary of the Federal Highway Administration report *Novel Highway Signs To Support Infrastructure-Based Motorcycle-Crash Countermeasures: Phase II* (FHWA-HRT-21-010).[1]

OBJECTIVE

Motorcycle crashes make up a disproportionately high number of crashes on the Nation's roadways. Warning signs have the potential to reduce crashes by drawing the attention of road users to situations that may be particularly hazardous for motorcyclists. The current study examined the potential for novel signs to be used as motorcycle-crash countermeasures. The objectives of the project were threefold:

- To develop novel highway sign alternatives that have the potential to act as crash countermeasures for motorcyclists.
- To conduct comprehension and legibility testing of these novel signs.
- To develop a prioritized list of highway sign alternatives that may serve as effective motorcycle-crash countermeasures.

The research team first conducted a review of the literature on existing signing practices. Next, the team generated a preliminary set of novel signs designed specifically to target the needs of motorcyclists. Feedback on this preliminary sign set was solicited from motorcyclists via an online questionnaire. The research team used the results from the questionnaire to narrow and refine the stimulus set. Finally, the team conducted an experimental assessment of sign comprehension and legibility of the novel signs using both motorcyclists and nonmotorcyclists. The result is a prioritized list of five novel signs that may serve as effective motorcycle-crash countermeasures.

REVIEW OF EXISTING SIGNING PRACTICES

Based on research conducted as part of the New/Novel Highway Signs to Support Infrastructure-Based Motorcycle-Crash Countermeasures: Phase I Project and a review of relevant literature, the research team selected four potential sign categories: motorcycle awareness, advance curve warning, pavement condition, and limited sight distance.[2]

Motorcycle-Awareness Signs

A longstanding concern within the transportation safety and motorcyclist communities is the overrepresentation of motorcycle crashes involving moving violations by drivers of other vehicles.[3,4] Multiple factors are

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likely to contribute to the high occurrence of motorcycle crashes involving other drivers, including drivers' expectations about motorcyclists.[4] Because the number of vehicles with four wheels will typically outnumber those with two, drivers scanning the roadway are more likely to look for cars and trucks than motorcycles. Since expectations influence perception, updating drivers' expectations of traffic to include motorcycles could increase motorcycle safety by making it easier for drivers to notice and react appropriately to motorcyclists.[5] For example, Australia uses the sign shown in figure 1 to increase motorcycle awareness.[6,7]

In the United States, the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD) is the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel.[8] To become part of this national standard, new signs (with the exception of signs with word-only messages not otherwise provided for in the manual) must undergo experimentation in accordance with the provisions of the manual and must be approved by the Federal Highway Administration (FHWA). The MUTCD does not currently include any motorcycle-awareness signs. Novel motorcycle-awareness signs, or signs that remind drivers to watch for motorcycles, may have the potential to reduce crashes between motorcycles and other vehicles.

Figure 1. Illustration. Signs designed to increase awareness of motorcycles.[7]

Advance Curve-Warning Signs

Motorcyclists are highly susceptible to crashes when rounding curves in part due to reduced friction. The increased skill required to navigate curves when operating a motorcycle, compared to that required when operating a passenger vehicle, puts motorcyclists at risk, especially when navigating sharp curves (i.e., curves with small radii).[6,9,10] Advance curve-warning signs can alert motorcyclists to the presence of a curve and allow them to take appropriate action before entering the curve, thereby reducing crash risk. The MUTCD contains provisions for several horizontal curve-warning signs that are based on the speed limit on the approach to the curve in combination with the sharpness of the curve, such as Curve (W1-2), Combined Curve and Advisory Speed (W1-2a), Reverse Turn (W1-3), Hairpin Curve (W1-11), 270-Degree Curve (W1-15), and Winding Road (W1-5).[8] For particularly high degrees of curvature, Australia, which uses similar signs, offers the option of adding a supplementary Curve Tightens plaque, shown in figure 2.[6,7] Novel curve signs that are specifically designed to warn about sharp curves or locations with multiple curves could also help motorcyclists navigate curves more safely.

Figure 2. Illustration. Advance curve-warning sign with supplementary Curve Tightens plaque.[7]

Pavement-Condition Signs

Motorcyclists' crash risk increases under adverse pavement conditions. Motorcyclists recognize the importance of warning signs that allow them to identify changes in pavement quality and condition.[11] The MUTCD includes a selection of surface-condition signs (e.g., Loose Gravel (W8-7), Rough Road (W8-8), Grooved Pavement (W8-15), Metal Bridge Deck (W8-16)) to warn road users about road surfaces that may be hazardous.[8] Recognizing the specific risks these conditions pose to motorcyclists, the MUTCD allows State and local transportation agencies the option of installing a motorcycle plaque (W8-15p) as a supplement to these signs. Even so, several transportation agencies have created customized pavement-condition signs that use text and images of motorcycles to warn motorcyclists about potential hazards (figure 3). Novel pavement signs that specifically target motorcyclists have the potential to serve as a useful motorcycle-crash countermeasure.

Note that these customized signs do not comply with the MUTCD and, if not under official experimentation through FHWA, are noncompliant with national standards, so they must be approved by FHWA prior to use in the United States.[11–18]

Limited-Sight-Distance Signs

Since motorcyclists need to monitor the roadway closely for hazards, situations where sight distance is limited can put motorcycle operators at risk. Limited-sight-distance signs have the potential to warn motorcyclists about situations where the road ahead is not visible due to either vertical curves (e.g., steeply graded hills) or horizontal curves (e.g., tight bends in the roadway). The MUTCD currently provides the sign Hill Blocks View (W7-6) to warn about limited sight distance due to vertical curves. This sign has high comprehension and legibility rates among drivers.[19] The potential for motorcyclists to benefit from limited-sight-distance signs that specifically target motorcyclists approaching vertical curves has not been tested. There is also a need for signs that warn drivers, and especially motorcyclists, of limited sight distance due to horizontal curves.

NOVEL SIGN DESIGNS CONSIDERED

Warning signs have the potential to reduce motorcycle crashes by drawing motorcyclists' and other road users' attention to each other's presence as well as to selected areas and features of the roadway that are particularly hazardous to motorcyclists. After reviewing relevant literature and examining signs currently in use by local, State, and international transportation agencies, the research team generated a preliminary sign set comprising 12 novel signs specifically designed to target the needs of motorcyclists.

The research team sought input and feedback from relevant stakeholders to reduce and refine the preliminary sign set. To solicit this feedback, the team created a questionnaire and distributed it to members of the motorcycle riding community. The questionnaire asked motorcyclists to rate the usefulness of each sign in the preliminary sign set. After viewing all the novel signs, participants were asked to select the three signs they felt were the most useful. Participants were then allowed to provide written feedback about the signs they had seen and about any additional signs they thought could be used to increase motorcycle safety.

Motorcyclist Feedback

A group of 1,025 motorcyclists from across the country volunteered to provide feedback using an online questionnaire. To determine mean usefulness values, researchers asked participants to rate each of the novel signs in the preliminary sign set on a scale of 1 through 4, with 1 being very useful, 2 being somewhat useful, 3 being not very useful, and 4 being not at all useful. Signs already included in the MUTCD were also rated to serve as control stimuli to which the novel signs could be compared.

Figure 3. Illustration. Examples of customized signs used to warn motorcyclists about pavement conditions.[16, 18]

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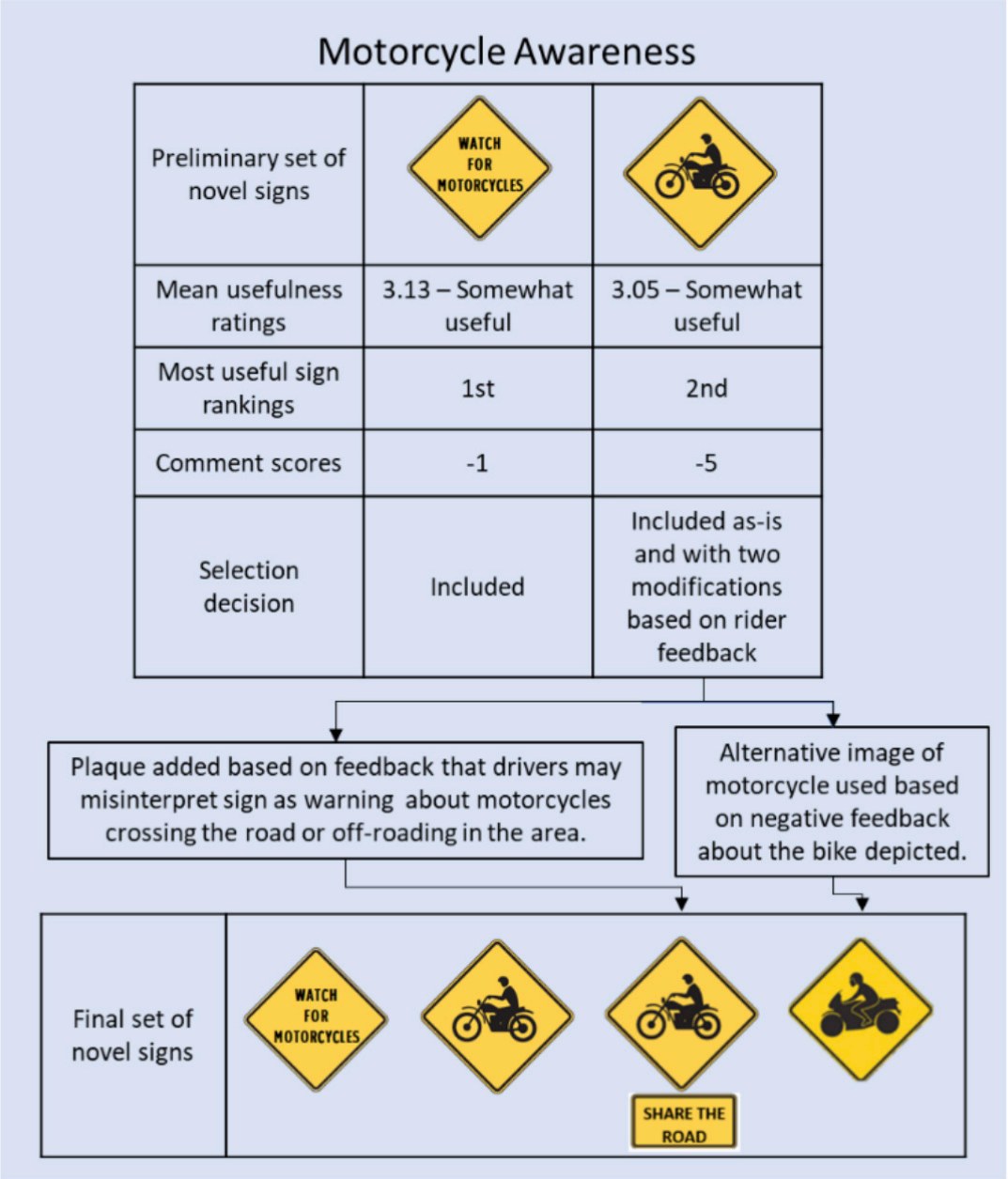
Figure 4. Graphic. Selection process for motorcycle-awareness signs.



Source: FHWA.

Participants were shown a table containing all the novel signs and asked to indicate which sign was the most useful, second most useful, and third most useful. Responses were given weighted scores based on the frequency with which they were chosen for each position, with signs chosen as more useful receiving higher weights. Weighted scores were used to order the signs from 1st to 20th most useful.

Researchers encouraged participants to provide comments and suggestions about the signs. To quantify these comments, each comment was categorized as either positive or negative (table 1). Comments scores were generated by counting the number of positive comments for each sign then subtracting the number of negative comments from that total. The majority of comments about signs were critical or provided suggestions for improvement. As a result, most signs had negative comment scores.

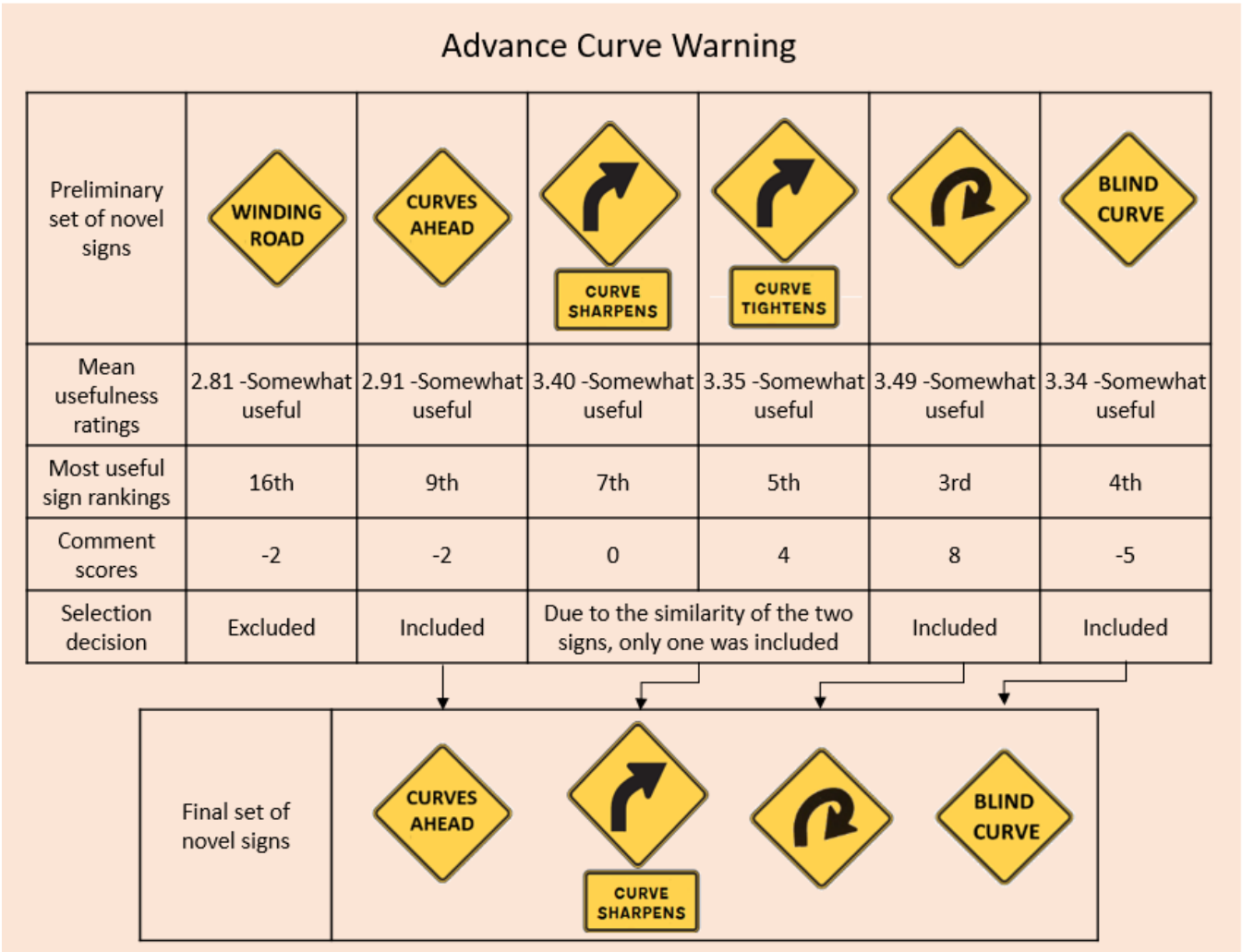
The research team used the feedback from the motorcyclists who completed the questionnaire to select the final set of stimuli to include in the comprehension and legibility experiment. The selection process was based on a combination of each sign's mean usefulness rating, most useful ranking, comments score, and feedback from motorcyclists. The selection process for the motorcycle-awareness signs is outlined in figure 4.

Table 1. Example of positive and negative comments for two novel signs.

Sign	Example of Positive Comment	Example of Negative Comment
	"Please put up more [of this sign] to make motorists aware of motorcycles on the road."	"When a dual-purpose bike is shown it tends to make me think it is for that type of bike only."
	"[This sign] is important when conditions call for it."	"I think that it's important to keep signs as simple and easy to read as possible. For that reason, I don't think that [this sign] would be as effective as the others."

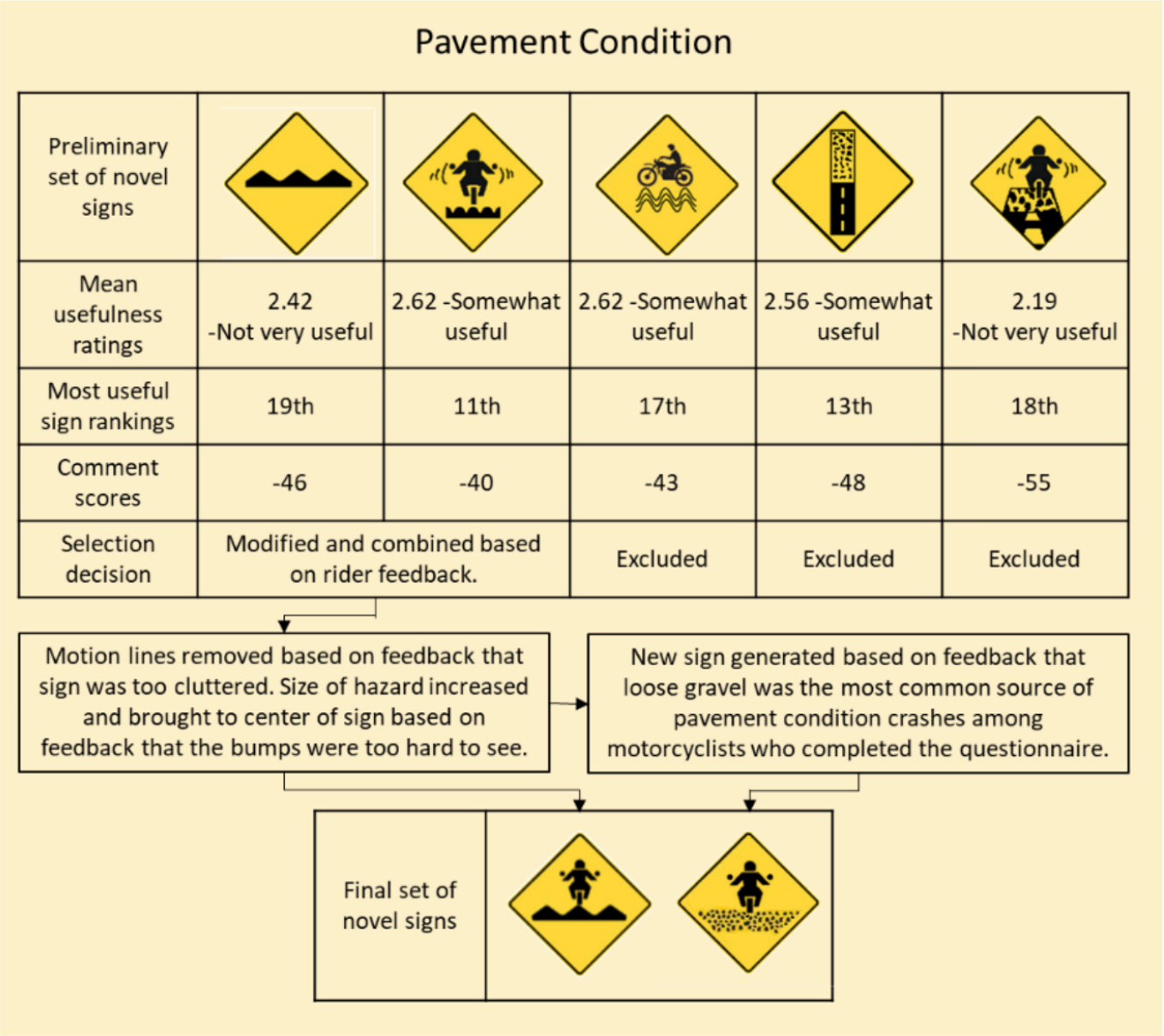
Source: FHWA.

Figure 5. Graphic. Selection process for advance curve-warning signs.



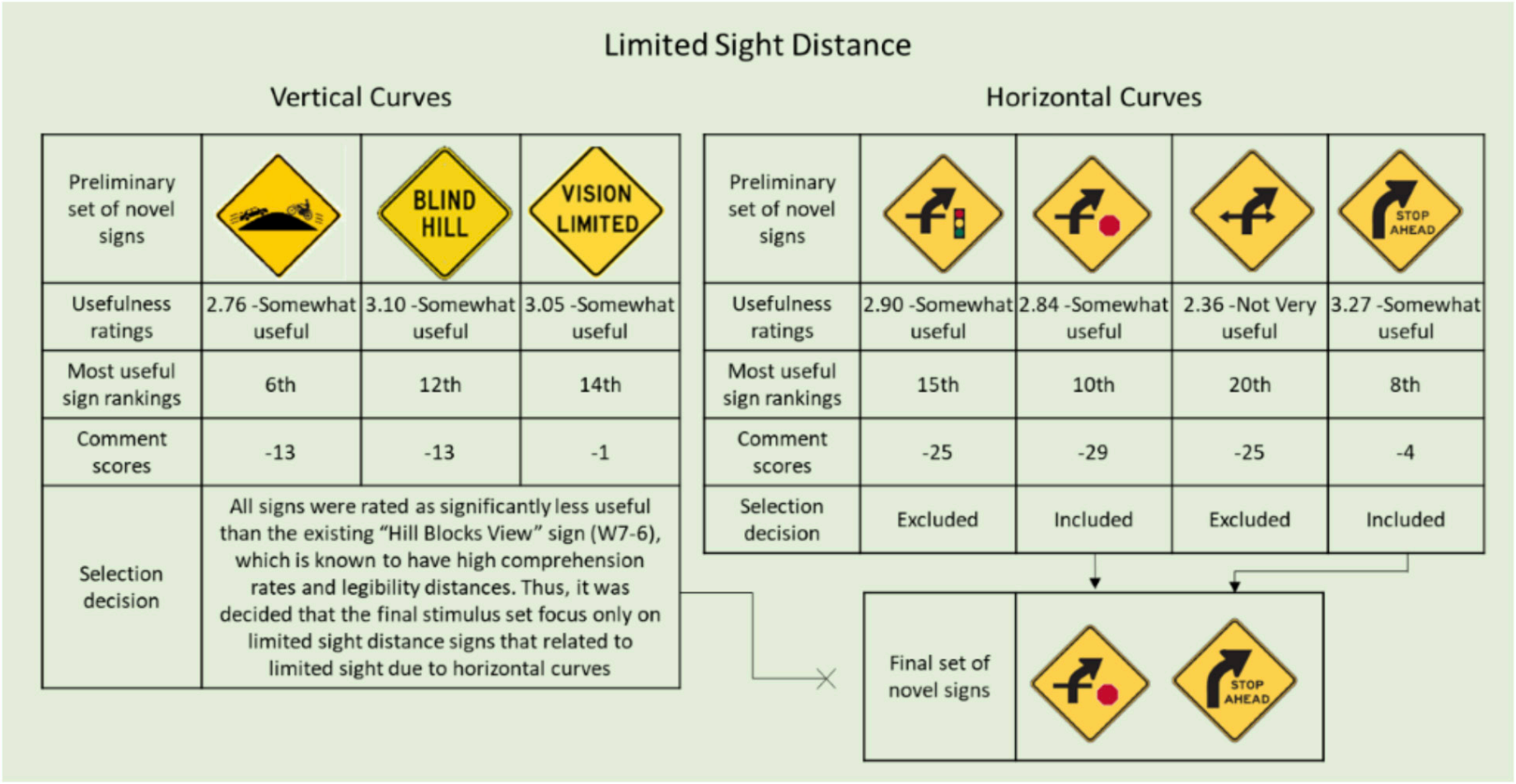
Source: FHWA.

Figure 6. Graphic. Selection process for pavement-condition signs.



Source: FHWA.

Figure 7. Graphic. Selection process for limited-sight-distance signs.



Source: FHWA.

Figure 5 describes the process for selecting advance curve-warning signs, while figure 6 and figure 7 describe the selection processes for pavement-condition and limited-sight-distance signs, respectively.

COMPREHENSION AND LEGIBILITY EXPERIMENT

The comprehension and legibility experiment assessed the final set of novel signs using both motorcyclists and nonmotorcyclists. Comprehension testing compared participants' understanding of the novel signs to their understanding of signs that are already part of the MUTCD. Legibility of the novel signs was also tested to determine whether the novel signs can be seen and understood at distances comparable to those of existing MUTCD signs and at legibility distances recommended by the MUTCD.

Participants

Fifty licensed drivers participated in the study. All participants were at least 18 yr of age and were recruited from the Washington, DC, metropolitan area. Participants were recruited to represent the gender distribution of motorcyclists in the United States. Half of the participants were motorcyclists.

Procedure

Testing was conducted at the Turner-Fairbank Highway Research Center in the Highway Sign Design and Research Facility. After reviewing and signing an informed consent certification, each participant performed comprehension and legibility testing. During each trial, participants were shown an image of a sign positioned on the edge of a roadway. Participants from the motorcycle riding community were asked to imagine they encountered the sign while riding their motorcycle. Participants who were not motorcyclists were asked to imagine they encountered the sign while driving. All participants were asked to describe the meaning of the sign, and open-ended responses were recorded. Next, participants were asked to indicate the intended audience for each sign to assess whether signs designed for motorcyclists are still seen as relevant to other drivers (figure 8). Finally, participants were given a description of the intended meaning of the sign and asked to rate how effectively the sign conveyed that message on a scale of 1 through 4, with 1 being very effective, 2 being somewhat effective, 3 being somewhat ineffective, and 4 being not at all effective. Participants also ranked the motorcycle-awareness signs from most effective to least effective.

To assess legibility, the signs were shown one at a time beginning at a simulated distance of 1,000 ft. The signs then expanded in size to simulate an approach speed of 45 mi/h. Participants pressed a button to indicate when the sign became legible and, after verifying legibility, the legibility distance was recorded.

Results and Conclusions

The comprehension and legibility results for the four sign types are described in the following sections.

Motorcycle-Awareness Sign Alternatives

The intent of motorcycle-awareness signs, illustrated in figure 9, is to increase awareness among the broader driving population (i.e., both motorcyclists and non-motorcyclists) of the presence of motorcycles on the roadway. Of the signs tested, sign m2, which features an image of a motorcycle, was described accurately most often during the open-ended response portion of the comprehension testing and had the greatest legibility distance. Sign m3, which uses the same image of a motorcycle and includes a Share the Road plaque, received the highest ratings of effectiveness and was ranked as most effective at raising motorcycle awareness during the ranking task. Overall, the results speak to the potential for signs m2 and m3 to serve as motorcycle-crash countermeasures.

Advance Curve-Warning Sign Alternatives

The advance curve-warning signs tested during the comprehension and legibility experiment are shown in table 2. Sign c3, an arrow sign that depicted a particularly sharp curve, was found to have high potential utility as a crash countermeasure. The sign had comprehension rates that were higher than those

Figure 8. Screenshot. Example of a sign used for comprehension testing.

Source: FHWA.

for other novel signs tested but similar to those for the curved arrow signs that are already part of the MUTCD. Similarly, legibility distances for sign c3 were greater than the other novel signs tested and not significantly different for those found for existing signs c11 (W1-5) or c12 (W1-11). The findings suggest that sign c3 may have value as a motorcycle-crash countermeasure; however, it is not necessarily advisable to use a symbol that overstates the sharpness of the upcoming curve or to use an excessive number of curve signs in any given area. Installation of the sign would need to be carefully considered to confirm it is installed in locations where the curve depicted in the sign can serve as an accurate representation of the curve it is intended to warn about and that measures are taken during installation to reduce sign clutter as necessary.

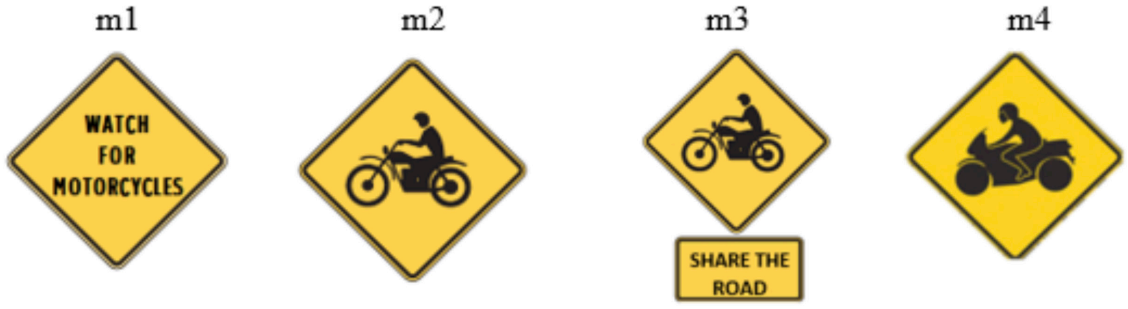
Pavement-Condition Sign Alternatives

The pavement-condition signs, shown in table 3, included two traditional, text-based signs (p11, Rough Road (W8-8) and p12, Loose Gravel (W8-7)) as well as two novel, symbol-based signs, p1 and p2, which were similar to those used in some other countries.[14] Signs p1 and p2 were the only signs described as being specifically intended for motorcyclists more frequently than being meant for all road users, a finding resulting from the use of motorcycle images on the sign. The use of the motorcycle image on the sign allowed the sign to target motorcyclists but did not increase the comprehension ratings among that group. Motorcyclists rated the traditional text-based signs (p12 and p11) as more effective at conveying their intended meanings than the novel signs (p1 and p2). Sign p2, where the gravel appears to be somewhat inconspicuous, showed reduced legibility distance relative to the other signs. Based on these results, it is unlikely that the novel signs would be more effective crash countermeasures than the existing text-based signs. However, the novel sign p1 may be a candidate for installation in situations where a text-based sign would not be as effective, such as on a roadway where English is not the primary language for a large number of motorcyclists.

Limited-Sight-Distance Sign Alternatives

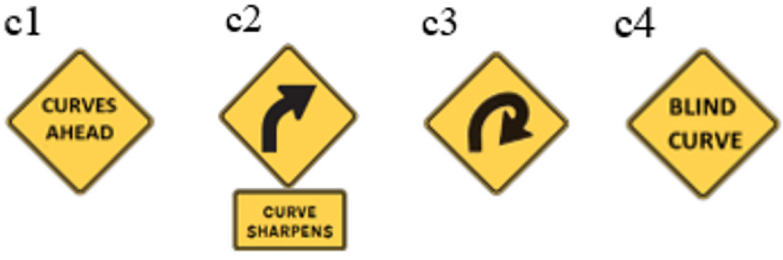
The four signs that focused on alerting drivers to locations where sight-distance limitations exist due to horizontal curves are shown in table 4. When participants in the comprehension and legibility experiment were asked the meaning of the novel limited-sight-distance signs, both signs were described

Figure 9. Illustration. Motorcycle-awareness sign alternatives.



Source: FHWA.

Table 2. Advance curve-warning sign alternatives.

MUTCD Advance Curve-Warning Signs	Novel Advance Curve-Warning Signs
	

Source: FHWA.

with nearly perfect accuracy. Additional ratings of comprehension and legibility revealed that sign s1, which uses symbols, had higher legibility distances but lower comprehension ratings than sign s2, which included text. These results demonstrate important differences in sign efficacy frequently seen in the literature. Symbol-based signs are generally recognizable at greater distances than text-based signs, but text-based signs are generally easier to understand.[19]

RECOMMENDATIONS AND CONCLUSIONS

A list of novel signs that have the potential to serve as motorcycle-crash countermeasures is displayed in table 5. Advance curve-warning and limited-sight-distance signs may be easier to implement than motorcycle-awareness signs because candidate locations for these signs are likely to be easier to identify than for the motorcycle-awareness signs. Advancements in wireless communication, in particular vehicle-to-vehicle (V2V) communication, could help increase other motorists' awareness of motorcyclists. V2V technologies could detect motorcyclists on the roadway and communicate that information to the motorist using in-vehicle alerts with messaging similar to that tested in the current study.

The following list provides recommendations and considerations for potential on-road MUTCD experimentation using the recommended signs. These recommendations are based on the results of the human-factors evaluation, including both comprehension and legibility, as well as the practical applicability of the various sign alternatives. Conclusions regarding the use of potential sign alternatives also follow:

- Text-based signs are generally easier to understand than symbols, although symbols are easier to see from a distance. Combining text with symbols does not necessarily address these concerns due to font size decreasing when text is included with a symbol or as a plaque.
- The sign types that are likely to produce the most tangible impacts on driver behavior are the advance curve-warning and limited-sight-distance signs, in that order. Candidate locations for the available sign alternatives are likely to be straightforward to identify based upon crash data, roadway inventory data, or local knowledge of the roadway network. Motorcycle-awareness signs will be more challenging to deploy due to the need for long-term research on more detailed motorcycle-specific volume data.

Table 3. Pavement-condition sign alternatives.

MUTCD Pavement-Condition Signs		Novel Pavement-Condition Signs	
p11	p12	p1	p2
			

Source: FHWA.

Table 4. Limited-sight-distance signs.

MUTCD Limited-Sight-Distance Signs		Novel Limited-Sight-Distance Signs	
s11	s12	s1	s2
			

Source: FHWA.

Table 5. List of recommended sign alternatives.		
Advance Curve-Warning Sign Alternatives	Limited-Sight-Distance Sign Alternatives	Motorcycle-Awareness Sign Alternatives
c3 	s1  s2 	m2  m3 

Source: FHWA.

- Advance curve-warning signs are likely to present the most potential for safety improvement; however, they should not necessarily be installed at all types of curves as the sign impacts may degrade if installed at gradual curves where the symbol tends to overstate the actual sharpness of the curve. In addition, consideration should be given to users' ability to comprehend the sign when combined with an advisory speed plaque and the effect that this combination would have on motorcyclists and other road users' behavior.
- The limited-sight-distance signs include two novel signs that were newly evaluated. Ultimately, research has shown that sight distance tends to be a particular concern on horizontal curves only when there is a hidden intersection or driveway; this is the scenario in which such signage is likely to have the greatest impact.

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