Identifying Infrastructure-Based Motorcycle-Crash Countermeasures: Phase I

Final Workshop Finding Report

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U.S. Department of Transportation
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Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

To date, efforts to address motorcycle crashes have largely focused on driver-behavior issues. Infrastructure-based motorcycle-crash countermeasures can significantly improve motorcycle-rider safety; however, identifying effective countermeasures can be challenging. Research is needed to identify infrastructure-based countermeasures that could be used to reduce the frequency and consequences of injurious and fatal motorcycle crashes.

To respond to this need, the Federal Highway Administration sponsored a project to identify three to five infrastructure-based motorcycle-crash countermeasures to consider for future research. A workshop, Identifying Infrastructure-Based Motorcycle-Crash Countermeasures, was conducted to develop a list of prioritized infrastructure-based motorcycle-crash countermeasures. This report presents the workshop overview and results. This report will be of interest to engineers, academics, researchers, industry partners, and riders involved in the design, construction, installation, and testing of infrastructure-based countermeasures to address motorcycle crashes.

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Acting Director, Office of Safety Research and Development

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16. Abstract
In 2017, the Federal Highway Administration sponsored a project to identify three to five infrastructure-based motorcycle-crash countermeasures to consider for future research. To develop a list of prioritized infrastructure-based motorcycle-crash countermeasures, a workshop titled Identifying Infrastructure-Based Motorcycle-Crash Countermeasures was conducted on February 13, 2018, in Arlington, VA. The workshop opened with an introduction that provided participants with results from the prior tasks of the project, including an analysis of the data from the Motorcycle Crash Causation Study and a literature review. Participants discussed countermeasures from the prior tasks as well as the addition of other countermeasures. At the end of the workshop, a number of participants voted for their preferred countermeasures to develop a list of prioritized countermeasures. This report presents the workshop overview and results.

17. Key Words
Motorcycle safety, motorcyclist fatalities, infrastructure-based countermeasure

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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LIST OF ABBREVIATIONS

FHWA	Federal Highway Administration
ITS	intelligent transportation system
MCCS	Motorcycle Crash Causation Study
MUTCD	*Manual on Uniform Traffic Control Devices*
NASS GES	National Automotive Sampling System General Estimates System

CHAPTER 1. INTRODUCTION

In 2017, the Federal Highway Administration (FHWA) sponsored a research project to identify three to five infrastructure-based motorcycle-crash countermeasures to consider for future research. The first project within task B was to conduct a literature review to identify the range of infrastructure-based motorcycle-crash countermeasures that are currently deployed or could be deployed to lessen motorcycle-crash risks, including mitigating injuries and reducing fatalities. The second project activity within task B consisted of an indepth analysis of the Motorcycle Crash Causation Study (MCCS) database to determine what infrastructure-based motorcycle-crash countermeasures, if implemented on a wide scale, could address the greatest number of motorcycle crashes.[(1)] The results of both activities within task B provided critical information regarding available infrastructure-based motorcycle-crash countermeasures and crash analyses to a multidisciplinary group of motorcycle stakeholders. Using this information, the stakeholders were asked to prioritize the list of countermeasures to consider for further research.

To refine the prioritization of infrastructure-based motorcycle-crash countermeasures, a workshop was conducted on February 13, 2018, in Arlington, VA, to solicit input from key stakeholders. This activity was task C of the project.

This report is an overview of the workshop and documents its results and conclusions. The workshop was a 4-h meeting to solicit input from key stakeholders on the proposed countermeasures, including their perceptions of which to consider for further research. The workshop began with an introduction and project overview by the FHWA project Task Order Contracting Officer's Representative, an introduction by the FHWA Office of Safety Research and Development Director, and introductions by key stakeholders who joined the meeting in person and by Web-conference platform. An overview of the project and workshop activities and goals was followed by a presentation of the literature review and a presentation of the MCCS database-analysis results. The key stakeholders then discussed the identified countermeasures and conducted the countermeasure prioritization activity. The final segment of the workshop consisted of a presentation of the finalized countermeasure prioritization as well as an evaluation of the workshop by the key stakeholders in attendance. Within 1 mo after the conclusion of the workshop, the FHWA project staff reviewed the stakeholder-prioritized list and established a final prioritization.

This report also summarizes the workshop activities and includes a list of key questions that could be answered using the MCCS database as well as a logical mapping between the questions and the highest priority countermeasures. Collectively, the prioritization activity conducted during the workshop provided a list of infrastructure-based motorcycle-crash countermeasures to consider for future research.

CHAPTER 2. WELCOMING REMARKS, WORKSHOP OBJECTIVES, AND FHWA PERSPECTIVE

The workshop began with welcoming remarks from Mr. Yusuf Mohamedshah, Research Highway Safety Specialist at FHWA, and Ms. Monique Evans, former Director of the Office of Safety Research and Development at FHWA. Their introductions included the following:

- A welcoming for all attendees.
- An explanation that the workshop was part of a deliverable for an FHWA-funded project.
- An introduction to the MCCS and its relation to the workshop.
- A discussion of the potential for the workshop results to inform future research.

ATTENDEE INTRODUCTIONS

Following the introductions by Mr. Mohamedshah and Ms. Evans, attendees introduced themselves. Attendees included broad representation from motorcycle manufacturers, research institutes, academic institutions, Federal Government, private companies, and engineering and safety consultants. In addition, a majority of the attendees were active motorcycle riders.

REVIEW OF THE PROJECT, PREWORKSHOP MEETINGS, AND WORKSHOP GOALS

A brief overview of the workshop agenda and documents in the attendee folders was provided. Next, an overview of the project goal, which was to identify three to five infrastructure-based motorcycle-crash countermeasures to consider for future research, was provided. To reach this goal, the project outlined the following tasks:

- Analyze the MCCS database to identify crash-causation factors that could be addressed by infrastructure-based motorcycle-crash countermeasures.

- Review literature of infrastructure-based motorcycle-crash countermeasures.

- Conduct a preworkshop meeting to narrow the countermeasures being considered.

- Conduct a workshop to identify three to five countermeasures to consider for future research.

Attendees who agreed to participate in the workshop also took part in the preworkshop meetings on February 2 or February 5, 2018. The goals of the preworkshop meeting were as follows:

- Review the MCCS database analysis and the results of the analysis.

- Review the infrastructure-based motorcycle-crash countermeasures identified in the literature review.

- Describe the rationale for prioritizing the list of countermeasures.
- Conduct an initial prioritization of the countermeasures to arrive at a list of 10 for an indepth discussion during the workshop.

The goals of the workshop were as follows:

- Discuss and reprioritize the top 10 infrastructure-based motorcycle-crash countermeasures identified during the preworkshop meeting.
- Prioritize a list of MCCS database questions.
- Link the prioritized countermeasures with the MCCS questions.

CHAPTER 3. SUMMARY

REVIEW OF COUNTERMEASURES AND IDENTIFICATION OF COUNTERMEASURE-IMPLEMENTATION BARRIERS

The following list contains the top 10 countermeasures prioritized in the preworkshop. The items appear in order of rank and include the identification number in parentheses:

1. Guardrail continuous-protection system (5.1).
2. Pavement-condition repair (2.3).
3. High-friction surface treatment (2.1).
4. In-curve warning signs (5.7).
5. Lighting (1.6).
6. Remove roadside trees and poles (5.10).
7. Signals (1.4).
8. Punctual energy absorber (5.3).
9. Limited-sight-distance warning signs (1.2).
10. Prohibitive signs (1.3).

Attendees raised the notion that the list of 10 countermeasures was diverse, but none of the countermeasures would prevent a crash or help a rider survive a crash. This idea resulted in a group discussion of what countermeasures should be included in the prioritization activity. Attendees agreed that it is always more desirable to prevent a crash than to mitigate a fatality or injury after a crash. The list of countermeasures from the preworkshop prioritization activity focused on both crash mitigation and prevention, whereas countermeasures identified in the MCCS database analysis focused primarily on crash prevention. After a detailed discussion of the crash-prevention and crash-mitigation approaches, attendees had two recommendations: that the remainder of the workshop discussion be focused on the top eight countermeasures identified in the previous MCCS analysis and that these countermeasures serve as the core list for the prioritization task with the option to include additional countermeasures identified in the literature review as needed.

Researchers agreed that the approach attendees recommended was appropriate, but it necessitated a significant modification to the workshop agenda. If time did not permit, it was allowable to not pursue prioritizing the list of MCCS database questions and linking the prioritized countermeasures with the MCCS questions. The discussion about identifying barriers to countermeasure implementation concluded early to ensure sufficient time to review of the MCCS database analysis.

SUMMARY OF THE REVIEW OF THE MCCS DATABASE ANALYSIS

The review of the MCCS database analysis began with a short description of the MCCS. The purpose of the MCCS was to update the Hurt Report, which was used to collect data in the late 1970s.[1,2] In contrast, the MCCS data were collected from 2011 to 2016.[1] Similar to the Hurt Report, the MCCS data represented motorcycle crashes that occurred in Orange County, CA.[1] The MCCS database includes information on 351 motorcycle crashes and 702 motorcycle-crash control cases.[1] The three main components of the MCCS analysis included completing the following:

- Determining how well the MCCS data represented motorcycle crashes at the national level.

- Identifying infrastructure-based motorcycle-crash countermeasures that could address the major crash categories observed in the MCCS data.

- Estimating the potential benefit of implementing those infrastructure-based motorcycle-crash countermeasures at the national level.

Eight countermeasures that could address at least 500 motorcycle crashes per yr were identified from the MCCS analysis. These countermeasures included the following:

- Improving sight distance for intersections.
- Improving sight distance for nonintersections.
- Installing no-left-turn signs.
- Installing retroreflective striping.
- Installing warning signs for intersections ahead and for merging/oncoming traffic.
- Installing stop signs.
- Installing curve-speed warning signs.

Researchers then discussed the benefits of the MCCS database. These benefits included the fact that the MCCS database is a rich source of information that contains structured data, narratives, photographs, and diagrams. The MCCS database is unique in that it contains extensive data on infrastructure-related factors at the time of the crash; however, a limitation of the database is that the data represent a small geographic area (Orange County, CA), which may not be representative of the entire United States. Researchers addressed this limitation by calibrating the MCCS database so the data more closely matched the crash distribution in the National Automotive Sampling System General Estimates System (NASS GES) dataset.[3] Due to the limited sample, the analysis may have missed infrastructure-based motorcycle-crash countermeasures that were important regionally or nationally. An additional limitation was that crashes from the MCCS database could not be mapped appropriately to the NASS GES database to fully explore the potential benefit of some countermeasures (e.g., ensuring proper cross slope, side of roadway parking, and retrofit concrete barrier).

UPDATE STAKEHOLDER COUNTERMEASURE PRIORITIZATION

Researchers then led a group discussion of the eight countermeasures from the MCCS analysis. The group discussed adding countermeasures as well as any previously unidentified countermeasures to this list from the literature review. Attendees added the following countermeasures:

- Pavement-condition repair (2.3).
- High-friction surface treatment (2.1).
- Textured pavement markings (2.2).

- Positive guidance in a work zone (5.11).
- Pavement-change warning signs (2.6).
- Guardrail continuous-protection system (5.1).
- Retrofit concrete barrier (5.2).

Attendees discussed and combined similar countermeasures. First, they combined high-friction surface treatment (2.1) and textured pavement markings (2.2). Second, attendees combined guardrail continuous-protection system (5.1) and retrofit concrete barrier (5.2) into a general category titled "barrier treatments for motorcycles." Table 1 lists the countermeasures included in the prioritization activity.

Table 1. List of countermeasures for prioritization.

Countermeasure Number	Countermeasures Identified in the MCCS Database Analysis	Countermeasures Identified in the Review of Literature
1.2	Sight distance—intersection; sight distance—segment	Limited-sight-distance warning signs
1.3	Stop sign; no-left-turn sign	Prohibitive signs
1.4	New signal with protected turn	Signals
1.5	Warning intersection/driveway-ahead sign	Intersection/merging traffic warning signs
2.1; 2.2	—	High-friction surface treatment; textured pavement markings
2.3	—	Pavement-condition repair
2.6	—	Pavement-change warning signs
3.1	Sight distance—intersection; sight distance—segment	Design for motorcycle sight distance
5.1; 5.2	—	Guardrail continuous-protection system; retrofit concrete barrier
5.5	Curve-speed warning sign	Curve-speed warning
5.8	Retroreflective striping	Pavement markings
5.11	—	Positive guidance in a work zone

—No countermeasure identified in the MCCS database analysis.

In addition to finalizing the list for prioritization, the group discussed how to weight the countermeasures, such as by cost, number and rate of crashes reduced, implementation cost and timeline, and number of lives saved, to name a few. However, based on the discussion, it was clear that each attendee had a unique opinion, and therefore, they were instructed to weight according to personal preference.

Eligible attendees were instructed to vote using an online voting platform. The poll asked attendees to "Please rank the top motorcycle safety infrastructure-based countermeasures identified from the MCCS analysis and our discussion today from top (most preferred) to bottom (least preferred)." To vote, attendees selected a countermeasure and moved it higher or lower in the list. The online voting platform automatically assigned the highest ranked countermeasure a score of 1 and the lowest ranked countermeasure a score of 12 and created a final list by averaging the participant scores for each countermeasure. Table 2 displays the ranking results.

Table 2. Ranking results of countermeasure prioritization.

Final Rank	Average Rank Score	Countermeasure	Alignment to MCCS Analysis
1	4.63	High-friction surface treatment (2.1); textured pavement markings (2.2)	—
2	4.94	Pavement-condition repair (2.3)	—
3	5.56	Limited-sight-distance warning signs (1.2)	Sight distance—segment; sight distance—intersection
4	6.31	Pavement-change warning sign (2.6)	—
5	6.34	Design for motorcycle sight distance (3.1)	Sight distance—segment; sight distance—intersection
5	6.34	Curve-speed warning (5.5)	Curve-speed warning signs
6	6.44	Guardrail continuous-protection system (5.1); retrofit concrete barrier (5.2)	—
7	6.82	Positive guidance in a work zone (5.11)	—
8	7.13	Pavement markings (5.8)	Retroreflective striping
9	7.50	Signals (1.4)	New signal with protected turn cycle
10	7.88	Intersection/merging traffic warning signs (1.5)	Warning intersections/driveway-ahead sign
11	8.07	Prohibitive signs (1.3)	Stop sign; no-left-turn sign

—No countermeasure aligned with the MCCS data analysis.

Workshop attendees also discussed several other motorcycle-related safety issues and crash countermeasures to consider for future research, including the following:

- As improvements to intelligent transportation systems (ITSs) are made, attendees agreed on the need for further research regarding ITSs to better understand their impact on motorcycle crashes. For example, what is the impact of red-light-violation warning systems on motorcycle-crash rates?

- Attendees disagreed on whether ITS implementation in the near future was realistic. They agreed other countermeasures should be pursued over ITS. However, attendees agreed that, as ITS improves over time, there is real potential for this countermeasure to reduce motorcycle crashes.

- Attendees agreed on the need for research regarding the impact of crack sealing (i.e., tar snakes), including the impact on road surface and overapplication, as well as research regarding adding material, such as sand, to the tar to increase the friction coefficient of the crack sealant.

- Attendees indicated there was a need for research regarding the impact of warning signs on motorcycle-crash rates, specifically focusing on the impact of riders' speed on the propensity of crashes.

- Attendees agreed on a need for future research regarding work-zone signs. Attendees were concerned about the potential effectiveness of work-zone signs and agreed that examination into their basic effectiveness would be warranted. In addition, attendees thought work-zone crashes may be overrepresented in certain geographical areas and felt an important topic to explore is where work zones are an issue.

- Attendees discussed the need for future research on the effectiveness of guardrails relative to rider safety. Attendees also agreed on the need for future research regarding environmental impacts of continuous guardrails, including limiting animals' ability to move beyond the barrier and off the road, thus remaining a risk to riders.

A primary workshop goal was to provide FHWA a list of three to five countermeasures to consider for future research to improve motorcyclist safety. The countermeasure prioritization task allowed experts in motorcycle safety to rank a list of infrastructure-based motorcycle-crash countermeasures. The five highest ranked countermeasures were as follows:

1. High-friction surface treatment (2.1) and textured pavement markings (2.2).
2. Pavement-condition repair (2.3).
3. Limited-sight-distance warning signs (1.2).
4. Pavement-change warning signs (2.6).
5. Designing for motorcycle sight distance (3.1).

A potential limitation discussed by workshop attendees is the ability to design and implement a single study to evaluate each countermeasure. This is particularly true of the first countermeasure, which contains two uniquely diverse approaches for improving friction that may require two different evaluation approaches. In addition, the second countermeasure addresses the general concept of improving roadway conditions through repairs, but there will likely be significant challenges when designing a single study to address the wide range of possible repairs.

IDENTIFICATION OF BARRIERS TO IMPLEMENTATION

At the onset of the workshop, researchers indicated the need to identify any barriers that would inhibit countermeasure implementation. Throughout the workshop and particularly during the countermeasure discussion, attendees identified several implementation barriers for FHWA to consider including the following:

- The cost of implementation for any countermeasure, including the cost of installation and long-term maintenance.

- The time required for implementation.

- An agency's willingness to install infrastructure-based countermeasures when motorcycles only account for a small percentage of road users and injuries/fatalities.

- A need to know the impact on both nonmotorcycle road users and motorcyclists.

Attendees also identified specific implementation barriers for some countermeasures, which included the following:

- Guardrail continuous-protection system.
  - The best solution is to implement guardrails at all possible locations but doing so is not feasible. The issue is prioritizing locations for guardrail installation so the locations with the greatest risk are addressed. Closely related to this issue is the notion that agencies may be found liable if a motorcycle crash occurs on a curve without a guardrail despite an analysis that indicated no need for a guardrail.

  - Environmental problems associated with continuous guardrails, such as animal crossings, are important factors to consider.

  - Changes to guardrails, such as adding a rub rail, will result in the guardrail needing to be retested, which would most likely be resisted.

- Warning-sign placards.
  - Some Professional Transportation Operations Engineers (an Institute of Transportation Engineers certification) may resist installing placards (e.g., 18 by 18 inches) warning motorcycle riders of a hazard ahead unique to motorcycles (e.g., a warning for grooved pavement). Resistance may be because the placard denotes a particular motorized vehicle that the *Manual on Uniform Traffic Control Devices* (MUTCD) deems unusual.(4) However, graphics of vehicles (e.g., commercial trucks, firetrucks, tractors) do appear in the MUTCD. Attendees noted that warning-sign placards are employed in European countries.

UPDATING THE LIST OF MCCS DATABASE QUESTIONS

Due to reorganizing the agenda, prioritization activity, and extended group discussion about countermeasures, researchers and FHWA staff decided not to enlist the help of attendees to update the list of MCCS database questions during the workshop. Instead, researchers met after the workshop and generated a list of MCCS database questions that included the following:

- Which infrastructure-based countermeasures should be examined in combination?

- For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?

- Does the ranking of infrastructure-based countermeasures differ for crash prevention versus improvement of injury severity?

- Does the ranking of infrastructure-based countermeasures differ for scooters and mopeds versus motorcycles?

- Does the ranking of infrastructure-based countermeasures differ for single-motorcycle crashes versus multivehicle crashes?
- What pavement markings, other than retroreflective striping, could reduce crashes or their severity?
- How do crash frequency and severity differ regarding improving sight distance of the motorcyclist versus improving sight distance of vehicle drivers so they can more readily see the motorcycle and rider?
- Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
- What injury diagnoses are associated with each infrastructure-based countermeasure?
- Which infrastructure-based countermeasures are not a top concern in the MCCS database but are important from a national or regional perspective based on additional analysis of the NASS GES database and possibly other datasets.

UPDATING THE MAPPING BETWEEN COUNTERMEASURES AND THE MCCS DATABASE QUESTIONS

Due to reorganizing the agenda, prioritization activity, and extended group discussion of the countermeasures, researchers decided not to pursue mapping the countermeasures to the MCCS database questions during the meeting. Instead, researchers met after the workshop and mapped the MCCS database questions to each of the five highest rated countermeasures. The mapping results are as follows:

- High-friction surface treatment (2.1); textured pavement markings (2.2):
    - Which infrastructure countermeasures should be examined in combination?
    - For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?
    - Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
    - What injury diagnoses are associated with each infrastructure-based countermeasure?
    - What pavement markings, other than retroreflective striping, could reduce motorcycle crashes or their severity?
- Pavement-condition repair (2.3):
    - Which infrastructure-based countermeasures should be examined in combination?

- For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?
- Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
- What injury diagnoses are associated with each infrastructure-based countermeasure?

- Limited-sight-distance warning signs (1.2); sight distance—segment; sight distance—intersection:
  - Which infrastructure-based countermeasures should be examined in combination?
  - For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?
  - Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
  - What injury diagnoses are associated with each infrastructure-based countermeasure?
  - How do crash frequency and severity differ regarding improving sight distance of the motorcyclist versus improving sight distance of vehicle drivers so they can more readily see the motorcycle and rider?

- Pavement-change warning sign (2.6):
  - Which infrastructure-based countermeasures should be examined in combination?
  - For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?
  - Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
  - What injury diagnoses are associated with each infrastructure-based countermeasure?

- Design for motorcycle sight distance (3.1); sight distance—segment; sight distance—intersection:
  - Which infrastructure-based countermeasures should be examined in combination?
  - For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?

- Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
- What injury diagnoses are associated with each infrastructure-based countermeasure?
- How do crash frequency and severity differ regarding improving sight distance of the motorcyclist versus improving sight distance of vehicle drivers so they can more readily see the motorcycle and rider?

- Curve-speed warning (5.5); curve-speed warning signs:
  - Which infrastructure-based countermeasures should be examined in combination?
  - For combinations of infrastructure-based countermeasures, is the order of implementation potentially important?
  - Are there infrastructure-based countermeasures that may be especially effective in certain geographic areas or areas with specific roadway characteristics where impaired or distracted motorcycle crashes are common?
  - What injury diagnoses are associated with each infrastructure-based countermeasure?

SUMMARY OF WORKSHOP EVALUATION AND FINAL INSTRUCTIONS FOR STAKEHOLDERS

The workshop concluded with a summary of the review and an update of the stakeholder countermeasure prioritization. Attendees were invited to discuss their impressions of the prioritization. They generally agreed on the prioritization with the exception of one attendee, who was surprised that the countermeasure pavement markings (5.8) was not included in the final ranking (see table 4) because, in the attendee's opinion, this particular infrastructure-based motorcycle-crash countermeasure could be deployed broadly and have a significant impact on reducing motorcycle crashes.

Once the discussion of countermeasures ended, researchers thanked all attendees for participating in the workshop. Traveling attendees were given a reminder to complete all travel documents required for reimbursement. In addition, workshop attendees who voted in the prioritization activity were asked to complete either a paper or electronic evaluation depending on their mode of participation.

WORKSHOP EVALUATION RESULTS

Attendees who participated in the prioritization activity completed a workshop evaluation. In-person attendees used a paper evaluation form, and Internet-conferencing attendees used an online survey.

Overall, the workshop received positive feedback, as evidenced by the following ratings (where *n* indicates the number of attendee responses):

- 38.46 percent (*n* = 5) ranked the overall workshop as excellent.
- 46.15 percent (*n* = 6) ranked the overall workshop as very good.
- 15.38 percent (*n* = 2) ranked the overall workshop as good.

Table 3 provides a summary of the evaluation results.

Table 3. Workshop evaluation results.

Evaluation Items	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The premeeting webinar was beneficial.	71.43% (*n* = 10)	28.57% (*n* = 4)	0.00% (*n* = 0)	0.00% (*n* = 0)	0.00% (*n* = 0)
The preprioritization voting was easy to use.	73.33% (*n* = 11)	26.67% (*n* = 4)	0.00% (*n* = 0)	0.00% (*n* = 0)	0.00% (*n* = 0)
The workshop was well organized.	33.33% (*n* = 5)	46.67% (*n* = 7)	13.33% (*n* = 2)	0.00% (*n* = 0)	0.00% (*n* = 0)
The goals of the workshop were clearly stated.	26.67% (*n* = 4)	53.33% (*n* = 8)	13.33% (*n* = 2)	6.67% (*n* = 1)	0.00% (*n* = 0)
The workshop goals were met.	33.33% (*n* = 5)	60.00% (*n* = 9)	6.67% (*n* = 1)	0.00% (*n* = 0)	0.00% (*n* = 0)
The agenda for the meeting was followed.	26.67% (*n* = 4)	40.00% (*n* = 6)	26.67% (*n* = 4)	6.67% (*n* = 1)	0.00% (*n* = 0)
The facilities (e.g., meeting room, Internet conferencing) were appropriate.	42.86% (*n* = 6)	50.00% (*n* = 7)	7.14% (*n* = 1)	0.00% (*n* = 0)	0.00% (*n* = 0)
The workshop met your expectations.	46.67% (*n* = 7)	46.67% (*n* = 7)	6.67% (*n* = 1)	0.00% (*n* = 0)	0.00% (*n* = 0)
The countermeasure prioritization was well organized.	40.00% (*n* = 6)	53.33% (*n* = 8)	6.67% (*n* = 1)	0.00% (*n* = 0)	0.00% (*n* = 0)
The countermeasure prioritization was fair.	53.33% (*n* = 8)	40.00% (*n* = 6)	0.00% (*n* = 0)	6.67% (*n* = 1)	0.00% (*n* = 0)

Attendees also responded to the open-ended questions very positively. When asked what they liked best or found most useful about the workshop, attendees expressed positive feedback about the following:

- The group of experts brought in for the workshop.
- The enthusiasm of the group.
- The easiness and thoroughness of participation and discussion.

- The well-organized delivery of information.
- The ability to share information on motorcycle safety.

Attendees enjoyed their interactions with the staff who hosted and organized the workshop.

As indicated in their responses, what attendees least liked or found less useful included the following:

- Articulation of workshop goals.

- Articulation of the end goal.

- Difficulty in keeping Internet-conferencing attendees focused on the end goal.

- Too much focus on the engineering side of infrastructure-based countermeasures and not enough focus on the data analysis.

Attendees commented negatively on the technical issues experienced at the start of the workshop, which were resolved by using a different phone microphone. Once resolved, attendees commented that the reorganization of the workshop was for the better because it facilitated attendees' comprehension and then rank the infrastructure-based motorcycle-crash countermeasures. It is clear that the changes to the agenda that occurred early on in the workshop negatively impacted the workshop organization, and such changes should have been better articulated.

When attendees were asked if they had any other comments or suggestions, they recommended the following:

- Using specific criteria for ranking countermeasures.
- Recording unrelated or off comments per topic and addressing these at a later time.
- Seeing a more diverse audience of attendees from the highway industry.

FHWA-RECOMMENDED RANKING

After the workshop conclusion, researchers provided the results of the countermeasure prioritization ranking to FHWA. Using an internal process, FHWA reviewed and modified the ranking. This activity resulted in the ranking of five countermeasures from highest to lowest with the highest countermeasure indicative of those to consider for future research. Table 4 displays these results.

Table 4. Results of FHWA countermeasure prioritization ranking.

FHWA Ranking	Workshop Ranking	Average Rank Score	Countermeasure	Alignment to MCCS Analysis
1	1	4.63	High-friction surface treatment (2.1); textured pavement markings (2.2)	—
2	3	5.56	Limited-sight-distance warning signs (1.2)	Sight distance—segment; Sight distance—intersection
3	4	6.31	Pavement-change warning sign (2.6)	—
4	5	6.34	Curve-speed warning (5.5)	Curve-speed warning signs
5	11	8.07	Prohibitive signs (1.3)	Stop sign; no-left-turn sign

—No countermeasure aligned with the MCCS database analysis.

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