Improving Motorcycle Safety by Enhancing Roadway Design

Requested by
Mitchell Prevost, Division of Traffic Operations

October 17, 2017

Table of Contents

Executive Summary

Background

Caltrans is currently implementing safety measures to prevent motorcycle crashes and fatalities. Certain design elements, such as predictable road geometry, good visibility, obstacle-free zones and a high-quality road surface with high levels of skid resistance may be especially important to enhance the safety of motorcycles. While safety awareness campaigns and modified guardrails have proved to be effective countermeasures, Caltrans is interested in ways to further enhance roadway design to improve motorcycle safety.

To assist with this information-gathering effort, CTC & Associates examined domestic and international research and related resources that address roadway design to enhance motorcycle safety, with a focus on:

- Roadway design elements and the countermeasures that prevent or decrease the rate of motorcycle crashes and fatalities.
- Infrastructure-related causes of motorcycle crashes.
- Effective awareness and education campaigns that may focus on roadway design.

Summary of Findings

Below is a summary of some of the key resources we identified that may inform Caltrans' efforts to enhance roadway design to improve motorcycle safety. Refer to the **Detailed Findings** section of this report for additional citations.

State Practices

We highlight motorcycle safety plans developed by state departments of transportation (DOTs) and motorcycle interest groups in Florida, Michigan, Missouri, Tennessee and Texas. These plans recommend roadway engineering strategies that address signage, pavement maintenance practices, modifications to median barriers and other countermeasures expected to reduce motorcycle crashes and motorcyclist injury severity.

Design and Countermeasures

National Guidance

A project in progress sponsored by the National Highway Traffic Safety Administration (NHTSA), scheduled to conclude this fall, is expected to identify trends and gaps in motorcycle-related safety research and showcase promising potential countermeasures. Other national guidance includes a 2013 NHTSA publication that prioritizes recommendations for motorcycle safety and a 2008 NCHRP report addressing motorcycle collisions that includes several roadway design-related objectives.

The Crash Modification Factors Clearinghouse offers a searchable online database of crash modification factors (CMFs) and guidance and resources for using and developing CMFs. A CMF is "used to compute the expected number of crashes after implementing a countermeasure on a road or intersection." Use of the search term "motorcycle" to query the online database identifies CMFs in these categories: access management; advanced technology and intelligent transportation systems (ITS); highway lighting; intersection geometry; roadway; and speed management.

General Design

Among the domestic publications addressing roadway design are a 2017 conference paper that examined ITS technologies with potential relevance to motorcycle safety and a 2011 domestic scan focused on the planning and implementation of infrastructure improvements that improve motorcyclist safety. International guidance includes an urban design handbook that provides a comprehensive look at motorcycle safety design in London, and a Federal Highway Administration-sponsored International Technology Scanning Program Report that examined infrastructure improvements, maintenance practices and traffic operations strategies to enhance motorcyclist safety in five European countries (Belgium, England, France, Germany and Norway).

Specific Design Elements

This section of the report highlights journal articles and association publications that address specific design elements, including curve, lane and shoulder design; the use of barriers; and safety measures associated with work zones and maintenance. These publications include the following:

- A 2014 journal article examines factors that increase the likelihood of motorcycle crashes, including lane and shoulder widths, an increase in horizontal degree of curvature and an increase in maximum vertical grade.
- A 2012 European motorcyclist association publication reviews the standards for road restraints and offers guidelines on where and how they should be used.
- A 2011 guide offers recommendations to work crews with regard to surface conditions, elevation changes, signage, delineation of steel plates and elevated obstructions, and positioning pavement marking.

Infrastructure-Related Causes of Crashes

General Design

The most recent domestic research effort we identified, the Motorcycle Crash Causation Study, is a pooled fund project wrapping up this fall. This project focused on “all relevant aspects of motorcycle crashes that could be susceptible to countermeasures that will either prevent motorcycle crashes from occurring or will lessen the harm resulting from them.”

Other domestic research reports and journal articles include a 2016 Texas DOT project that constructed a motorcycle crash database and conducted an analysis of data with an emphasis on preventing fatal and incapacitating injury crashes. More than 20,000 fatal motorcycle crashes in the United States were examined in a 2013 analysis that concluded driver and rider behavior are more significant factors in the number of fatal motorcycle crashes than roadway design. Other projects examined motorcycle road safety audit cases to identify the conditions that challenge motorcyclists, the impact of lane splitting in California, and motorcyclists’ lane position and its impact on right of way violation collisions.

International publications considered the impact of infrastructure improvements and the factors contributing to motorcycle injury crashes in Australia. A 2015 report prepared by a working group designated by the International Transport Forum describes a set of countermeasures and recommends the introduction of self-explaining and forgiving roads, and a 2011 conference paper identified several infrastructure features with the potential to improve motorcycle safety in Sweden.

Specific Design Elements

This section of the report highlights research reports and journal articles that address specific design elements that may be related to motorcycle crashes. The impact of curves on motorcycle crashes is examined in three projects:

- A Florida DOT project, expected to wrap up this year, seeks to develop effective countermeasures by exploring the contributing factors to motorcycle crashes occurring at horizontal curve segments.
- Researchers found that the strongest predictor of crash frequency was curve radius when examining motorcycle-to-barrier crash frequency on horizontally curved roadway sections in Washington.
- After analyzing crash records in Ohio, researchers concluded that the radius and length of each horizontal curve significantly influence the frequency of motorcycle crashes. Shoulder width, average annual daily traffic and the location of the road segment in relation to the curve also affect crash frequency.

The impact of traffic barriers on serious injury and fatal motorcycle crashes is examined in a range of domestic projects and publications, including an NCHRP project that was expected to conclude in 2016 (the project is listed as active and no final report has been posted). Researchers associated with this NCHRP project note that "[t]here is virtually no in-depth analysis of data describing motorcycle crashes involving traffic barriers in the United States."

The comprehensive NCHRP analysis of barriers is supplemented by journal articles that examine the roadway characteristics associated with motorcycle-to-barrier crashes and the effect of barrier type on injury severity. International research published in a 2013 Transportation Research Circular presents best practices and strategies in the United Kingdom and Australia to reduce fatal or serious injury crashes into guardrail posts. This section of the report concludes with an Ohio DOT research report that provides results of a national survey that highlight roadway-based solutions to address motorcycle crashes in work zones.

Education and Awareness Campaigns

Domestic education and outreach efforts are highlighted in Florida, Missouri and Texas, including the following programs:

- Ride Smart Florida is the communication and outreach arm of the Florida Motorcycle Safety Coalition. In addition to its work to develop, implement and evaluate countermeasures, Ride Smart Florida offers a wide range of printed material, educational videos and other promotional materials.
- Missouri's Arrive Alive, a program developed by the Missouri Coalition for Roadway Safety, offers promotional materials related to motorcycle safety.
- Look Learn Live, the motorcycle safety and awareness campaign developed by Texas DOT and its partners, offers print and web promotional materials, as well as radio and TV spots.

We also present a national assessment of state motorcycle safety programs and a discussion of public education efforts in New South Wales, Australia.

Gaps in Findings

Several publications highlighted in this Preliminary Investigation's sampling of research indicate that more research is required. Some researchers identified specific areas of research requiring more attention. For example, NCHRP researchers examining the impact of traffic barriers other than guardrails highlight the dearth of research in this topic area.

Other infrastructure elements that may impact motorcycle safety (signage and pavement markings, and roadway lighting) also appear to have received less of researchers' attention than other roadway design elements (curves and work zones). While these other infrastructure elements may be referenced in the research and other guidance documents, we found few details about their specific impact.

Some projects in progress have not published final results. These include NHTSA's project to review the state of the knowledge with regard to motorcycle safety, the Transportation Pooled Fund Program's Motorcycle Crash Causation Study and the NCHRP project examining the impact of traffic barriers.

Next Steps

Moving forward, Caltrans could consider:

- Contacting states that have developed detailed motorcycle safety plans (Florida, Michigan, Missouri, Tennessee and Texas).
- Reviewing the Crash Modification Factors Clearinghouse and the CMFs specific to motorcycles to determine their relevance to California roadways.
- Evaluating how international research might be applied to Caltrans' examination of design elements that enhance motorcycle safety in California.
- Watching for the publication of final reports associated with research projects in process.
- Consulting with the states that support education and awareness campaigns addressing motorcycle safety (Florida's Ride Smart Florida, Missouri's Arrive Alive and Texas DOT's Look Learn Live) to learn more about program development, successes and challenges.

Detailed Findings

An examination of domestic and international research and related resources sought information about motorcycle safety and the ways in which roadway design can enhance motorcycle safety in the following topic areas:

- **Design and countermeasures:** Roadway design elements and the countermeasures that prevent or decrease the rate of motorcycle crashes and fatalities.
- **Infrastructure-related causes of crashes:** The impact of various aspects of the roadway infrastructure on the incidence of motorcycle crashes.
- **Education and awareness campaigns:** Effective campaigns to educate or raise the awareness of riders, highway designers, motorists and other stakeholders with regard to motorcycle safety.

Results of this literature search are organized in four sections:

- State Practices.
- Design and Countermeasures.
- Infrastructure-Related Causes of Crashes.
- Education and Awareness Campaigns.

State Practices

Motorcycle safety plans and related documents published by transportation-related agencies in Florida, Michigan, Missouri, Tennessee and Texas are highlighted below. These plans address a wide range of topics, from recommendations for highway design to strategies that can help agencies more effectively communicate with riders and other stakeholders.

Florida

Florida Motorcycle Strategic Safety Plan, Florida Department of Transportation, June 2016.
http://www.fdot.gov/safety/2A-Programs/Motorcycle/Floridamotorcyclesafetyplann2016.pdf
This plan supplements and expands on the Florida Strategic Highway Safety Plan "by providing more detailed strategies and action steps to improve motorcycle safety in Florida." Roadway engineering strategies begin on page 30 of the plan (page 37 of the PDF), including the following:

- Encourage use of advance warning signs and pavement markings to warn motorcyclists of dangerous conditions or countermeasures to reduce left-turn conflicts (such as median access control, signal phasing and roundabouts).
- Promote removal of roadway debris from the roadway and roadside that may be hazardous for motorcyclists.
- Encourage use of high-traction pavement markings and surface materials for motorcycles during construction.
- Incorporate motorcycle safety considerations into roadway safety inspections or audits.

- Develop hazardous roadway conditions educational materials and reporting system for motorcyclists.
- Inform and encourage agencies using the Ride Smart Florida web site, FIRES, Signal Four Analytics and [Florida Motorcycle Safety] Coalition resources to access motorcycle safety and crash-specific information. (See the note below.)

Note: The web sites and groups highlighted above are described in more detail in the following:

Ride Smart Florida is "the communication and outreach extension of the Florida Motorcycle Safety Coalition." See page 29 of this Preliminary Investigation for more information.

FIRES (Florida's Integrated Report Exchange System) is a "portal into the state of Florida's repository for traffic crash reports completed by Florida law enforcement agencies." See https://www.firesportal.com/Pages/Public/Home.aspx for more information.

Signal Four Analytics is "an interactive, web-based system designed to support the crash mapping and analysis needs of law enforcement, traffic engineering, transportation planning agencies and research institutions in the state of Florida." See https://s4.geoplan.ufl.edu/ for more information.

Strategies for communications and outreach begin on page 33 of the plan (page 40 of the PDF).

Briefing Book: 2014 Florida Motorcycle Safety, prepared for the 2014 Florida Motorcycle Assessment by the National Highway Traffic Safety Administration, Florida Department of Transportation, 2014.
https://www.cutr.usf.edu/wp-content/uploads/2014/04/1-FL-Motorcycle-Assessment-2014-Briefing-Book.pdf
Florida Department of Transportation (Florida DOT) prepared this document in connection with a 2014 assessment of the agency's activities related to motorcycle safety. Among the safety-related topics addressed in this briefing book are highway engineering (page 35 of the document, page 40 of the PDF); motorcycle rider conspicuity and motorist awareness programs (page 37 of the document, page 42 of the PDF); and the agency's communication program (page 38 of the document, page 43 of the PDF).

Michigan

Michigan Motorcycle Safety Action Plan, Michigan Motorcycle Safety Action Team 2017-2022, December 2014.
https://www.michigan.gov/documents/msp/MC_Safety_Action_Plan_12-01-2014_478724_7.pdf
This action plan addresses a wide range of topics, from program management to law enforcement to motorist awareness programs. Below are the strategies recommended for highway engineering (see page 9 of the plan):

Strategy #1 Examine and enforce the policies and practices of the following maintenance activities: Excessive use of low friction joint sealants and crack fillers, low friction pavement markings, and excessive grooving of concrete pavement. Ensure that surface treatments to control traction are applied immediately if needed, with particular attention to ramps and curves.

Strategy #2 Collaborate with state, county and local road maintenance and work zone personnel on safety concerns of motorcyclists have such as: pothole maintenance, raised manhole covers, uneven pavement conditions, gravel or debris on roadway, chip sealers used on roadways, excessive over-band crack fillers and joint sealants, and stop light loop detection systems that do not detect a motorcycle.

Strategy #3 Educate transportation professionals of the operational characteristics of motorcycles and the roadway design and maintenance needs specific to motorcyclists, and continue to involve motorcyclists in the new designs, treatments and materials.

Strategy #4 Study the impact of the new "*Safety Edge*" roadway shoulder edge-drop treatments.

The plan also provides these strategies for communication (see page 9 of the plan):

Strategy #1 In advance of the riding season, the "*Michigan Motorcycle Safety Action Team*" (MMSAT) should coordinate and develop an explicit, annual strategic communication plan. The plan should identify priority problem areas and messaging supported by available data. The plan should articulate measurable communication objectives, and assign responsibility for specific actions for critical stakeholders.

Strategy #2 Following the riding season, convene a meeting of the MMSAT to review communication campaign outcomes, evaluate new data on each problem area, and propose improvements for the following riding season.

Strategy #3 Raise public awareness of motorcyclist training opportunities, motorcycle rider endorsement requirements, motorist awareness of motorcycles, and use of High-Viz riding gear through the "May is Motorcyclist Safety Awareness Month" campaign and promote at motorcyclist events around the State of Michigan.

Strategy #4 Through the *"Ride Safe to Ride Again"* campaign, continue to promote the importance of a comprehensive safe motorcycling mindset. Foster the acceptance and use of High-Viz riding gear, expand access to and awareness of training opportunities for motorcyclists, and communicate to unendorsed motorcycle owners the benefits of being trained and endorsed.

Strategy #5 Through the *"Look Twice Save a Life"* campaign, educate motorists, making them more aware of motorcyclists by speaking at and distributing literature in driver's education classrooms and placement of motorcyclist awareness signs.

Missouri

State of Missouri Highway Safety and Performance Plan and Section 405 Grant Program, Missouri Department of Transportation, 2016.
http://contribute.modot.mo.gov/safety/documents/FY16HSPand405.pdf
This safety and performance plan includes a motorcycle assessment that begins on page 294 of the plan (page 298 of the PDF). Recommendations associated with a National Highway Traffic Safety Administration (NHTSA) assessment are presented in a tabular format that includes the recommendation, whether the recommendation will be followed, tasks to be completed, target date for completion and current status.

Tennessee

Tennessee Motorcycle Safety Strategic Plan, Governor's Highway Safety Office, Tennessee Department of Transportation, March 2015.
http://tntrafficsafety.org/sites/default/files/FR1_TNDOT_MtrcyclStrtPln_Report_Mar15.pdf
Strategies associated with highway engineering are presented on page 15 of this plan (page 18 of the PDF), including the following:

Strategy 2 – Identify opportunities to enhance design and maintenance policies/protocols to improve motorcycle safety and consider motorcyclists during maintenance and selection of materials.

- Continue using signage to warn motorcyclists of hazardous conditions (e.g., advanced warning of hazards to allow motorcyclists to reroute if desired).
- Require contractors to remove loose gravel and debris from construction zones on a regular basis.
- Consider motorcycles when placing metal plates in the right of way.
- Examine the use of skid resistant paint materials to avoid slippery surfaces.
- Modify median barriers to accommodate motorcycles, when appropriate (e.g., distance from roadway, widen gap beneath lower cable and ground).
- Consider using TDOT incident management vehicles/personnel to remove hazardous debris from roadway (e.g., gators).
- Review and improve secondary roadway construction protocols.
- Examine roadways with frequent maintenance operations to identify potential opportunities to reduce hazards to motorcyclists during maintenance.

Texas

Development of a Statewide Motorcycle Safety Plan for Texas: Technical Report, Patricia Turner, Laura Higgins and Srinivas Geedipally, Texas Department of Transportation, June 2013.
http://tti.tamu.edu/documents/0-6712-1.pdf
From the abstract: The objective of this research project was to develop a statewide plan to reduce motorcycle crashes and injuries in the state of Texas. The project included a review of published literature on current and proposed countermeasures for reducing the incidence and/or severity of motorcycle-involved crashes and related injuries, a review of existing and emerging Intelligent Transportation System (ITS) and other advanced technologies for motorcycles and other vehicles, an analysis of Texas motorcycle crash and injury data, and a statewide survey of Texas motorcycle riders that explored the demographics, riding histories, training and licensing status, use of protective gear, crash involvement, and attitudes toward various motorcycle safety countermeasures. These data collection activities culminated in a list of potential motorcycle crash and injury countermeasures; these countermeasures were then evaluated and prioritized in a workshop attended by motorcycle safety experts and advocates.

Related Resource:

> **Texas Strategic Action Plan for Motorcycles 2013-2018**, Texas Department of Transportation, 0-6712-P2, June 2013.
> http://tti.tamu.edu/documents/0-6712-P2.pdf
> As this document indicates, "[t]he project goal was to develop a broad-based plan that includes strategies and action steps aimed to prevent and/or mitigate motorcycle crashes and injuries." This five-year plan includes countermeasures to reduce motorcycle crashes; countermeasures to reduce motorcyclist crash injury severity; ITS technologies to improve motorcycle safety; and implementation and outreach. The Texas Motorcycle Safety Coalition oversees implementation of the plan.

Design and Countermeasures

The following presents a representative sampling of research and related resources that address design elements and countermeasures intended to improve motorcycle safety in these categories:

- National guidance.
- General design.
- Curve, lane and shoulder design.
- Barriers.
- Work zones and maintenance.

Publications are further organized by domestic and international resources in the latter four categories of publications.

National Guidance

Research in Progress: Motorcycle Safety—A Review of the State of the Knowledge, Kathryn Wochinger, National Highway Traffic Safety Administration, expected completion date: September 2017.
Citation at https://trid.trb.org/View/1453687
From the abstract: The objective of this study is a comprehensive, up-to-date review of the literature on motorcycle safety for the purpose of providing an empirical basis for research and program planning and policy decision-making. A comprehensive review of the state of knowledge about motorcycle traffic safety in the United States supports the development and implementation of safety programs and public policy. The review shall highlight trends and gaps in safety research, and showcase features that show promise as potential countermeasures. One of the goals of the review is to serve as an important resource for researchers, highway safety and public health professionals, rider instructors, safety advocates and others.

"**A Guide for Addressing Collisions Involving Motorcycles,"** *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*, Vol. 22, 2008.
https://www.nap.edu/read/14204/chapter/1
This report addresses several roadway design-related objectives, including:

- **Objective 11.1 A** (beginning on page V-7 of the guide, page 22 of the PDF): Incorporate motorcycle-friendly roadway design, traffic control, construction and maintenance policies and practices.
    - Provide full paved shoulders to accommodate roadside motorcycle recovery and breakdowns.
    - Consider motorcycles in the selection of roadside barriers.
    - Identify pavement markings, surface materials and other treatments that reduce traction for motorcycles and treat or replace with high-traction material.
    - Maintain the roadway to minimize surface irregularities and discontinuities.
    - Maintain roadway surfaces in work zones to facilitate safe passage of motorcycles.
    - Reduce roadway debris from the roadway and roadside, including gravel, shorn treads, snow and ice control materials (sand and salt), and debris from uncovered loads.
    - Provide advance warning signs to alert motorcyclists of reduced traction and irregular roadway surfaces.
    - Incorporate motorcycle safety considerations into routine roadway inspections.
    - Provide a mechanism for notifying highway agencies of roadway conditions that present a potential problem to motorcyclists.
- **Subobjective 11.1 F3** (beginning on page V-102 of the guide, page 117 of the PDF): Educate operators of other vehicles to be more conscious of the presence of motorcyclists. This objective focuses on marketing and advertising campaigns and outreach activities that aim to reduce vehicle collisions by making motorists more aware of motorcyclists in traffic. Safety campaigns in Maryland, Oregon and Wisconsin are highlighted.
- **Subobjective 11.1 G1** (beginning on page V-107 of the guide, page 122 of the PDF): Include motorcycles in the research, development and deployment of intelligent transportation systems (ITS). The section identifies technical and organizational issues to consider when selecting appropriate ITS technology. Frequently ITS applications only consider vehicles; for example, traffic sensors at intersections fail to recognize motorcycles in left-turn lanes, forcing riders to wait for another vehicle to enter the lane and trigger the sensor, or to violate traffic codes and make unauthorized left turns.

Crash Modification Factors Clearinghouse, Safety Research Center, Federal Highway Administration, undated.
http://www.cmfclearinghouse.org
From the web site:

> A crash modification factor (CMF) is used to compute the expected number of crashes after implementing a countermeasure on a road or intersection. The Crash Modification Factors Clearinghouse provides a searchable online database of CMFs along with guidance and resources on using CMFs in road safety practice. It also provides guidance to researchers on best practices for developing high quality CMFs.

The web site further defines a CMF as “a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. A CMF reflects the safety effect of a countermeasure, whether it is a decrease in crashes (CMF below 1.0), increase in crashes (CMF over 1.0), or no change in crashes (CMF of 1.0)."

Using the search term "motorcycle" will identify CMFs in these categories:

- Access management.
- Advanced technology and ITS.
- Highway lighting.
- Intersection geometry.
- Roadway.
- Speed management.

Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices, Eighth Edition, Arthur Goodwin, Libby Thomas, Bevan Kirley, William Hall, Natalie O'Brien and Kate Hill, National Highway Traffic Safety Administration, November 2015.
http://www.nhtsa.gov/staticfiles/nti/pdf/812202-CountermeasuresThatWork8th.pdf
Chapter 5, Motorcycle Safety (beginning on page 5-1 of the report, page 240 of the PDF), presents motorcycle safety countermeasures. Education is the emphasis of countermeasures, although motorcycle design is also addressed. Roadway design and maintenance issues, such as slippery surfaces and markings, surface irregularities and debris, unpaved shoulders and unforgiving roadway barriers, are outside of the scope of the report. The authors recommend A Guide for Addressing Collisions Involving Motorcycles (see citation on page 10 of this Preliminary Investigation) for a discussion of strategies related to roadway design.

Prioritized Recommendations of the National Agenda for Motorcycle Safety, Final Report, National Highway Traffic Safety Administration, June 2013.
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/811789.pdf
This update to the National Agenda for Motorcycle Safety (NAMS) notes that roadway design and upkeep are critical, and that the impact of roadway environment and other factors in motorcycle safety has not been correlated well with motorcycle accidents and safety measures. Highway and Environment, Subject Area 40 on the NAMS list, is addressed in Appendix D (beginning on page D-80 of the report, page 121 of the PDF). Strategies include improving signage for hazards; identifying obvious hazards like debris and pavement irregularities as well as less obvious hazards like slippery pavement sealants; educating road design and maintenance staff about conditions hazardous to motorcyclists; revising design, construction and maintenance standards to meet motorcyclist needs; and creating a working group to recommend changes to highway standards for the needs of motorcycle riders.

National Agenda for Motorcycle Safety Implementation Guide, National Highway Traffic Safety Administration, December 2006.
https://www.nhtsa.gov/document/implementation-guide-motorcycle-safety
Section 6, Highway and Environment (beginning on page 39 of the guide, page 43 of the PDF), addresses roadway and environmental issues related to motorcycle safety, including strategies for signage and road maintenance as well as education for road design and maintenance staff. The discussion includes specific action steps, practices used by other transportation agencies, and related resources and activities.

General Design

Domestic

"State of the Practice of Motorcycle Safety and Intelligent Transportation Systems," Erin Flannigan, Aldo Tudela Rivadeneyra and Katherine Blizzard, *TRB 96th Annual Meeting Compendium of Papers*, Paper #17-00715, 2017.
Citation at https://trid.trb.org/view.aspx?id=1437328
From the abstract: Intelligent Transportation Systems (ITS) present an array of promising ways to improve motorcycle safety. While ITS technologies have predominantly targeted automobiles and commercial vehicles, little has been done to specifically address motorcycles and motorcycle safety. This project surveyed a wide range of ITS technologies with potential relevance to motorcycles. Technologies with the highest relevance were investigated further to determine their potential to improve motorcycle safety. The project employed a two-pronged methodology in its survey of ITS technologies, consisting of (1) a comprehensive literature review and (2) interviews with stakeholders representing a cross section of the motorcycle industry and community. The synthesis of this research identified certain areas where future research efforts should focus, including: improving the availability of robust motorcycle safety data, taking advantage of possible synergies between ITS technologies, connecting vehicles to riders through better ITS interphases, evaluating the safety benefits of ITS technologies, and further researching opportunities to harmonize motorcycle ITS with connected vehicles technology.

Leading Practices for Motorcyclist Safety, NCHRP Project 20-68A, Domestic Scan 09-04, National Cooperative Highway Research Program, September 2011.
http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_09-04.pdf
From the report purpose:

> The focus of the scan was on the planning and implementation of infrastructure improvements to improve motorcyclist safety. The scan team also reviewed design, construction, and maintenance policies and initiatives regarding roadside safety devices, traffic operations, work zone practices, and safety data as they relate to motorcyclists.

Chapter 2 of the report (beginning on page 2-1 of the report, page 21 of the PDF) addresses infrastructure issues, improvements and practices, including drainage and shoulders, communicating road conditions, pavement conditions, traffic control devices and road maintenance crew training.

International

Urban Motorcycle Design Handbook, Transport for London, 2017.
http://content.tfl.gov.uk/tfl-urban-motorcycle-design-handbook.pdf
This handbook provides a comprehensive look at motorcycle safety infrastructure design in London. It includes design information about factors affecting surface grip, visibility, roadside features, traffic calming and filtering of motorcyclists into bicycle lanes or alongside automotive and rail traffic.

Evaluation of the Motorcycle Blackspot Program, Peter Cairney, Ben Mitchell, Deny Meyer, Sarah Van Dam and Tariro Makwasha, VicRoads, July 2015.
https://www.vicroads.vic.gov.au/~/media/files/documents/safety-and-road-rules/evaluation-of-the-motorcycle-blackspot-program.pdf%3Fla%3Den&sa=U&ved=0ahUKEwjv9rnvpMvWAhWhjlQKHbcRDZQQFggFMAA&client=internal-uds-cse&usg=AFQjCNEf9CwHxonn0t2rVyunYa7LKkU6Bg
Victoria's Motorcycle Blackspot Program has reduced motorcycle accidents involving injuries by 27 percent, and serious injuries and deaths by 31 percent. Funded by a motorcycle safety levy collected from all registered motorcycles, the program "funds treatments to improve motorcycle safety at locations throughout the state with a history of motorcycle crashes." The program emphasizes a number of road treatments, including barrier protection, resurfacing, shoulder sealing and roadside hazard removal.

Making Roads Motorcycle Friendly—A New Zealand Guide for Roading Asset Owners, Designers and Maintenance Contractors, Motorcycle Safety Advisory Council and NZ Transport Agency, September 2014.
https://www.nzta.govt.nz/assets/resources/safer-journeys-motorcyclists/Making-Roads-Motorcycle-Friendly.pdf
The guide provides best practices in road design and maintenance. Among the recommended strategies are defect-free, adequate grip road surfaces; clear sightlines on curves, corners and intersections; roadsides free from obstructions; shoulders that allow for safe recovery for motorcycles leaving the road; drainage systems that minimize manholes in roadways; avoidance of raised roadway features; reduced use of metal service covers at corners; and low-intrusion road service.

"Making Roundabouts a Safe System Solution for Motorcyclists," K. Beer, E. Aninipoc, D. Andrea and T. Beer, *Proceedings of the 2014 Australasian Road Safety Research, Policing and Education Conference*, November 2014.
http://acrs.org.au/files/arsrpe/full-paper_1984.pdf
From the abstract: This paper reviews roundabout design, maintenance and operation that may influence motorcycle safety. This includes turbo-roundabouts. It also reports the results of an in-depth engineering investigation of some roundabouts in Victoria where motorcycle crashes have occurred. Factors identified and discussed include geometric design, sight distance, lighting, pavement markings, signing, landscaping, street furniture, speed limits and surface issues.

Infrastructure Countermeasures to Mitigate Motorcyclist Crashes in Europe, International Technology Scanning Program, Federal Highway Administration, August 2012.
https://international.fhwa.dot.gov/scan/12028/12028.pdf
This study evaluated infrastructure improvements that enhance motorcycle safety in five European countries (Belgium, England, France, Germany and Norway). The scan examined infrastructure improvements, maintenance practices and traffic operations strategies to enhance motorcyclist safety. The summary of findings indicates that "the scan team found great similarities between the United States and the countries visited in these areas. With the exception of motorcycle-friendly roadside barriers, the types of infrastructure safety improvements used were those that improved safety for all vehicle classes, such as roadside clear zones and pavement management. The biggest differences between the United States and the countries visited were in the areas of behavioral safety, helmet laws, training and licensing. Another difference the team noted was the great cooperation between European road authorities and stakeholder groups representing motorcycle riders."

The abstract noted that recommendations for U.S. implementation “include filling in knowledge gaps to improve motorcycle safety, conducting research on motorcycle infrastructure safety, and updating design guidelines to accommodate motorcyclist safety.”

Guidelines for PTW-Safer Road Design in Europe, Association of European Motorcycle Manufacturers, 2006.
http://www.acem.eu/images/stories/doc/publications/d_ACEMinfrastructurehandbookv2_74670.pdf
From the foreword: This handbook describes the specific needs of riders and contains guidelines for those responsible for road design and road maintenance. It includes recommendations and examples from all over Europe. Predictable road geometry can be achieved by a good road design with consistent, clear traffic signs and road markings, and by improving traffic management, PTW [powered two wheeler] riders can be better guided on the road.

In addition to road design and traffic management two other aspects have been included in this handbook: the use of a formalised and systematic assessment of road facilities and road safety campaigns considering PTWs, both are a vital ingredient in a mix of initiatives to address PTW safety.

Curve, Lane and Shoulder Design

Domestic

“A Segment Level Analysis of Multi-Vehicle Motorcycle Crashes in Ohio Using Bayesian Multi-Level Mixed Effects Models,” Thomas Flask, William Schneider and Dominique Lord, *Safety Science*, Vol. 66, pages 47-53, July 2014.
http://daneshyari.com/article/preview/589090.pdf
This study identified factors that increase the likelihood of motorcycle crashes, including lane and shoulder widths, an increase in horizontal degree of curvature and an increase in maximum vertical grade.

International

“Country Report: Update on Geometric Design Activities in Austria,” T.E. Hofbauer, *4th International Symposium on Highway Geometric Design*, 2010.
Citation at https://trid.trb.org/view.aspx?id=1098922
From the abstract: The brand-new Instruction RVS 02.02.42 gives Recommendations for the Improvement of Motorcycle Traffic Safety with a view to enhancing all other endeavours to avoid traffic accidents with motorized bicycles and/or minimize the danger and the extent of injuries caused by such accidents. It describes situations in which action must be taken, the types of measures to be adopted in order to increase traffic safety, in particular on roads with conspicuous areas and roads with increased risks of motorcycle accidents, and remediary procedures to be introduced in order to respond to accidents.

Barriers

International

New Standards for Road Restraint Systems for Motorcyclists—Designing Safer Roadsides for Motorcyclists, Federation of European Motorcyclists' Associations, 2012.
http://www.svmc.se/smc_filer/SMC%20centralt/Rapporter/2012/Guidelines.pdf
From the introduction: This document aims at providing accurate and complete information on the solutions available to road authorities and infrastructure operators who wish to upgrade road restraint systems, by presenting the current technical standards available, statistical data and in-depth research, accident profiles configurations, as well as best practices and success stories. In addition, it features a comprehensive list of road restraint products available on the market today, their characteristics, their use, the standards against which they are tested, and guidelines on where and how they should be used to the best benefit.

Work Zones and Maintenance

Domestic

Guidelines on Motorcycle and Bicycle Work Zone Safety, American Road and Transportation Builders Association Work Zone Safety Consortium and Federal Highway Administration, 2011.
https://www.workzonesafety.org/files/documents/training/courses_programs/rsa_program/RSP_Guidance_Documents_Download/RSP_MotorcyclesGuidance_Download.pdf
This guide offers recommendations to work crews for making work zones safer for motorcyclists. It focuses on surface conditions, and reducing or directing around hazards like degraded surface conditions, wet pavement and loose gravel, discontinuities in pavement and abrupt elevation changes, and degradations in roadway geometrics. It specifies lowering elevation changes, limiting speed limit drop for temporary median crossovers, requiring signage warning of specific degradations or hazardous conditions, delineating steel plates and elevated obstructions like manhole covers in travel lanes, and using pavement marking in motorcycle-friendly ways like positioning them in the center of lanes and on the outside of curves and transition areas.

"Maximizing Motorcycle Safety in Work Zones," Travis Parsons, *2010 Traffic Safety Conference*, March 2010.
https://conferences.tti.tamu.edu/traffic_safety10/program/breakout1/parsons.pdf
This conference presentation recommends incorporating motorcycle provisions into state project design, practice manuals and contract documents.

Related Resources:

> **Work Zone Traffic Control Guidelines for Maintenance Operations**, M54-44.05, Washington State Department of Transportation, December 2014.
> http://www.wsdot.wa.gov/publications/manuals/fulltext/M54-44/Workzone.pdf
> Section 1.8.3 of the guidelines (page 1-15 of the report, page 23 of the PDF) describes surface conditions that can be dangerous to motorcyclists and specifies warning signs for these conditions.

“Maintenance and Protection of Traffic in Highway Work Zones,” Chapter 16, *Highway Design Manual Revision No. 48,* Daniel D’Angelo, Engineering Bulletin No. 06-004, New York State Department of Transportation, January 20, 2006.
https://www.dot.ny.gov/divisions/engineering/design/dqab/hdm/hdm-repository/rev48.pdf
Section 16.4.4.4 (A) (page 16-83 of the manual, page 95 of the PDF) provides design and other safety-related provisions associated with motorcycles in work zones. Section 16.3.2 (page 16-48 of the manual, page 60 of the PDF) recommends using net barriers in addition to Type III barricades, plastic drums and adequate signage to prevent motorcycles from entering work zones.

Infrastructure-Related Causes of Crashes

Research and related resources that examine the infrastructure-related causes of motorcycle crashes are presented in the following topic areas:

- General design.
- Curve, lane and shoulder design.
- Barriers.
- Work zones and maintenance.

Publications in each category are further organized by domestic and international resources.

General Design

Domestic

Research in Progress: Motorcycle Crash Causation Study, Transportation Pooled Fund Program, Federal Highway Administration. (Data collection is complete. The final report, study documentation and data will be available later in 2017.)
Project description at http://www.pooledfund.org/Details/Study/480/
Project overview at https://www.fhwa.dot.gov/research/tfhrc/projects/safety/motorcycles/mccs/
From the project description: The primary objective of the Motorcycle Crash Causation Study is to investigate the causes of motorcycle crashes and to enable the development of countermeasures that can be effective in reducing these crashes. Using the field tested methodology developed by the Organization for Economic Co-operation and Development (OECD), the study will focus on all relevant aspects of motorcycle crashes that could be susceptible to countermeasures that will either prevent motorcycle crashes from occurring or will lessen the harm resulting from them. The objective of this transportation pooled fund study is to provide additional funding to increase the number of crash investigations that will be used to expand the database.

Comprehensive Analysis of Motorcycle Crashes in Texas: A Multi-Year Snapshot, Revision 1a, Eva M. Shipp, Robert Wunderlich, Marcie Perez, Myunghoon Ko, Ashesh Pant, Michael Martin, Byron Chigoy and Amber Trueblood, Texas Department of Transportation, September 2016.
http://www.looklearnlive.org/wp-content/uploads/2016/12/MOTO_ReportRev1a.pdf
From the introduction:

> [T]he purpose of this project was to understand the complex nature of motorcycle crashes in Texas through construction of a motorcycle crash database and a multi-year analysis of

these data with an emphasis on the prevention of fatal and incapacitating injury crashes. To aid in this effort, researchers used the most comprehensive analysis of motorcycle crash causation—a report led by H. H. Hurt titled *Motorcycle Accident Cause Factors and Identification of Countermeasures*—as a guide. The analysis is usually referred to simply as the Hurt Report after the name of its primary author. This report was released in 1981 and documents in-depth analyses of motorcycle crashes in the City of Los Angeles, California, from 1976–1977. Although it is over 35 years old, it remains among the most referenced pieces of motorcycle safety literature. Many of the research questions answered in this report for Texas were guided by key findings in the Hurt Report, which also allowed for making comparisons with this prior seminal work.

A summary of the project, available at https://tti.tamu.edu/2017/07/05/tti-researchers-conduct-five-year-motorcycle-crash-analysis/, highlighted these findings:

- About 50% of motorcycle crashes were single vehicle crashes.
    - 65% involved the motorcycle overturning.
    - 24% involved the motorcycle hitting a fixed object.
- Among multivehicle crashes at intersections, the most common contributing factor (25%) was failure to yield the right of way while turning left.
- Among motorcycle crashes occurring on curves, 75% occurred on those with a large radius (1400+ feet).
- Rural areas present unique crash risks for motorcycles (e.g., large wildlife).
    - Of animal-involved motorcycle crashes in rural areas, 35% were fatal or incapacitating. In urban areas, 19% of animal-involved motorcycle crashes were fatal or incapacitating.

Motorcycle Road Safety Audit Case Studies, Dan Nabors, Elissa Goughnour and Jon Soika, Federal Highway Administration, May 2016.
https://safety.fhwa.dot.gov/rsa/resources/docs/fhwasa16026.pdf
Investigators evaluated road safety audits from three high-accident sites—two in North Carolina and one in Washington—and identified conditions that challenge motorcyclists, including:

- Inability to recover from lane departures.
- Effect of road design such as compound or spiral curve designs and changes in roadway superelevation in short sections of road.
- Debris on the roadway.
- Visibility to other road users.
- Roadside features such as trees, utility poles and guardrail.
- Lack of continuity in features that help riders maintain visual focus, such as centerline markings.
- Complex situations on vertical and horizontal curves where traffic may be exiting or entering the roadway.
- Environmental factors such as sudden changes in lighting between shaded and sunny sections.

Motorcycle Lane-Splitting and Safety in California, Thomas Rice, Lara Troszak and Taryn Erhardt, Safe Transportation Research and Education Center, University of California Berkeley, May 29, 2015.
http://www.ots.ca.gov/pdf/Publications/Motorcycle-Lane-Splitting-and-Safety-2015.pdf
As the introduction to this report indicates, "Lane-splitting is the practice of riding between lanes of traffic or sharing a lane with another motor vehicle. It is legal in California, but it is controversial and has not been studied." Researchers concluded that "[l]ane-splitting appears to be a relatively safe motorcycle riding strategy if done in traffic moving at 50 MPH or less and if motorcyclists do not exceed the speed of other vehicles by more than 15 MPH." The report's abstract highlights the following research results:

- Compared with other motorcyclists, lane-splitting motorcyclists were more often riding on weekdays and during commute hours, were using better helmets and were traveling at lower speeds.
- Lane-splitting riders were also less likely to have been using alcohol and less likely to have been carrying a passenger. Lane-splitting motorcyclists were also injured much less frequently during their collisions.
- Lane-splitting riders were less likely to suffer head injury (9 percent versus 17 percent), torso injury (19 percent versus 29 percent), extremity injury (60 percent versus 66 percent), and fatal injury (1.2 percent versus 3.0 percent).
- Both traffic speed and motorcycle speed differential (the difference between motorcycle speed and traffic speed) were important in predicting the occurrence of injury. There was no meaningful increase in injury incidence until traffic speed exceeded roughly 50 mph.
- Speed differentials of up to 15 mph were not associated with changes in injury occurrence; above that point, increases in speed differential were associated with increases in the likelihood of injury of each type.

"Motorcyclist's Lane Position as a Factor in Right-of-Way Violation Collisions: A Driving Simulator Study," Bertrand Sager, Matthew Yanko, Thomas Spalek, David Froc, Daniel Bernstein and Farhad Dastur, *Accident Analysis and Prevention*, Vol. 72, pages 325-329, November 2014.
Citation at http://www.sciencedirect.com/science/article/pii/S0001457514002152
From the abstract: In the present study, we examined a different characteristic of the motorcycle, namely its trajectory of approach. Seventeen participants faced oncoming traffic in a high-fidelity driving simulator and indicated when gaps were safe enough for them to turn left at an intersection. We manipulated the size of the gaps and the type of oncoming vehicle over 135 trials, with gap sizes varying from 3 to 5 s, and vehicles consisting of either a car, a motorcycle in the left-of-lane position, or a motorcycle in the right-of-lane position. Our results show that drivers are more likely to turn in front of an oncoming motorcycle when it travels in the left-of-lane position than when it travels in the right-of-lane position.

"Contributory Factors of Powered Two Wheelers Crashes," Pierre Van Elslande, George Yannis, Veonique Feypell, Eleonora Papadimitriou, Carol Tan and Michael Jordan, *Selected Proceedings of the 13th World Conference on Transport Research*, July 2013.
http://www.wctrs-society.com/wp/wp-content/uploads/abstracts/rio/selected/2875.pdf
After reviewing 23,322 fatal motorcycle crashes in the United States, researchers concluded that driver and rider behavior are more significant factors in the number of fatal motorcycle accidents than road design and environment such as roadside obstacles and barriers or traffic calming installations, which mostly influence accident severity.

“Estimation of Motorcyclist Injury Severity and Evaluation of Motorcycle Related Safety Strategies, a California Study,” Soyoung Jung, Xiao Qin and Yoonjin Yoon, *TRB 92nd Annual Meeting Compendium of Papers*, Paper #13-1631, 2013.
Citation at https://trid.trb.org/view.aspx?id=1241094
From the abstract: The intent of this study was to quantitatively examine factors associated with motorcyclist fatalities and assess the relevant improvement strategies for motorcyclist safety with an emphasis on the young and older aged motorcyclist victims. To accomplish this goal, injury severities for young and older motorcyclist victims were separately estimated using multinomial logit models and pseudo-elasticity with data from five-year motorcycle involved collisions. … Based on the statistically significant factors identified, the following safety strategies are convinced as effective methods to reduce motorcyclist fatalities: public education of sobriety, enforcement of heavy vehicle violation, helmet use promotion, clear roadway design and street lighting system, and motorcyclist training.

“Motorcyclists' Speed and ‘Looked-But-Failed-to-See’ Accidents,” Nicolas Clabaux, Thierry Brenac, Christophe Perrin, Joël Magnin, Bastien Canu and Pierre Van Elslande, *Accident Analysis & Prevention*, Vol. 49, pages 73-77, November 2012.
Citation at http://www.sciencedirect.com/science/article/pii/S0001457511002107
From the abstract: This article deals with the effects that the motorcyclist’s speed has in [“looked-but-failed-to-see” (LBFS)] accidents. It is based on the in-depth study and precise kinematic reconstruction of 44 accident cases involving a motorcyclist and another road user, all occurring in intersections. The results show that, in urban environments, the initial speeds of motorcyclists involved in LBFS accidents are significantly higher than in other accidents at intersections. In rural environments, the difference in speed between LBFS accidents and other accidents is not significant, but further investigations would be necessary to draw any conclusions. These results suggest that speed management, through road design or by other means, could contribute to preventing LBFS motorcycle accidents, at least in urban environments.

“Roadway Factors Associated with Motorcycle Crashes,” Alberto M. Figueroa Medina and Juan C. Torrens Soto, *Moving Toward Zero: 2011 ITE Technical Conference and Exhibit*, 2011.
Citation at http://trid.trb.org/view/1103870
From the abstract: This paper focuses on the evaluation of road information and motorcycle crash data to identify roadway design elements that are significantly associated with motorcycle crashes. The study performed a road inspection process of 39 road segments and employed the use of correlation, ANOVA, and multiple regression analyses. In addition, a survey of motorcycle riders was performed to identify their perception about the relation between the roadway condition and motorcycle safety. The study results indicate that the main roadway elements associated with motorcycle crash rates are the cross-section type and width, the intersection density, the posted speed limit, the presence of on street parking, pavement defects, and residential developments. These roadway elements and conditions can be targeted on new road construction and roadway improvement projects, in which motorcycles are considered in the road design. Establishing effective road maintenance practices that focus on these particular roadway elements can alleviate the problem of motorcycle crashes.

International

"Contributing Factors to Motorcycle Injury Crashes in Victoria, Australia," T. Allen, S. Newstead, M.G. Lenné, R. McClure, P. Hillard, M. Symmons and L. Day, *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 45, pages 157-168, February 2017.
http://trid.trb.org/view/1455248
From the abstract: The purpose of this study was to use case-series data collected from a recent motorcycle case-control study to analyze contributing factors to crashes using a safe systems approach. … For multi-vehicle crashes the most common crash scenario involved another vehicle failing to give way to the rider, and the primary contributor was a perception failure or traffic scan error on the part of the other road user. A number of secondary factors were found to be significantly associated with human error type (other road user or rider error), including rider age, traffic density, inappropriate speed of the PTW [powered two wheeler], and a road design issue. For single vehicle crashes, the most common primary contributor was a misjudgment or control error on the part of the rider, with inappropriate speed as the most frequent secondary contributor. Despite the complexity of factors involved in PTW crashes resulting in injury, a number of significant associations exist between road users as the primary contributing factor (rider or other road user) and secondary factors, including rider age, traffic density, speed and road design issues.

Infrastructure Improvements to Reduce Motorcycle Casualties, David Milling, Joseph Affum, Lydia Chong and Samantha Taylor, Austroads, July 2016.
https://www.amda.org.au/images/docs/AP-R515-16_Infrastructure_Improvements_to_Reduce_Motorcycle_Casualties.pdf
From the abstract: This report presents the technical findings of a two-year study which sought to identify effective infrastructure improvements to reduce motorcycle crash risk and crash severity, based on how riders perceive, respond and react to infrastructure they encounter. … The research highlights that motorcycles should be identified as an individual road user group and considered as a 'design vehicle' during road design and asset management and maintenance practices. It is concluded that motorcycle crash risk can be managed, but requires changes in practice, in design, asset management funding and routine maintenance performance contracts. One example is in the identification of road sections and/or routes that pose the highest crash risk to motorcyclists, so that they can be managed and maintained appropriately. In addition, the author advocates proactive motorcycle specific network safety assessments and road safety audits, as well as fine-tuning in design parameters for roads carrying significant volumes of motorcyclists (e.g. horizontal geometry, sight lines, lane and shoulder width, intersection types, intersection quality and controls). It is also suggested that the range and detail of mitigation measures be expanded.

Improving Safety for Motorcycle, Scooter and Moped Riders, International Transport Forum, Organisation for Economic Co-operation and Development, 2015.
http://www.svmc.se/smc_filer/SMC%20centralt/Rapporter/2016/OECD%20Report_Improving%20safety%20for%20motorcycle.pdf
From the executive summary: The International Transport Forum set up a Working Group on the Safety of Powered Two-Wheelers in 2010 to review trends in powered two-wheeler crashes and examine the factors contributing to these crashes and their severity. This report is the result of that effort. It describes a set of countermeasures targeting user behaviours, the use of protective equipment, the vehicles and the infrastructure and discusses motorcycle safety strategies in the context of a Safe System approach.

Among the report's recommendations (page 11 of the report, page 13 of the PDF):

- **Reduce crash risk for powered two-wheelers by introducing self-explaining and forgiving roads.** Infrastructure should be improved with the development of self-explaining roads which guide drivers and riders to adopt appropriate speed behaviour along with traffic calming measures and PTW-friendly infrastructure ("forgiving" roads). Engineers, road designers and providers, local authorities, road safety auditors and inspectors should be trained to consider PTWs in the design, construction, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions.
- **Do more research to extend understanding of powered two-wheeler mobility and crash mechanisms.** There is a great need to develop and apply relevant methods, tools and indicators to measure PTWs in traffic flows and analyse their mobility and behaviour. In particular, exposure data are needed to better understand the specific crash characteristics of PTWs. Operational research and development is needed to achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. Intelligent Transport Systems (ITS) require more research and development on their capacity to prevent and mitigate PTW crashes. Further investigation is required regarding the content and effectiveness of training, including post-licence training.

Inquiry Into Motorcycle Safety in New South Wales, Joint Standing Committee on Road Safety, Parliament of New South Wales, November 2015.
https://www.parliament.nsw.gov.au/committees/DBAssets/InquiryReport/ReportAcrobat/5581/Final%20Report%20-%20No%201%2056%20-%20Inquiry%20into%20Motorcycle%20S.pdf
Recommendations in this report include implementing a quality assurance and auditing process of all road designs, establishing policies and practices to make barrier systems less harmful, developing a partnership among road agencies to resolve road safety management issues and develop solutions for safer roads, and enhancing road safety audits. Investigators also recommend improving the road hazard reporting system by developing a mobile phone app to encourage road users to report road safety issues.

"Motorcycle Safety Route Review: A Case Study," A. Thomas, W. Smart, M. de Roos, K. Webster and C. Gibbs, *Australasian Road Safety Research, Policing and Education Conference*, November 2011.
http://casr.adelaide.edu.au/rsr/RSR2011/2CPaper%20006%20Thomas.pdf
From the abstract: A working party (consisting of road safety practitioners, asset maintenance staff and NSW [New South Wales] police) was formed to examine road use, driver behaviour and various elements of the current design of the road. The group identified a range of low cost treatments that were able to be implemented in a short time frame and were targeted at areas where clusters of crashes were occurring. The treatments adopted included installation of high visibility signage, motorcycle specific awareness campaigns, speed zone reductions and a number of engineering treatments. Analysis of the crash statistics in the three years since the treatments were installed shows a decrease in motorcycle crashes.

"The Potential of Different Countermeasures in Reducing Motorcycle Fatal Crashes: What In-Depth Studies Tell Us," Matteo Rizzi, Johan Strandroth, Roger Johansson and Anders Lie, *22nd International Technical Conference on the Enhanced Safety of Vehicles,* Paper #11-0191, 2011.
https://www-esv.nhtsa.dot.gov/Proceedings/22/files/22ESV-000191.pdf
Using four years of data on motorcycle fatalities in Sweden, researchers identify several infrastructure features with potential to improve motorcycle safety, including median barriers,

improved sight distances, clear roadside space and motorcycle-friendly side barriers. Safe intersections on rural roads was the most promising infrastructure countermeasure cited, although researchers acknowledged the lack of a specific road design. In urban settings, they recommended using roundabouts. Motorcycles traveling at high speeds, however, could make any facilities and infrastructure recommendations ineffective.

Curve, Lane and Shoulder Design

Domestic

Research in Progress: Study on Motorcycle Safety in Negotiation with Horizontal Curves in Florida and Development of Crash Modification Factors, Florida Department of Transportation, expected completion date: April 30, 2017. (This project is classified as active on the Florida DOT web site.)
Project description at http://trid.trb.org/view/1372953
From the project description: This project aims to identify the contributing factors to motorcycle crashes at horizontal curve segments for the development of effective countermeasures to reduce motorcycle crashes at horizontal curve segments of roadways. More specifically, the research objectives are: I) The research team will conduct a comprehensive analysis to identify "unsafe" factors that significantly increase the risk of motorcycle crashes and aggravate their injury-severity at horizontal curve segments in Florida. 2) The research team will develop motorcycle Crash Modification Factors/Functions (CMFs) to quantify the impacts of horizontal curvature and/or other factors. The developed CMFs will be compatible with the Highway Safety Manual. 3) The research team will conduct a preliminary assessment on the effectiveness of selected countermeasures, which have been implemented in Florida Department of Transportation (FDOT) District 7, in reducing the risk of curved-related motorcycle crashes, especially fatalities. 4) The team will develop recommendations on effective countermeasures to improve motorcycle safety at horizontal curve segments, including motorcycle-optimized horizontal curve designs and traffic controls. The recommendations can be used to update *The Florida Greenbook*, FDOT Plans Preparation Manual, or other standards.

Related Resources:

"Safety Effects of Horizontal Curve Design on Motorcycle Crash Frequency on Rural, Two-Lane, Undivided Highways in Florida," Chunfu Xin, Zhenyu Wang, Pei-Sung Lin, Chanyoung Lee and Rui Guo, *Transportation Research Record 2637*, pages 1-8, 2017.
Citation at http://trid.trb.org/view/1439173
From the abstract: The association between horizontal curve design (e.g., radius and type) on rural, two-lane, undivided highways and motorcycle crash frequency is not well documented in existing reports and publications. This study aimed to investigate the effects of design parameters and associated factors on the occurrence of motorcycle crashes with consideration of the issue of unobserved heterogeneity. … The major conclusions are the following: (a) an increase in curve radius, on average, significantly and near-logarithmically reduced motorcycle crash frequency on rural, two-lane, undivided highways (this effect was more significant when the curve radius was less than 2,000 ft); (b) 74.8% of reverse curves tended to reduce motorcycle crash frequency on rural, two-lane, undivided highways (for the remaining 25.2%, the effect had an opposite effect; on average, the likelihood of motorcycle crashes on reverse curves decreased by 39%); (c) the crash modification function (CMF) for curve radius on rural, two-lane, undivided highways was established, given the radius of 5,000 ft as the baseline, as a power formula, CMF = (radius/5,000)–0.208.

"Modeling Safety Effects of Horizontal Curve Design on Injury Severity of Single-Motorcycle Crashes with Mixed-Effects Logistic Model," Chunfu Xin, Zhenyu Wang, Chanyoung Lee and Pei-Sung Lin, *Transportation Research Record 2637*, pages 38-46, 2017.
Citation at http://trid.trb.org/view/1439155
From the abstract: The current study aimed to investigate and quantify the effects of horizontal curve design and associated factors on the injury severity of single-motorcycle crashes with consideration of the issue of unobserved heterogeneity. A mixed-effects logistic model was developed on the basis of 2,168 single-motorcycle crashes, which were collected on 8,597 horizontal curves in Florida for a period of 11 years (2005 to 2015). Four normally distributed random parameters (moderate curves, reverse curves, older riders and male riders) were identified. The modeling results showed that sharp curves (radius < 1,500 ft) compared with flat curves (radius ≥ 4,000 ft) tended to increase significantly the probability of severe injury (fatal or incapacitating injury) by 7.7%. In total, 63.8% of single-motorcycle crashes occurring on reverse curves are more likely to result in severe injury, and the remaining 26.2% are less likely to result in severe injury. Motorcyclist safety compensation behaviors (psychologically feeling safe, and then riding aggressively, or vice versa) may result in counterintuitive effects (e.g., vegetation and paved medians, full-access-controlled roads, and pavement conditions) or random parameters (e.g., moderate curve and reverse curve). Other significant factors include lighting conditions (darkness, darkness with lights), weekends, speed or speeding, collision type, alcohol or drug impairment, rider age, and helmet use.

"Influence of Horizontally Curved Roadway Section Characteristics on Motorcycle-to-Barrier Crash Frequency," Douglas J. Gabauer and Xiaolong Li, *Accident Analysis & Prevention*, Vol. 77, pages 105-112, April 2015.
Citation at http://trid.trb.org/view/1346236
From the abstract: The purpose of this study was to investigate motorcycle-to-barrier crash frequency on horizontally curved roadway sections in Washington State using police-reported crash data linked with roadway data and augmented with barrier presence information. Data included 4915 horizontal curved roadway sections with 252 of these sections experiencing 329 motorcycle-to-barrier crashes between 2002 and 2011. Negative binomial regression was used to predict motorcycle-to-barrier crash frequency using horizontal curvature and other roadway characteristics. Based on the model results, the strongest predictor of crash frequency was found to be curve radius. This supports a motorcycle-to-barrier crash countermeasure placement criterion based, at the very least, on horizontal curve radius. With respect to the existing horizontal curve criterion of 820 feet or less, curves meeting this criterion were found to increase motorcycle-to-barrier crash frequency rate by a factor of 10 compared to curves not meeting this criterion. Other statistically significant predictors were curve length, traffic volume and the location of adjacent curves. Assuming curves of identical radius, the model results suggest that longer curves, those with higher traffic volume, and those that have no adjacent curved sections within 300 feet of either curve end would likely be better candidates for a motorcycle-to-barrier crash countermeasure.

Developing an Effective Shoulder and Centerline Rumble Strips/Stripes Policy to Accommodate All Roadway Users, Mohamed Ahmed, Mirza A Sharif and Khaled Ksaibati. Wyoming Department of Transportation, 2015.
http://trid.trb.org/view/1373026
This report identifies lane departure, run-off-road crashes, opposite direction sideswipes and head-on crashes as the most severe accidents. It focuses on the use of rumble strips and

identifies issues with a lack of standardization in design and its impact on motorcycles and other vehicles. *From the abstract*:

> Although the advantages of rumble strips were generally found to outweigh the disadvantages, several issues and concerns have been identified regarding the implementation of rumble strips; noise, maintenance, and the adverse effects on bicyclists and motorcyclists are among the most recognized concerns. This study demonstrated that despite the fact that rumble strips have been used for many years, there are no standardized practices used in the U.S.

"Investigation Motorcycle Safety at Exit Ramp Sections by Analyzing Historical Crash Data and Rider's Perception," Hongyun Chen, Chanyoung Lee and Pei-Sung Lin, *Journal of Transportation Technologies*, Vol. 4, No. 1, pages 107-115, January 2014.
https://www.researchgate.net/publication/273745064_Investigation_Motorcycle_Safety_at_Exit_Ramp_Sections_by_Analyzing_Historical_Crash_Data_and_Rider%27s_Perception
From the abstract: The purpose of this study is to evaluate the safety performance of four exit ramp types and the major contributing factors on motorcycle crashes and injury severity of motorcycle riders. A six-year crash data were collected in Florida, and a web-based survey (234 samples) was conducted. … For a diamond exit, both the survey and crash data showed that this type was safer and more preferable by motorcycle riders; while a loop exit was the most dangerous exit due to the sharp curve and a certain length of curve with limited visibility. For a directional exit, longer ramp lengths and the reverse curvature are the major factors causing motorcycle crashes. For an outer connection exit, the riders rated it as a safe type; however, the data showed higher average crash frequency and rate than those at diamond exits or directional exits. The possible reason could be the unexpected curvature in the middle of the ramp, which could be dangerous if the rider is not familiar with the exit ramp location or doesn't pay attention to the ramp curvatures.

"Effects of Horizontal Curvature on Single-Vehicle Motorcycle Crashes Along Rural Two-Lane Highways," William H. Schneider IV, Peter T. Savolainen and Darren N. Moore, *Transportation Research Record 2194*, pages 91-98, 2010.
Citation at http://trid.trb.org/view/910123
From the abstract: The data used in this study include crash records for the years 2002 through the spring of 2008, in combination with available geometric design information, for those curves maintained by the State of Ohio. The analysis data set includes 30,379 horizontal curves that experienced a total of 225 motorcycle crashes during the study period. The findings show that the radius and length of each horizontal curve significantly influence the frequency of motorcycle crashes, as do shoulder width, annual average daily traffic, and the location of the road segment in relation to the curve.

"Right-Angle Crash Vulnerability of Motorcycles at Signalized Intersections: Mixed Logit Analysis," M. Mazharul Haque and Hoong Chor Chin, *Transportation Research Record 2194*, pages 82-90, 2010.
Citation at http://trid.trb.org/view/910469
From the abstract: The objective of this study is to explore how variations in roadway characteristics, environmental factors, traffic factors, maneuver types, human factors, and driver demographics influence the right-angle crash vulnerability of motorcycles at intersections. … Nighttime riding shows a positive association with the vulnerability of motorcyclists. Moreover, motorcyclists are particularly vulnerable on single-lane roads, on the curb and median lanes of multilane roads, and on one-way and two-way roads relative to divided highways. Drivers who deliberately run red lights and those who are careless toward motorcyclists, especially when turning at intersections, increase the vulnerability of motorcyclists. Drivers appear more

restrained when there is a passenger onboard, and this factor has decreased the crash potential for motorcyclists. The presence of red light cameras also significantly decreases right-angle crash vulnerabilities of motorcyclists.

Barriers

Domestic

Research in Progress: Factors Related to Serious Injury and Fatal Motorcycle Crashes with Traffic Barriers, NCHRP Project 22-26, expected completion date: December 2016. (The project web site indicates this project is active; no final report has been posted.)
Project description at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2516
From the project description: Although limited, research appears to indicate that motorcycle riders are dramatically overrepresented in the number of serious injuries and fatalities resulting from guardrail impacts. Not much is known about impacts with other types of traffic barriers (e.g., concrete barriers, cable barriers, bridge rails, crash cushions and end terminals). Many factors related to motorcycle crashes make analysis difficult, for example:

- Motorcycle usage, roadway design, and crash data collection practices differ among states.
- Typical coding on crash reports may not reflect the actual sequence of events and cause of injury. It may be unclear if both the motorcycle and the motorcyclist impacted the barrier or if the motorcyclist separated from the motorcycle prior to striking the barrier.
- Impact with the barrier may not have been the most harmful event.

There is virtually no in-depth analysis of data describing motorcycle crashes involving traffic barriers in the United States. This lack of crash data analysis prevents an understanding of injury mechanisms in motorcycle-barrier crashes. As such, an in-depth investigation is needed of serious injury and fatal motorcycle crashes involving traffic barriers.

"Characterization of Roadway Geometry Associated with Motorcycle Crashes into Longitudinal Barriers," Douglas J. Gabauer, *Journal of Transportation Safety & Security*, Vol. 8, No. 1, pages 75-96, January 2016.
Citation at http://trid.trb.org/view/1376824
From the abstract: The objective of this study was to determine specific roadway characteristics associated with motorcycle-to-barrier crashes in the context of other motorcycle crash types and identify features of locations experiencing multiple barrier crashes. Data included a total of 1,511 police reported motorcycle crashes coupled with detailed roadway data from two U.S. states, Washington and Ohio. Compared to all other single-vehicle motorcycle crashes, motorcycle impacts with barriers were found to be significantly more likely on smaller radius horizontal curves and sections with grade in excess of 3%. With regard to the sole quantitative recommendation of placing countermeasures on horizontal curves with radii fewer than 820 feet, agencies may want to carefully consider whether direct application of this criterion is prudent given the available data.

"Effect of Barrier Type on Injury Severity in Motorcycle-to-Barrier Collisions in North Carolina, Texas and New Jersey," Allison Daniello and Hampton Gabler, *Transportation Research Record 2262*, pages 144-151, 2011.
Citation at http://trrjournalonline.trb.org/doi/abs/10.3141/2262-14
From the abstract: This study analyzed 951 motorcycle-barrier crashes involving 1,047 riders from 2003 to 2008 in North Carolina, Texas and New Jersey to determine the effect of barrier type on injury severity in crashes. … Of the people involved in W-beam collisions with known injury severity, 40.1% were fatally or severely injured. Likewise, 40.3% of people involved in cable barrier collisions with known injury severity were fatally or severely injured. The odds of severe injury in W-beam crashes to concrete barrier crashes were 1.164 (95% confidence interval: 0.889 to 1.524) for all riders involved in the barrier crashes analyzed, which was not significant at the 0.05 level. However, if the rider was helmeted, the odds of severe injury in a W-beam guardrail collision were 1.419 (95% confidence interval: 1.024 to 1.966) times as great as the odds of severe injury in concrete barrier collisions, a factor found to be significant at the 0.05 level. For both helmeted and unhelmeted riders, there was no significant difference in the odds of severe injury between the cable barrier collisions and the W-beam guardrail collisions. However, a smaller number of cable barrier collisions than W-beam guardrail collisions were included in the analysis.

International

"Best Practices and Strategies to Reduce Fatal or Serious Injury Crashes into Guardrail Posts by Motorcyclists: United Kingdom Experience," Gavin Williams, *Roadside Safety Design and Devices: International Workshop*, Transportation Research Circular E-C172, pages 89-92, February 2013.
http://onlinepubs.trb.org/onlinepubs/circulars/ec172.pdf (see page 89 of the circular; page 97 of the PDF)
From the abstract: This paper examines the background to the use of motorcyclist protection systems (MPS) within the United Kingdom by first presenting a case study of the first MPS installation in the United Kingdom. This installation increased awareness of the use of MPS systems within the United Kingdom and this, together with discussions from motorcyclist organizations and enquiries through Parliamentary Questions, persuaded both the Highways Agency (HA) and Transport Scotland to initiate research into incidents between motorcyclists and safety barriers. This paper presents the results of this research, and explains how this research may lead to implementation guidelines for future MPS use in the United Kingdom.

"Best Practices and Strategies to Reduce Fatal or Serious Injury Crashes into Guardrail Posts by Motorcyclists: Australian Experience," Raphael Grzebieta, Mike Bambach and Andrew McIntosh, *Roadside Safety Design and Devices: International Workshop,* Transportation Research Circular E-C172, pages 93-105, February 2013.
http://onlinepubs.trb.org/onlinepubs/circulars/ec172.pdf (see page 93 of the circular; page 101 of the PDF)
From the abstract: The role of roadside safety barriers in motorcyclist trauma has been an area of concern among motorcyclists, road authorities, road safety researchers, and advocates despite the number of barrier-related deaths being relatively small. Roadside barriers include safety barriers positioned either at road edges or within medians and are typically steel W-beam, concrete, or wire-rope. As a result, a major research project focusing on motorcycle crashes into roadside barriers in both Australia and New Zealand was started in 2008. … The results presented in this paper focus on impacts into barrier posts. Presented are extracts from reports and papers already published by the authors elsewhere and listed in the references.

Work Zones and Maintenance

Domestic

The Examination of Factors Associated in Motorcycle Crashes in Work Zones, Brandon Stakleff, Alex Maistros and William H. Schneider IV, Ohio Department of Transportation, January 2013.
http://worldcat.org/arcviewer/7/OHI/2013/04/12/H1365781416629/viewer/file1.pdf
Researchers gathered data in three areas: practices used throughout the country on this topic; crash reports and the construction documents pertaining to these crashes; and a national survey of the motorcycling community. Results of the national survey highlighted these roadway-based solutions to enhance the safety of motorcycle riders in work zones (see page 15 of the report; page 33 of the PDF):

- Installing temporary asphalt wedges to give a transition from the pavement to an obstruction such as a steel plate or an exposed manhole cover.
- Tapering new pavement to eliminate edge drop-offs.
- Reducing the length of grooved pavement and the time that grooved pavement is exposed.
- Creating specifications stating that the roadway must be kept free of debris.
- Reducing the height of vertical pavement edges.
- Mitigating edge transitions and other temporarily elevated obstructions.
- Increasing emphasis of continuous pavement condition monitoring.
- Incorporating motorcycle-specific practices into project designs, traffic manuals and contract documents.
- Adding skid-resistant material to steel plates.
- Leaving a gap in transverse rumble strips for motorcyclists to pass through.

Education and Awareness Campaigns

Education and outreach efforts in Florida, Missouri and Texas are highlighted below. Also included are a national assessment of state motorcycle safety programs and a discussion of public education efforts in New South Wales, Australia.

Florida

Ride Smart Florida, Traffic Safety Office, Florida Department of Transportation, undated.
https://ridesmartflorida.com/
From the web site:

> Ride Smart Florida is the communication and outreach extension of the Florida Motorcycle Safety Coalition, a group of safety partners from around the state who share the common goal of reducing fatalities of motorcycle riders and their passengers. Ride Smart Florida uses data-driven research to develop, implement and evaluate counter measures and works with safety partners around the state to reduce fatalities and serious injuries to motorcycle riders and their passengers.

Printed material, educational videos and promotional materials are available on the web site at https://ridesmartflorida.com/media/.

Related Resources:

Florida Motorcycle Safety Coalition, Traffic Safety Office, Florida Department of Transportation, undated.
http://ridesmartflorida.com/about-us/florida-motorcycle-safety-coalition/
Led by Florida DOT, with administrative assistance from the Center for Urban Transportation Research at the University of South Florida, the coalition "is a group of safety partners from around the state who meet quarterly to share the common goal of reducing fatalities of motorcycle riders and their passengers." See the citation below for a brief history of the coalition and its early impact.

2010 Winner: The Florida Motorcycle Safety Coalition, Peter K. O'Rourke Special Achievement Awards, Governor's Highway Safety Association, 2010.
http://www.ghsa.org/about/safety-awards/2010-winner-florida-motorcycle-safety-coalition
This description of a 2010 award provides a brief history of the Florida Motorcycle Safety Coalition and some of its early accomplishments.

Missouri

Arrive Alive, Missouri Coalition for Roadway Safety, 2016.
https://savemolives.com/safety-topics/topic/motorcycles
From the web site: The Missouri Coalition for Roadway Safety is a large group of safety advocates who banded together in 2004 to create Missouri's Blueprint for Safer Roadways. Partners include law enforcement, educators, emergency responders and engineers who have launched statewide efforts to reduce fatalities and create safer roads in Missouri.

Promotional materials related to motorcycle safety are available at https://savemolives.com/campaigns/details/motorcycle-awareness-month.

Related Resource:

Missouri's Blueprint: A Partnership Toward Zero Deaths 2016-2020, Missouri Coalition for Roadway Safety, 2016.
http://s3-us-west-2.amazonaws.com/modot-pdfs/Blueprint_2016-2020.pdf
A discussion of motorcycle safety begins on page 80 of the document (page 84 of the PDF). Strategies are offered in these categories: education, emergency response, enforcement, engineering, technology, public policy/other and performance measures.

Texas

Look Learn Live, Texas Department of Transportation, 2017.
https://www.looklearnlive.org/
From the web site: Look Learn Live is a Texas motorcycle safety and awareness campaign developed by the Texas Department of Transportation, Texas A&M Transportation Institute and the Texas Motorcycle Safety Coalition.

A wealth of print and web promotional materials are available at https://www.looklearnlive.org/media/print-and-web-materials/. Radio and TV spots are also available.

Multiple States

Review of State Motorcycle Safety Program Technical Assessments, Justin Baer and Melanie Skemer, National Highway Traffic Safety Administration, January 2009.
http://www.ddot-hso.com/ddot/hso/documents/Publications/Motorcycle_Safety/2009/Review%20of%20State%20Motorcycle%20Safety%20Program%20Technical%20Assessment-Jan%202009.pdf
Chapter 8, Public Information and Education (beginning on page 42 of the report, page 48 of the PDF), provides information about "efforts made by states to promote motorcycle safety and licensing through a variety of channels aimed at both motorcyclists and the general public." Among the recommendations related to education and awareness:

- Fund and develop a coordinated, statewide public information and education plan to promote motorcycle safety issues. The plan should include research and evaluation components.
- Use research to determine the most effective means of reaching target audiences with motorcycle safety messages.
- Measure media response by creating specific web pages or phone numbers to measure the audience.
- Encourage businesses and private organizations to participate in motorcycle safety public information and education campaigns.
- Develop an action plan to respond in the event of high profile motorcycle safety issues, making information and spokespersons available to the media.

International

"Methodologies Used for Economic Appraisals of Road Safety Educational or Informational Campaign Programs in NSW," Baojin Wang and Julieta Legaspi, *Australasian Transport Research Forum 2016 Proceedings*, November 2016.
http://atrf.info/papers/2016/files/ATRF2016_Full_papers_resubmission_104.pdf
From the abstract: From 2012 to 2016, TfNSW [Transport for NSW, or New South Wales] has undertaken the economic appraisal of 39 individual campaigns covering speeding, speed camera, drink driving, drug driving, driver fatigue, seat belt, children restraint, school zones, mobile phone distraction whilst driving, bicycle safety, bus safety, motorcycle safety, driveway safety and driver courtesy. … This paper summarises the models describing the relationships between educational campaign and driver behavioural change; the initial campaign effect and subsequent decay profile and ultimately campaign's impact on road safety outcome. The paper aims to contribute to transport research by outlining practical methodologies to estimate the economic benefits of road safety campaigns.

"Helping Motorcyclists 'Ride to Live': Developing a Large-Scale Public Education Campaign for Motorcyclists Using Research and Stakeholder Consultation," Lauren Fong, Ralston Fernandez, Evan Walker, Martin O'Reilly, Anja-Mia Woodward-Watson, Nicole Douglas and Gabrielle Suchard, *Australasian Road Safety Conference*, October 2015.
http://acrs.org.au/files/papers/arsc/2015/FongL%20195%20Helping%20motorcyclists%20Ride%20to%20Live.pdf
From the abstract: Research was undertaken in 2012 to understand the knowledge, attitudes and behaviours of NSW riders and drivers in relation to motorcycle safety. The research revealed that riders place a high degree of importance on skills and their own riding abilities, as well as externalise blame for crashes. A key challenge was to develop campaign messaging that was relevant and credible to riders without reinforcing stereotypes that suggest riders are non-compliant, risk-taking road users. The 'Ride to Live' campaign was subsequently designed around acknowledging motorcyclists' passion for riding, whilst challenging riders to better manage their risks on the road. Campaign executions highlight common scenarios for commuter and recreational riders and illustrate the consequences of different choices riders can make in response to each hazard. … Findings from the research were instrumental in developing an evidence-based campaign, along with strong collaboration with key stakeholder groups including NSW Motorcycle Alliance and Motorcycle Council of NSW. This extended to using important motorcycle networks to gain access to rider expertise and get a stronger campaign reach.