MOTORCYCLE ROAD SAFETY AUDIT CASE STUDIES

U.S. Department of Transportation
Federal Highway Administration

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FHWA-SA-16-026

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Dan Nabors, Elissa Goughnour, Jon Soika	

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16. Abstract

Road Safety Audits (RSAs) are a formal safety performance examination of an existing or future roadway or off-road facility and are conducted by an independent, experienced, multidisciplinary team. This case study document provides a review of the RSA process and three case study examples of RSAs that had a demonstrated high-frequency of crashes involving motorcyclists. The case studies include photographs, a project background, and key RSA findings and suggestions. These case studies will help Federal, State, Tribal, and local agencies better understand conditions that affect motorcyclists and how to effectively address safety in the RSA process.

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Purpose

The purpose of this report is to help Federal, State, Tribal, and local agencies understand conditions that affect the safety of motorcyclists and how to address road safety issues and identify opportunities for improvement through the Road Safety Audit (RSA) process.

This report describes three RSAs conducted from 2012 to 2014 on facilities with documented motorcycle crashes. The Federal Highway Administration (FHWA) sponsored these three RSAs to demonstrate the benefits of using the RSA process to reduce motorcycle fatalities, injuries, and crashes. This report attempts to synthesize the findings from the three RSAs and identify lessons learned about challenges and opportunities facing agencies as they seek to improve motorcycle safety.

The RSAs selected for this study included areas known for their popularity with motorcyclists. (Credit: Dan Nabors)

Background

This section provides an overview of the RSA process in general, including steps for conducting an RSA and the benefits and costs involved.

An RSA is an effective tool for proactively improving roadway safety. FHWA defines an RSA as a "formal safety performance evaluation of an existing or future road or intersection by an independent, multidisciplinary team." The primary focus of an RSA is safety, while working within the context of other aspects such as mobility, access, surrounding land use, and aesthetics. An RSA conducted by a team that is independent of the design and operations of the facility can address safety through a thorough review of roadway, traffic, environmental, and human factors conditions. By using an

unbiased and multidisciplinary team to perform a comprehensive review and an evaluation of geometric, operational, and human factors-related safety issues for a given study area, RSAs make sure that safety is adequately considered. The RSA team is typically composed of at least three members having expertise in road safety, traffic operations, and road design. Other potential team members may have a background in enforcement, emergency medical services, maintenance, human factors analysis, transportation planning, pedestrian safety, bicyclist safety, or any other discipline deemed relevant to the context of the facility being evaluated.

RSAs can be performed at any stage in a project's life:

- ***A Pre-Construction RSA (planning and design stages)*** examines a road before it is built. This may occur at the system or project planning, feasibility, or project development stage or could occur during the design state, beginning with preliminary design stage and ending with final design stage. An RSA at this stage identifies potential safety issues before crashes occur. The earlier a Pre-construction RSA is conducted, the greater potential it has to effectively mitigate possible safety concerns. For example, a planning stage RSA can examine a system of roads before a specific project has been identified for project development, design, and construction. The RSA team assesses the transportation system at the earliest point to identify, assess, prioritize, and program projects and activities that would considerably enhance traveler safety, in the context of and in collaboration with other multimodal transportation investments.
- ***Construction RSAs (work zone, changes in design during construction, and preopening)*** examine temporary traffic management plans associated with construction or other roadwork and changes in design during construction. RSAs at this stage can also be conducted when construction is completed but before the roadway is opened to traffic.
- ***A Post-Construction or Operational RSA (existing road)*** examines a road that is operating and is usually conducted to address a demonstrated crash problem.

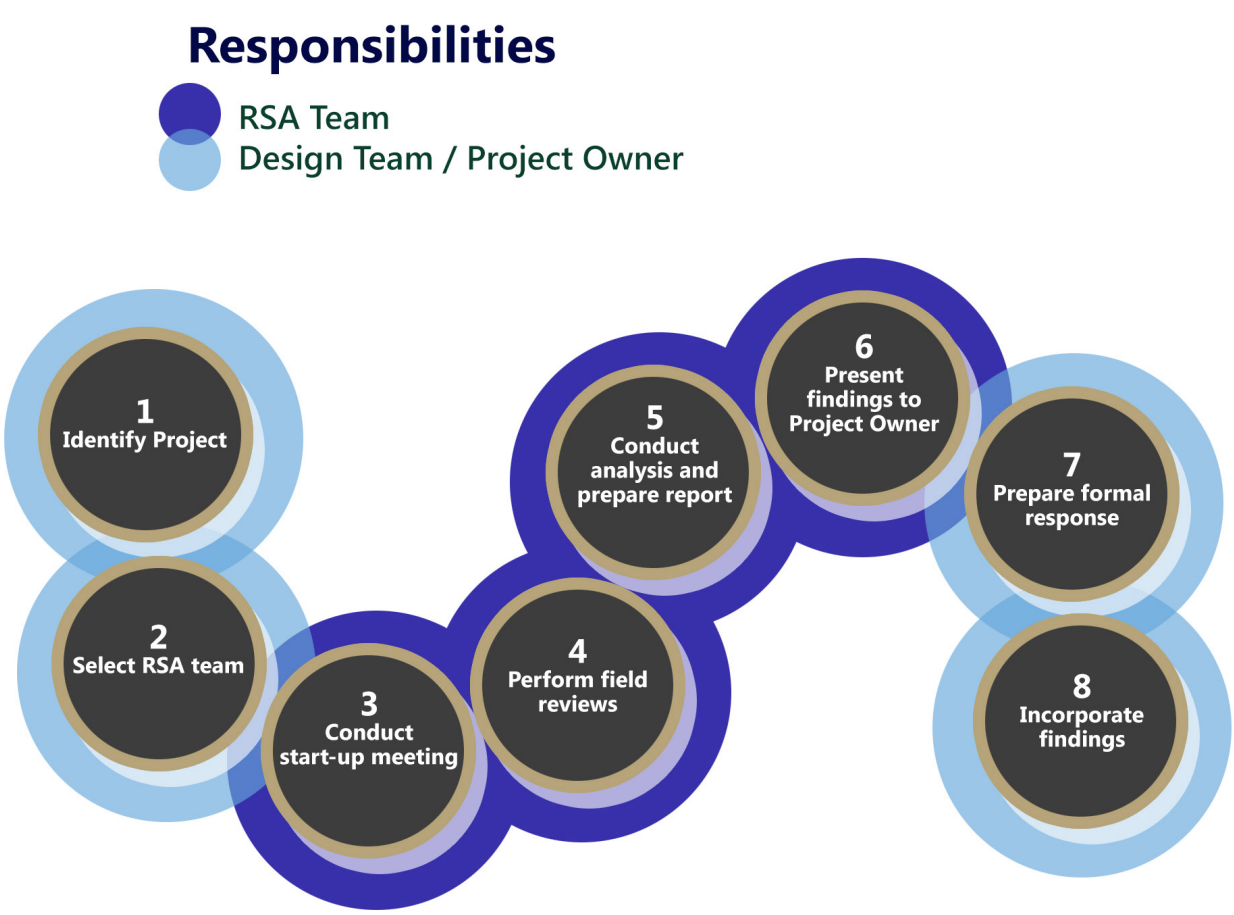


Figure 1: Typical Eight-step RSA Process.

Eight Steps of an RSA

The eight steps of an RSA, shown in Figure 1, follow the procedures outlined in the FHWA *Road Safety Audit Guidelines* document (Publication Number FHWA-SA-06-06).

The **RSA Project** is selected (Step 1) prior to assembling the RSA Team (Step 2), which should be interdisciplinary and typically includes engineering, planning, and enforcement staff from various levels of government, in cluding Federal, State, municipal, and metropolitan planning organizations (MPOs).

All meetings and site visits for the RSAs in the case studies project are conducted over two or three day periods. The RSAs typically begin with a start-up meeting (Step 3) attended by the Project Owner and/or Design Team (hereafter referred to as the Owner), and the RSA team:

- The Owner describes concerns regarding the roads and intersections to be assessed, why the sites have been chosen for an RSA, and any constraints or limitations. Typically, the reasons for the RSA site selection center on high-profile crashes or public safety concerns.
- The multidisciplinary RSA team then describes the RSA process. This includes an overview of the RSA process with examples of typical safety issues and potential measures to address them.
- This step may include discussion of additional issues, such as planned roadway improvements.

Following the start-up meeting and a preliminary review of the design or site documentation, the RSA team conducts a **field review** (Step 4). The purpose of the field review is to observe geometric and operating conditions. The RSA team observes site characteristics such as road geometry, sight distances, clear zones, drainage, signing, lighting, and barriers; traffic characteristics such as typical speeds and traffic mix; surrounding land uses including traffic and pedestrian generators; and link points to the adjacent transportation network. The RSA team also considers human factors issues, including road and intersection "readability," sign location and sequencing, and older-driver limitations. The RSA team conducts field reviews under a variety of environmental conditions, such as daytime and nighttime, and operational conditions, such as peak and off-peak times.

The team conducts the **RSA analysis** (Step 5) in a setting in which all team members reviewed available background information, such as traffic volumes and collision data, in light of the observations made in the field. On the basis of this review, the RSA team identifies and prioritizes safety issues, including features that could contribute to a higher frequency and/or severity of crashes. For each safety issue, the RSA team generates a list of possible measures to mitigate the crash potential and/or severity of a potential crash.

At the end of the analysis session, the Owner and the RSA team reconvenes for a **preliminary findings meeting** (Step 6). In presenting the preliminary findings verbally in a meeting, the RSA team gives the Owner an opportunity to ask questions and seek clarification on the RSA findings, and also provides a useful forum for the Owner to suggest additional or alternative mitigation measures in conjunction with the RSA team. The discussion provides practical information that can be subsequently used to write the RSA report.

In the weeks following the on-site portion of the RSA, the RSA team writes and issues the **RSA report** (also part of Step 6) to the Owner documenting the results of the RSA. The main content of the RSA report is a prioritized listing and description of the safety issues identified – illustrated using photographs taken during the site visit – with suggestions for improvements.

The Owner is encouraged to write a brief **response letter** (Step 7) containing a point-by-point response to each of the safety issues identified in the RSA report. The response letter identifies the action(s) to be taken, or explains why no action would be taken. The formal response letter is an important "closure" document for the RSA. As a final step, the Owner is encouraged to use the RSA findings to identify and implement safety improvements when policy, resources, and funding permit (Step 8).

RSAs: Benefits and Costs

RSA Benefits

The primary benefits of RSAs are the reduction of crashes and associated crash costs as road safety is improved. The US Department of Transportation estimates the costs of automotive crashes as:[1]

- $9,197,370 for a traffic fatality (category K).
- $5,454,040 for a critical injury (category A1).
- $2,446,500 for a severe injury (category A2).
- $965,724 for a serious injury (category B1).
- $432,276 for a moderate injury (category B2).
- $27,592 for a minor injury (category C).
- $6,500 for property damage only (PDO).

Other benefits of RSAs include reduced life-cycle project costs due to crash reduction, and the development of good safety engineering and design practices, including consideration of the surrounding land use and development in combination with potential multimodal safety issues and integrating human factors issues in the design, operations, and maintenance of roads. Additional benefits may include enhanced traveler experience and access management, reduced travel delay and travel time, and improved travel reliability.

In 2012, FHWA sponsored a study of nine RSA programs and five RSA projects. The project documented key strategies underpinning the success of the nine RSA programs, as well as the quantitative safety benefits of specific improvements implemented through the five specific RSA projects. FHWA report *Road Safety Audits: An Evaluation of RSA Programs and Projects* (FHWA-SA-12-037) provides the results of this study. Other local and regional studies have attempted to quantify the benefits of RSAs; practitioners are encouraged to consult partnering agencies with regard to the success in implementing RSAs.

RSA Costs

Three main factors contribute to the cost of an RSA:

- RSA team costs.
- Design team and Owner costs.
- Costs of design changes or enhancements.

1 U.S. Department of Transportation, Memorandum to Secretarial Officers and Modal Administrators from Polly Trottenberg, Under Secretary for Policy, February 28, 2013.

The *RSA team costs* reflect the size of the team and the time required for the RSA, which in turn depend on the complexity of the RSA project. RSA teams are typically composed of three to four persons, although they can be larger when multiple owners are involved.

Opening and closing meetings, site visits, and RSA analysis sessions are typically conducted in a two- or three-day period for each RSA. Prior to and following the on-site portion of the RSA, time is required for analysis (such as analysis of collision records, and research on applicable design standards or mitigation measures) along with writing the RSA report.

The *design team and owner costs* reflect the time required for staff to attend the start-up and preliminary findings meetings, and to subsequently read the RSA report and respond to its findings. In addition, staff time is required to compile project or site materials for the RSA team.

The final cost component entails those costs resulting from *design changes or enhancements*, which reflect the number and complexity of the issues identified during the RSA.

Basic Principles of Motorcycle Safety

This section provides an overview of the factors affecting the safety of motorcyclists. This includes the general characteristics of motorcyclists, licensing and training, and roadway design.

From 2003 to 2008, fatalities and injuries for motorcyclists increased by 43 percent nationally. Between 2008 and 2009, a sharp decrease occurred in fatalities and a lesser decrease occurred in injuries. However, from 2009 to 2012, the upward trend reestablished itself with an 11 percent increase in fatalities and a 3 percent increase in injuries, including a peak of 15 percent from 2011 to 2012.[2]

Motorcyclists are at a greater risk than many other roadway users. In 2012, motorcycles made up three percent of all registered vehicles in the U.S., yet motorcyclist fatalities accounted for 15 percent of the total vehicle related fatalities.[3] While total traffic-related deaths in the U.S. have trended downward in recent years—from approximately 42,000 in 1997 to 32,675 in 2014—both the number and the proportion of motorcycle-related fatalities have increased significantly during that same time. There were approximately 2,100 motorcycle-related deaths in 1997, comprising nearly one in every 20 motor vehicle fatalities; in 2014, there were more than 4,500 motorcycle fatalities, which equates to one in every seven motor vehicle fatalities.[4] Figure 2 displays the trends in motorcycle-related and total traffic-related crashes in the U.S. from 1997 to 2014.

2 U.S. Department of Transportation, *Traffic Safety Facts 2012 Data: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, June 2014.

3 National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS). Available at: http:/www-fars.nhtsa.dot.gov/Main/index.aspx

4 National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS). Available at: http:/www-fars.nhtsa.dot.gov/Main/index.aspx

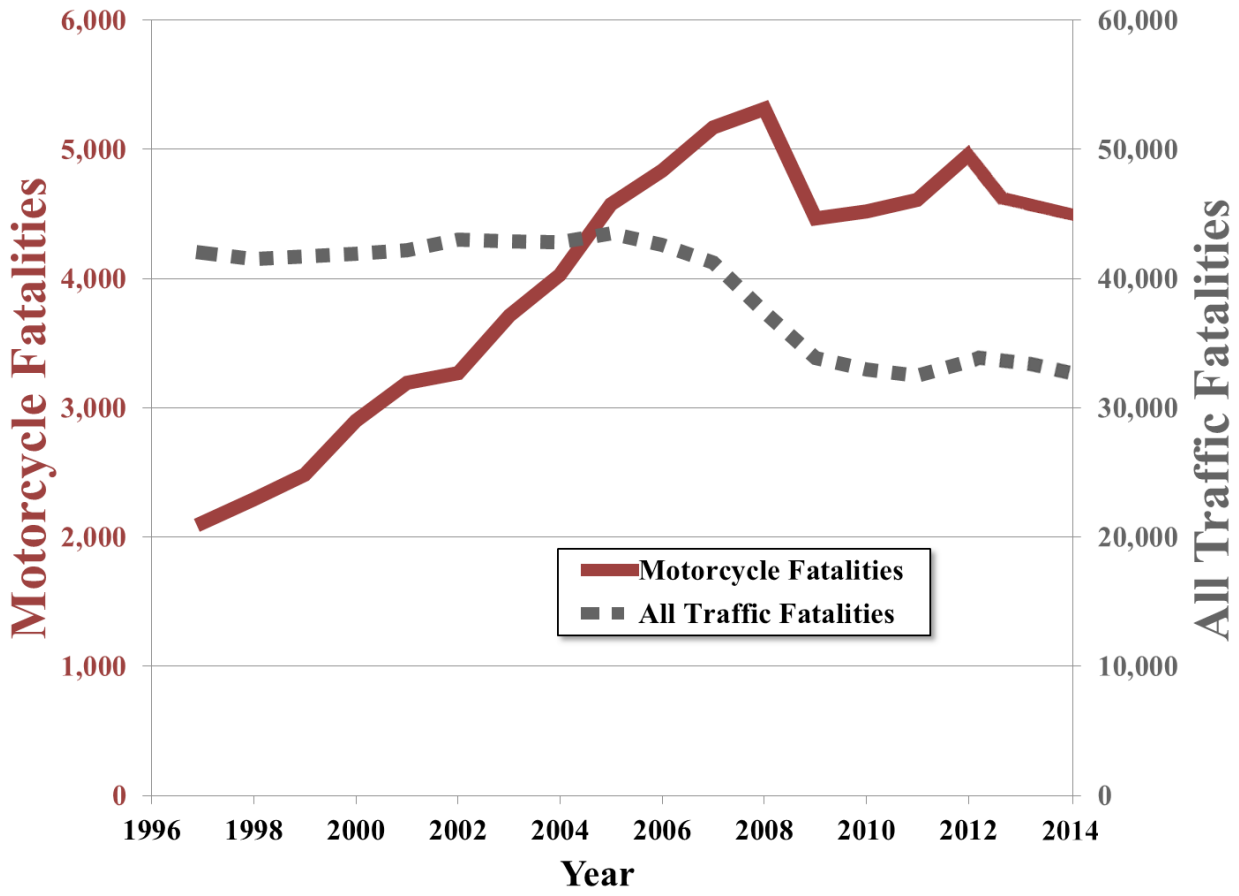


Figure 2. Trends in All Traffic-Related and Motorcycle-Related Fatalities in the U.S. from 1997 - 2014. (Source: NHTSA FARS Encyclopedia.)

Having an understanding of crash patterns for motorcyclists will help identify the factors leading to the high rates of fatalities and injuries among motorcyclists. However, to understand motorcycle safety it is necessary to know local laws and enforcement of these laws, as these elements may indicate behaviors and practices that directly affect safety. Understanding these components of safety will assist RSA teams in suggesting countermeasures to address this high-risk group and may encourage the testing and development of design standards, policies, and other strategies to improve motorcyclist safety.

Characteristics of Motorcyclists and Motorcycles

Motorcycling in general can vary from state to state, particularly with regard to factors such as age, rider experience, motorcycle type, frequency of use, and purpose of travel. There is also a wide variation in laws regarding helmet use, licensing, and training. One common characteristic is certain – motorcycles lack an occupant enclosure. This characteristic alone means that even minor loss of control can lead to crashes with serious or fatal consequences.[5] While all motor vehicle operators

5 NCHRP Scan Team, *Leading Practices for Motorcyclist Safety*, NCHRP Project 20 68A, Scan 09 04, September 2011.

have a responsibility to practice the safest driving habits possible, the risk of not doing so is amplified for motorcyclists.[6]

Motorcyclists are permitted an equal amount of space as automobile operators in the travel way, but require much less of it. This could lead to undesirable behaviors by all vehicle operators caused by the perception of the space needs of a motorcyclist within the existing roadway infrastructure.

In fatal crashes in 2012, motorcyclists represented the highest proportion (27 percent) of vehicle operators having a blood alcohol concentration (BAC) higher than 0.08g/dL at the time of the crash, despite the fact that motorcyclists represent only three percent of all registered vehicles.[7] An increase in accessible education and awareness of the dangers of impaired riding could serve this target audience.

The same education and awareness practices can be employed for increasing helmet and safety gear use. The USDOT's *Traffic Safety Facts* reports that helmets are 37 percent effective in preventing fatal injuries for motorcycle riders.[8] The same report also notes that in states without universal helmet laws, 62 percent of motorcyclists killed in 2012 were not wearing helmets, as compared to only nine percent in states with universal helmet laws.

There are many different types of motorcycles available to riders. The more common categories of street legal motorcycles include, but are not limited to: touring, cruiser, chopper, standard, dual-purpose, and various classifications of sport motorcycles. Motorcycles with these categories differ based on characteristics such as riding position, intended use, and driving dynamics.[9] Along these same lines, size, weight, and performance characteristics differ among motorcycle styles. Driver training and education may cover basic riding techniques on standard motorcycles, but may not educate or prepare riders on the dynamics, capabilities, and limitations of different types of motorcycles.[10] Figure 3 provides an overview of the characteristics of common motorcycle types.

6 Zegeer, C. et al, *Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users,* July 2010.

7 U.S. Department of Transportation, *Traffic Safety Facts 2012 Data: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, June 2014.

8 U.S. Department of Transportation, *Traffic Safety Facts 2012 Data: Motorcycles*, June 2014.

9 Insurance Institute for Highway Safety, Memorandum from Adrian K. Lund, President, Insurance Institute for Highway Safety, to Victor Mendez, Administrator, Federal Highway Administration, June 29, 2010.

10 For the purposes of this report, education pertains to raising users' awareness of laws, regulations, etc. Training pertains to providing instruction on how to ride a motorcycle safely.

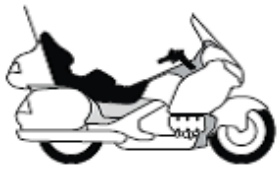
Cruiser Riding Position: Feet forward and upper body erect. Handling/Performance: Limited turning ability, less horsepower. Weight: Among the heaviest.	
Chopper Riding Position: Feet forward and upper body erect. Handling/Performance: Longer wheelbase due to the extended fork, which reduces maneuverability. Weight: Among the heaviest.	
Touring Riding Position: Upright position comfortable for longer distances. Handling/Performance: High-performance/high-torque engines for carrying passenger and luggage. Weight: Among longest and heaviest.	
Dual Purpose Riding Position: Typically forward. Handling/Performance: Similar to off-road motorcycles, with on-road safety features. Weight: Lighter than heavier classes.	
Standard Riding Position: Typically upright position similar to cruiser, but with foot pegs placed farther rearward. Handling/Performance: Better handling due to riding position and greater ground clearance. Weight: Lighter than heavier classes.	
Sport (Includes sport, sport touring, unclad sport, and super sport) Riding Position: Generally, feet under seat and hands below shoulder height, body leans forward. Handling/Performance: Powerful, with high power-to-weight ratio. Weight: Varies among the types of sport motorcycles.	

Figure 3: Motorcycle Classification (Source: IIHS).

Traditional Roadway Infrastructure Design

In general, motorcycles have not been explicitly considered in roadway design practices in the U.S.[11] FHWA or American Association of State Highway and Transportation Officials (AASHTO) guidelines accommodating motorcycles do not exist and the Manual on Uniform Traffic Control Devices (MUTCD) did not contain motorcycle warning signs until the last revision in 2009. Increasing our understanding of motorcyclist safety needs is an important area of continued research. This research can build on the important work already done by the National Cooperative Highway Research

11 Zegeer, C. et al, *Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users*, July 2010.

Program, whose *Guide for Addressing Collisions Involving Motorcycles* is intended to assist state and local agencies in reducing motorcyclist injuries and fatalities.[12] Aspects of roadway design and maintenance such as drainage and shoulders, communication of roadway conditions, pavement conditions, traffic control devices, and curves are usually designed around automobiles, yet their effects are often more critical for motorcyclists.

In 2004, the European Commission released a major motorcycle crash causation study entitled "MAIDS – Motorcycle Accidents In-Depth Study," which discovered that environmental conditions – including roadway design, among other things – were the third largest contributing factors to crashes.[13] The study discovered that human error is responsible for the vast majority of crashes, but notes that multiple precursors can lead to these errors.

Attention to safety concerns for motorcyclists continues to grow. In 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU) mandated the establishment of the Motorcyclist Advisory Council to FHWA (MAC–FHWA). The mission of the group was to "advise the [Federal Highway] Administrator on infrastructure issues of concern to motorcyclists."[14] The Fixing America's Surface Transportation (FAST) Act, signed into law in December 2015, reinstated the MAC-FHWA, which had lapsed under the Moving Ahead for Progress in the 21st Century Act (MAP-21). FHWA's Motorcycle Crash Causation Study is a comprehensive investigation into crash causes, rider demographics, and countermeasure development. The study, which involves federal and state transportation agencies, local police jurisdictions, researchers, and the motorcycle industry, will produce a dataset that offers unprecedented perspective on motorcycle-specific crash-causation factors.

In addition, 35 states and the District of Columbia have identified motorcycle safety as an emphasis area in their Strategic Highway Safety Plans. Several states also have created motorcyclist safety coalitions to address motorcyclist concerns. These coalitions include stakeholder representatives that provide perspective on the riding characteristics of motorcycles and how roadway design, construction, and maintenance practices affect motorcyclist safety.[15]

Motorcyclist Training & Licensing Requirements

A majority of states offer rider education for individuals who wish to obtain a motorcycle license. The courses provide basic training instruction, and research has found that the effects of initial training are greatly beneficial for the first six months of operating a motorcycle.[16] In some states, motorcyclists can even obtain a license through a one-day license-testing course. While demand to take such courses in the hopes of receiving licensure remains high, many individuals do not further progress their riding ability through formal instruction.

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12 Potts, I. et al, *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan: A Guide for Addressing Collisions Involving Motorcycles*, NCHRP Report 500, Vol. 22, Transportation Research Board, Washington, DC, 2008.
13 U.S. Department of Transportation, *Infrastructure Countermeasures to Mitigate Motorcyclist Crashes in Europe*, August 2012.
14 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), 23 U.S.C. § 1914 (2005).
15 NCHRP Scan Team, *Leading Practices for Motorcyclist Safety*, NCHRP Project 20 68A, Scan 09 04, September 2011.
16 Zegeer, C. et al, *Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users*, July 2010.

Some states report a much lower attendance rate for advanced motorcycle training than for the basic course necessary to acquire a license. Higher participation in such courses could lead to lower motorcycle crash rates, but riders frequently have no incentive to participate in such courses. It is realistic to believe that the incidence of one type of crash – collisions with fixed objects – could drastically decrease if riders were more familiar with advanced riding techniques. As it currently stands, motorcycles are more likely to be involved in such crashes than any other vehicle type.[17] Furthermore, loopholes in the initial licensing process in some states allow seasonal riders to repeatedly obtain temporary permits without ever becoming fully licensed.[18]

It is possible for states and local agencies to address these issues. Implementing measures such as the development of motorcycle coalitions may help improve awareness of motorcycling as a form of transportation. Evaluating licensure and training policies along with design standards could improve the ability to address the education, enforcement, and engineering measures related to motorcyclists. Moreover, it is crucial to assess the safety of motorcyclists holistically to determine resources that can be utilized at every level to promote a safer riding environment.

Motorcyclists in the RSA Process

RSA Project Selection

This case study effort included three RSAs in different regions of the country with crashes involving motorcyclists, as shown in Table 1. Each RSA followed the standard eight-step RSA process documented by FHWA. These sites were selected based on the following criteria:

- A demonstrated high-frequency of crashes involving motorcyclists
- Availability of detailed data
- Variation in geographic location

A more detailed report of these three RSAs is included in Appendix A.

Table 1: RSAs Conducted at Locations with High Frequency of Motorcycle Crashes.

Host Agency	Location	Facility Type and Project Stage	Length of Segment Studied
North Carolina Department of Transportation (NCDOT)	North Carolina (NC) Route 28 and NC Route 143 in Graham County near the Tennessee border	Existing two-lane rural highway	NC 28: ~1.75 miles NC 143: ~3 miles
Washington State Department of Transportation (WSDOT)	Three locations on Washington State Route 7 (SR 7): an urban segment and two rural intersections.	Existing urban, multi-lane highway and existing two-lane rural highway	Urban segment approximately 11 miles
National Park Service	Blue Ridge Parkway near and south of Asheville, NC	Existing two-lane rural highway in a National Park	Approximately 60 miles

17 U.S. Department of Transportation, *Traffic Safety Facts 2012 Data: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, June 2014.

18 Zegeer, C. et al, *Safer Vulnerable Road Users: Pedestrians, Bicyclists, Motorcyclists, and Older Users*, July 2010.

How Motorcycle Safety was Incorporated into the RSA Process

RSAs were conducted on existing facilities based on crash frequency (Step 1 in the RSA process). Each location had a high frequency of crashes involving motorcyclists. RSA teams consisted of the typical participants such as persons with expertise in road safety, traffic operations, and road design, and law enforcement (Step 2). The law enforcement officers selected to participate all had riding experience or were part of active motorcycle patrols. Other RSA team members also had expertise critical to understanding conditions affecting motorcyclists, such as members from departments of licensing and motorcycle safety clubs and other groups and organizations.

Crash data and the experience of motorcyclists from local clubs and other organizations were reviewed and discussed by the RSA team during the start-up meeting (Step 3) and during the RSA analysis workshop (Step 5). During the start-up meeting, those familiar with riding described and interpreted data to help determine contributing factors to crashes and their potential effect. They also provided details concerning critical conditions or locations. The RSA team reviewed these conditions in the field (Step 4). Furthermore, during each RSA, several team members were able to ride the locations under investigation and relate their knowledge and experience to the RSA team. Later, during the RSA analysis workshop (Step 5), the team discussed these conditions in more detail. The objective of this review was to discuss the analysis results and to compare these results with conditions observed in the field. Based on this analysis, the RSA team considered conditions critical to the safety of motorcyclists and suggested measures that may reduce the risk to motorcyclists.

The RSA team applied this process to understand the safety needs of motorcyclists. The RSAs helped bring attention to safety issues affecting motorcyclists by highlighting the effects of design and maintenance practices and by bringing together a multidisciplinary and multimodal group of safety professionals that were able to clarify issues that may not have been adequately understood previously. Furthermore, through the RSAs conducted as part of this study, the RSA teams discussed positive measures, challenges, and opportunities for advancement of motorcycle safety. The following section describes these in further detail.

Positive Measures

Commitment to safety. The RSAs demonstrated that agencies are seeking specific measures to address the safety of motorcyclists. This interest in motorcycle safety has been driven partly by crash data showing high crash frequencies in some locations, and overall trends showing an increase in motorcycle crashes and a higher severity of motorcycle crashes.

Collaboration with motorcycle safety clubs/organizations. Motorcycle groups and clubs, who have a stake in protecting their members, have been a primary driver of increased awareness of motorcycle safety. Including motorcyclists and their advocates in discussions of safety and roadway design is critical to improving safety outcomes. For example, in North Carolina, the Motorcycle Safety Foundation helps provide driver training and education. During the RSA, their membership provided critical

perspectives on the needs of motorcyclists. National studies have realized the necessity of engaging motorcyclist stakeholders in transportation safety, including recommendations on the creation of motorcycle safety coalitions in each state.[19]

Beyond providing a better understanding of the safety needs of motorcyclists, collaboration has led to the implementation of motorcycle-specific safety measures. The following measures were implemented by the RSA host agencies or were recommended as part of this project:

Motorcyclist-specific signage. Signage specific to motorcyclists was developed and installed on the Blue Ridge Parkway by NPS and on North Carolina State Route 28 by NCDOT in response to a documented crash problem on curves. Motorcyclist-specific signage on the Blue Ridge Parkway, a supplemental motorcycle plaque known locally as the "motoman sign," requires experimental permission from FHWA. NCDOT's motorcyclist-specific signage – which includes a curve warning sign with flagging, a supplemental advisory speed plaque, and a supplemental motorcycle plaque – is MUTCD-compliant.

Left: NCDOT installed signage on North Carolina State Route 28 that includes curve warning signage, flagging, and a supplemental advisory speed plaque in addition to the motorcycle-specific supplemental plaque (Credit: Dan Nabors). Right: The "motorman" supplemental motorcycle plaque, which is not MUTCD-compliant, on the Blue Ridge Parkway (Credit: NPS).

Motorcyclist education and enforcement. Each RSA recognized law enforcement personnel's responsibility in enforcing laws for the protection of the public, responding to incidents with other emergency response personnel, and educating the public. In Washington State, the state's Traffic Safety Commission launched a motorcycle safety education campaign known as "It's a Fine Line," which uses social media, electronic newsletters, and community outreach to promote the state's

19 NCHRP Scan Team, *Leading Practices for Motorcyclist Safety*, NCHRP Project 20 68A, Scan 09 04, September 2011.

Target Zero road safety initiative to motorcyclists. The Washington State Patrol has targeted high-risk groups of motorcyclists, and also works with Joint Base Lewis-McChord to educate soldiers about motorcycle safety.

On the Blue Ridge Parkway, the NPS has reduced the posted vehicle speed from 45 miles per hour to 35 miles per hour in some heavily traveled commuter zones. The NPS has supplemented this change with a public outreach campaign about the new speed limits and increased speed enforcement in these zones. This strategy is intended to improve driver awareness and attention and reduce crash severity, and thereby improve safety outcomes where potential crash exposure is greatest. This measure has not been evaluated for effectiveness, but law enforcement rangers cited anecdotal improvements in crash incidence and driver violations.

Providing paved aprons at gravel driveways. This measure will help reduce loose material on the road, which can cause a motorcycle to lose control. North Carolina has installed paved aprons at a number of gravel driveways.

Providing corridor access management (CAM). CAM strategies seek to preserve the flow of people and freight, and enable safe access to businesses and neighborhoods using a combination of policies and strategies, such as closing, consolidating, or improving driveways, median openings, and intersections. CAM strategies may also seek to define a consistent cross-section to minimize lane shifts and conflicts with entering traffic. CAM strategies provide better awareness of motorcycles, which may be more difficult for motorists to notice due to their slim profile. In addition, CAM strategies reduce conflict zones created from wide driveways and improve sight distance at driveways and intersecting streets. WSDOT has instituted CAM strategies on a portion of SR 7 outside of the RSA study area, and they were suggested along the urban segment of SR 7 as part of the RSA.

A Spiral Curve Warning Sign. Note: sign not MUTCD-compliant. (Credit: Dan Nabors)

Installing warning signs depicting unusual conditions. The National Park Service developed a warning sign with a "SPIRAL CURVE" placard and deployed it on spiral curves on a downgrade to alert all roadway users of a condition that may violate driver expectation. This may be particularly helpful messaging for motorcyclists, who must maintain balance while maneuvering through a curve.

Motorcycle pullouts. NCDOT is designing motorcycle pullouts on the Cherohala Highway, which forms part of NC State Route 143. Initial plans are for the placement of kiosks and/or signs in the pullouts to provide information to motorcyclists covering topics such as safety and travel planning.

Challenges

The RSAs included in this report demonstrated that agencies face several challenges to address the safety of motorcyclists. These challenges range from the lack of data needed to assess issues to a lack of standardization in laws governing operation of a motorcycle in the public right of way.

Understanding the problem. On each of the RSAs conducted, data on motorcyclists was limited. Limited data describing the details of crashes involving motorcycles were available for the Blue Ridge Parkway. Data describing the number motorcyclists (volume), types of motorcycles, and exposure were not available for any of the RSA locations.

Detailed crash data to identify driver trends such as age and rider experience help assess overall tends and contributing factors to crashes. Data on motorcycle types involved in crashes are helpful as well, as trends may reveal higher crash rates for specific motorcycle types or users. This data may help target not only higher-risk groups, but motorcycle dealers and manufacturers of higher-risk motorcycle classes as well. Anecdotally, multiple law enforcement representatives involved in the RSAs mentioned the tendency for motorcycle crashes to be underreported, which poses an additional challenge to obtaining reliable crash data.

Volume data on motorcycle use, which would help determine exposure of motorcyclists to get a better understanding of the severity of safety issues, were not available in any of the case study RSAs. Volume data are critical to understanding trends in motorcycle ridership, the proportion of motorcycles on the roadway, and popular motorcycle riding routes, and allow for more targeted implementation of the 4 Es of safety (engineering, enforcement, education, and emergency medical services). It can be challenging to obtain accurate count data, as deployed traffic counters may not accurately count motorcycles. Estimating rider exposure based on licensing is not effective; due to the variation in licensing requirements, it can be difficult to document the number of motorcyclists.

Understanding conditions affecting motorcyclists. Roadway, roadside, and environmental conditions may present particular challenges for motorcyclists that may not be evident. Having an experienced motorcyclist on the RSA team will help provide a better understanding of particular conditions that may increase risk for a motorcyclist. During the RSAs conducted on this project, team members noted several issues that may present increased risks to motorcyclists when compared with other motor vehicles:

- Inability to recover from lane departures, including pavement edge dropoff and lack of area for recovery (e.g., lack of shoulder).
- The effect of roadway design, to include compound or spiral curves designs and changes in roadway superelevation, in particular changes in short sections of road.
- Presence of debris on the roadway.
- Visibility of motorcyclists to other road users, in particular changes in cross-section or lane shifts where motorcyclists may occupy a driver's blind spot.

- Roadside features, such as trees, utility poles, and guardrail, that could be better designed for motorcyclists.
- Lack of continuity in features that help riders maintain visual focus, such as centerline markings.
- Awareness of other complex situations that may tax the abilities of an operator of a motorcycle, such as locations that are on vertical and horizontal curves where traffic may be exiting or entering the roadway.
- Effect of environmental factors on a motorcyclist, such as sudden changes in lighting traveling between shaded and sunny sections. The combination of changes in lighting and roadway alignment may lead to a situation where a rider brakes too late to navigate the alignment and/ or loses the visual path of the roadway.
- The lack of an occupant enclosure on motorcycles means that speed poses a greater risk to motorcyclists than to operators of enclosed vehicles such as passenger cars, as motorcyclists face increased chances of severe injury or death from crashes at posted speeds than do operators of most other types of vehicles.

Sudden changes in lighting on the roadway, particularly when motorcyclists are wearing sunglasses, may cause motorcyclists to lose visual path of the roadway. (Credit: Dan Nabors)

These conditions may merit consideration for safety measures given the potential for higher frequency of motorcycle crashes in areas exhibiting these characteristics. Improved data may help target specific roadway features, but may also better define motorcycle operators or classes of motorcycles that are at greater risk.

Education and experience. While basic training will help a motorcycle operator understand the fundamentals of riding, more advanced training is often necessary. Different classes of motorcycles can have very different handling characteristics and roadways can vary in terms of design, both of which can challenge the skills and experience of a motorcyclist. In 2012, the Washington State Department of Licensing (WSDOL) reported that 33 percent of the motorcyclist fatalities involved riders with two years of experience or less. Motorcycle fatalities greatly drop off for riders with three to five years' experience; this group comprised 11 percent of the total motorcyclist fatalities. In an effort to improve rider education, particularly for less experienced riders, WSDOL developed and encouraged motorcyclists to take advanced motorcycle training courses. Most courses entail a $125 fee.

Training and licensing. Training and licensing varies greatly from state to state. In some instances, motorcyclists from other states may not understand the local laws, or they may have training focused only on local laws and riding conditions, when in fact most of their riding may be touring in other states. For example, data from North Carolina show that only 15 percent of motorcyclists involved in crashes were from North Carolina; 28 percent of motorcyclists involved in a crash were from neighboring states and 57 percent were from other states. Current training conducted by the state only reaches a fraction of the motorcyclists using the roads. Likewise, variations in licensing from state to state may permit unlicensed motorcycle operators on the road. Motorcycle operators in some states are able to ride using a permit or endorsement only, enabling them to ride within their state of residence or enter another state without a license.[20] For example, of all motorcycle fatalities in Washington State in 2012, 40 percent involved endorsed but not trained drivers and 30 percent involved drivers neither trained nor endorsed.

Enforcement. Enforcing traffic laws for motorcyclists often presents a challenge. Some motorcyclists may frequently speed or may exhibit other high-risk behaviors. Law enforcement may be unable to ticket these riders, as safety concerns for the public as a whole may make them unable to safely pursue a speeding motorcyclist and conduct a traffic stop. Furthermore, some enforcement measures, such as automated speed enforcement, may have the opposite effect on motorcyclist behavior. For example, in several locations with automated speed enforcement, there is anecdotal information that motorcyclists actually speed up.

Opportunities

Motorcycle clubs, safety organizations, and experienced riders should form the core of any effort to address motorcycle safety. Improved data detailing conditions affecting motorcyclists is also key. This section identifies opportunities in addressing motorcycle safety.

Stronger stakeholder engagement. During the course of the RSAs, experienced motorcyclists were able to highlight issues critical to motorcyclists. The involvement of experienced motorcyclists on the RSA team is one of the primary factors contributing to the success of the RSAs. Many states have realized the necessity to engage experienced motorcyclists in safety efforts and have brought together stakeholders to address motorcycle safety for the creation of Motorcycle Safety Strategic Plans (MSSPs) to guide their state's efforts and have formed their own state motorcycle coalitions. Stakeholders can collaborate on other initiatives that support safety as well, such as education activities and even data gathering.

20 A motorcycle permit allows an individual to operate a motorcycle for a limited period of time while that individual is learning to ride, and often entails restrictions on when that individual can operate a motorcycle and prohibitions on carrying passengers. In many states, a permit is a prerequisite to obtaining a license or endorsement. A motorcycle license grants an individual the full scope of rights available to licensed motorcyclists in that state, and usually requires a rider to pass both a road/skills and a written test. An endorsement grants similar privileges to the holder, but is not a formal document; instead, it piggybacks on the holder's existing driver's license.

Improved data. Improved data will help provide a more thorough understanding of features, conditions, and behaviors that increase risk for motorcyclists. Targeting specific at-risk groups for education, whether it be by age, experience, type of motorcycle, or a combination of these and other factors, may improve awareness of risks. Improved data will also help define specific roadway and other environmental conditions that may increase risk to motorcycle operators. RSA teams identified some of these conditions during the three RSAs conducted; these at-risk conditions appeared to be reflected in the available crash data, but further investigation and research is needed. Training law enforcement on the importance of crash reports can lead to the collection of more complete and more reliable crash data, which in turn will facilitate improved data and analysis.

Improved training. All riders may benefit from more advanced, specific training and information about road rules, responsibilities, and local conditions. Additional, more advanced training may target operators with fewer years of experience or those that may only be seasonal or occasional riders.

National standards for training and safety would help provide a basic skill requirement for the operation of a motorcycle. In advance of national standards, state and local agencies can work with motorcycle safety groups to provide access to safety materials for trip planning, particularly for long journeys that may include states with different requirements and riding conditions.

Enhanced motorcycle-specific signage. RSA teams noted that agencies have installed measures to improve awareness of curves that may be particularly challenging for motorcyclists. Agencies should analyze these applications for efficacy and other motorcyclist-specific messaging that clearly warns riders of specific risks.

Safety countermeasures. Ideally, practitioners consider the safety of motorcyclists in the planning and design stages of a project before issues arise. However, there is a need to consider countermeasures on existing roads, as made clear by the safety issues identified by crash data and in field reviews conducted as part of this RSA effort and other studies. The RSA teams identified measures for all 4 Es of safety, including engineering measures to address the issues affecting motorcycle safety. Those measures included:

- Posting educational materials at major biker gathering locations.
- Trimming vegetation to improve sight distance.
- Repairing pavement where potholes, debris, longitudinal cracks, vertical displacement, and reduced friction are apparent.
- Installing Safety Edge^{SM}, particularly along curves or areas where motorcyclists are more likely to run off the road.
- Exploring opportunities to apply Advanced Pavement Markings specific to motorcyclists within the travel lanes to provide warning of conditions that may be particularly challenging to motorcyclists, such as “slow” at the entrance to curves.

- Continuing dash marks through gaps in the centerline or edgeline markings, to help keep motorcyclists from losing visual focus of the roadway.
- Providing curve delineation; potentially motorcycle-specific signage.
- Providing intersection/driveway delineation and warning.
- Enhancing awareness of other complex situations that may overload an operator of a motorcycle, such as locations that are on vertical and horizontal curves where traffic may be exiting or entering the roadway; this can be done through signage, education or a combination of the two, such as at motorcycle pulloffs with information kiosks.
- Installing delineation devices per the MUTCD on the full length of guardrail to improve nighttime conspicuity.
- Re-grading roadsides and removing hazards to eliminate the need for guardrail.
- Paving shoulders on the inside of curves, especially gravel shoulders as motorcyclists may try to steer away from these to avoid debris.
- Evaluating superelevation of curves for consistency with adjacent curves and, if inconsistent, providing motorcycle-specific warning or improvements to superelevation.
- Implementing corridor access management, to include:
    - »Limiting parking near intersections and driveways to improve visibility of entering vehicles and approaching vehicles.
    - »Restricting left turns from driveways and entrances where feasible, only permitting them in certain designated locations.
    - »Minimizing changes in cross-section or lane shifts where motorcyclists may occupy a driver's blind spot.
- Conducting motorcycle RSAs, which can engage all motorcycle safety stakeholders.

More detailed discussion of the issues and measures suggested can be found in the case studies presented in Appendix A.

Conclusions and Recommendations

The purpose of this document is to help Federal, State, Tribal, and local agencies:

1. Understand conditions that affect the safety of motorcyclists.
2. Apply the RSA process to address these conditions.

RSA teams conducted three RSAs on corridors with a high frequency of crashes involving a motorcycle. The RSA locations included rural, scenic roadways and an urban arterial. Each RSA included a multidisciplinary team of experts and specialists as well as enforcement, practitioners, and members of motorcycle clubs/safety groups, the latter of which provided in-depth information with regard

to features, behaviors, and other conditions that increase risk for motorcyclists. This perspective, coupled with the experience of other RSA team members, was critical to defining approaches to improving motorcycle safety using the 4 E approach to safety. The involvement of experienced motorcyclists on the teams was one of the primary factors contributing to the success of the RSAs.

RSA teams identified existing countermeasures or those under review that may improve the safety of motorcyclists. These include the use of motorcyclist-specific warning signage and the creation of pull-off areas that provide a respite and key safety and trip planning information for motorcyclists.

A lack of detailed data is a key issue inhibiting a fuller understanding of the factors that affect the safety of motorcyclists. This includes detailed crash data, but is particularly true with regard to motorcycle count data. Count data for motorcyclists were unavailable, perhaps due in part to the difficulty in obtaining such data. Because of the lack of data the RSA team was unable to determine the exposure of motorcyclists, the corresponding crash rate, and if motorcycles of a particular type are at higher risk.

During the RSAs, the RSA team concluded that certain conditions appear to present challenges to motorcyclists. These were:

- Inability to recover from lane departures, including pavement edge dropoff and lack of area for recovery (e.g., lack of shoulder).
- The effect of roadway design, to include compound or spiral curves designs and changes in roadway superelevation, in particular changes in short sections of road.
- Presence of debris on the roadway.
- The lack of an occupant enclosure on motorcycles means that speed poses a greater risk to motorcyclists than to operators of enclosed vehicles such as passenger cars, as motorcyclists face increased chances of severe injury or death from crashes at posted speeds than do operators of most other types of vehicles.
- Visibility of motorcyclists to other road users, in particular changes in cross-section or lane shifts where motorcyclists may occupy a driver's blind spot.
- Roadside features, such as trees, utility poles, and guardrail, that could be better designed for motorcyclists.
- Lack of continuity in features that help riders maintain visual focus, such as centerline markings.
- Awareness of other complex situations that may tax the abilities of an operator of a motorcycle, such as locations that are on vertical and horizontal curves where traffic may be exiting or entering the roadway.
- Effect of environmental factors on a motorcyclist, such as sudden changes in lighting traveling between shaded and sunny sections. The combination of changes in lighting and roadway alignment may lead to a situation where a rider brakes too late to navigate the alignment and/or loses the visual path of the roadway.

RSA teams suggested a number of treatments to address these issues, many of which should be tried and tested to determine their effectiveness in addressing the safety needs of motorcyclists on our nation's roadways.

As the case studies in this document demonstrate, RSAs can be a useful tool in addressing motorcycle safety. Collaboration with experienced motorcyclists and motorcycling clubs or other organizations is key to that success. Future RSAs should consider more detailed motorcyclist data and should coordinate with other stakeholders that may be part of state motorcycle safety initiatives.

APPENDIX A: MOTORCYCLE ROAD SAFETY AUDIT CASE STUDIES

RSA Case Study No. 1—NC 28 and NC 143, Graham County, North Carolina

Project Overview	
Project Location:	Approximately 1.75 miles of NC 28 (MP 14.25-15.0 and MP 18.25-19.25) and 3 miles of NC 143 (MP 20.5-23.5) in Graham County near the Tennessee border.
Project Environment:	Rural
Project Design Stage:	Existing roadway
Project Owner(s):	North Carolina Department of Transportation
RSA Overview	
Date of RSA:	August 19-21, 2014
RSA Stage(s):	RSA of existing roads
RSA Team:	Representatives from the Federal Highway Administration, North Carolina State Highway Patrol, Motorcycle Safety Foundation, Graham County, North Carolina Department of Transportation, and VHB.

Project Background

Routes that cross the mountains of western North Carolina and eastern Tennessee are widely known among motorcyclist communities as the "Tail of the Dragon" because of their extensive horizontal and vertical curvature (see Figure A-1). North Carolina Route (NC) 28 and North Carolina Route (NC) 143 are two-lane roadways in rural Graham County, North Carolina marketed by local businesses and motorcyclist/automobile club websites as Tail of the Dragon corridors. Each year, the region's scenic beauty and renown as a thrill-seeker's destination draw thousands of motorcyclists of all experience levels.

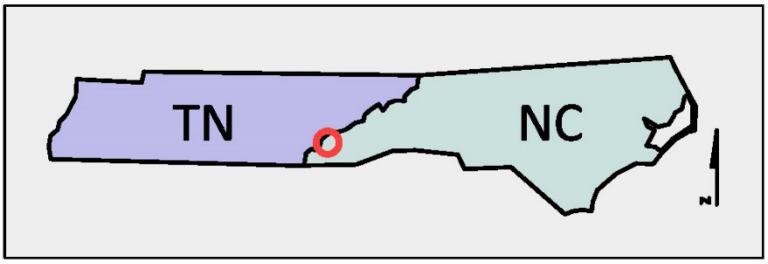


Figure A-1: Vicinity Map for North Carolina's "Tail of the Dragon" Corridors.

From 2012 to 2014, the North Carolina Department of Transportation (NCDOT) conducted RSAs at seven locations along NC 28 and NC 143 in Graham and Swain Counties near the Tennessee border. NCDOT selected these seven locations because of high crash rates and high severity of crashes, many

of which involved motorcyclists. RSA teams suggested the following countermeasures to address run off the road crashes:

- Edgeline rumble strips
- Enhanced curve warning to include:
  - »Double indicate curve warning signs and use flags on signs in Westbound / Northbound direction; involves three additional signs (duplicates) and flagging
  - »Add Large Arrow warning sign
  - »Place additional chevrons in some locations for increased curve delineation
  - »Place decreasing chevrons to give the illusion of driving faster
  - »Check angle of chevrons
- Check advisory speeds
- Consider signing for declining radius
- Use of mile markers
- Speed reduction pavement markings
- Investigate use / availability of high friction pavement markings
- Adding signage to notify drivers of upcoming pull-offs
- Investigate gravel on pull-off
- Consider paved shoulders
- Fill in low shoulder at pulloff to smooth the transition
- Repair / replace existing guardrail
- Extend existing guardrail
- Enhanced education and enforcement

After the completion of the RSAs, some treatments were installed to address the issues identified. However, other areas with high frequency of crashes remained. Due to the persistent motorcycle crash incidence and the length of the subject corridors, the FHWA supported an RSA on NC 28 and NC 143 to identify issues and measures to address issues at additional high crash locations.

Pilot Overview

An RSA team held a start-up meeting at the NCDOT office in Sylva, North Carolina. The team reviewed the methodology for conducting an RSA using the eight-step process detailed in the FHWA RSA Guidelines. During that meeting, staff from NCDOT reviewed issues, suggestions, and measures implemented from the previous seven RSAs. NCDOT staff also reviewed crashes and issues for the additional segments under review as part of the NC 28 and NC 143 RSA. Representatives from the Motorcycle Safety Foundation, a national nonprofit that develops education and training curricula for motorcyclists, provided information about some of the behavioral issues affecting the safety

of motorcyclists in the state. This information was helpful in understanding the broader context of motorcycle safety in the study area. The RSA team also reviewed motorcycle crash data in the study area. Law enforcement officers who ride motorcycles and conduct rider education provided first-hand knowledge of rider behavior and enforcement issues as well.

The RSA team drove and walked the RSA sites to gain a more complete understanding of the issues affecting motorcyclists. Having skilled riders on the RSA team was essential to fully understanding the key roadway features and conditions that affect the behavior of cyclists.

The RSA concluded with an RSA workshop and preliminary findings meeting in accordance with the eight-step RSA process.

Licensing, Driver Requirements, and Behavioral Data

In order to operate a motorcycle on North Carolina roadways, an individual must have a motorcycle endorsement on their driver's license or a motorcycle learner permit. In order to obtain an endorsement, one must take the following tests:

- vision test;
- traffic signs test;
- knowledge test that includes questions on motorcycling; and
- off-street skills test.

The knowledge test is waived for renewals. North Carolina accepts a motorcycle endorsement from other states.

If an individual is not prepared to take the skills test, that person can obtain a motorcycle learner permit by taking the knowledge test only. Permits are issued for 12 months, and can be renewed one time for a period of six months.

North Carolina state law requires motorcycle riders to wear a safety helmet. Motorcycles must carry liability insurance by law.

Crash History

The RSA team reviewed crash data, provided by NCDOT, from January 2009 through April 2014 and identified three specific segments as the focus of this RSA:

1. NC 28 from milepost 18.25 to milepost 19.25.
2. NC 28 from milepost 14.25 to milepost 15.
3. NC 143 from milepost 20.5 to milepost 23.5.

Table A-1 presents a summary of crashes occurring at the three study locations during the analysis period.

Table A-1: RSA Study Area Crash Summary.

Location	Length (mi)	Total Crashes	Crash Rate (per mi per yr)	MC Crashes	MC Crash Rate (per mi per yr)	MC Fatal Crashes	MC Injury Crashes (A,B)	Predominant MC Crash Type(s)
NC 28, MP 18.25-19.25	1	25	4.7	20	3.8	2	7	Overturn/ Rollover (15)
NC 28, MP 14.25-15	0.75	14	3.5	14	3.5	0	11	Overturn/ Rollover (10)
NC 143, MP 20.5-23.5	3	78	4.9	59	3.7	2	37	Overturn/ Rollover (32); Fixed Object (10); Head On (7)

The crash data indicate there were 117 reported crashes across the three study segments from January 2009 through April 2014. Ninety (90) of these crashes—nearly four in every five—involved a motorcycle, including four (4) fatal crashes and 55 crashes that resulted in disabling or evident injury. The study segments experienced 3.5 to 3.8 motorcycle crashes per mile per year.

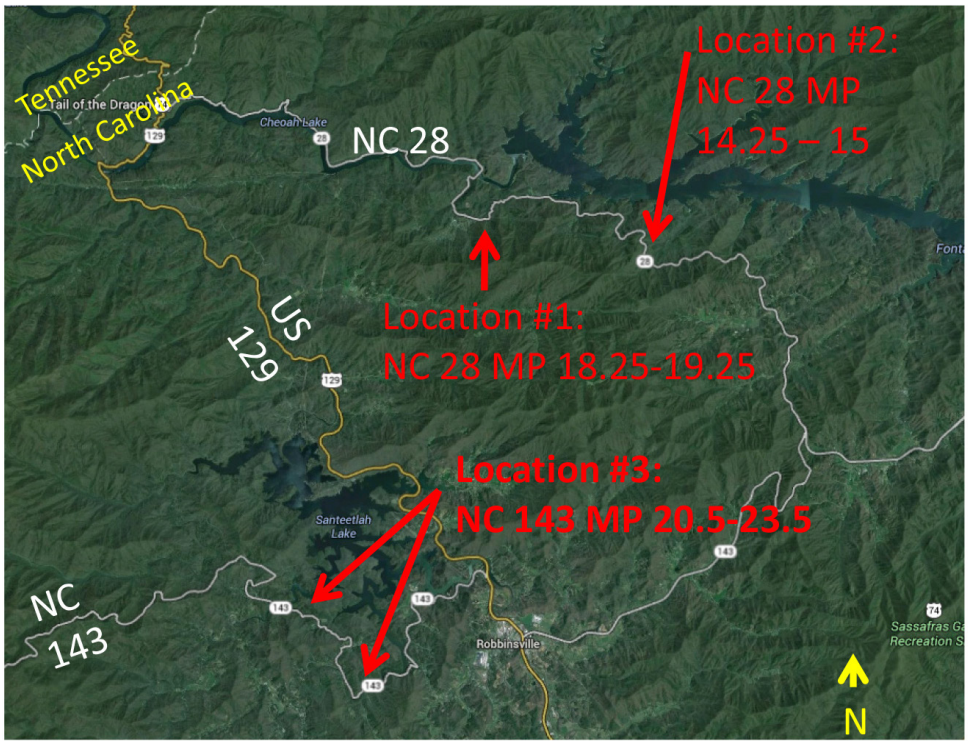


Figure A-2: Locations of the Three RSA Segments in Graham County, NC. (Source: Google Maps)

Positive Features

The RSA team reviewed some of the efforts from the previous seven RSA, and considered these efforts as positive means to improve motorcycle safety. Specific positive characteristics of the roadways within the RSA study area include the following:

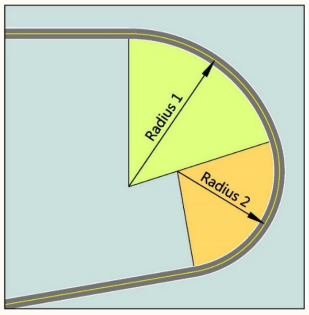
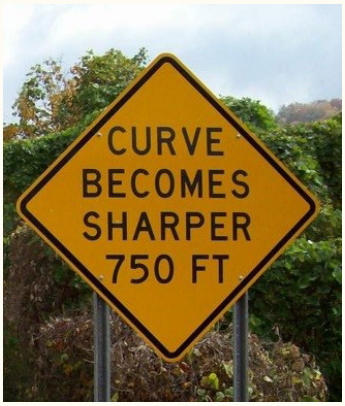
- Curve warning signage with flagging and supplemental motorcycle plaques.
- The planned construction of a pull-off area for motorcyclists upon entering the corridor.
- Advance signing for overlooks.
- Paved aprons at driveways.
- Provision of stopping points.
- Advanced Pavement Markings.

RSA Motorcycle Crash Findings and Suggestions

Upon completing the data analysis and field observations, the RSA team identified a number of issues and suggestions. The following presents a summary that highlights several main points.

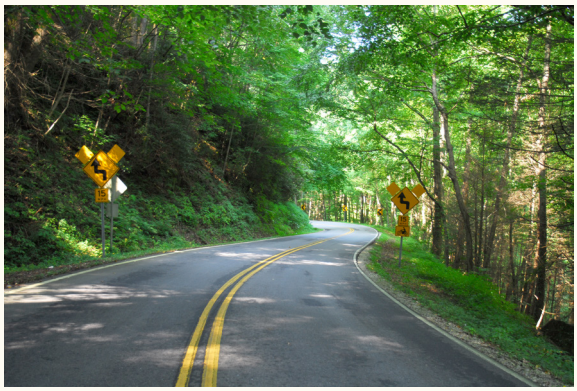
Overarching Safety Issues, NC 28 and NC 143 Corridors	
Issue Description	**Suggested Action**
Motorcyclist Characteristics and Cultural Challenges •NCDOT determined that more than half of motorcycle operators involved in crashes along US 129, NC 28, and NC 143 were not from North Carolina or neighboring Tennessee and Georgia. The following summarizes the proportions of home states among the motorcycle operators involved in reported crashes: » NC—15% » GA—10% » TN—18% » Other—57% •The previous NCDOT RSAs also provided the ages of motorcycle operators involved in crashes: » 15 and younger—0.5% » 16-19—2.5% » 20-24—8% » 25-34—17% » 35-44—17% » 45-54—24% » 55-64—22% » 65-74—7% » 75 and older—2% Age does not always translate to experience or ability, as evidenced by the crash data. Nearly half of the motorcycle crashes involved operators between the ages of 45-64. •The motorcyclists who visit the study area represent many geographic areas. There are no national standards in terms of motorcyclist training and licensure, resulting in skill-level inconsistencies. •There are unique factors related to the "Tail of the Dragon" motif that may motivate some motorcyclists to travel at excessive speeds: » Multiple businesses offer timestamped photography/ videography along the corridors, which can be interpreted by some motorcyclists as a challenge to increase speed. » Several websites track and post individual travel times within the subject corridors.	**Near Term/Intermediate (On-going)** •Develop data resources to identify specific causes of motorcycle crashes, motorcycle volumes, volumes by type of bike, and common factors (age, bike types). •Collaborate with riding clubs, DMV, safety groups, and EMS to provide riding safety education as well as data. •Post educational materials at major biker gathering locations. •Provide incentives for bikers to take advanced rider training. •Install milepost markers along the study corridors at mile or half-mile increments or on existing road signs to aid emergency responders in locating the crash and in reporting the exact location of the crash. •Post signage at key locations to communicate motorcyclist crash statistics and speeding fines. Consider installation of motorcycle pull-off areas for trip planning and safety information. •Create and post safety information that will rank highly in internet search engines (it is easy to find information that emphasizes the more "thrilling" aspects of riding a motorcycle in this area). •Focus all education efforts on most vulnerable riders, including the least experience riders and certain higher risk age groups. •Continue conducting targeted speed and traffic law enforcement. •Collaborate with Tennessee Department of Transportation to understand issues and provide awareness of conditions that affect motorcyclists. For example, the character of the roadway changes drastically between Tennessee and North Carolina (US 129). Roadway features in Tennessee appear to feature shorter curve radii with a higher degree of superelevation. •Collaborate with State Motorcycle Safety Administrators (SMSAs) in neighboring states to promote motorcycle safety awareness. •Collaborate with the Insurance Institute for Highway Safety and insurance companies to understand issues and conditions that affect motorcyclist safety, and to identify and leverage opportunities for motorcyclist safety education.

Overarching Safety Issues, NC 28 and NC 143 Corridors	
Issue Description	**Suggested Action**
Considering Motorcycle Characteristics in Engineering •Established engineering practices may not adequately consider the unique characteristics of motorcycles. For instance, the conventional approach to establishing advisory speeds at horizontal curves (e.g., the ball-bank indicator) was developed with the traditional motor vehicle in mind. •Because it is imperative for motorcyclists—especially those traveling at high speeds—to keep their focus on the road before them, pavement markings on the road may be as useful as roadside signs in communicating to motorcyclists. For example, the ad hoc application of the painted message "SLO" at several locations along the study corridors suggests advanced pavement marking messages may be effective in this regard (see photo of marking below). •Some engineering measures may have an unintended effect in areas with large proportions of motorcycle traffic. » Speed feedback signs may adversely affect the speed of motorcyclists based on observations of the RSA team (i.e., some motorcyclists may actually speed-up). » Standard guardrail types are not designed for strikes by motorcyclists and may increase the severity of a crash.  ***Example of information applied by road users to provide a variety of conditions. (Credit: NCDOT)***	**Near Term/Intermediate** •Explore opportunities to apply advanced pavement marking messages within the travel lanes to warn of curves. Consider the material properties of the candidate markings so as not to reduce the surface friction beyond acceptable levels. Conditional approval from FHWA will be required for non-standard applications. •Review locations with "SLO" pavement markings applied to identify potential patterns in roadways features. •Continue application of unique signage at locations with high frequency of motorcycle crashes, or locations where motorcycling constitutes a high proportion of the traffic volume (see photo of sign used on NC 28 below). •Consider removing existing speed feedback signs or enforcement measures in conjunction with placement of existing signs. •Consider installing delineation devices per the MUTCD on the full length of guardrail to improve nighttime conspicuity. • Consider re-grading roadsides and removing hazards to eliminate the need for guardrail.  ***Signs implemented by NCDOT at study location. (Credit: Dan Nabors)***

Overarching Safety Issues, NC 28 and NC 143 Corridors	
Issue Description	**Suggested Action**
Complexity of Motorcycling Relative to Geometric Design •Motorcyclists typically traverse a curve by "picking and holding a line" (i.e., selecting a position within the lane and leaning their bikes toward the center of the curve at a near-constant angle throughout the curve). Adjacent horizontal curves in the same direction but of varying radii are known as compound curves (see below).  ***Example of compound curves.*** Because compound curves are not typical, a primary concern with compound curvature is that it can "mislead the motorist's expectation of how sharp the curve radius is."[21] While this can cause moderate discomfort for drivers and passengers of motor vehicles, the impacts to motorcyclists can be more acute. It is difficult for motorcyclists to adjust their leaning angles suddenly when encountering a compound curve. •Transitioning between throttling and braking is more complex for a motorcyclist than a driver of a traditional automobile. Such action is necessary at every sag and crest vertical curve. Even greater skill is required when these transition points coincide with changes in horizontal alignment (i.e., horizontal curves).	**Near Term** •Trim vegetation to maximize sight distance. •Explore opportunities to employ alternate signing or pavement markings to warn of impending compound curvature and sag or crest vertical curves.  ***Example of sign implemented by NCDOT in other locations. (Credit NCDOT)*** •Collaborate with state DOTs, SMSAs, riding clubs, safety groups, and EMS to provide riding safety education and promote opportunities for advanced motorcycle rider training. **Long Range** •Consider realigning effected locations to eliminate instances of compound curvature and relocating conflict points such as intersecting roads and pull-off areas.

21 American Association of State Highway and Transportation Officials, *A Policy on Geometric Design of Highways and Streets*, "Turning Roadways," 6th ed., Sec. 3.3.7, 2011.

Focus Area #1: NC 28, MP 18.25-19.25

Selected Safety Issue	Suggested Action
Northbound This location presents the first set of sharp curves in the northbound direction. This factor coupled with the shade created by the tree canopy may lead a rider to lose the visual path of the roadway. To address motorcycle crashes, NCDOT installed motorcycle-specific signage in July 2013. At the first curve in the series of curves there is also a steep dropoff/ravine (see photo below of signage improvements at the first curve in the northbound direction).  ***View approaching series of curves on northbound NC 28. (Credit: Dan Nabors)*** **Southbound** Similar issues to northbound direction. The visibility of the chevrons is affected by the shading created by the canopy and their number, spacing, and placement (see photo below).  ***View approaching series of curves on southbound NC 28. (Credit: Dan Nabors)*** In addition to the described horizontal curvature, this area is on a sag vertical curve.	**Near Term/Intermediate** •Overall: enhance signage for motorcyclists approaching this set of curves from both directions. •Install flexible post-mounted delineators on the shoulder to enhance visibility of the curve. •Install motorcyclist-specific signage to warn of specific features that may increase risk for a motorcyclist. •Consider reflective panels on signs to enhance conspicuity. •Consider replacing/adjusting placement/ additional larger chevrons in the southbound direction. •Consider using fluorescent signage to enhance conspicuity. •Consider applying wider centerlines and edgelines. •Investigate the application of motorcycle-specific pavement markings (SLOW). •Consider attenuation device for motorcyclists. •Remove clear zone obstructions where possible; focus on locations with a high frequency of run off road crashes. •Collaborate with state DOTs, SMSAs, riding clubs, safety groups, and EMS to provide riding safety education and promote opportunities for advanced motorcycle rider training. •Provide educational materials at major motorcyclist gathering locations. **Long Term** •Consider major reconstruction of principal sharp curve to include: •Move earth to fill in ravine, thereby reducing dropoff. •Potential realignment to reduce curvature.

Focus Area #2: NC 28, MP 14.25 – 15	
Selected Safety Issue	**Suggested Action**
There are several features of this area that change abruptly from the sections preceding this location in both directions. There is a pull-off overlook in this section with two access points (see photos). The overlook is on a crest vertical and horizontal curve. Other conditions that are dissimilar from the sections approaching it are as follows: •Change in the roadway canopy – the pull-off is in an open section. •No advance warning of curve or pull-off. •Potential distractions include the scenic view and slowing or stopping vehicles.	**Near Term** •Install advance warning signs indicating the presence of an overlook (Skyway signage). •Designate overlook with name and milepost. •Encourage law enforcement to use mileposts in crash reporting. •Reduce gap in centerline markings with hash markings (see photos; each access already has edgeline skip markings) to help riders maintain visual focus of the roadway curvature. •Due to lack of cell phone service, investigate feasibility of installing a call box at this location to allow for more timely crash reporting and EMS response. Keep in mind that a landline hookup would not be available.
 ***Photo of the easternmost access point. (Credit: Dan Nabors)***	 ***Photo of the westernmost access point. (Credit: Dan Nabors)***

Focus Area #3: NC 143, MP 20.5-23.5

Selected Safety Issue	Suggested Action
Changes in Road Character From the Tennessee border (MP 0) to Santeetlah Road (MP 17.8), NC 143 is also known as the Cherohala Skyway—a 42-mile National Scenic Byway connecting Robbinsville, NC, with Tellico Plains, TN. In North Carolina, the Skyway features 11-foot travel lanes, several long straightaways, no driveways or intersections, 45 mph posted speed limit, and an open view of the skies above. Conversely, 10-foot travel lanes, a more winding alignment, numerous driveways, commercial entrances, and intersections, a statutory speed limit of 55 mph, and a dense tree canopy characterize NC 143 east of Santeetlah Road (which coincides with the RSA study area). For motorcyclists traveling east, the transition from the Skyway to the non-Skyway section is abrupt.	**Near Term** •Consider conducting a speed study and exploring opportunities to reduce the speed limit from the current statutory limit of 55 mph along NC 143 east of the Cherohala Skyway. •Consider installing a warning sign along eastbound NC 143 to denote the end of the Skyway. Consider incorporating one or more warning beacons with this sign.
Apparent & Observed Behavior of Motorcyclists Motorcyclists were observed crossing the centerline. Crash data demonstrated a prevalence of head-on and sideswipe opposite direction crashes along NC-143 compared to run-off-road crashes along NC-28. Possible factors influencing this behavior and crash pattern include: •Possible dragging floorboards and overcorrecting. •Large gap in pavement markings. •Presence of intersecting roadways. •Presence of gravel shoulders. •Worn centerline markings, indicating vehicles/ motorcycles crossing the centerline.	**Near Term** •Clear vegetation to improve sightline around curves, especially locations with nearby driveways, commercial entrances, and intersections. •Provide warning signs for intersecting roadways. •Pave shoulders on inside of curves, especially gravel shoulders as motorcyclists may try to steer away from these to avoid debris. •Repaint centerline and provide centerline skip marks through intersections to help motorcyclists maintain visual focus. •Consider additional warning signage to warn motorcyclists/drivers of sharp roadway curvature. •Consider motorcyclist-specific signage at critical locations, such as at sag or crest curves that also have horizontal curvature. •Conduct education and enforcement focused on crashes involving motorcyclists crossing the centerline or dragging floorboards. •Conduct crash analysis to determine safety concerns for all motorized vehicles and identify measures to address safety for all roadway users.

Photo showing motorcyclist crossing centerline on a sag vertical curve and horizontal curve. There is an intersecting roadway and driveway within the curve. (Credit: Dan Nabors)

Conclusions

North Carolina Route (NC) 28 and North Carolina Route (NC) 143 are rural, two-lane roadways in an area known not only for its scenic beauty, but also as a popular destination for motorcyclists. The North Carolina Department of Transportation (NCDOT) reported a high number of severe crashes involving motorcyclists on these roadways. From 2012 to 2014, the NCDOT conducted RSAs at seven locations along NC 28 and NC 143. However, other high-crash locations remained, and three segments with the highest frequency of crashes involving motorcyclists were the subject of this RSA.

The RSA organizers selected a multidisciplinary team to conduct the RSA. In addition to RSA team members with traditional skillsets, RSA organizers selected team members with specific experience driving a motorcycle. Representatives from the Motorcycle Safety Foundation provided insight on some of the behavioral issues affecting the safety of motorcyclists in the study area, and the representatives of law enforcement, emergency medical services, and local NCDOT staff provided first-hand knowledge of rider behavior and enforcement issues, as well. The participants were critical for the RSA team to understand motorcyclist' behavior, needs, and concerns and addressing these areas within the context of safety.

There are a number of factors that likely contribute to the high incidence of severe motorcycle collisions within the study segments. The region's unique combination of natural beauty and renown among the motorcyclist community attracts riders of all types, including those who have limited motorcycling experience. There are notable differences in roadway character within the region that may present challenges for riders unfamiliar with the area. However, the RSA team noted common conditions at all three RSA locations that, when combined with other factors, may contribute to increased risk for motorcyclists. These factors include the following:

- Changes in tree canopy, which causes sudden changes in roadway lighting.
- There was a reversal of grade at or near the apex of a horizontal curve on each section.

Given that all three RSA locations had these elements in common, other locations may be reviewed for these elements and consideration of the safety of motorcyclists.

The RSA team reviewed measures installed as a result of the RSAs and confirmed curve warning signage with flagging and supplemental motorcycle plaques as helpful in conveying warnings to motorcyclists about critical locations. The team considered other planned treatments as positive, such as the construction of a pull-off area to provide a preparation area and information area for motorcyclists upon entering the corridor. Measures suggested by the RSA team include:

- Develop data resources to identify specific causes of motorcycle crashes, motorcycle volumes, volumes by type of bike, and common factors (age, bike types).
- Collaborate with riding clubs, DMV, safety groups, and EMS to provide riding safety education as well as data.

- Conduct targeted speed and traffic law enforcement.
- Explore opportunities to apply advanced pavement marking messages specific to motorcyclists within the travel lanes to provide warning of curves.
- Continue application of unique signage at locations with high frequency of motorcycle crashes, or locations where motorcycling constitutes a high portion of the traffic volume.
- Consider installing delineation devices per the MUTCD on the full length of guardrail to improve nighttime conspicuity.
- Consider re-grading roadsides and removing hazards to eliminate the need for guardrail.
- Trim vegetation to maximize sight distance especially locations with nearby driveways, commercial entrances, and intersections.
- Pave shoulders on inside of curves, especially gravel shoulders as motorcyclists may try to steer away from these to avoid debris.

RSA Case Study No. 2— State Route 7 (SR 7), Tacoma, Washington

Project Overview	
Project Location:	Three locations: an urban segment (MM 48-59); intersection of SR 7 and Alder Cutoff Road (near curve); north of the intersection of SR 7, Tanwax Road, and 66th Avenue (near curve)
Project Environment:	Rural and Urban
Project Design Stage:	Existing roadway
Project Owner(s):	Washington State Department of Transportation (WSDOT)
RSA Overview	
Date of RSA:	March 18-19, 2014
RSA Stage(s):	RSA of existing roads
RSA Team:	Representatives from the Federal Highway Administration, Washington State Department of Transportation (WSDOT), Washington State Patrol, Washington State Department of Licensing, Washington Traffic Safety Commission, and VHB.

Project Background

Washington State Route 7 (SR 7) is an approximately 60-mile long roadway that generally runs north-south between Tacoma in the north and Morton in the south. SR 7 provides connections to popular parks and natural environments such as Mount Rainier, and as such attracts vehicles ranging from large recreational vehicles to motorcyclists. The northern end of the roadway is characterized by urban development, and terminates at the junction of I-5. The cross-section of the roadway in this section changes between and a four- and five-lane cross section with relatively closely spaced signalized intersections, occasional on-street parking, and multiple access points. Heading south the roadway becomes more rural in nature, with significant horizontal curvature, and has a two-lane cross section with shoulders of varying width. At the southern end of the roadway there is a rumble strip and reflective raised pavement markers on the centerline of the road. Figure A-3 illustrates the sections of SR 7 studied during the RSA.

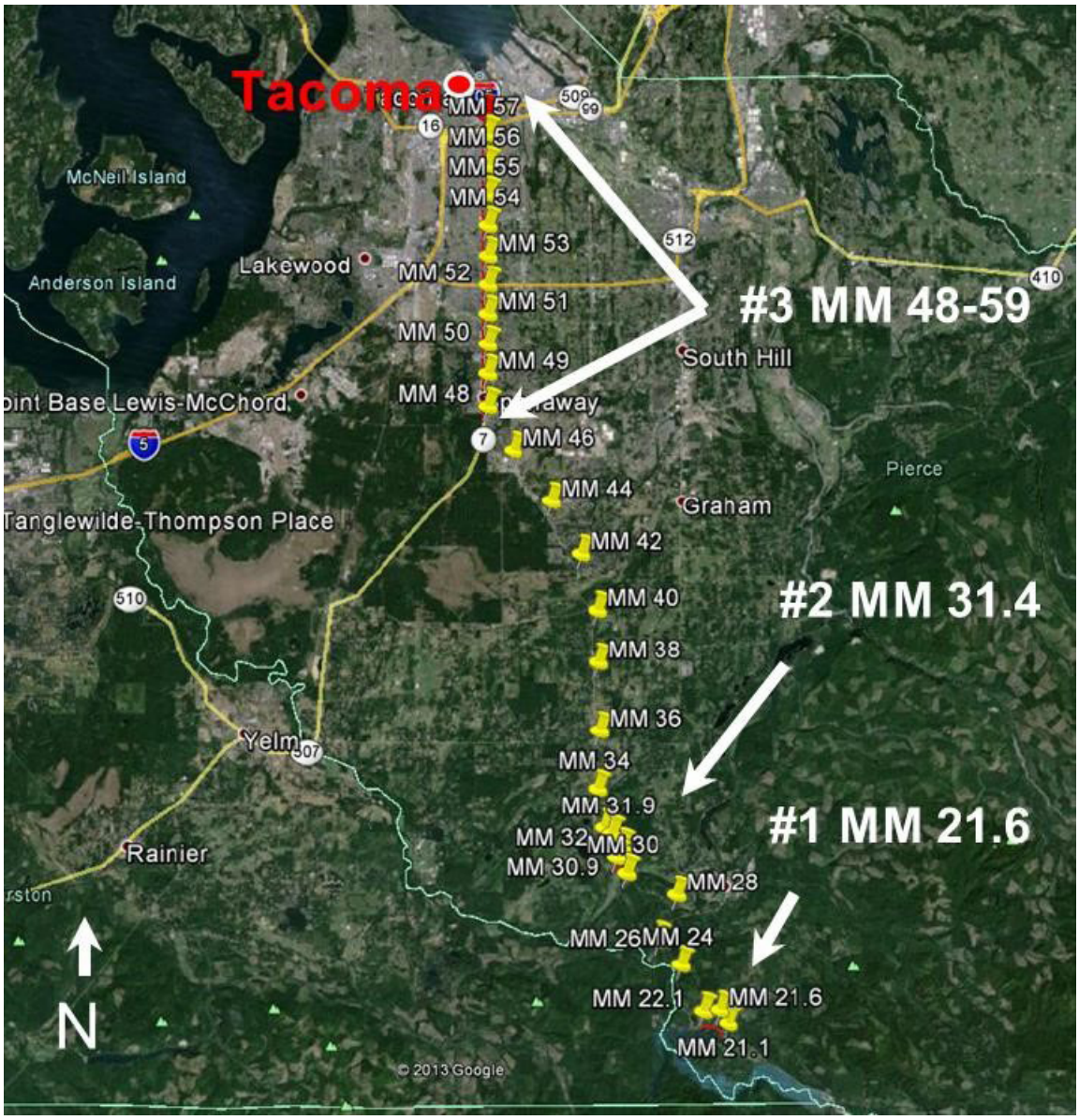


Figure A-3: State Route 7 Study Area. (Source: Google Maps)

Pilot Overview

The RSA team held a start-up meeting at the WSDOT office in Tacoma, and reviewed the methodology for conducting an RSA using the eight-step process detailed in the FHWA RSA Guidelines. During that meeting, staff from Washington State Department of Licensing (WSDOL) provided licensing information and data to illustrate some of the behavioral issues affect the safety of motorcyclists in the state. This information was helpful in understanding the broader context of motorcycle safety in the state. The RSA team also reviewed crash data for motorcyclists in the study area. Key licensing, user, and crash data are summarized in the next section. Law enforcement officers who ride motorcycles and conduct rider education provided first-hand knowledge of rider behavior and enforcement issues as well.

The RSA team drove and walked the RSA sites to gain a more complete understanding of the issues affecting motorcyclists. Having skilled motorcycle riders on the RSA team was essential to fully understanding the key roadway features and conditions that affect the behavior of cyclists.

The RSA concluded with an RSA workshop and preliminary findings meeting in accordance with the eight-step RSA process.

Licensing, Driver Requirements, and Behavioral Data

An instruction permit or motorcycle endorsement is required to operate a motorcycle on Washington State roadways.[22] Drivers must pass a written test to obtain a permit. The permit is valid for 90 days; however, riders may apply for a permit up to three times if they have taken a training course. Obtaining an endorsement requires a driver to pass both a written and skills test. This is possible by successfully completing either an approved training class or testing at an approved site.

Washington State law requires that drivers:

- Wear glasses, goggles, or a face shield, unless the motorcycle has a windshield.
- Wear a helmet that meets USDOT standards and that is fastened properly.
- Do not allow passengers under the age of five to ride on their motorcycle.

Motorcyclists are not required to have insurance.

Data from WSDOL indicated that number of registered motorcycles and endorsed motorcycle drivers has risen steadily from 2003 through 2012. WSDOL also investigated the motorcycle fatalities in 2012 to identify the level of training and endorsement. It was determined, as shown in Figure A-4 , that 39 percent were endorsed but not trained, 33 percent were neither endorsed nor trained, 25 percent were trained and endorsed through the state Motorcycle Safety Program (MSP), and three percent were trained and endorsed by another MSP.

The WSDOL data also showed a clear link between riding experience and fatalities. Figure A-5 shows fatalities by years of riding experience; one-third of all motorcyclist fatalities involved motorcyclists with two or fewer years riding experience.

22 Washington Department of Licensing, Motorcycle Operator Manual. Available at http://www.dol.wa.gov/driverslicense/docs/motomanual.pdf.

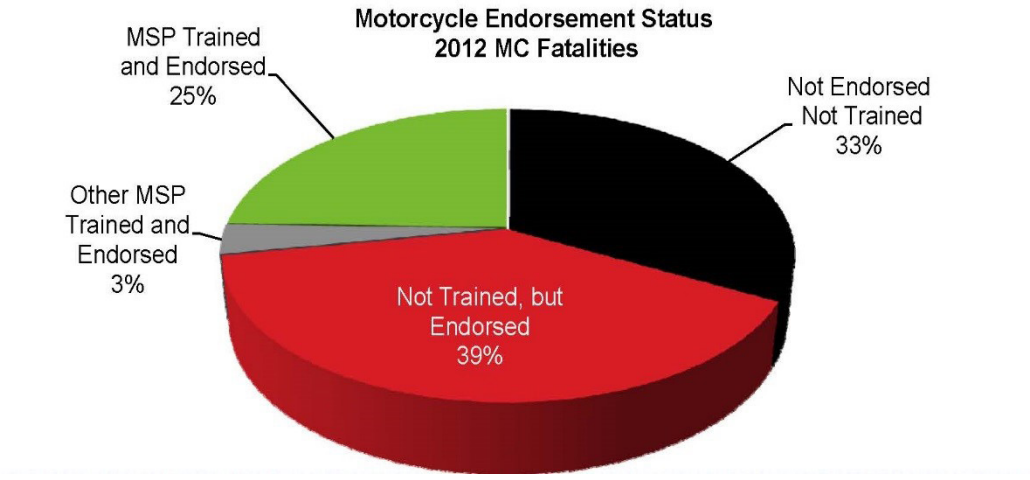


Figure A-4: 2012 Motorcycle Fatality Endorsement Status (Source: WSDOL).

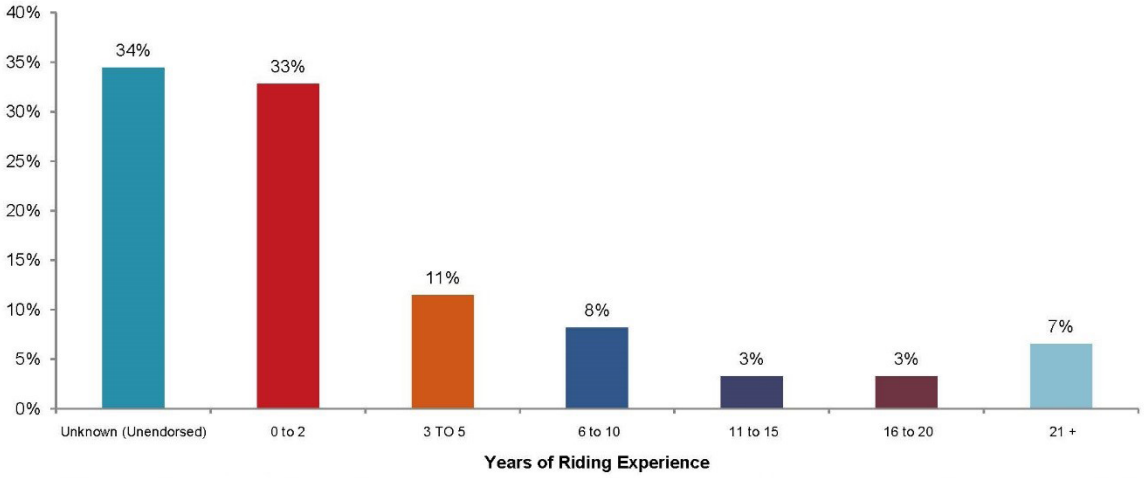


Figure A-5: 2012 Washington State Motorcycle Fatalities by Years of Riding Experience (Source: WSDOL).

Crash History

The Washington State Department of Transportation (WSDOT) provided motorcycle-specific crash data from Mileposts 16 to 59 for a five-year period, from 2008 through 2012. During that period, there were 135 reported motorcycle crashes involving 139 motorcycles for an average of 27 motorcycle crashes per year. The majority of the crashes (59 percent) occurred during the months of May through August, as shown in Figure A-6. Motorcycle crashes peaked during the month of August, which accounted for 20 percent of all motorcycle crashes.

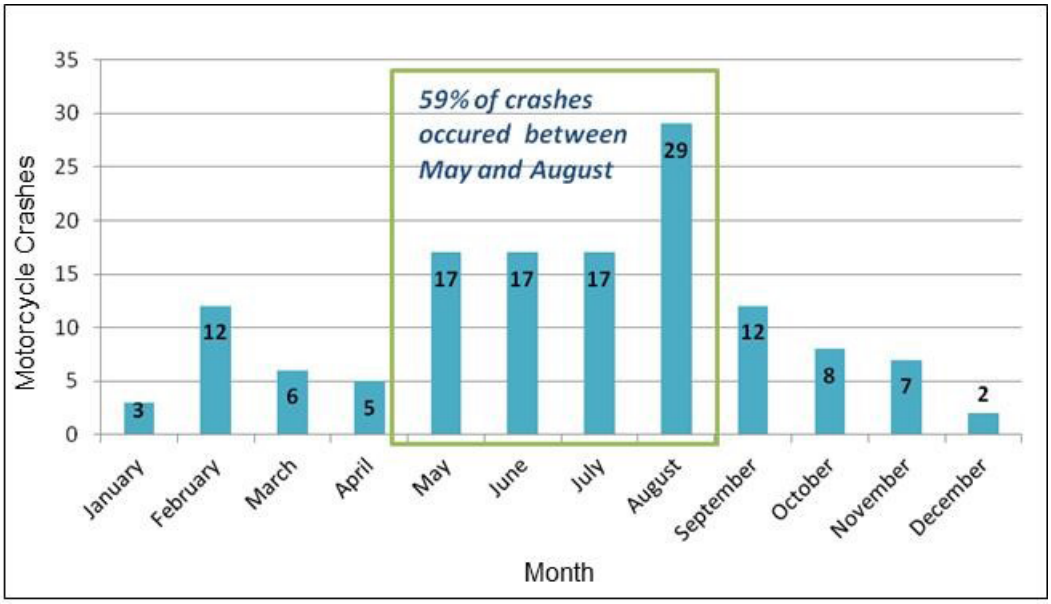


Figure A-6: Motorcycle Crashes by Month (2008-2012).

The motorcycle drivers varied in age from 18 to 78 years old. Certain age groups were identified as being involved in the most crashes (see Figure A-7), with 26 and 41 year olds being the age groups most frequently involved in crashes, comprising over 10 percent of motorcycle crashes.

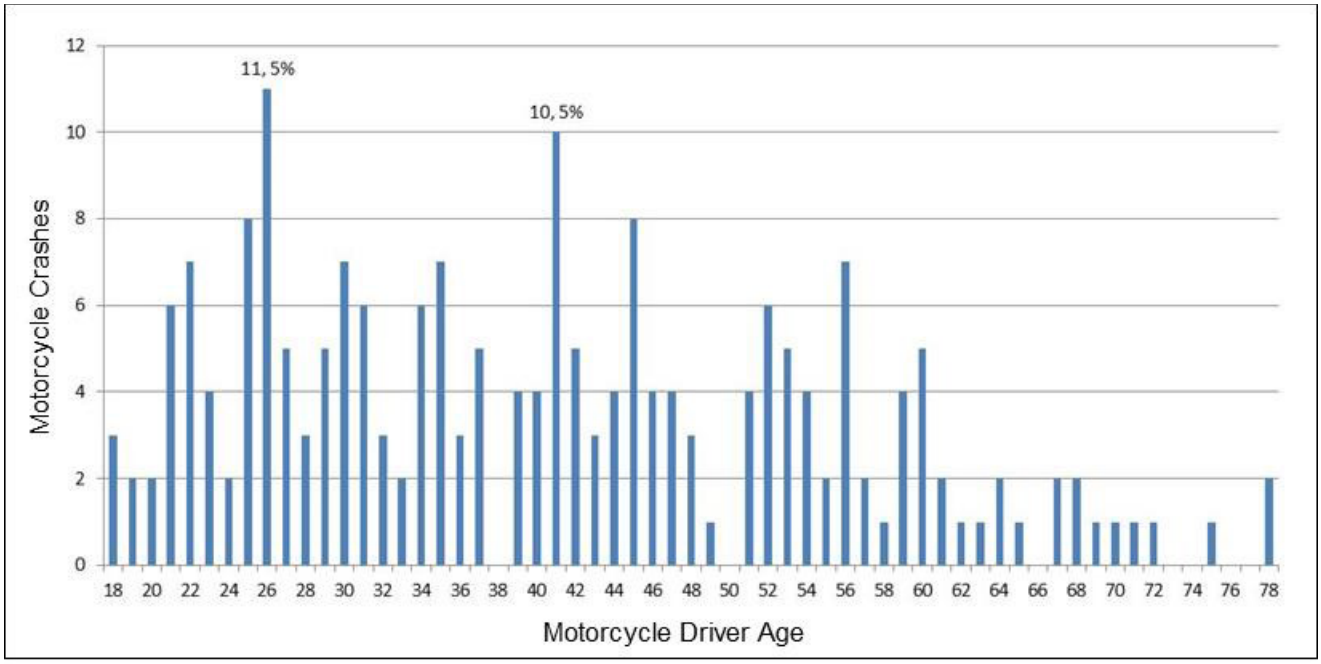


Figure A-7: Motorcycle Crashes by Driver Age (2008-2012).

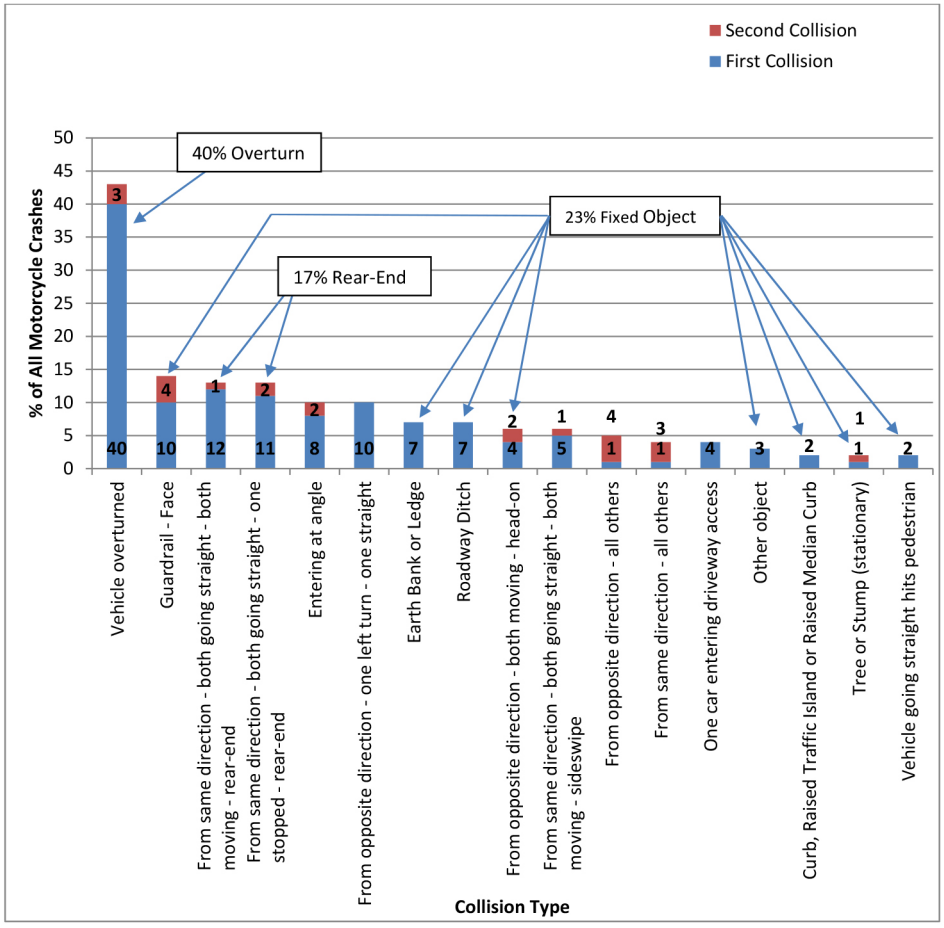


Figure A-8: Motorcycle Crash Collision Types (2008-2012).

The first collisions types throughout the study area were primarily "overturn" (40 percent), followed by "fixed object" (23 percent), and rear-end (17 percent) as shown in Figure A-8.

Positive Features

Some of the positive features noted by the RSA team include:

- Education and training opportunities provided through Department of Licensing motorcycle safety program.
- Law enforcement works closely with the nearby military base, Joint Base Lewis-McChord, to provide motorcycle education and outreach.
- Access management strategies implemented on the corridor.

RSA Motorcycle Crash Findings and Suggestions

After completing the RSA field review, the RSA team developed a list of overarching and site specific issues as part of the RSA process.

Focus Area #1: MP 21.6 (Vicinity of intersection of SR 7 and Alder Cutoff Road)	
Selected Safety Issue	**Suggested Action**
Expectancy •There were seven (7) crashes at this intersection. •Approximately two-thirds occurred at or were related to a driveway or intersection. Drivers may not expect to encounter vehicles entering or exiting driveways in this area.	**Short Range** •Remove vegetation from inside of curve and near driveway/intersection to improve sight distance. •Provide additional intersection/driveway delineation and warning. •Combine wayfinding and safety education materials, such as scenic route maps that include motorcycle safety information. •Consider warning signs depicting the roadway alignment and road/driveway intersections. If additional warning is needed, beacons can be added to the warning signs.

Top photo: Northbound on SR 7, near two private driveways, and heading towards the intersection with Alder Cutoff Road. Bottom photo: View of northbound on SR 7 at the intersection with Alder Cutoff Road and showing the parking area to the left. (Credit: Dan Nabors)

Examples of intersection warning signs that depict the location of intersections along a curve. The sign on the left is an example of sign that could be used for northbound drivers on SR 7, as it depicts the intersection with Alder Cutoff Road on the right, and the parking lot entrance on the left. Consider combining the warning sign with a flashing beacon, as shown.

Focus Area #2: MP 31.4 (Curve near the intersection of SR 7, Tanwax Road, and 66th Avenue)

Selected Safety Issue	Suggested Action
•There were 12 crashes at this location. Most of the motorcycles were traveling in the southbound direction. •Superelevation » The RSA team noted a difference in the superelevation between the curve at the intersection of SR 7, Tanwax Road, and 66th Avenue and the curve to the south of the intersection. The curve at the intersection was noticeably flatter than the curve to the south. » The RSA team measured the superelevation, with readings varying from 0.9 to 2.6 degrees. •Delineation » Gap of pavement markings and center line rumble strips at intersection with two roads » Lack of delineation of intersecting roads/island » Lack of curve delineation	**Short Range** •Remove vegetation on inside of curve to improve sight distance. •Evaluate superelevation of curve though a ballbank test. •Provide additional curve delineation and warning through the use of warning signs indicating the location of the intersection (in both the northbound and southbound directions), reflective post mounted delineators that are evenly spaced throughout both sides of the curve, and dotted edgeline through the intersection. Additional positive guidance could be provided through wider 6-inch edge and centerlines.

Top: Southbound view of the curve at the intersection of SR 7, Tanwax Road, and 66th Avenue. This curve is fairly flat, particularly in comparison to the curve to the south. Bottom: Southbound view of northern curve, at the intersection of SR 7, Tanwax Road, and 66th Avenue. This curve warning sign is the only one used on the curve in either direction. There are also a couple post-mounted delineators. (Credit: Dan Nabors)

4-inch edge and center lines (top). Wider 8-inch edge and center lines (bottom). (Credit: FHWA)

•Consider applying wider edge and centerlines and shoulder rumble strips.

Long Range

•If the curve superelevation is found to be less than what is specified by the appropriate design policy and values, or inconsistent with other curves in the area, consider reconstructing curve with the appropriate superelevation.

Focus Area #3: MP 48-59 (Intersection of SR 7 and 182nd Street to the intersection with Interstate 5)

Selected Safety Issue	Suggested Action
Cross-Section •Changes in cross section may lead to improper lane positioning and changing of lanes. •Wide outside lanes may encourage higher speeds. •Shoulders of varying width, which may result in their use for unintended purposes such as stopping. •Varying cross-sections may cause unexpected shifts in alignment. •Vehicles parked on the curb or next to intersections and driveways limit sight distance between the road and intersecting streets and driveways. On-street or curb parking increases friction between vehicles in the travel lane and parked vehicles.	**Short Range** •Provide consistency in the corridor through pavement markings or raised pavement markers that define travel lanes. » This can be combined with an access management plan, explained on the following page.

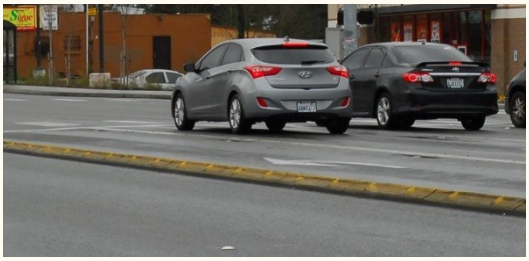
SR 7 near the intersection at 159th street: a wide edgeline separates the vehicular travel lanes from the bike lanes. The edge lines are not present or are much narrower on the northern portion of the corridor. (Credit: Dan Nabors)

Photo top: SR 7 before implementation of access management. Photo below: the same location on SR 7 after access management implementation (Source: Analysis of Access Management Implementation: A Success Story, WSDOT). The access management project helped provide consistency in roadway cross section by defining the lanes with additional pavement markings and curb.

Intermediate Range

Review parking regulations to provide consistency in where to locate parking and how to define those areas with parking using pavement markings and signage. Changes to the parking policies may help to reduce or eliminate friction between vehicles in the travel lane and those utilizing the parking.

A section of SR 7 near 43rd street. The wide outside lane may encourage higher speeds. Traffic parked on the curb limits sight distance between the road and intersecting streets and driveways. Investigate the reason vehicles are parking on the curb. (Credit: Dan Nabors)

Focus Area #3: MP 48-59 (Intersection of SR 7 and 182nd Street to the intersection with Interstate 5) (Cont.)	
Selected Safety Issue	**Suggested Action**
	Intermediate Range (Cont.) •Parking policies can include the review of: » On-Street parking: removing, reducing, or consistently defining locations with on-street parking. Almost 60 percent of intersection-related crashes were between the hours of 2 PM and 7 PM. Restricting on-street parking during those times may help to reduce the potential for conflicts. » The ability to park alongside the road (on the grass, sidewalk, or sidewalk buffer) » Daylighting: limiting parking near intersections, driveways, and crosswalks to help improve visibility of entering vehicles/pedestrians and traffic control devices.   ***Top: Section of SR 7 near S 64th Street where the road transitions from a section with unmarked, on-street parking to a narrower section no on-street parking. The parking is not defined with an edgeline, creating a wide outside lane that may encourage unintended maneuvers and speeding. (Credit: Dan Nabors) Bottom: Example of pavement markings that could define on-street parking. The markings can be used to restrict parking near driveways and intersections, improve visibility of intersections, and define parking so that there is a consistent cross -section throughout the corridor. Signage can be used to restrict parking during times of day when crashes are more prevalent (e.g., 2 PM to 7 PM). (Source: Google Maps)***
Access points •Drivers can turn left across numerous lanes of traffic and may have difficulty seeing motorcycles when trying to find a gap. •There are numerous driveways throughout this portion of the corridor and drivers are able to turn in and out of these driveways onto both directions of SR 7, creating many conflict points. Also, because turning drivers have to cross many lanes of traffic, their ability to judge acceptable gaps in traffic is reduced. •Wide accesses and numerous access points increase the potential for conflict. •In combination with wide-open accesses, limited sight distance at intersections or driveways and changes in roadway cross-section present drivers with additional challenges.	•Restrict left turns from driveways and entrances onto SR 7, only permitting them in certain designated locations. Use signage, pavement markings, and physical barriers to restrict left turns.  ***Example of an existing barrier on SR 7. (Credit: Dan Nabors)***

Focus Area #3: MP 48-59 (Intersection of SR 7 and 182nd Street to the intersection with Interstate 5) (Cont.)	
Selected Safety Issue	**Suggested Action**
	Long Range •Create a corridor access management plan, similar to the plan created for SR 7 between MP 47.3 to MP 52.70. An analysis conducted by WSDOT found that access management contributed to a significant decrease in accident severity and societal costs, particularly during PM peak travel periods. **Examples of Corridor Access Management Issues**

There are portions of the corridor with wide-open accesses. Wide accesses, like the one shown above, increase the potential for conflict. Creating discrete access points would reduce the number of conflict points and would increase drivers' expectancy. (Credit: Dan Nabors)

A section of SR 7 near 84th Street. There are multiple points of conflict in this section of the corridor, including left-turning vehicles from the two-way left-turn lane, traffic in the unmarked parking lanes, and vehicles entering from side streets and driveways. (Credit: Dan Nabors)

Near the intersection of SR 7 and 116th Street, there are several intersections and driveways with limited sight distance due to the retaining walls and change in elevation. The limited sight distance increases the risk in this location, where there are numerous conflict points as drivers turning left from side streets or driveways cross sidewalks, bike lanes, four travel lanes, and a two-way left-turn lane. (Credit: Dan Nabors)

Conclusions

SR 7 is an approximately 60-mile long roadway that provides connections between the City of Tacoma and popular parks and natural environments, and as such attracts vehicles ranging from large recreational vehicles to motorcyclists. The Washington State Department of Transportation (WSDOT) reported a high number of severe crashes involving motorcyclists on this roadway. An analysis of the crash data showed three locations with the highest frequency of crashes involving motorcyclists. The locations were two rural intersections and one urban segment; these locations were the subject of this RSA.

During the RSA start-up meeting, staff from Washington State Department of Licensing (WSDOL) provided information about licensing and data to illustrate some of the behavioral issues affect the safety of motorcyclists in the state. Law enforcement officers whom ride motorcycles and conduct rider education provided first-hand knowledge of rider behavior and enforcement issues as well. These participants were critical for the RSA team to understand motorcyclists' behavior, needs, and concerns and addressing these areas within the context of safety.

The RSA team noted the following strategies as important in addressing the safety of motorcyclists:

- Education and training opportunities provided through Department of Licensing motorcycle safety program.
- Law enforcement working closely with the nearby military base, Joint Base Lewis-McChord, to provide motorcycle education and outreach.
- Access management strategies implemented on the corridor.

Measures suggested by the RSA team on the rural sections include:

- Remove vegetation to improve sight distance.
- Provide additional curve delineation and intersection warning through use of warning signs indicating the location of intersections. Consider motorcycle specific signage.
- Evaluate superelevation of curve though a ballbank test. If inconsistent with adjacent curves, provide motorcycle-specific warning.

Measures suggested by the RSA team on the urban section include:

- Provide additional intersection/driveway delineation and warning.
- Limit parking near intersections, driveways, and crosswalks to help improve visibility of entering vehicles and approaching vehicles.
- Provide consistency in the corridor through pavement markings or raised pavement markers that define travel lanes.
- Restrict left turns from driveways and entrances, only permitting them in certain designated locations. Use signage, pavement markings, and physical barriers to restrict left turns.
- Create a corridor access management plan.

RSA Case Study No. 3— Blue Ridge Parkway, Asheville, North Carolina

Project Overview	
Project Location:	Approximately 60 miles of the Blue Ridge Parkway from milepost 382 (Asheville area) to milepost 439
Project Environment:	Rural and Rural Developed
Project Design Stage:	Existing roadway
Project Owner(s):	National Park Service
RSA Overview	
Date of RSA:	August 21-23, 2012
RSA Stage(s):	RSA of existing roads
RSA Team:	Representatives from the Federal Highway Administration, Blue Ridge Parkway staff from different districts (landscape architect, cultural resource protection specialist, maintenance, rangers, and Denver Service Center), Natchez Trace Parkway staff (civil engineer, maintenance, ranger), Great Smoky Mountains National Park staff, North Carolina Department of Transportation district engineer, and VHB.

Project Background

The Blue Ridge Parkway (BLRI) is a 469-mile long rural parkway that travels through both Virginia and North Carolina. A map showing the location of the Parkway is shown in Figure A-9. Under the provisions of the Organic Act approved by Congress on August 25, 1916 (39 Stat. 535) creating the National Park Service, the intended purpose of the Blue Ridge Parkway is to conserve, interpret and exhibit the unique natural and cultural resources of the central and southern Appalachian Mountains, as well as provide for leisure motor travel through a variety of environments. The original design of the Parkway developed in the 1930s and 1940s envisioned leisurely touring where visitors would enjoy the scenery, hike the trails, and stay and eat in the concession areas. Today, the Blue Ridge Parkway is technically the most visited park in the National Park system, with over 20 million visitors annually. Vehicles traveling on the Parkway range from large recreational vehicles to large groups of motorcyclists. The unique combination of recreational character and winding alignment of the Blue Ridge Parkway contribute to elevated motorcycle activity on the roadway.

Figure A-9: Blue Ridge Parkway Location Map.

FHWA selected BLRI for RSA assistance because of the high visitation and frequency and type of crashes. From 2007-2012, there were 723 motorcycle crashes on the Parkway; motorcycle crashes accounted for 38% of all crashes during this time period. Furthermore, motorcycle ridership on BLRI has increased significantly in the past 10 years, increasing the potential for motorcycle crashes.

Pilot Overview

The RSA team held a training session at the Parkway Headquarters, during which the team reviewed the methodology for conducting an RSA using the eight-step process detailed in the FHWA RSA Guidelines, established the role and responsibilities for an RSA champion, identified RSA team members and partners, and identified resources for developing recommendations through RSAs. The RSA trainers emphasized special RSA program elements that apply to the Parkway, including motorcycle safety. In conjunction with the training on how to conduct an RSA and implement an RSA program, NPS staff received technical assistance in conducting an RSA. The intent was for this experience to provide a foundation for NPS staff to conduct additional RSAs in the future. RSA team members included park rangers experienced in riding a motorcycle.

Crash History

The RSA team reviewed and analyzed available crash data from 2007-2012, and selected specific locations for review during the RSA based on crash frequency. Table A-2 provides a summary of the crash data for the locations selected.

Table A-2: RSA Study Area Crash Summary.

Location	Total Crashes	Injury Crashes[1]	Fatal Crashes[1]	MC Crashes[2]	Night Crashes	Wet/Snow/Fog Conditions	Predominant Crash Types
BLRI/Route 70 Interchange (MP 382)	15	2	0	0	3	2	Ran-off-road, Fixed Object
BLRI/Route 74 Interchange (MP 384)	49	19	0	5	6	1	Rear-end, Angle, Ran-off-road (traffic island)
BLRI/Route25 Interchange (MP 389)	25	6	0	4	7	4	Rear-end, Ran-off-road (traffic island)
BLRI/Route191 Interchange (MP 393)	13	5	0	2	1	0	Animal-related, Ran-off-road, Fixed Object
BLRI/Route276 Interchange (MP 412)	9	4	0	4	0	1	Motorcycle, Fixed Object (snow gate)
East Fork Overlook (MP 418)	5	5	0	5	0	0	Motorcycle (loss of control)
Graveyard Fields Overlook (MP 419)	3	2	0	2	0	0	Motorcycle
Curve 1 (MP 427)	11	5	0	9	0	0	Motorcycle (loss of control)
Curve 2 (MP 437)	7	4	0	5	0	1	Motorcycle (loss of control)
Curve 3 (MP 439)	15	11	0	14	0	2	Motorcycle (loss of control)

Notes: [1]Refers to the number of injury or fatal crashes, not number of persons involved.
[2]Motorcycle crashes

The crash data indicated that motorcycle crashes were by far the most common type of crash along curve segments in the study area. The motorcycle crashes during the period studied had a high rate of injury, although there were no reported fatalities. All of the crashes in the curve segments occurred during daytime conditions.

Positive Features

In response to the high number of crashes involving motorcycles and crashes on curves in general, BLRI staff implemented a signage program to address vehicle speed and loss-of-control crashes on curves with a descending radius – that is, "spiral curves." The signage program entails installation of unique messaging intended to provide drivers with advance warning of the curvature in the roadway. The signs are comprised of a 48x48-inch aluminum yellow warning sign displaying a black rounded arrow indicating the direction of curvature and a supplemental yellow placard with a black "SPIRAL CURVE" message.

Spiral Curve Warning Sign along the Blue Ridge Parkway. (Credit: Dan Nabors)

Installation of the spiral curve warning signs started as a one-year pilot in 2001 and targeted locations along descending grades in mountainous sections of the parkway. NPS has continued to install additional signs and has 15 signs at different locations on the parkway. BLRI staff have been measured in their use of the signs, both to avoid diminishing the effectiveness of the signs through overuse and to avoid significant impacts to the cultural and historical character of the parkway.

BLRI staff installed spiral curve warning signs based on the following criteria:

- Target the 10 worst curve crash locations
- Only install facing a descending grade approach to a curve
- Only install on segments with obstructed visibility of the end of curvature

BLRI staff have also developed motorcyclist-specific signage. The "motoman" sign was developed and used by the park in locations with a high incidence of run-off-the-road motorcycle crashes (Figure A-10).

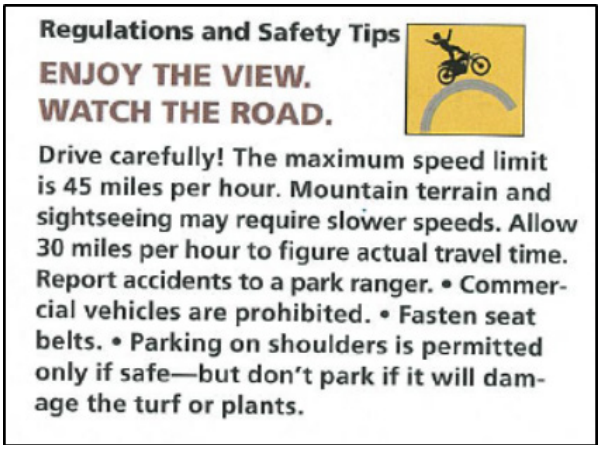


Figure A-10: Excerpt from Blue Ridge Parkway Brochure Illustrating the "Motoman" Sign. (Source: NPS)

RSA Motorcycle Crash Findings and Suggestions

After completing the RSA field review, the RSA team developed a list of eight critical issues as part of the RSA process. The RSA team identified motorcycle crashes as the second most critical issue on the Blue Ridge Parkway, after poor roadway conditions/maintenance, which can contribute to motorcycle safety issues as well.

In general, the RSA team considered data limitations as a critical limitation in understanding factors that increase risk for motorcyclists. The NPS keeps records of reported crashes on the Blue Ridge Parkway and summarizes this data by milepost location, date, time of day, weather conditions, and severity. However, the standard NPS crash data summaries do not provide additional details regarding a variety of crash attributes, including direction of travel, collision type, number of vehicles, participant ages, or other contributing factors. Furthermore, the lack of volume data, particularly for motorcyclists, restricts the ability to assess risk based on motorcyclists' exposure. Other behavioral data may also help define issues specific to motorcyclists.

Blue Ridge Parkway, MP 382-439	
Selected Safety Issue	**Suggested Action**
Conditions Affecting Motorcyclists •Pavement surfaces have a greater effect on motorcycles than larger vehicles. Uneven surfaces, cracks and potholes, loose debris, and fluid spills, can cause a motorcycle to lose control and potentially crash. •Pavement edge drop-offs are a greater hazard to motorcyclists than larger vehicles.  ***A fluid spill near mile marker 418. Fluid spills can contribute to loss of control crashes for motorcycles. This is particularly critical at this location due to horizontal curvature and limited sight distance. (Credit: Dan Nabors)***  ***The pavement has been damaged by fallen rock and the roadway width is impacted by the encroachment of vegetation. (Credit: Dan Nabors)***	**Short Range** •Monitor and repair pavement where potholes, debris, longitudinal cracks, vertical displacement, and reduced friction are apparent. •Target law enforcement at locations with high crash incidence, based on NPS crash records. •Install signage at key locations to communicate motorcycle crash statistics and speeding fines. •Implement a program to install Safety Edge^{SM} along the parkway roadside, particularly in areas with higher volumes, along curves, or at locations where data suggest motorcycles run off the road. **Long Range** •Implement a program to install Safety Edge^{SM} along the Parkway roadside, particularly in areas with higher volumes, along curves, or at locations where data suggests motorcycles run off the road.

Blue Ridge Parkway, MP 382-439	
Selected Safety Issue	**Suggested Action**
Motorcycling Skill/Expertise •Motorcyclists may have difficulty negotiating grades and curves. Cruiser bikers may be particularly at risk because of the size and different handling characteristics of this type of motorcycle. •Motorcyclists are largely a visitor population and may not be familiar with BLRI attributes. •Driving too fast for conditions has been cited as an issue.  ***Motorcyclists exhibit a range of riding behaviors. In this photo, the last motorcyclist is riding very close to the centerline around a curve with limited sight distance. (Credit: Dan Nabors)***	**Short Range** •Partner with riding clubs, DMV, safety groups, EMS to provide motorcycle safety education in the park. •Focus educational efforts on the most vulnerable rider types (i.e., cruiser bikers). •Post fines for speeding and reckless driving at entrances to the Parkway. •Review geometric conditions to determine if additional spiral curve warning signs are warranted based on existing placement conditions. **Intermediate Range** •Post educational materials at major motorcyclist gathering locations on BLRI. •Continually review crash data and install additional SPIRAL CURVE warning signs at the highest incidence curve locations. **Long Range** •Collect data on motorcycle usage (volume and classification) and detailed crash information (motorcycle classification and make). Use volume data to determine crash rates for targeting countermeasures and enforcement. Use detailed crash information to target at-risk types or groups of riders for education efforts with enthusiast groups, dealers, and manufacturers. •Establish speed zones in areas where data suggests speed is a primary factor contributing to crashes. •Coordinate with Federal, State, and local partners to develop additional safety-related public outreach programs.

Conclusions

FHWA sponsored an RSA on the Blue Ridge Parkway to address safety. The RSA team was comprised of local practitioners with a full range of skill sets, along with representatives from the National Park Service assigned to various parks in the region. Park rangers with experience riding a motorcycle were also part of the team and provided valuable insight into motorcycle issues on the Parkway.

The RSA team reviewed conditions affecting motorcycle safety and found that the Spiral Curve Warning Signs were a positive strategy to address a unique condition along the Parkway and that a rigorous analysis should confirm their efficacy. Detailed data on motorcycle crashes, volumes, and types considered a critical limitation in fully understanding risks to motorcyclists. Other measures suggested by the RSA team to improve safety for motorcyclists include:

- Collaborate with riding clubs, DMV, safety groups, EMS to provide riding safety education on the Parkway.
- Post educational materials at major motorcyclist gathering locations on the Parkway.

- Repair pavement where potholes, debris, longitudinal cracks, vertical displacement, and reduced friction are apparent.
- Target speed and traffic law enforcement at locations with high crash incidence, based on NPS crash records.
- Implement a program to install Safety Edge^{SM} and/or pavement edge striping along the Parkway roadside, particularly along curves or areas where data suggests motorcycles run off the road.