# Upper Savannah Council of Governments

# Roadway Departure Safety Implementation Plan

November 10, 2023

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The Upper Savannah Council of Governments (USCOG) and South Carolina Department of Transportation (SCDOT) developed this document to aid in the identification of potential countermeasures for roadway departure crashes. The content included in this report provides potential options to help reduce the number and severity of roadway departure crashes. The countermeasures noted in the report represent one set of recommendations for these agencies but are not the only possible countermeasure options for the noted sites or highways.

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## ABBREVIATIONS / ACRONYMS

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| BIL | Bipartisan Infrastructure Law |
| BUILD | Better Utilizing Investments to Leverage Development |
| CMF | Crash Modification Factor |
| DEM | Digital Elevation Model |
| DUI | Driving Under the Influence |
| FARS | Fatal Fatality Analysis Reporting System |
| FAS | Focused Approach to Safety |
| FHWA | Federal Highway Administration |
| GIS | Geographic Information System |
| HFST | High Friction Surface Treatment |
| HSIP | Highway Safety Improvement Program |
| HSM | Highway Safety Manual |
| MHE | Most Harmful Event |
| MUTCD | Manual on Uniform Traffic Control Devices |
| NHTSA | National Highway Traffic Safety Administration |
| RAISE | Rebuilding American Infrastructure with Sustainability and Equity |
| RDSIP | Roadway Departure Safety Implementation Plan |
| RwD | Roadway Departure |
| RRPMs | Raised Reflective Pavement Markers |
| RSA | Road Safety Audit |
| SC | South Carolina |
| SCDOT | South Carolina Department of Transportation |
| SHSP | Strategic Highway Safety Plan |
| SS4A | Safe Streets and Roads for All |
| STBG | Surface Transportation Block Grant |
| TOPS | Traffic Operations and Safety |
| US | United States |
| USCOG | Upper Savannah Council of Governments |
| USDOT | United States Department of Transportation |
| VMT | Vehicle-Miles Traveled |

# EXECUTIVE SUMMARY

From 2017 to 2021, roadway departure (RwD) crashes in USCOG accounted for approximately 55 percent of statewide fatal crashes, resulting in approximately 590 fatalities annually. In the six-county Upper Savanah Council of Governments (USCOG) region, RwD crashes accounted for approximately 69 percent of fatal crashes, resulting in approximately 40 fatalities annually. To address these severe crashes, the USCOG, in conjunction with the South Carolina Department of Transportation (SCDOT), supported by the Federal Highway Administration (FHWA), is developing a *Roadway Departure Safety Implementation Plan*, referred to as the Plan in this document. This document includes a summary of the data analysis and recommendations for improvements targeted at reducing these severe RwD crashes.

SCDOT, in 2017, identified that nearly 30 percent of rural fatal and serious injury crashes occur on just over 5 percent (or approximately 1,900 miles) of SCDOT's roadway network. These roadways consist of the State's rural major routes, primarily consisting of United States and SC highways. To combat these crashes, SCDOT implemented the Rural Road Safety Program, breaking the network into 10-mile segments addressing these roadways over a 10-year period. SCDOT has been addressing these corridors using lower cost treatments installed on a wider scale. The USCOG contains a small mileage of the priority network, as the USCOG is a more rural area by its nature.

This plan identifies higher risk locations specific to the six-county USCOG region, including focus facility types over-represented with severe RwD crashes. This plan supports addressing severe RwD crashes at high-risk locations using low-cost safety improvements. The USCOG, in partnership with SCDOT, can use the priority locations included in this plan to conduct site investigations, including road safety audits (RSAs) to prioritize appropriate countermeasures based on site-specific conditions. This plan can further serve as a model for other rural planning agencies within South Carolina to address fatal and serious injury RwD crashes on State and locally owned roadways.

This plan provides recommendations on how these safety enhancement strategies can be effectively implemented. An annual reduction of approximately 57 fatal and injury crashes per year (and approximately 161 total crashes per year) requires an annual investment of approximately $5.8 million for each of the next 5 years. Following deployment and continuous maintenance of these treatments, the number of lives saved due to RwD crashes can be expected to continue to decrease on USCOG highways beyond the next 5 years.

For additional information about the FHWA RwD Focus State Initiative, contact Joseph Cheung, FHWA Office of Safety, at joseph.cheung@dot.gov. For additional information about USCOG please contact Rick Green at rgreen@uppersavannah.com.

# ROADWAY DEPARTURE SAFETY GOAL

## BACKGROUND

The Federal Highway Administration (FHWA) Focused Approach to Safety (FAS) program provides additional resources to eligible high priority States, including technical assistance, training, and awareness on critical severe crash types. In 2021, FHWA identified South Carolina (SC) as a Focus State for roadway departure (RwD) crashes based on 2014-2019 data from the Fatality Analysis Reporting System (FARS), summary information from the State Strategic Highway Safety Plan (SHSP) database, data from the United States (US) Census, and FHWA Highway Statistics.

To combat RwD fatalities and serious injuries on all public roads, the FHWA and the South Carolina Department of Transportation (SCDOT) agreed to engage with the Upper Savannah Council of Governments (USCOG) to develop a RwD safety implementation plan (RDSIP) which will serve as a model for other regional planning organizations within the State. Figure 1 identifies the location of USCOG among the 10 SC COGs. The USCOG consists of six counties: Abbeville, Edgefield, Greenwood, Laurens, McCormick, and Saluda. The USCOG assists SCDOT in long-range planning of regional transportation improvements including highway infrastructure and works with jurisdictions in the region to prioritize local needs and make recommendations to SCDOT for funding of highway and transit projects.

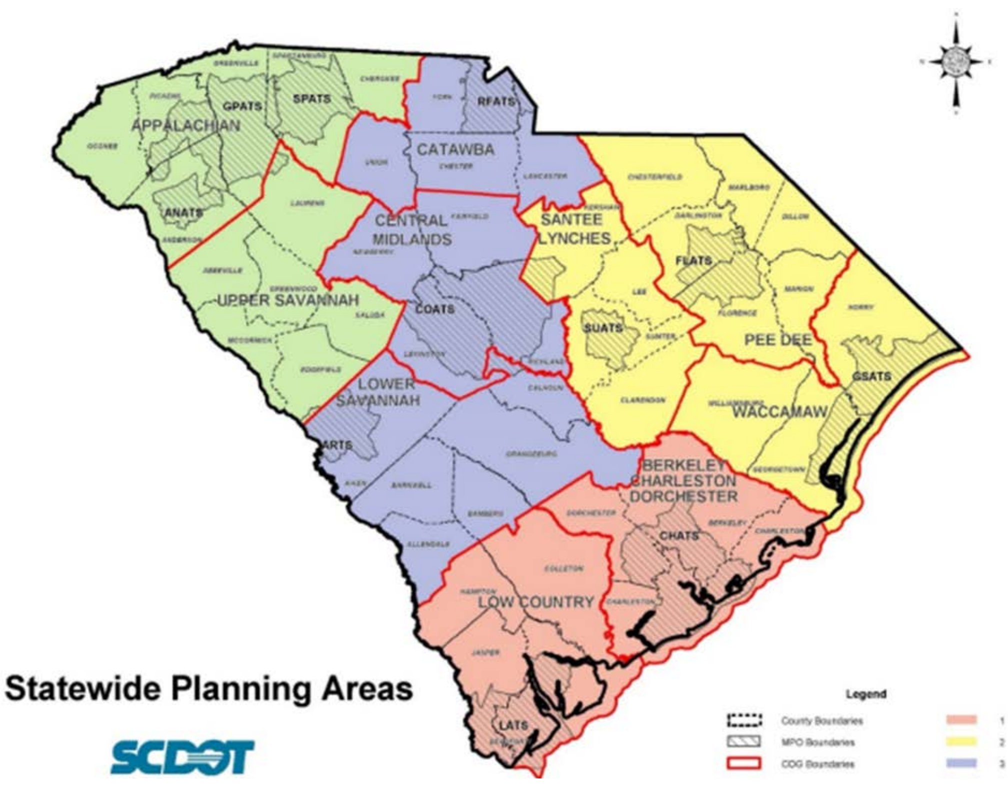


**Figure 1. Location of USCOG**

SC RwD fatal crashes account, on average, for approximately 55 percent of all fatal crashes within SC, based on 2017 to 2021 FARS data, as shown in Table 1. Some of the causes for these crashes include a failure to maintain control, speed, impairment, and failure to obey traffic control devices. Table 2 highlights that RwD fatal crashes account for approximately 68 percent of fatal crashes within the USCOG, specifically.

**Table 1. SC Fatal Crashes and Fatal RwD Crashes by Year (2017 – 2021)**

| Year | Fatal Crashes | | |
|---|---|---|---|
| | Total Fatal Crashes | Total Fatal RwD Crashes | Percent of Annual Fatal Crashes |
| 2017 | 925 | 526 | 57 |
| 2018 | 969 | 534 | 55 |
| 2019 | 927 | 510 | 55 |
| 2020 | 964 | 531 | 55 |
| 2021 | 1,112 | 584 | 53 |
| **Total** | **4,333** | **2,512** | **55** |

**Table 2. USCOG Fatal Crashes and Fatal RwD Crashes by Year (2017 – 2021)**

| Year | Fatal Crashes | | |
|---|---|---|---|
| | Total Fatal Crashes | Total Fatal RwD Crashes | Percent of Annual Fatal Crashes |
| 2017 | 55 | 40 | 73 |
| 2018 | 61 | 40 | 66 |
| 2019 | 38 | 26 | 68 |
| 2020 | 52 | 33 | 63 |
| 2021 | 50 | 36 | 72 |
| **Total** | **4,333** | **2,512** | **68** |

FHWA further identified, based on 2016 to 2020 FARS data, that approximately 56 percent of all fatalities in SC are the result of RwDs. Fifty percent are RwD only, while six percent include RwD and a second focus area. Figure 2 provides a breakdown of RwD fatalities by most harmful event (MHE). Tree-related crashes account for the highest proportion of RwD fatalities, followed by head-on, and then rollover crashes. These three MHEs, combined, account for 79 percent of RwD fatalities in SC.

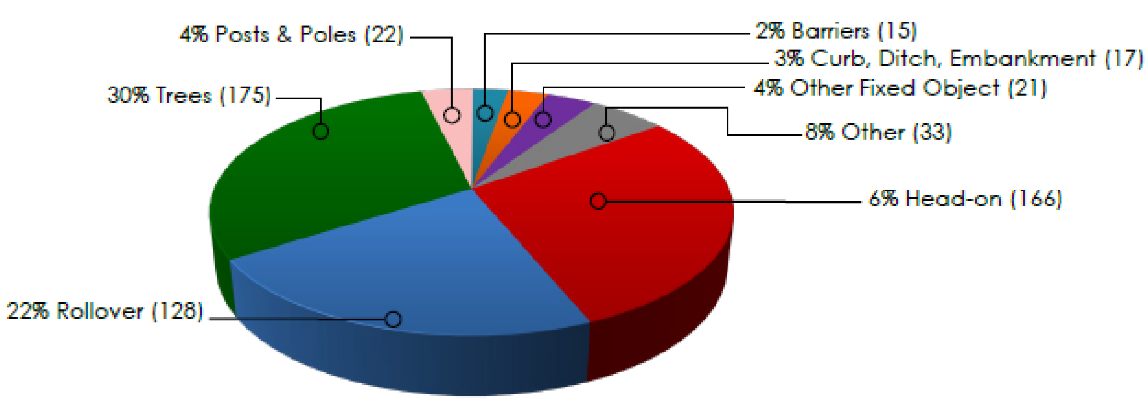


**Figure 2. RwD Fatalities by MHE (2016-2020 FARS)**

Based on these findings, the FHWA FAS team is providing support to the USCOG to develop a *Roadway Departure Safety Implementation Plan* (RDSIP), referred to as the Plan in this document. This Plan includes a systemic approach to identifying and prioritizing sites for low-cost safety countermeasures as well as identifies a set of countermeasures, and expected costs, for deployment.

## PROBLEM

### SC Strategic Highway Safety Plan (SHSP) (1)

In 2020, the SC Department of Public Safety and the SCDOT published a 2020 – 2024 SHSP. The SHSP establishes statewide priorities and identifies critical emphasis areas based on analysis of statewide crash data and input from stakeholders. The SHSP identifies 12 emphasis areas, arranged by infrastructure, high-risk behaviors, and vulnerable roadway users, as shown in Figure 3. The RwD emphasis area represents the highest percentage of fatal and serious injury collisions. Several emphasis areas focus on or are directly related to RwD crash outcomes. The SHSP identifies proven effective strategies addressing engineering, education, enforcement, emergency medical services, and public policy elements with a goal to reduce fatalities and serious injuries on all public roadways.

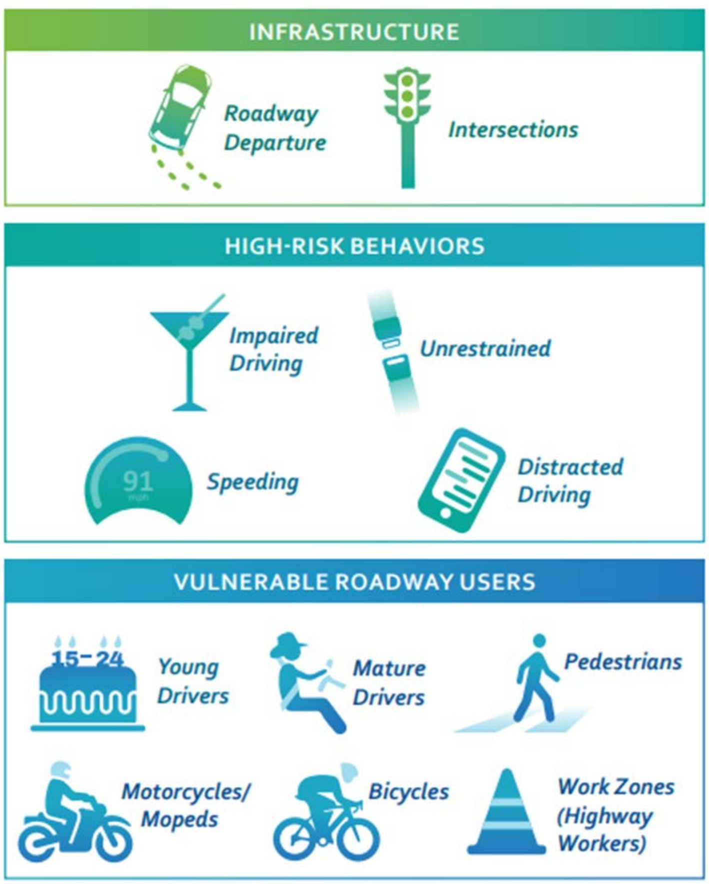


**Figure 3. SC 2020 – 2024 SHSP Emphasis Areas. (1)**

The SHSP highlights that SCDOT invests $70 million annually on RwD solutions for rural road safety, interstate safety, and upgrading facilities to include rumble strips on all eligible roads throughout the State. Additionally, the SHSP highlights the need for and implementation of the Rural Road Safety Program, which is described in the next section. Moreover, SCDOT has invested in reducing impaired driving and speeding as well as in increasing seat belt use.

The SHSP provides countermeasures for each strategy listed above for the RwD emphases area, including the following:

- Continuing implementation of South Carolina’s Rural Road Safety Program.
- Deploying center line and edge line rumble strips in accordance with SCDOT policy.
- Installing enhanced pavement markings, six-inch edge line, or embedded wet-reflective pavement markings on sections with narrow or no paved shoulders.
- Maintaining shoulders to reduce debris and edge drop offs, use safety edge, identify opportunities to upgrade or improve shoulders to provide additional recovery area.
- Increasing road surface skid resistance using high friction surface treatments.
- Improving safety at horizontal curves through inventory and assessment of curves to comply with Manual on Uniform Traffic Control Devices (MUTCD) requirements.
- Installing delineation on fixed objects that cannot be removed from the clear zone.
- Studying the need for clear zone reclamation by removing trees and brush.
- Studying the need to remove/relocate objects located in the clear zone.
- Continuing to maintain roadside safety hardware, including installation of new hardware and removal or replacement of existing barriers that are damaged or non-functional.
- Studying the need to add raised medians or other access control measures on minor arterials.
- Performing targeted speed and driving under the influence (DUI) enforcement on roads with a high proportion of RwD crashes.
- Conducting briefings with local law enforcement on contributing factors and locations representing a high number of collisions resulting in RwDs.
- Increasing public awareness of the dynamics of RwD collisions.
- Working with partner agencies to integrate new content into the driver education curriculum and driver manual.
- Raising awareness about the dynamics of texting and other distractions with safety partners.

- Improving emergency response time to rural locations.
- Working with state and local fire, emergency medical services, law enforcement, and incident response personnel to identify opportunities for reducing secondary collisions through coordinated incident response.

South Carolina's Rural Road Safety Program implements proven safety countermeasures using the following strategies:

- Keep vehicles on the roadway, provide for safe recovery, and reduce the severity of the crash.
- Keep vehicles from encroaching into the opposite lane.
- Reduce nighttime RwD collisions.
- Educate roadway users to understand the causes and implications of RwD crashes.

**Rural Road Safety Program**

Analysis of statewide data indicated that nearly 30 percent of rural fatal and serious injury crashes occur on just over 5 percent (or approximately 1,900 miles) of SCDOT's roadway network. However, it is unclear what portion of the statewide vehicle-miles traveled (VMT) for which this mileage accounts. These roadways consist of the State's rural major routes, primarily consisting of US and SC highways. This program breaks the network into 10-mile segments addressing those roadways over 10-years. Figure 4 highlights the Rural Road Safety Program corridors in the USCOG region. Very few miles in the six-county region are included in the program. SCDOT has been addressing these corridors using the following:

- Rumble strips.
- Wider and brighter pavement markings.
- Brighter signs.
- High-friction surface treatments.
- Wider/paved shoulders.
- Improved clear zones.
- Guardrail/cable barrier.
- Safety Edge.

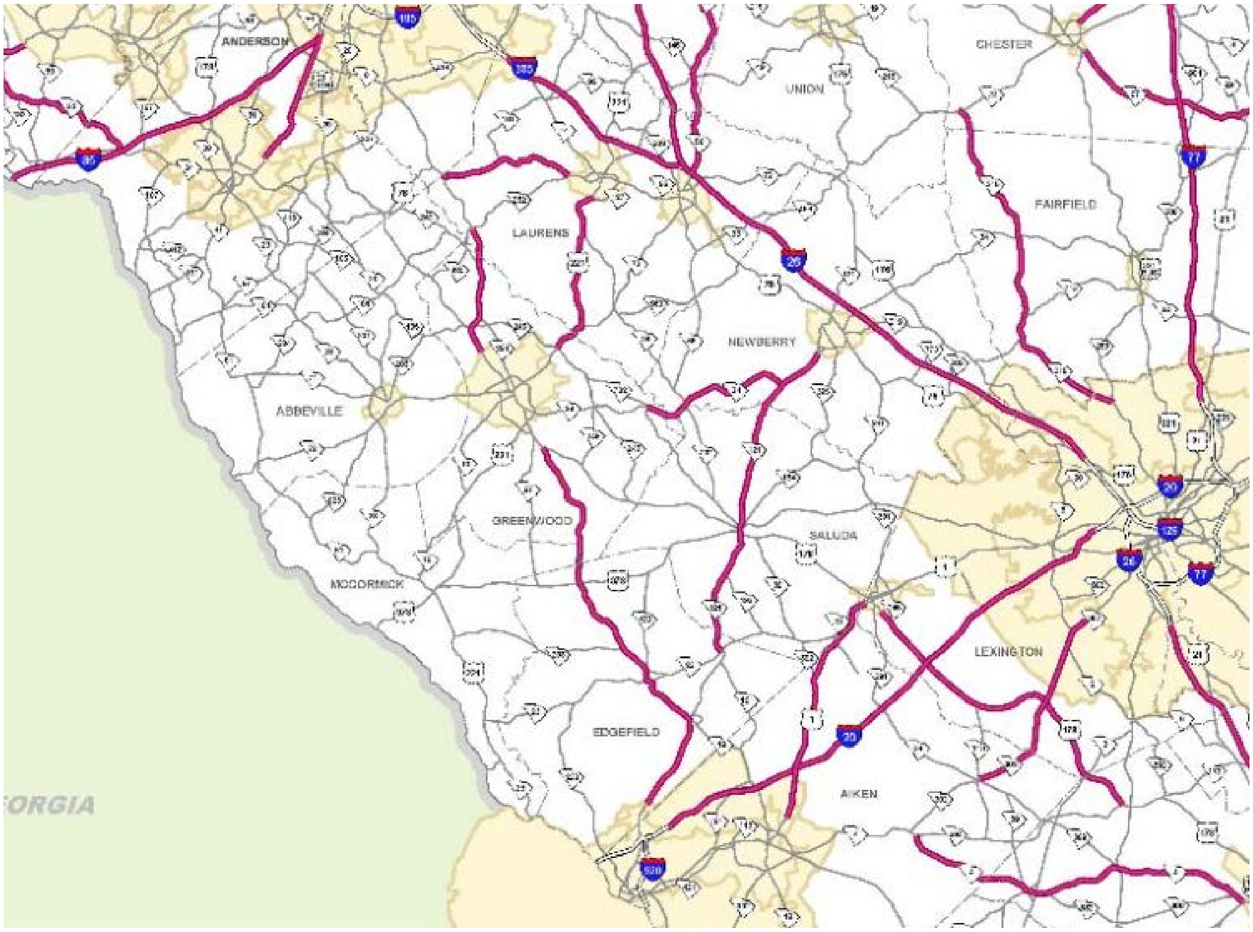


**Figure 4. Rural Road Safety Program in USCOG Region**

### Highway Safety Improvement Program (2)

SCDOT has most recently published the 2022 edition of its Highway Safety Improvement Program (HSIP) annual report. In this report, SCDOT indicated they spent approximately $20 million on RwD safety, including $11 million on the Interstate Safety Program and $9 million on the RwD Mitigation Program (described in the next section). Since the State maintains the fourth largest highway system in the nation, and approximately 93 percent of fatal crashes occur on State-maintained roadways, funding is focused on State-maintained roadways. SCDOT also indicated that approximately 60 percent of HSIP funds are used to address systemic safety improvements, including the following:

- Cable median barriers.
- Clear zone improvements.
- High friction surface treatments.
- Installing/improving lighting.

- Installing/improving pavement markings and/or delineation.
- Installing/improving signing.
- Pavement/shoulder widening.
- Rumble strips.
- Safety edge.

**Roadway Departure Mitigation Program [3]**

Effective April 2017, SCDOT issued an Engineering Directive detailing the process for prioritizing and selecting projects for RwD mitigation. As noted in the SHSP and HSIP report, the purpose of the program is to achieve a significant reduction in traffic fatalities and serious injuries through implementation of infrastructure-related improvements. The RwD mitigation list includes segments where a minimum of 30 percent of total crashes are RwD and must have a minimum of 10 RwD crashes per segment. The list is then prioritized by the highest number of fatal and serious injury RwD crashes. Once the prioritized list is assembled, each candidate segment is screened based on assessment of crash data, field conditions, and evaluation of potential effectiveness of countermeasures under consideration. Candidates are then selected for projects based on the potential for reducing RwD crashes and if no other active projects are currently ongoing. Typical safety improvements under this program include the following:

- Two-foot paved shoulders, resurfacing, center line, and edge line rumble strips where the posted speed limit is 45 mph or greater.
- Additional yellow bidirectional 4-inch x 4-inch markers at a 40-foot spacing along the center line of all curves.
- Two-foot white dash edge lines through all intersections.
- Six-inch center line and edge line thermoplastic pavement markings.
- Guardrail upgrades, guardrail installation, and installation of guardrail delineators.
- Removing limbs and/or selected trees along the existing ditch line and within the SCDOT right-of-way.

**SCDOT Historic Approaches Conclusions**

These approaches have been effective at reducing RwD crash frequency, particularly serious injury crash frequency in SC. These approaches have traditionally focused on SCDOT-owned roadways and the Rural Road Safety Program has highlighted the need for addressing the Primary Road system based on statewide needs. The RwD mitigation program provides an additional focus on addressing locations with a history of multiple RwD crashes. Overall, RwD safety can benefit from an additional approach of prioritizing locations, particularly on the rural secondary system, for low-cost safety improvements based on risk for RwD crashes, even if a crash has not happened at that location recently. This approach is imperative for addressing the needs of very rural counites, such as those in the USCOG.

### DEFINITION OF RWD CRASHES

The FHWA report titled *Federal Highway Administration Focus Area Data Definitions* provides an overview of the FHWA definition of RwD crashes.(4) In the early 2000s, the FHWA calculation for these crash types separately identified single-vehicle and multiple-vehicle crashes in an effort to avoid double counting crashes within the two broad categories. At that time, many transportation agencies defined a single-vehicle RwD crash as a single vehicle run-off-road crash. These agencies expanded this definition for multiple-vehicle crashes as the following collision types:

- Front-to-front (i.e. head-on).
- Front-to-side, opposite direction (i.e. opposite direction angle crash).
- Sideswipe, opposite direction (i.e. opposite direction sideswipe crash).

In 2009, FHWA refined the criteria used to define RwD crashes by incorporating vehicle event disaggregation. Vehicle event disaggregation provided a sequence of up to six events specific to each vehicle involved in the crash and included elements such as "ran-off-road -- right" and "cross median/centerline." FHWA also excluded intersection crashes at that time, primarily because most RwD countermeasures are not applicable at intersections.

The new FHWA definition of a RwD crash is "a crash in which a vehicle crosses an edge line, a centerline, or leaves the traveled way." (5) The single change to the coding is to remove the intersection filter.

Based on the SCDOT data elements, RwD crashes include head-on, sideswipe opposite direction and sideswipe same direction (where the first harmful event does not include in transport or stopped motor unit) collisions. Crash severity is measured using the KABCO scale as is described in the following section.

Typically, the systemic approach focuses on fatal and serious injury crashes; however, due to sample sizes in the USCOG B-level injury crashes are included in all analyses and C-level injury crashes are included in analyses for head-on crashes. Note that crash over-representation focuses on comparing KA-level injury crashes to BCO-level crashes to seek over-representation in KA-level injury crashes.

## APPROACH

The goal of this Plan is to help reduce RwD fatal and serious injury crashes in USCOG. The RwD crash data include the maximum severity of each crash on the KABCO scale. The KABCO scale uses the following definitions for injury severity:

- K: Fatal: Any injury that results in death.
- A: Suspected Serious Injury: Any non-fatal injury that prevents the victim from walking, driving, or normally continuing activities.
- B: Suspected Minor Injury: Any injury evident to observers at the scene of the crash that is not fatal or incapacitating.
- C: Possible injury: Any reported or claimed injury that is not immediately evident.
- O: Property damage only: No injury was reported in the crash.

This Plan focuses on fatal (K), suspected serious injury (A) crashes, and suspected minor injury (B) crashes. Table 3 summarizes annual breakdowns of total and KAB RwD crashes by county.

**Table 3. Annual Distribution of RwD Crashes by County (2017 – 2021)**

| County | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | KAB | Total | KAB | Total | KAB | Total | KAB | Total | KAB |
| Abbeville | 194 | 48 | 216 | 44 | 159 | 30 | 189 | 38 | 243 | 26 |
| Edgefield | 175 | 31 | 163 | 31 | 171 | 35 | 143 | 21 | 182 | 18 |
| Greenwood | 540 | 95 | 597 | 75 | 522 | 100 | 510 | 83 | 659 | 74 |
| Laurens | 673 | 95 | 802 | 102 | 614 | 113 | 655 | 112 | 902 | 99 |
| McCormick | 75 | 12 | 69 | 15 | 63 | 12 | 50 | 9 | 72 | 12 |
| Saluda | 85 | 42 | 175 | 25 | 156 | 25 | 172 | 18 | 215 | 30 |
| **Total** | **1,842** | **323** | **2,022** | **292** | **1,685** | **315** | **1,719** | **281** | **2,273** | **259** |

The Plan explores a variety of analysis techniques for optimizing and selecting study sites and their associated candidate safety enhancements. An effective and efficient Implementation Plan requires a strategic approach. In addition to support and facilitation of enforcement and training activities, deployment of safety treatments can enhance roadway safety at locations where RwD crashes may be expected. This Plan blends traditional site-specific analysis techniques with state-of-practice systemic safety procedures to help identify locations where the deployment of safety treatments will provide the best opportunity to reduce fatal and serious injury crashes in the USCOG. Additionally, employing a systemic safety approach allows SCDOT and its local partners to proactively address RwDs at high-risk locations which may have yet to observe crashes historically.

## DISTRIBUTION OF RWD CRASHES

A review of RwD crash and injury severity data for USCOG can help to identify insights into the distribution and characteristics of these observed crashes. As a starting point, Table 4 summarizes the annual distribution of total RwD crashes and KAB RwD crashes annually by route type.

**Table 4. Annual Distribution of USCOG RwD Crashes by Route Type**

| Route Type | 2017 | | 2018 | | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | KAB | Total | KAB | Total | KAB | Total | KAB | Total | KAB |
| Interstate | 130 | 13 | 168 | 12 | 127 | 9 | 116 | 9 | 182 | 10 |
| US Route | 299 | 51 | 306 | 48 | 274 | 61 | 289 | 63 | 411 | 52 |
| SC Route | 460 | 90 | 499 | 80 | 430 | 92 | 439 | 69 | 618 | 71 |
| Secondary | 772 | 139 | 871 | 131 | 702 | 134 | 731 | 128 | 906 | 114 |
| Local | 176 | 29 | 176 | 21 | 147 | 18 | 143 | 12 | 155 | 12 |
| Ramp | 5 | 1 | 2 | 0 | 5 | 1 | 1 | 0 | 1 | 0 |
| **Total:** | **1,842** | **323** | **2,022** | **292** | **1,685** | **315** | **1,719** | **281** | **2,273** | **259** |

The data indicates that secondary roads account for the highest number of RwD crashes in the USCOG. However, it is important to keep in mind this does not account for VMT on these facilities. Relationship to exposure is considered in further analyses.

Table 5 provides a summary of key contributing factors identified in USCOG RwD crashes. Table 5 provides totals for KA RwD crashes separately from BC RwD crashes to allow the reader to compare the percentages of fatal and serious injury crashes (KA) as compared to less severe injuries (BC).

For collision type, trees, head-on, and curb/ditch/embankment result in the highest number of KA RwD crashes. Notably, nearly 50 percent of KA RwD crashes occur at night and approximately 18 percent occur on wet pavement.

More than 31 percent of KA RwD crashes were flagged as DUI involved and more than 55 percent were speeding-related. In both cases, these proportions were much higher KA RwD crashes compared to BCO RwD crashes. Additionally, the presence of unbelted occupants is over-represented in KA RwD crashes, with 42 percent of crashes having unbelted occupants. Only six percent of BCO RwD crashes had unbelted occupants.

As expected, the majority of RwD crashes, for all injury severities, were at non-intersection locations in rural areas. RwD crashes were scattered among facility types (highlighting the systemic nature of these crashes); however, rural minor arterials, major collectors, and local roads had the highest RwD crash counts. It should be noted that these numbers do not account for exposure and may not be directly indicative of where occurrences of crashes are greater than would be expected. This is directly addressed in the systemic analysis and identification of focus facility types.

**Table 5. Key Contributing Crash Characteristics in USCOG RwD Crashes**

| Characteristic Type | Characteristic | KA RwD Crashes | | BC RwD Crashes | |
|---|---|---|---|---|---|
| | | Crashes | Percent | Crashes | Percent |
| Collision Type | Barrier | 15 | 3.1 | 677 | 7.5 |
| | Curb/Ditch/Embankment | 98 | 20.2 | 2,284 | 25.2 |
| | Head-on | 100 | 20.6 | 1,298 | 14.3 |
| | Other | 16 | 3.3 | 1,103 | 12.2 |
| | Other fixed object | 12 | 2.5 | 523 | 5.8 |
| | Post and Poles | 26 | 5.4 | 999 | 11.0 |
| | Rollover | 39 | 8.0 | 263 | 2.9 |
| | Trees | 179 | 36.9 | 1,909 | 21.1 |
| Light Conditions | Daylight | 239 | 49.3 | 4,682 | 51.7 |
| | Night | 246 | 50.7 | 4,374 | 48.3 |
| Road Surface Condition | Dry | 399 | 82.3 | 7,026 | 77.6 |
| | Wet | 86 | 17.7 | 2,030 | 22.4 |
| DUI Involved | No | 333 | 68.7 | 8,092 | 89.4 |
| | Yes | 152 | 31.3 | 964 | 10.6 |
| Speeding Involved | No | 217 | 44.7 | 6,424 | 70.9 |
| | Yes | 268 | 55.3 | 2,632 | 29.1 |
| Intersection Traffic Control | None | 393 | 81.0 | 7,267 | 80.3 |
| | Present | 92 | 19.0 | 1,789 | 19.8 |
| Area Type | Rural | 374 | 77.1 | 6,679 | 73.8 |
| | Urban | 105 | 21.7 | 2,289 | 25.3 |
| | NA | 6 | 1.2 | 88 | 1.0 |
| Functional Class | Rural Principal Arterial – Interstate | 13 | 2.7 | 658 | 7.3 |
| | Rural Principal Arterial – Other | 50 | 10.3 | 827 | 9.1 |
| | Rural Minor Arterial | 82 | 16.9 | 1,136 | 12.5 |
| | Rural Major Collector | 144 | 29.7 | 2,454 | 27.1 |
| | Rural Minor Collector | 10 | 2.1 | 186 | 2.1 |
| | Rural Local | 75 | 15.5 | 1,418 | 15.7 |
| | Urban Principal Arterial – Interstate | 3 | 0.6 | 49 | 0.5 |
| | Urban Principal Arterial – Other | 14 | 2.9 | 485 | 5.4 |
| | Urban Minor Arterial | 22 | 4.5 | 347 | 3.8 |
| | Urban Major Collector | 53 | 10.9 | 814 | 9.0 |
| | Urban Minor Collector | 0 | 0.0 | 1 | 0.0 |
| | Urban Local | 13 | 2.7 | 593 | 6.6 |
| | NA | 6 | 1.2 | 22 | 1.9 |
| Total Unbelted | 0 | 283 | 58.4 | 8,522 | 94.1 |
| | 1 or more | 202 | 41.7 | 534 | 5.9 |

## METHODOLOGY

### Comprehensive Safety Management

The roadway safety management process involves identifying locations for potential safety improvement and then executing a data-driven approach to selecting appropriate solutions to cost-effectively improve safety performance by reducing crash frequency and/or crash severity. There are three primary approaches to address severe RwD crashes, including the following:

1. Site-specific: This approach, also known as a hot-spot approach, focuses on identifying locations with concentrations of crashes where the site is over-represented with a particular crash outcome. Treatments are tailored to the location to provide improvements for that specific location.
2. Systematic: This approach, also known as a policy-based approach, focuses on installing low-cost countermeasures for all sites qualifying based on meeting certain criteria. Treatment deployment is widespread but may not focus on those locations at highest risk for future crashes.
3. Systemic: This approach, also known as a risk-based approach, focuses on installing low-cost countermeasures at locations prioritized based on risk for future crashes. Treatment deployment does not solely focus on a location's crash history; therefore, countermeasure prioritization will include locations that may not have a history of crashes but are at high risk for a crash to occur in the future.

When used together, these approaches form a comprehensive approach for roadway safety management. As highlighted in the Problem section, SCDOT has primarily focused on the site-specific approach to addressing severe RwD crashes but has used the systemic safety approach focusing on statewide RwD safety. This section provides an overview of the systemic approach used to inform this Plan.

### Systemic Analysis

According to 23 USC 148(a)(12), the term "systemic safety improvement" means an improvement that is widely implemented based on high-risk roadway features that are correlated with particular crash types, rather than crash frequency. A fundamental challenge on rural roads is that RwD departure crash locations are random and tend to change from year to year. It is not typically cost-effective to apply countermeasures only where crashes have already happened when they are unlikely to happen at the same location in the future. The systemic approach manages risk by taking a broader view and evaluating risk across the system.

The systemic approach typically involves the following tasks:

1. Selecting focus crash types.
2. Selecting focus facilities.

3. Identifying and evaluating risk factors.
4. Conducting risk assessment and prioritizing focus facility locations.
5. Identifying, screening, and selecting countermeasures for deployment.
6. Creating a decision process for countermeasure selection.
7. Developing safety projects and prioritizing projects for implementation.

This Plan focuses on the first six steps of the systemic approach giving USCOG and SCDOT the tools needed to develop safety projects and prioritize those projects for implementation. The following section provides an overview of the data collection and analysis supporting the first three steps of the systemic safety approach. This Plan separates the remaining tasks in the following sections:

- Data Analysis and Evaluation section: risk assessment and prioritization (Step 4).
- Countermeasures section: countermeasure identification and selection (Step 5).
- Action Plan section: decision process for implementation (Step 6).

As part of a comprehensive safety management approach, the Addressing Site-Specific RwD Crash History section of this plan provides details on locations with observed RwD crashes during the last five years.

## DATA ANALYSIS AND EVALUATION

This Plan focuses on using a systemic approach to identify potential sites for RwD safety projects. The following sections describe the data, methodology, and results of the systemic analysis.

### Data

SCDOT provided the RwD FAS team with crash, roadway, and traffic volume data in a spatial format to support the systemic safety analysis approach. The RwD FAS team engaged the University of Wisconsin's Traffic Operation and Safety (TOPS) laboratory to use the CurveFinder tool to identify horizontal curve data in the USCOG region. The TOPS lab used the LRS data to identify and classify curves as well as to evaluate the horizontal curve radius. Further, the US Geological Survey's National Map provided data supporting identification of approximate vertical gradients. The following is an overview of the data elements obtained and their definitions.

#### *Crash Data*

SCDOT provided 2017 through 2021 crash data to support risk factor and site-specific RwD crash history identification. The definitions of RwD crashes and fatal and serious injury crashes, along with summary data, were provided in the Definition of RwD Crashes section.

### *Roadway Characteristics*

The RwD FAS team used the roadway inventory data for the USCOG to support identifying focus crash and facility types and to identify risk factors for RwD crashes. The roadway inventory data was provided by SCDOT, and it contains State and local roads. The completeness of certain variables is detailed in Table 6. Average Annual Daily Traffic (AADT) is the average of five years (2017-2021).

**Table 6. Road Inventory Characteristic Completeness**

| Attribute | Feature Complete (%) | Mileage Complete (%) |
|---|---|---|
| Average Annual Daily Traffic | 99.8 | 99.8 |
| Number of lanes | 39.2 | 63.0 |
| Median type | 39.2 | 63.0 |
| Functional class | 100 | 100 |
| Area type | 15.3 | 12.6 |
| Speed limit | 7.7 | 18.4 |
| Left outside sidewalk | 100 | 100 |
| Right outside sidewalk | 100 | 100 |

### *Horizontal Curve Data*

The University of Wisconsin used the CurveFinder, to extract horizontal curve location and geometric information including curve type, direction, length, degree of curvature and radius automatically from geographic information system (GIS) roadway maps. Approximately 47 percent of the centerline data had curves, accounting for 30 percent of the total mileage. The remaining mileage is tangent. Additionally, Table 7 provides distributions of mileage by horizontal curve type and radius of curvature categories for all roads.

**Table 7. Distribution of Mileage by Curve Type and Radius Categories**

| Curve Type | Radius ≤300 ft (%) | Radius 301-600 ft (%) | Radius 601-1,000 ft (%) | Radius > 1,000 ft (%) | Average Radius (ft) |
|---|---|---|---|---|---|
| Compound curve | 12.34 | 2.59 | 0.95 | 0.46 | 239.1 |
| Horizontal angle point | 3.81 | 0.00 | 0.00 | 0.00 | 0 |
| Independent horizontal curve | 10.26 | 5.27 | 2.20 | 1.23 | 373.9 |
| Reverse curve | 50.34 | 7.62 | 2.08 | 0.84 | 191.9 |

### *Vertical Curve/Grade Data*

The RwD FAS team downloaded USCOG's elevation data from the US Geological Survey's National Map using the10-meter (1/3 arc~second Digital Elevation Model (DEM)) horizontal resolution, which is one of the highest resolution seamless DEM datasets with full coverage. Although higher resolution elevation data can provide more accurate and reliable results, 10-meter DEMs have been shown to be satisfactory for systemic analysis and result in manageable file sizes. The elevation data was used to extract the grade (average slope) data to supplement the roadway inventory.

## Systemic Methodology

This section describes the process used to identify the following components of the systemic safety approach:

1. Focus crash types.
2. Focus facility types.
3. Risk factors for focus crash types.

For each component, this section describes the analysis procedure and summarizes the results. When applicable, the appendices include additional details on the analysis and results.

### *Focus Crash Types*

The RwD FAS team used 2017 through 2021 RwD crash data provided by the SCDOT to identify focus crash types. While this plan focuses on RwD crashes in general, the purpose of this analysis was to identify specific RwD crash subtypes that can be directly tied to countermeasures for correction.

The analysis included using FHWA's *Crash Data Summary Template* to identify potential over-representation in crash characteristics associated with more severe RwD crashes (i.e., contributing factors that tend to result in a K or A-level (combined as KA) crash compared to lower severity crashes) based on the following two criteria:

- The percentage of KA RwD crashes with a certain characteristic is more than double of the percentage associated with BCO RwD crashes.
- The percentage of KA RwD crashes with a certain characteristic is more than five percent higher than the percentage associated with BCO RwD crashes.

Table 5 summarizes KA RwD crashes versus BC RwD crashes by contributing factors. Those crash types meeting the two criteria were selected as ***Focus Crash Types***. Note that while head-on crashes did not meet the two criteria, it was selected as focus crash types due to the percentage of crashes compared to the proportion of traffic occurring during those conditions.

Initially, the RwD FAS team identified six focus crash types for USCOG based on the over-representation analysis. However, separate curve data are included in this effort which resulted in an additional four focus crash types. The RwD FAS team further added a category including all RwD crashes that occurred on curves to support analysis of a larger sample size on curves specifically. Finally, the RwD FAS team developed eight focus crash types that formed the basis for focus facility type development in the crash tree analysis. Additionally, B crashes were added to KA crashes to help bolster the sample size for analysis. The following focus crash types formed the basis for focus facility type development:

- Head-on RwD KABC crashes.
- Tree RwD KAB crashes.
- Tree RwD KAB crashes (on curve).
- Nighttime RwD KAB crashes.
- Nighttime RwD KAB crashes (on curve).
- Wet surface RwD KAB crashes.
- Speeding-related RwD KAB crashes.
- Speeding-related RwD KAB crashes (on curve).
- DUI involved RwD KAB
- RwD KA crashes (on curve).

### *Focus Facility Types*

The next step of systemic analysis identifies priority facility types. The RwD FAS team used FHWA's *Crash Tree Diagram Tool* to identify common roadway and traffic characteristics associated with focus crash types. This frequency-based analysis determines the characteristics most associated with a focus crash type, regardless of any exposure metric. This analysis produced ***Focus Facility Types*** for network-wide risk factor analysis.

The RwD FAS team identified fourteen focus crash and facility type combinations for USCOG using crash tree analysis. For any focus crash type, the crashes were categorized in the following order of priority:

1. Area type: Rural versus urban.
2. Number of lanes.
3. Functional class.

Figure 5 provides an example crash tree for the nighttime KAB RwD crashes focus crash type. This crash tree shows there were 681 nighttime RwD KAB-level injury crashes in the USCOG from 2017 through 2021. The tree then breaks the crashes by area type, number of travel lanes, and roadway functional classification. In this example, more than 75 percent of crashes were on rural roadways. Of those, nearly 85 percent were on two-lane roadways. Review of the crash tree indicates that nighttime KAB RwD crashes primarily occur on rural two-lane local and minor arterial/major collector roadways. In addition to the number of focus crashes, the RwD FAS team selected focus facility types based on a comparison of crash frequency to VMT for the facility

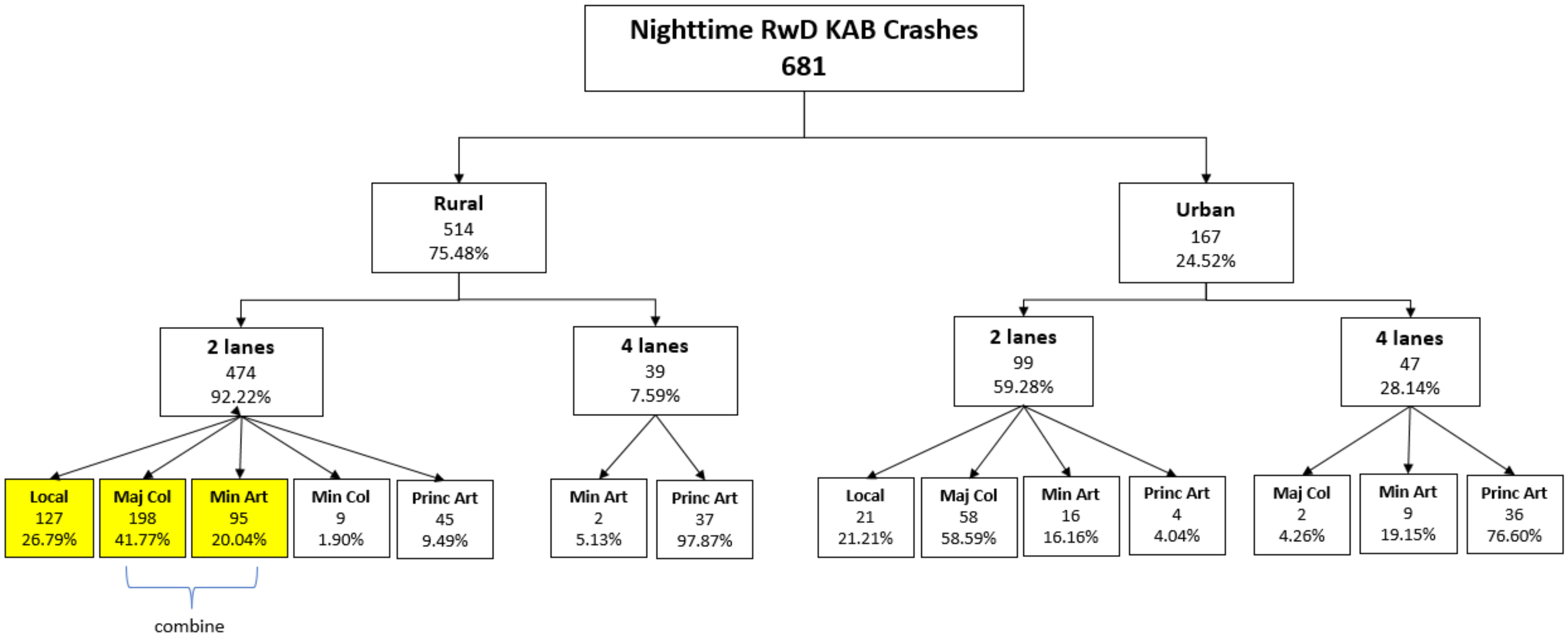


**Figure 5. Nighttime KAB RwD Crash Tree**

type. The RwD FAS team combined minor arterials and major collectors due to similarities in facility types, similarity in outcomes, and to improve the sample size for risk factor analysis. Appendix A includes all crash trees for focus crash types.

Finally, the focus facility types were selected based on the frequency of KAB RwD crashes in the sample and comparison to mileage for the facility type. Table 8 presents the fourteen facility types selected as focus facility types for USCOG. Note that KABC crashes were considered for head-on crashes due to a small sample size for crashes.

**Table 8. Focus Facility Types for USCOG**

| Focus Crash Type | Focus Facility Type |
|---|---|
| Head-on RwD KABC crashes | • Rural two-lane major collector/minor arterial |
| Tree RwD KAB crashes | • Rural two-lane local roads and<br>• Rural two-lane major collector/minor arterial |
| Tree RwD KAB crashes (on curve) | • Rural two-lane major collector/minor arterial |
| Nighttime RwD KAB crashes | • Rural two-lane local roads and<br>• Rural two-lane major collector/minor arterial |
| Nighttime RwD KAB crashes (on curve) | • Rural two-lane major collector/minor arterial |
| Wet surface RwD KAB crashes | • Rural two-lane major collector/minor arterial |
| RwD KAB crashes (on curve) | • Rural two-lane local roads and<br>• Rural two-lane major collector/minor arterial |
| Speeding-related RwD KAB crashes | • Rural two-lane local roads and<br>• Rural two-lane major collector/minor arterial |
| Speeding-related RwD KAB crashes (on curve) | • Rural two-lane major collector/minor arterial |
| DUI-involved RwD KAB crashes | • Rural two-lane major collector/minor arterial |

### *Risk Factors*

Using the focus crash type and focus facility type combinations, the RwD FAS team analyzed crash and roadway data to identify characteristics contributing to severe RwD crashes. By comparing the presence of certain roadway elements in KA RwD focus crash types with the proportion of VMT with the same attributes, the RwD FAS team determined which attributes were associated with a higher probability of severe crashes. These attributes, where the percentage of crashes was higher than the percentage of VMT, were labeled as "Risk Factors".

Figure 6 demonstrates an example risk factor comparison for nighttime KA RwD crashes on local rural two-lane minor arterials and major collectors. Approximately 29 percent of nighttime KA RwD crashes occurred on roads with an average slope greater than 3 percent, compared to roughly 22 percent of VMT. As a result, grades higher than three percent are selected as a risk factor for nighttime KA RwD crashes on rural two-lane minor arterials and major collectors. As noted below, the RwD FAS team used the level of over-representation to assign a weight for each risk factor for prioritization. Appendix B provides all risk factor plots for each focus crash and facility type combination and individual risk factors.

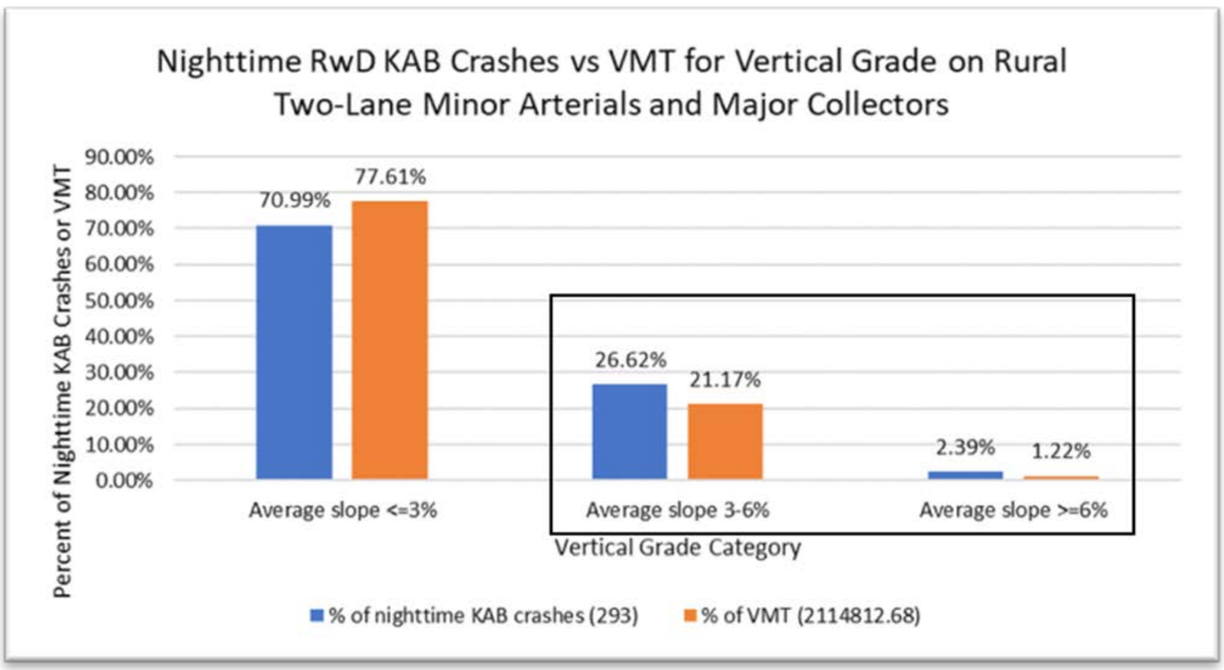


**Figure 6. Vertical Grade Risk Factor Analysis for Nighttime KA RwD Crashes on Rural Two-Lane Minor Arterials and Major Collectors**

Table 9, Table 10, and Table 11 summarize the risk factors for rural two-lane minor arterials and major collectors, horizontal curves only on rural two-lane minor arterials and major collectors, and rural two-lane local roads, respectively. The summarized risk factors are the results of the risk factor plots provided in Appendix B. Each table also provides risk points for each of the risk factors based on the level of over-representation found in the analysis. For example, for tree crashes on rural two-lane minor arterials and major collectors, horizontal curves with a radius of 600ft or less are assigned 2 risk points, and curves with a radius of 600 ft to 1,000 ft are assigned 1 risk point. These risk points are combined to calculate a final risk score for each roadway segment on the focus facilities. Since the number of total potential risk factors differs by focus crash and facility type, the risk score for each segment can be normalized by dividing the risk score by the total potential risk factors for the respective facility type. In this way, segments can be prioritized across all facility types. Additionally, the RwD FAS team developed a combined risk score considering all focus crash types on a focus facility combined.

**Table 9. Risk Factors for Rural Two-Lane Minor Arterials and Major Collectors**

| Focus Crash Type | Population | Posted Speed | Grade | Curve Radius | AADT | Route Type |
|---|---|---|---|---|---|---|
| Head-on | > 1,000 [1] | 35 – 45 mph [1] | ≤ 3 percent [1] | ≤ 600 ft [1] | > 4,000 [1] | -- |
| Tree | N/A | N/A | > 3 percent [1] | ≤ 600 ft [2]<br>601 – 1,000 ft [1] | ≤ 1,000 [2]<br>1,001 – 2,000 [1] | Secondary [2] |
| Nighttime | N/A | N/A | > 3 percent [1] | ≤ 600 ft [2]<br>601 – 1,000 ft [1] | ≤ 500 [1]<br>501 – 2,000 [2] | Secondary [2] |
| Wet Surface | N/A | N/A | N/A | ≤ 300 ft [2]<br>All other curves [1] | ≤ 2,000 [2] | Secondary [2] |
| Speeding | *Abbeville or Laurens [1] | N/A | > 3 percent [1] | ≤ 600 ft [1] | ≤ 1,000 [2]<br>1,001 – 2,000 [1] | Secondary [2] |
| DUI | ≤ 1,000 [1]<br>*Abbeville, Greenwood, Laurens [1] | N/A | N/A | ≤ 600 ft [2] | ≤ 500 [1]<br>501 – 2,000 [2] | Secondary [2] |

Note: Risk points included in brackets, *indicates counties associated with increased risk in crash type. N/A indicates not applicable.

**Table 10. Risk Factors for Rural Two-Lane Minor Arterial and Major Collector Curves**

| Focus Crash Type | Grade | Curve Radius | AADT | Route Type | County |
|---|---|---|---|---|---|
| All RwD | > 3 percent [1] | ≤ 300 ft [2]<br>301 – 600 ft [1] | ≤ 1,000 [2]<br>1,001 – 2,000 [1] | Secondary [2] | N/A |
| Tree | > 3 percent [1] | ≤ 300 ft [2]<br>301 – 1,000 ft [1] | ≤ 1,000 [2]<br>1,001 – 2,000 [1] | Secondary [2] | N/A |
| Nighttime | > 3 percent [1] | ≤ 600 ft [2] | ≤ 500 [1]<br>501 – 2,000 [2] | Secondary [2] | N/A |
| Speeding | > 3 percent [1] | ≤ 300 ft [2]<br>301 – 600 ft [1] | ≤ 1,000 [2]<br>1,001 – 2,000 [1] | Secondary [2] | Abbeville, Edgefield, McCormick [1] |

Note: Risk points included in brackets. N/A indicates not applicable.

**Table 11. Risk Factors for Rural Two-Lane Local Roads**

| Focus Crash Type | Population | County | Grade | Curve Radius | AADT | Route Type |
|---|---|---|---|---|---|---|
| All RwD (curves) | ≤ 1,000 [1] | N/A | ≤ 3 percent [2] | 300 ft – 600 ft [1] | 501 – 1,000 [1] | Secondary [2] |
| Tree | N/A | N/A | ≤ 3 percent [1] | ≤ 600 ft [2] | 501 – 1,000 [1] | Secondary [2] |
| Nighttime | N/A | N/A | 3 – 6 percent [1] | ≤ 1,000 ft [1] | 501 – 1,000 [1] | Secondary [2] |
| Speeding | 2,500 – 4,999 [1] | Abbeville, Greenwood, or Laurens [1] | ≤ 3 percent [1] | ≤ 300 ft [1] | 501 – 1,000 [1] | Secondary [2] |

Note: Risk points included in brackets. N/A indicates not applicable.

Appendix C provides separate tables for each focus crash and facility type combination, including summaries of the risk factors and corresponding risk points. Each table includes total focus crash sample size, total VMT, and roadway mileage for each focus crash and facility type combination. Additionally, each table summarizes the proportion of focus crashes on segments with each risk factor, the corresponding VMT, and the proportion of the focus facility type mileage containing the risk factor for that focus crash and facility type. These tables provide an indication of the degree of over-representation for each risk factor.

### PRIORITY SEGMENTS

Table 12 provides a summary of the focus crash and facility types, facility type-specific mileage, maximum potential risk score, and mileage of facility having the maximum risk score. The total roadway network in the USCOG comprises 6,543 miles. Within that mileage, each facility type has a different length. For example, rural two-lane major collectors and minor arterials combined comprise 1,530 miles. Of those 1,530 miles, approximately 383 miles are horizontal curves. The purpose of Table 12 is to provide an indication of the number of miles with higher risk and what proportion of the focus facility network is prioritized based on higher risk. This shows that the mileage of higher risk segments or curves for any focus crash types represents a manageable portion of the overall roadway network in the USCOG. Higher risk segments or curves are those with the highest risk score or within 2 points of the highest risk score for each focus crash and facility type combination. The results indicate that segments or curves with all risk factors account for no more than three percent of the total mileage in the USCOG. Note that since focus facility types are not exclusive, in many cases the highest risk sites overlap among focus crash types.

Each focus crash type has a different number of risk factors and different weight assigned for risk factors. Therefore, the total risk score for each focus facility type and crash type combination differs. For example, a rural two-lane major collector or minor arterial segment may score up to five for a risk score for head-on crashes while a similar segment may score up to eight for speeding-related or DUI crashes. Using the proportion of risk factors present can be used as a tie breaker when prioritizing locations for potential improvements.

**Table 12. Mileage with Maximum Risk Scores on Focus Crash and Facility Combinations**

| Crash Type/Facility Type | USCOG Mileage | Facility Type Mileage | Highest Risk Score | Higher Risk Mileage | |
|---|---|---|---|---|---|
| | | | | Mileage | %* |
| Head-on RwD KABC crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 5 | 66.61 | 1.02 |
| Tree RwD KAB crashes on rural 2-lane local roads | 6,543.47 | 3,762.73 | 6 | 456.12 | 6.97 |
| Tree RwD KAB crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 7 | 335.00 | 21.89 |
| Tree RwD KAB crashes on rural 2-lane major collector and minor arterial curves | 6,543.47 | 383.47 | 7 | 156.65 | 40.85 |
| Nighttime RwD KAB crashes on rural 2-lane local roads | 6,543.47 | 3,762.73 | 5 | 895.96 | 23.81 |

**Table 12. Mileage with Maximum Risk Scores on Focus Crash and Facility Combinations**

| Crash Type/Facility Type | USCOG Mileage | Facility Type Mileage | Highest Risk Score | Higher Risk Mileage | |
|---|---|---|---|---|---|
| | | | | Mileage | %* |
| Nighttime RwD KAB crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 7 | 242.88 | 15.87 |
| Nighttime RwD KAB crashes on rural 2-lane major collector and minor arterial curves | 6,543.47 | 383.47 | 7 | 164.09 | 42.79 |
| Wet surface RwD KAB crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 6 | 771.20 | 50.40 |
| RwD KAB crashes on rural 2-lane local road curves | 6,543.47 | 526.82 | 5 | 311.30 | 23.67 |
| RwD KAB crashes on rural 2-lane major collector and minor arterial curves | 6,543.47 | 383.47 | 7 | 156.65 | 40.85 |
| Speeding-related RwD KAB crashes on rural 2-lane local roads | 6,543.47 | 1,673.64 | 6 | 705.41 | 18.75 |
| Speeding-related RwD KAB crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 7 | 443.91 | 29.01 |
| Speeding-related RwD KAB crashes on rural 2-lane major collector and minor arterial curves | 6,543.47 | 383.47 | 8 | 115.91 | 30.23 |
| DUI Involved RwD KAB crashes on rural 2-lane major collectors and minor arterials | 6,543.47 | 1,530.07 | 8 | 281.28 | 18.38 |

Based on the results of the risk factor analysis, the RwD FAS team developed a GIS-based risk map, indicating the priority segments and curves for each focus crash and facility type combination. Figure 7 identifies the six USCOG counties.

Furthermore, to support implementation, this Plan includes additional region-level maps for composite risk scores (combining risks of all focus crash types) for each focus facility type. Due to the number of attributes included in the risk factor analysis, little differentiation was found among risk factors between focus crash types on focus facilities. There is substantial overlap among high-risk locations for varying crash types. Site-specific

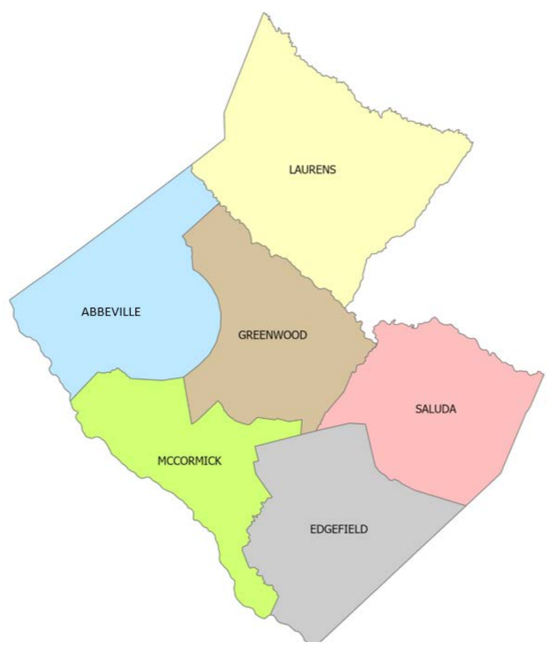


**Figure 7: USCOG Counties**

diagnosis is required to best tailor countermeasures for focus crash types. Therefore, the combined risk score map provides the best indication of prioritization for all focus crash types.

Figure 8 shows the combined risk score map on rural two-lane local roads in Abbeville County. The following designations are used by risk tier (note that the higher risk tiers account for the top 25 percent of high-risk locations based on combined risk score):

- Highest risk tier: Black:
- Second risk tier: Red.
- Third risk tier: Orange
- Fourth risk tier: Yellow.
- Lowest risk tier: No color.

Additionally, each map highlights the historically disadvantaged areas in each county according to the Office of Management and Budget. The GIS layers for all focus crash and facility type combinations as well as the combined metric are provided in a separate geodatabase to support USCOG in identifying and reviewing priority locations.

### ADDRESSING SITE-SPECIFIC RWD CRASH HISTORY

While the focus of this effort is on a systemic approach to RwD safety, this section includes a brief overview of those locations observing serious injury RwD crashes between 2017 and 2021 for further examination by USCOG and SCDOT. Fewer than five percent of roadway segments observed fatal and serious injury RwD crashes during this period. Due to the random nature of these crashes in the USCOG, very few segments observed more than one fatal or serious injury RwD crash. These locations can be further explored to help identify and prioritize site-specific locations for additional investigation and potential countermeasure installation. Additionally, these locations can serve as a tie breaker for segments and curves prioritized from the systemic analysis approach.

Figure 9 provides an example map of segments with KAB RwD crashes in Abbeville County. The map displays sites with one or more KAB RwD crashes. Blue sites identify crash segments on rural two-lane local roads, pink sites identify crash segments on minor arterials and major collections, and purple sites identify crash segments for other facility types. This map also highlights the historically disadvantaged areas to support potential project identification.

The separate GIS files providing the risk-based priority segment layers include additional layers for each facility type identifying segments with one or more KAB RwD crashes between 2017 and 2021.

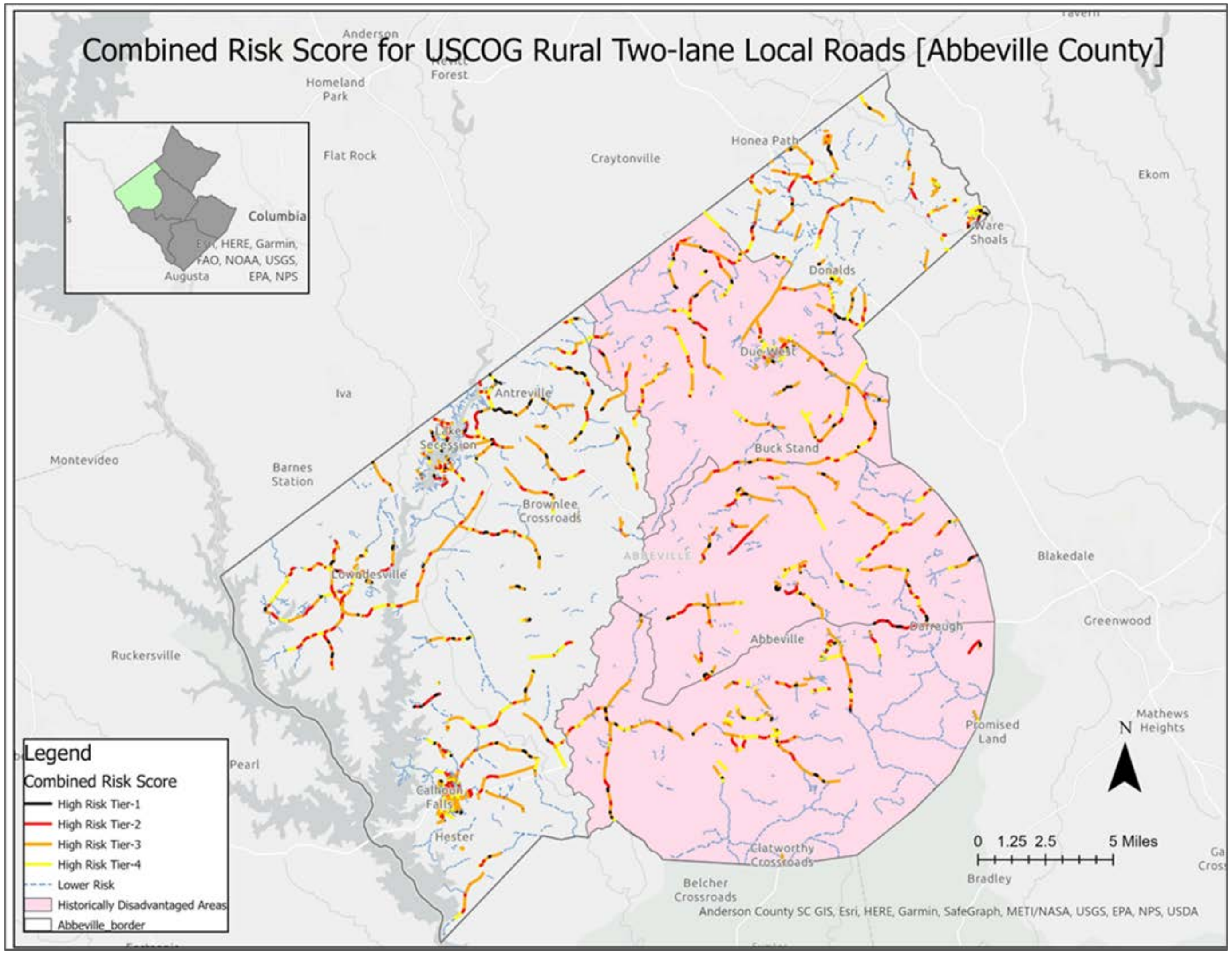


**Figure 8. Risk Score Map for Rural Two-lane Local Roads in Abbeville County**

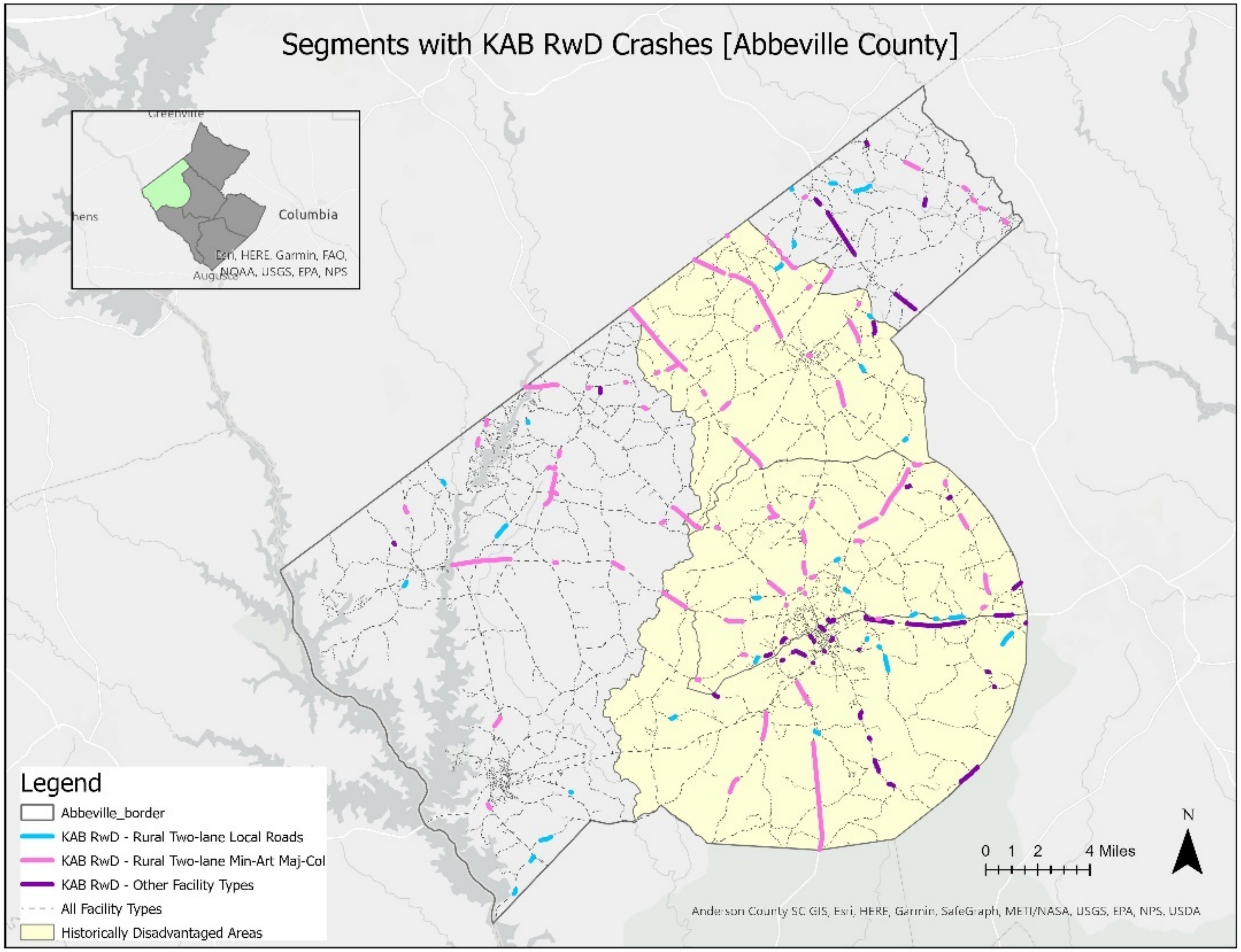


**Figure 9. Abbeville County Segments with KA RwD Crashes**

### SUMMARY OF RWD COUNTERMEASURE DEPLOYMENTS

Within the USCOG, SCDOT and local partners can deploy a wide variety of potential techniques targeted at mitigating the number of RwD crashes or, when the crash cannot be avoided, limiting the level of crash severity. This section includes details on the potential cost and effectiveness of implementing this Plan. The deployment numbers provided are based on assumptions on the percentage of mileage, or number of curves, that USCOG will install countermeasures. However, USCOG's actual deployment will be based on the following process:

1. Identifying priority locations based on risk-level provided as a separate GIS layer.
2. Conducting onsite investigations, field visits, and road safety audits (RSAs) to identify if locations can benefit from countermeasures included in this Plan.
3. Use the site-specific features, inventory of existing countermeasures, and contributing factors from site-specific crash history to identify an appropriate countermeasure or countermeasures.
4. Program and deploy recommended countermeasures based on the results of RSAs.

While the details provided in this Plan are based on assumptions on countermeasure installations, the final deployment of low-cost countermeasures will likely differ from the assumptions made due to site-specific conditions and concerns. The estimates provided in this plan serve as a guide for USCOG on the potential cost and effectiveness of implementing recommended countermeasures at priority locations based on the systemic analysis.

Table 13 provides an overview of the expected countermeasure installations, potential costs, and expected benefits for rural two-lane minor arterial and major collectors and Table 14 provides an overview for rural two-lane local roads. The methodology used to estimate potential deployment, total costs, and expected benefits follows the data analysis for focus crash and facility types. This Plan assumes that basic countermeasures will be applied at lower-risk locations and that higher-risk locations will be prioritized for enhanced countermeasure deployment. The RwD FAS team identified the following attributes for each countermeasure recommended in the Plan:

- Countermeasure. This column identifies the countermeasure proposed for implementation.
- Mileage or Curves. If the countermeasure is deployed in a linear manner, mileage is used. If the countermeasure is specific to horizontal curves, then the number of curves meeting the risk tier for the focus crash type is used. The mileage, or number of curves, is tied to the risk tier identified below.
- Total crashes. This provides the total number of crashes occurring over the 2017 through 2021 period for locations within the risk tiers being addressed.

**Table 13. Estimated Safety Effects and Costs for Proposed Countermeasures**

| Countermeasure | Mileage or Curves | Total Crashes | Estimated Improvements | CMF | Unit Cost | Construction Cost | KABC Crashes Proportion | Annual Crash Reduction | Annual KABC Crash Reduction |
|---|---|---|---|---|---|---|---|---|---|
| Curve Signing | 1,041 | 345 | 521 | 0.70 | $2,000 | $1,041,000 | 29.60 | 10.35 | 3.06 |
| Enhanced Curve Signing | 815 | 448 | 204 | 0.73 | $5,000 | $1,018,750 | 29.60 | 3.82 | 1.13 |
| Center and Edge Line Markings | 1,310 | 5,355 | 131 | 0.76 | $8,000 | $1,048,000 | 37.42 | 25.70 | 9.62 |
| 6” Edge Line Markings | 220 | 714 | 110 | 0.63 | $5,000 | $550,700 | 37.42 | 26.42 | 9.89 |
| HFST | 195 | 61 | 20 | 0.43 | $50,000 | $1,000,000 | 29.60 | 0.70 | 0.21 |
| Centerline Rumble Strips | 220 | 714 | 55 | 0.91 | $5,000 | $275,350 | 37.42 | 10.28 | 3.85 |
| Edge/Shoulder Rumble Strips | 220 | 714 | 22 | 0.83 | $5,000 | $110,140 | 37.42 | 2.43 | 0.91 |
| Curve Lighting | 195 | 61 | 10 | 0.79 | $20,000 | $200,000 | 29.60 | 0.13 | 0.04 |
| Safety Edge | 1,530 | 6,069 | 230 | 0.89 | $2,000 | $459,000 | 37.42 | 20.03 | 7.49 |
| Clear Zone Widening | 43 | 197 | 2 | 0.66 | $50,000 | $108,700 | 37.42 | 0.67 | 0.25 |
| Slope Flattening | 43 | 197 | 2 | 0.85 | $300,000 | $652,200 | 37.42 | 0.30 | 0.11 |
| Shoulder Widening | 43 | 197 | 2 | 0.87 | $250,000 | $543,500 | 37.42 | 0.26 | 0.10 |
| Guardrail Improvements | 220 | 714 | 2 | 0.52 | $150,000 | $330,420 | 37.42 | 0.69 | 0.26 |
| **Total** | | | | | | **$7,337,760** | | **101.76** | **36.91** |

Note: CMF = Crash Modification Factor

**Table 14. Estimated Safety Effects and Costs for Proposed Countermeasures**

| Countermeasure | Mileage or Curves | Total Crashes | Estimated Improvements | CMF | Unit Cost | Construction Cost | KABC Crashes Proportion | Annual Crash Reduction | Annual KABC Crash Reduction |
|---|---|---|---|---|---|---|---|---|---|
| Curve Signing | 6,163 | 448 | 1,233 | 0.70 | $2,000 | $2,466,000 | 37.45 | 5.38 | 2.01 |
| Enhanced Curve Signing | 5,808 | 437 | 581 | 0.73 | $5,000 | $2,904,000 | 37.45 | 2.36 | 0.88 |
| Center and Edge Line Markings | 2,261 | 835 | 565 | 0.76 | $8,000 | $4,522,000 | 34.04 | 10.02 | 3.41 |
| 6” Edge Line Markings | 910 | 1,020 | 227 | 0.63 | $5,000 | $1,137,475 | 34.04 | 18.87 | 6.42 |
| HFST | 1,202 | 136 | 61 | 0.43 | $50,000 | $3,050,000 | 37.45 | 0.78 | 0.29 |
| Centerline Rumble Strips | 910 | 1,020 | 227 | 0.91 | $5,000 | $1,137,475 | 34.04 | 9.18 | 3.12 |
| Edge/Shoulder Rumble Strips | 910 | 1,2020 | 91 | 0.83 | $5,000 | $454,990 | 34.04 | 3.47 | 1.18 |
| Curve Lighting | 1,202 | 136 | 61 | 0.79 | $20,000 | $1,220,000 | 37.45 | 0.29 | 0.11 |
| Safety Edge | 3,763 | 2,230 | 564 | 0.89 | $2,000 | $1,128,819 | 34.04 | 7.36 | 2.51 |
| Clear Zone Widening | 77 | 136 | 4 | 0.66 | $50,000 | $193,400 | 34.04 | 0.46 | 0.16 |
| Slope Flattening | 77 | 136 | 4 | 0.85 | $300,000 | $1,160,400 | 34.04 | 0.20 | 0.07 |
| Shoulder Widening | 77 | 136 | 4 | 0.87 | $250,000 | $967,000 | 34.04 | 0.18 | 0.06 |
| Guardrail Improvements | 910 | 1,020 | 9 | 0.52 | $150,000 | $1,364,970 | 34.04 | 0.98 | 0.33 |
| **Total** | | | | | | **$21,706,529** | | **59.52** | **20.56** |

Note: CMF = Crash Modification Factor

- Number of estimated improvements. This includes multiplying the total mileage or number of curves by an assumed proportion of sites that can be improved. For example, it is assumed that 20 percent of high-risk locations will have MUTCD-compliant basic curve signing recommended for installation on rural two-lane minor arterials and major collectors.
- Crash Modification Factor (CMF). This column provides an estimate of the expected safety benefit for the countermeasure.
- Unit cost. The approximate average cost of the countermeasure per mile or per curve.
- Construction cost. The combined total cost for all countermeasures combined.
- KABC crashes proportion. This provides the proportion of total crashes that are fatal and injury for each facility type for curves and for all segments.
- Annual crash reduction. The number of total crashes expected to be reduced through systemic installation of the countermeasure on an annual basis.
- Annual fatal and injury reduction. The number of fatal and injury crashes expected to be reduced through systemic installation of the countermeasure on an annual basis.

The RwD FAS team worked with the USCOG and SCDOT to identify assumptions on the proportion of locations for which it may be assumed countermeasures could be installed based on risk tier. Additionally, the RwD FAS team identified an approximate percentage of locations receiving the treatment of interest, assuming some locations will not have a countermeasure recommended and to avoid overlapping of countermeasures recommended at the same locations. Additionally, the following assumptions were made:

- Curve signing. The RwD FAS team assumed MUTCD-compliant curve signing would be applied on Tier 1 through Tier 4 risk horizontal curves. The team assumed 50 percent of rural two-lane minor arterial and major collector curves and 20 percent of rural two-lane local road curves would receive curve signing improvements.
- Enhanced curve signing. The RwD FAS team assumed enhanced curve signing would be applied on Tier 1 through Tier 3 risk horizontal curves. The team assumed 25 percent of rural two-lane minor arterial and major collector curves and 10 percent of rural two-lane local road curves would receive enhanced curve signing.
- Centerline and edge line markings. The RwD FAS team assumed centerline and edge line markings would be applied on Tier 4 segments. The team assumed 10 percent of rural two-lane minor arterial and major collector mileage and 25 percent of rural two-lane local road mileage would receive markings.

- Six-inch edge line markings. The RwD FAS team assumed wider edge line markings would be applied on Tier 1 through 3 segments. The team assumed 50 percent of rural two-lane minor arterial and major collector mileage and 25 percent of rural two-lane local road mileage would receive wider edge lines.
- High friction surface treatments (HFST). The RwD FAS team assumed HFST would be applied on Tier 1 curves. The team assumed 10 percent of rural two-lane minor arterial and major collector curves and 5 percent of rural two-lane local road curves would receive HFST.
- Centerline rumble strips. The RwD FAS team assumed centerline rumble strips would be applied on Tier 1 through 3 segments and 25 percent of segments on each focus facility type would receive centerline rumble strips.
- Shoulder/Edge line rumble strips. The RwD FAS team assumed shoulder/edge line rumble strips would be applied on Tier 1 through 3 segments and 10 percent of segments on each focus facility type would receive shoulder/edge line rumble strips.
- Curve lighting. The RwD FAS team assumed curve lighting would be applied on Tier 1 curves and 5 percent of curves on each facility type would receive curve lighting.
- Safety Edge. The RwD FAS team assumed Safety Edge would be applied on all segments and 15 percent of segments on each facility type would receive Safety Edge.
- Clear zone widening. The RwD FAS team assumed clear zone widening would be applied on Tier 1 segments and 5 percent of segments on each facility type would receive clear zone widening.
- Slope flattening. The RwD FAS team assumed slope flattening would occur on Tier 1 segments and 5 percent of segments on each facility type would receive slope flattening.
- Shoulder widening. The RwD FAS team assumed shoulder widening would occur on Tier 1 segments and 5 percent of segments on each facility type would receive shoulder widening.
- Guardrail improvements. The RwD FAS team assumed guardrail improvements would be applied on Tier 1 through Tier 3 segments and 1 percent of segments on each facility type would receive guardrail improvements.

The summary results indicate that implementation of this Plan will cost approximately $29 million dollars, or $5.8 million per year over a 5-year period and will result in a reduction of 161 annual crashes, 57 of which are fatal or injury.

## ACTION PLAN

Successful implementation of RwD safety enhancements can involve activities that include development of enhanced guidelines for countermeasure selection, field evaluation of candidate locations, and prioritization of projects and associated funding. In addition, an effective safety enhancement program should incorporate identification of performance measures that will ultimately strengthen the effective selection of safety enhancement treatments. The following summary includes a list of key action items.

- The RwD Safety Action Plan should be presented to the USCOG Board and counties as well as to SCDOT leadership, including representatives from the District Offices, Maintenance Division, Road Design Division, Traffic Engineering Division, Materials Control Soils and Testing Division, Planning Division, and Programming Division. Since locally owned roads are included, the Plan should also be presented to Local Technical Assistance Program leadership. The purpose of this activity is to share and review the Plan, obtain input, and identify action items towards a successful implementation of the Plan.
- Plan implementation should be coordinated with local road owners. The focus facility types included local functionally classified roadways, which were a mix of State-owned and locally owned roadways. Providing support and funding to local road owners will accelerate implementation and address severe RwD crashes on all roadways.
- An important aspect of this Plan will be the identification of sustained program funding to help pay for the cost of the safety enhancements while also enabling continued activities such as training, performance assessment, etc. Consequently, a helpful step is to assess funding sources, including HSIP, to determine ways to sustain the Plan in future years.
- Where feasible, SCDOT and local road owners should identify and program safety treatments typically deployed as part of maintenance, design, and operations activities. For this Plan, system-wide treatments that occur as a matter of policy are assumed to have associated programmed annual costs and so these costs are not directly considered.

Specific engineering, education, and enforcement strategies that SCDOT intend to implement to reduce the frequency and severity of RwD crashes are detailed in the subsequent sections. These strategies are designed to provide a comprehensive approach to decrease fatal and serious injury RwD crashes.

## ENGINEERING ACTION PLAN

USCOG, in partnership with SCDOT, identified the following strategies as engineering actions to reduce the frequency and severity of fatal and serious injury RwD crashes. SCDOT is the leading agency for implementing these actions:

### Engineering Action 1 – Use Systemic Analysis Results to Proactively Identify and Prioritize RwD Crash Locations for Further Investigation

#### *Strategy*

The systemic approach used in this Plan identified the facilities with the highest risk for future KAB RwD crashes. USCOG and SCDOT will use the risk factors and accompanying risk maps to prioritize candidate sites for treatment. Additionally, USCOG and SCDOT will use the maps highlighting site-specific RwD crash history to further identify overlap with high-risk segments for prioritizing candidate sites for treatment. Implementation of the systemic analysis will focus on the following facility types:

- Rural Two-Lane Minor Arterials and Major Collectors.
- Rural Two-Lane Local Roads.

This Plan provides separate risk factors, and associated segment and curve prioritization for each focus crash and facility type combination. USCOG and SCDOT should begin with those segments at highest risk for focus crash types and identify potential countermeasures as described in Engineering Action 3 for segments and Engineering Action 4 for horizontal curves. As noted in both Engineering Actions, there will be overlap in focus crash types for many high-risk segments and specific locations should be diagnosed for underlying contributing factors to prioritize countermeasures for implementation.

USCOG and SCDOT can evaluate high priority sites directly based on this Plan. In this approach, SCDOT and local partners can overlay high priority locations with maintenance and operations projects, such as pavement resurfacing, to conduct safety investigations in coordination with other ongoing efforts onsite. In this way, SCDOT and local partners can be efficient in the application of countermeasures while onsite doing other work. Further, USCOG and SCDOT can support local road owners by providing them with details on high-risk locations, supporting RSAs, or develop strategies to support local road owners in diagnosing issues and selecting appropriate countermeasures.

**Engineering Action 2 – Use Site-Specific Crash History Maps to Identify and Prioritize RwD Crash Locations for Further Investigation**

***Strategy***

This Plan includes site-specific RwD crash history maps for each region, focusing on segments with one or more fatal or serious injury RwD crash between 2017 – 2021. Due to the systemic nature of RwD crashes, few sites observed more than one crash during this period. In addition to using this information to support prioritization from the systemic approach, SCDOT and local partners can review these locations to diagnose specific issues that may be contributing to an increased risk of fatal and serious injury RwD crashes that may not have been included in the risk factor analysis from the systemic safety approach. For example, the presence of a narrow clear zone or drainage issue at a certain location may increase the likelihood of a fatal or serious injury RwD crash and was not captured in the dataset. Additionally, the site-specific RwD crash history maps identify segments on all facility types observing fatal and serious injury RwD crashes. These maps provide the opportunity to diagnose and determine the need for projects on facilities beyond the focus facilities, as needed. During the diagnosis stage, there is a need to review crash patterns such as the proportion of run-off-road left versus run-off-road right crashes as well as common crash conditions, such as speeding or wet pavement. This will help SCDOT and local partners to target countermeasures for specific crash contributing factors.

**Engineering Action 3 – Implement a Decision Framework for Deploying Countermeasures at High Priority Locations**

***Strategy***

To implement the systemic safety approach, SCDOT and its local partners will target RwD risks that are distributed throughout the road system rather than concentrated at high-crash locations. SCDOT and its local partners will employ a decision-making strategy to identify an appropriate countermeasure or countermeasure package for priority segments. Table 15 is a matrix of RwD countermeasures which SCDOT and local partners can use to identify which should be considered at a location based on contributing factors of crashes and risk factors present. SCDOT can employ RSAs to identify contributing factors and risk factors supporting countermeasure recommendation. Table 16 is a legend for the shorthand code used in Table 15.

## Table 15. RwD Countermeasure Matrix

| Strategy | Countermeasure | Crash Types | | | | Locations | | Curve Packages | | | Cost | Contributing Factors | Risk Factors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Head-On | Roll Over | Fixed Object | Night-time | Curves | Tangent | Level 1 | Level 2 | Level 3 | H-M-L | | |
| Minimize Severity / Reduce Potential for a Crash / Keep Vehicles on the roadway | Edge line markings (4",6") | ● | ✓ | ✓ | ✓ | ✓ | ✓ | | | P | L | DD, DE, ID, LM, VO | LTV, NSW, SR |
| | Center line markings | ✓ | ● | ● | ✓ | ✓ | ✓ | | | P | L | AD, DD, DE, ID, LM, VO | LTV, LW |
| | Snowplowable RRPMs | | | | ● | ● | ● | | | P | L | AD, DD, DE, ID, LM, VO | LTV, NSW, SR |
| | MUTCD Compliant Curve Warning Signs and Pavement Markings | ✓ | ✓ | ✓ | ✓ | ✓ | | P | | | L | AD, DD, DE, ID, LM, PF, TCD, VO | LTV, NSW, SR, HF |
| | Enhanced Curve Signs | ✓ | ✓ | ✓ | ✓ | ✓ | | | P | P | L-M | AD, DD, DE, ID, LM, PF, TCD, VO | LTV, NSW, SR, HF |
| | Shoulder Rumble Strips | ✓ | ✓ | ✓ | | | ✓ | | | | L | AD, DD, DE, ID | LTV, NSW |
| | Centerline Rumble Strips | | ● | ● | | | ✓ | | | | L | AD, DD, DE, ID | LTV, LW |
| | Friction | | ● | ● | | ● | ● | | | P | M | AD, PF | HF, DR |
| | Flashing Beacons/ Sequential Flashing Chevrons/ Driver Feedback Signs | | ● | ● | ● | ● | | | | P | M | AD, DD, DE, ID, LM, PF, VO | LTV, NSW, SR, HF |
| | Lighting | | | | ● | ● | | | | | M | AD, DD, DE, ID, LM, VO | SR |
| Minimize Severity / Reduce Potential for a Crash | Widen Shoulders | | ✓ | ✓ | | ✓ | | | | P | M-H | AD, DD, DE, ID, LM, PF, VO | NSW, SR, HF |
| | Sloped Pavement Edge | | ● | ● | | | ● | | | P | L | AD, DD, DE, ID | LTV, NSW, SR, ED |
| | Remove Fixed Objects/Widen Clear Zone | | ● | ✓ | | ● | | | | P | L-H | AD, DD, DE, ID | NSW, SR, RS, FO |
| | Flatten Slopes | | ✓ | ● | | ✓ | ✓ | | | P | M-H | AD, DD, DE, ID, PF | NSW, SR, RS |
| Minimize Severity | Barriers | ● | ● | ● | | ● | ● | | | P | M-H | AD, DD, DE, ID, PF | NSW, SR, LW, RS, FO |
| | Breakaway Supports | | | ● | | ● | | | P | | M | AD, DD, DE, ID | NSW, SR, FO |

Note: ✓ Primary countermeasure for this crash type; ● Countermeasure that should be considered; P Included in curve package

**Table 16. Legend for Codes Used in the RwD Countermeasure Matrix**

| Contributing Factors | | Risk Factors | | Costs | |
|---|---|---|---|---|---|
| **Contributing Factor** | **Code** | **General Risk Factor** | **Code** | **Cost** | **Code** |
| Aggressive Driving | AD | Low Traffic Volume | LTV | High | H |
| Distracted Driving | DD | Narrow Shoulder Width | NSW | Medium | M |
| Driver Error or Violation | DE | Sharp Horizontal Curve Radius | SR | Low | L |
| Impaired Driving | ID | High Side Friction Demand | HF | | |
| Lane Marking Improper or Inadequate | LM | Lane Width | LW | | |
| Pavement Friction | PF | Steep Roadside Slopes | RS | | |
| Traffic Control Device Improper or Not Working | TCD | Narrow Offset to Fixed Objects | FO | | |
| View Obstructed or Limited | VO | Edge Drop Off | ED | | |
| | | Poor Drainage | DR | | |

The candidate sites, prioritized based on risk level, are treated as a pool of potential locations for the associated countermeasures. Listing is not an assessment that the countermeasure is “needed” at any one site – engineering judgment is essential in selecting sites and countermeasures to build. Given the planning-level effort of this work, the sites were not reviewed for the appropriateness of the countermeasure or to determine if one or more of the countermeasures are already present. Conditions must be field verified prior to programming any improvements.

Note that benefit-cost ratio is not a focus for systemic application of treatments at individual sites. Due to the random nature of fatal and serious injury RwD crashes, it is possible that high-priority locations have not observed RwD crashes over the recent history. Prioritizing these locations in aggregate will result in benefit-cost ratios greater than 1.0 but may be less than 1.0 at individual locations. Additionally, the impacts of countermeasures on all crashes should be considered when estimating the benefit-cost ratio, not just fatal and serious injury RwD crashes.

For locations prioritized for treatment based on site-specific crash history, the benefit-cost ratio, considering the impact on all crashes, can be used to justify projects.

Due to the limited number of risk factors included in the analysis, the RwD FAS team found few differences in risk factors for varying crash types. Therefore, many high-priority locations for different focus crash types overlap on a given facility. Reviewing the site-specific crash history for contributing factors and additional general risk factors will support implementing countermeasures best suited to address the underlying issues related to target crash types. The best suited countermeasures may differ from location to location.

### Engineering Action 4 – Develop and Deploy Horizontal Curve Safety Improvement Packages

#### *Strategy*

SCDOT and its local partners will develop and implement countermeasure packages on horizontal curves throughout the USCOG region. The primary opportunity for improving safety on rural minor arterials and major collectors as well as rural local roads, is through low-cost safety improvements, such as signage. The analysis conducted for this Plan showed that horizontal curves are highly associated with risk for fatal and serious injury RwD crashes of all types. The results also showed that curves with sharper radii are at higher risk for fatal and serious injury RwD crashes. The RwD FAS team compiled a ranking of horizontal curves based on risk for focus crash types. The RwD FAS team also paired potential countermeasures with treatment packages based on level of risk. When evaluating priority horizontal curves, SCDOT and its local partners should consider the existing treatments on horizontal curves and the need for enhancement. If curves are already compliant with the MUTCD and continue to experience or be at risk for fatal and serious injury RwD crashes, higher cost enhancements should be considered.

Table 17 describes recommendations for horizontal curve packages, including identifying eligible locations and HSIP eligibility. These recommendations are tiered by risk, with more expensive or complex countermeasures included at higher risk levels. The tiers also include a set of standard treatments which should be included for all risk sites which are being addressed. Recommendations presume minimum signage is present as recommended in the MUTCD but include enhanced or supplemental signs under certain conditions.

### Engineering Action 5 – Engage the Public on Identifying High Risk Locations

#### *Strategy*

SCDOT provides the ability for the general public to submit work requests by phone or email. Users can submit requests at https://apps.scdot.org/mwro/ by describing the work needed and selecting a location on the map. SCDOT can further utilize this functionality, through coordination with the USCOG and through public awareness, to identify further high-risk locations based on user experiences. The priority locations included in this plan were based on limited data and may consist of sites that have already been treated. By engaging the public, SCDOT and the USCOG can further identify high-risk locations based on crowd-sourced information. SCDOT can update the Maintenance Work Request website to include a separate category for “identify safety concerns” or create a companion webpage for “High-Risk Safety Concerns” to separate Maintenance Work Requests from High-Risk Safety Concerns.

**Table 17. Countermeasure Curve Packages.**

| Level | Treatment | Eligible Locations | HSIP Eligibility |
|---|---|---|---|
| Level 1 - MUTCD | Required MUTCD horizontal alignment signs and pavement markings as specified in table 2C-5 of Section 2C-07, and Section 3B of the MUTCD. | All curves on all facilities | MUTCD compliant curve warning signs can be funded with HSIP. The initial installation only of pavement markings can be funded with HSIP. |
| Level 2 – Enhanced Signs | Level 1 plus any MUTCD compliant combination of horizontal alignment signs including:<br>• Oversized horizontal alignments signs.<br>• Recommended and optional horizontal alignment signs (see table 2C-5 of Section 2C-07 in the MUTCD).<br>• Reflectorized sleeves on signposts.<br>• Post-mounted or barrier mounted delineators.<br>• Breakaway sign supports (particularly for local roads)<br>• Wider edge lines.<br>• Curve warning pavement markings.<br>• Left and right warning sign placement. | Curves in Risk Tier-1 through Risk Tier-4 | Can be funded with HSIP at curves with at least one risk factor or a RwD crash history with no B/C required. |
| Level 3 - Remaining Countermeasures in RwD toolbox. | • Flashing beacons.<br>• Speed feedback signs.<br>• Sequential flashing chevrons.<br>• Shoulder and/or clear zone improvements,<br>• Fill slopes.<br>• Raised Reflectorized Snowplowable Pavement Markers,<br>• Barriers.<br>• Lighting.<br>• Friction treatments. | Curves in Risk Tier-1 and Risk Tier-2 or a history of RwD crashes. | Can be funded with HSIP at curves with multiple risk factors or a RwD crash history with no B/C required. Other locations require a B/C >= 1.<br><br>Friction treatments require a crash analysis and a B/C >=1 |

**Engineering Action 6 – Conduct Community Engagement to Support Grant Funding for Infrastructure Improvements**

***Strategy***

This current plan focuses on a risk-based approach to RwD safety. As it stands, this RDSIP cannot be used to directly apply for some grants, such as the Safe Streets and Roads for All (SS4A). To support implementation, the SS4A grant program requires a comprehensive safety action plan identifying the most significant roadway safety concerns in a community. The comprehensive plan requires key components not covered in this RDSIP, 1) community engagement and 2) equity considerations that target historically disadvantaged populations. Meaningful, comprehensive, and inclusive public engagement is integral to every planning process. and the MPO could consider the following approaches:

- **Engagement with Regional Leadership:** Reach out to elected officials and town/city councils and boards in the local region to gain insights into the jurisdiction's greatest needs and begin a shift towards a culture of safety.
- **Engagement with Public:** Reach out to key stakeholders to develop a Stakeholder Engagement Plan. The plan can prioritize reaching communities that are traditionally underserved and those that are disproportionately impacted by traffic fatalities and serious injuries. This could include working with community agencies or social service providers to reach communities for which traditional engagement methods are ineffective.
- **Engagement with Safety Stakeholders:** To supplement input from the public, conduct a series of stakeholder listening sessions with a broad group of safety representatives throughout the local region. These could include emergency medical services, health departments, schools, social services, law enforcement, local traffic safety and planning staff, bus/transit agencies and operators, advocates and special interest groups, and major employers. These sessions can help the team fully understand and prioritize the safety concerns across each stakeholder group.

**Engineering Action 7 – Evaluate the Effectiveness of RwD Countermeasures**

***Strategy***

The SCDOT has been addressing RwD safety through the Rural Road Safety Program. Since 2017, SCDOT has been installing low and medium-cost countermeasures on the State’s primary system. SCDOT can benefit from evaluating the effectiveness of these countermeasures, or countermeasure packages, on reducing fatal and serious injury RwD outcomes. SCDOT can further improve decision-making by identifying where and when these packages have been the most successful and applying additional lessons learned. Evaluating the safety effectiveness of countermeasures installed based on this plan can further refine decision-making and provide support evidence to other COGs on the benefits of developing and implementing a similar plan.

#### Engineering Action 8 – Expand Use of Centerline Rumble Strips

##### *Strategy*

SCDOT identified that edge line rumble strips have been installed in all eligible locations, including through shoulder widening. Engineering Directive 53 provides direction for selection and installation of shoulder and edge line rumble strips in South Carolina. The DOT has begun installing centerline rumble strips; however, centerline rumble strips have yet to be addressed in the Engineering Directive. SCDOT can benefit from providing clear and consistent guidance in centerline rumble strip selection and installation to support further installation of centerline rumble strips throughout the region and State.

#### Engineering Action 9 – Encourage the Use of Safety Edge

##### *Strategy*

Safety Edge was adopted by SCDOT in 2010 and has been a key feature of the Rural Road Safety Program and Roadway Departure Mitigation Program. SCDOT should consider expanding the use of Safety Edge in the USCOG region, including on all resurfacing projects.

### EDUCATION ACTION PLAN

#### Education Action 1 – Expand Educational Campaigns

##### *Strategy*

There are several ongoing educational efforts through the SC Department of Public Safety, SC Department of Motor Vehicles, and SCDOT. For example, there are efforts related to impaired driving (alcohol, drug, distracted and drowsy), motorcycle safety, seatbelt use and speeding. The analysis indicates that alcohol involvement contributed to 152 KA RwD crashes (31.3 percent), which is third on the list in terms of magnitude and overrepresented compared to all RwD crashes. Speeding involved were at the top of this list, with 268 KA RwD crashes, followed by unbelted crashes at 202 KA RwD crashes. SC will continue current educational efforts to address these contributing factors. In addition, there is an opportunity to develop and implement other educational strategies such as:

- **Education on infrastructure strategies**: This would inform non-technical audiences, including the public, of reasons for installing strategies such as rumble strips that are a source of complaints. These education approaches then follow the "Why? How? What?" approach – establishing the issue (RwD crashes are likely to result in a fatality or serious injury), how they can be addressed (reduce the probability and potential severity of RwD crashes), and what will be done to achieve that approach (various RwD countermeasures).

- **Education on enforcement strategies**: This would inform the audiences of the enforcement strategies being planned to address behavior contributors to RwD crashes. These education approaches then follow the "Why? How? What?" approach – establishing the issue (these behaviors are contributing to severe RwD crashes), how they can be addressed (reduce the prominence of this behavior by drivers), and what will be done to achieve that approach (use target enforcement campaigns to identify drivers exhibiting these behaviors).

- **Education on impaired driving alternatives**: This includes marketing alternatives for drivers to avoid impaired driving, including highlighting alternative transportation methods (such as public transportation, taxis, and rideshare programs) and the use of designated drivers.

- **Education on RwD issues**: This would focus on driver complacency on longer trips, particularly on roads that seem relatively safe (e.g., minor arterials). It's easy to develop a false sense of security and engage in other activities (distractions). While other drivers may be a source of head-on and intersection crashes, there is a need to remain vigilant to avoid RwD crashes.

- **Supplemental resources for new driver education**: There is an opportunity to provide supplemental resources for instructors. Related to RwD, it is important to educate new drivers on how to safely negotiate a curve, including the importance of deceleration *before* the curve and environmental factors such as rain, snow, and leaves (particularly on rural, low-volume roads).

In terms of implementation, there are opportunities for free media by partnering with the South Carolina Broadcasters Association and agency social media channels, as well as for earned media by hosting press events, issuing press releases and placing media stories. There are also opportunities for paid media, primarily through paid social media campaigns that could reach a wider audience than standard agency social media channels. Content development could include television and radio advertisements, print and social media materials, and other content as necessary.

### Education Action 2 – Educate Local Agencies on RwD Countermeasures

#### *Strategy*

It is important for this plan to incorporate all public roads in the USCOG. As such, SCDOT needs to coordinate with USCOG and county agencies to be proactive about RwD safety, implementing RwD countermeasures at sites with crash history or a high risk of severe crashes. To increase local support, SCDOT will work with USCOG to provide resources and training opportunities to introduce representatives from local agencies to preferred RwD countermeasures, including the context for using them, their expected safety benefits, and tips for acquisition and installation.

USCOG and SCDOT and their safety partners should also work with local law enforcement and local public health partners to encourage their involvement in addressing RwD crashes on local roads. It is important for these local agencies to receive information about RwD crashes so they can develop strategies which are specific to their roadway network and population.

## ENFORCEMENT ACTION PLAN

### Enforcement Action 1 – Increase Impaired Driving Enforcement

#### *Strategy*

The data analysis indicates that alcohol involvement contributed to 152 (31.3 percent) of KA RwD crashes, which is third on the list in terms of magnitude and highly overrepresented compared to all alcohol involved RwD crashes. Law enforcement should continue efforts to target impaired driving, regardless of whether the impairment is due to alcohol, illegal drugs, or prescription drugs. There is an opportunity to use the hot-spot map, systemic risk factors, and other data to prioritize locations for targeted enforcement for these behaviors. Targeted enforcement can consist of sobriety checkpoints and high-visibility saturation patrols supported by mass-media campaigns. It is important for these patrols to include DREs and the offices to receive ARIDE training to identify drug impairment as well as alcohol impairment.

### Enforcement Action 2 – Increase Speeding Enforcement

#### *Strategy*

The data analysis indicates that speeding contributed to 268 (55.3 percent) KA RwD crashes, which is first on the list in terms of magnitude. Law enforcement should continue efforts to target speeding behaviors, especially in locations where there is a history of speed involved RwD crashes. There is an opportunity to use the hot-spot maps, systemic risk factors, and other data to prioritize locations for targeted enforcement for speeding behaviors. Traditionally, this includes high-visibility speed limit enforcement, which is supported by awareness campaigns, highlighting where and when the enforcement will occur as well as what the expected safety benefits are. Where there is overlap, speeding enforcement campaigns can be integrated into impaired driving enforcement campaigns.

**Enforcement Action 3 – Increase Distracted Driving Enforcement**

***Strategy***

In SC, “It is unlawful for a person to use a wireless electronic communication device to compose, send, or read a text-based communication while operating a motor vehicle on the public streets and highways.” [(6)] At this time, there is no law prohibiting the use of hand-held cell phones, regardless of the age of the driver. South Carolina’s law enforcement agencies should consider regular use of high-visibility distracted enforcement campaigns to reduce the frequency of distracted driving behaviors. When this campaign takes place, it should be supported by an extensive media campaign. There is an opportunity to use the hot-spot map, systemic risk factors, and other data to prioritize locations for targeted enforcement of distracted driving behaviors.

**Enforcement Action 4 – Increase Seat Belt Enforcement**

***Strategy***

In SC, “The driver and every occupant of a motor vehicle, when it is being operated on the public streets and highways, must wear a fastened safety belt which complies with all provisions of federal law for its use.” [(7)] As of 2005, SC’s seat belt law changed from a secondary enforcement to primary enforcement. Review of RwD crashes showed that nearly 42 percent of KA crashes involved one or more unbelted occupants, while only 6 percent of BCO crashes involved one or more unbelted occupants. There is an opportunity to disseminate the disparity in fatal and serious crash outcomes to the general public through media and awareness campaigns. Additionally, enforcement of unbelted vehicle occupants can be done in coordination with distracted driving, speeding, and impaired enforcement campaigns.

## REVIEW OF LOW-COST COUNTERMEASURES FOR THE ABC AGENCY HIGHWAYS

The goal of this Plan is to identify optimal locations and countermeasures that collectively can help to reduce the number and severity of RwD crashes in SC. This initiative involves the identification of several potential low-cost, effective countermeasures targeted for the reduction of RwD crashes along USCOG roadway locations. The list of low-cost countermeasures is divided into categories that (1) first focus on keeping the vehicles on the roadway, (2) next target the provision of a safe roadside area, and (3) help to reduce crash severity in the event the crash occurs. The treatments evaluated in this Plan are as follows:

- Keep Vehicles on Roadway
  - Curve signing.
  - Pavement markings and markers.
  - Delineators.
  - Friction treatments.
  - Rumble strips.
  - Roadway lighting.
- Provide for a Safe Recovery Area
  - Shoulders.
  - Safety Edge.
  - Centerline buffer area.
  - Clear zones and roadside slopes.
- Reduce Crash Severity
  - Breakaway devices.
  - Barriers.
- Education and Enforcement Campaigns

Though this Plan focuses on relatively low-cost treatments, it is likely that higher cost countermeasures may be options at some of the identified locations. Due to ongoing safety initiatives in USCOG, SCDOT may have already constructed safety treatments at some of the identified locations. Consequently, this Plan further notes that SCDOT and local partners should conduct field visits as part of the initial scoping activities to determine if the condition persists that initially triggered attention to each site due to RwD crash concerns.

## TOOLBOX OF IMPLEMENTATION PLAN SAFETY ENHANCEMENT TREATMENTS

A variety of candidate safety treatments are available to help reduce the number of severe injury RwD crashes that occur on USCOG roadways. For the purposes of this Plan, the data supports the countermeasures presented in this chapter. The recommended countermeasures include proven treatments, and, in many cases, treatments already deployed on USCOG roadways. The SCDOT roadway inventory may not fully document the locations of existing safety treatments. Consequently, the Plan recommends that SCDOT and partners first assess the individual ranked sites to identify and remove locations where similar treatments have either already been deployed or are currently slated to be implemented. These ranked sites can be developed in a ranking spreadsheet tool.

This Plan explores the suitability of the list of countermeasures previously noted. The countermeasures do not include major infrastructure projects such as roadway reconstruction or major realignment since this type of enhancement, though effective, would be specific to a unique construction project at a location already known to be deficient.

Within this Plan, the estimates for effectiveness and cost for each treatment represent typical applications and SCDOT and local partners will need to make additional refinements based on unique field conditions. The following summaries review each potential safety treatment as it relates to USCOG applications.

### CURVE SIGNING

Often horizontal curves have visibility issues due to their geometry, roadway configuration, roadside landscape, and a variety of other potentially problematic roadway elements. To enhance the visibility of a horizontal curve, a variety of signing options are available. Curve warning signs are needed at locations with an advisory speed that is at least ten mph below the posted speed limit. Similarly, curve warning signs may be appropriate due to geometric features including length, radius, shoulders, or roadside features. In some instances, an unexpected feature may be located within the curve such as an intersection, geometric change, or similar. These example characteristics demonstrate the wide variety of issues that ultimately may trigger the need to install static curve warning signs. The road features that trigger static curve warning signs also apply to enhanced curve warning systems. An enhanced curve warning system can incorporate larger signs, better advanced warning, and in some cases companion flashing beacons to further enhance the curve warning system.

Horizontal curve signage, including advance warning signs (W1-1, W1-2, W1-3, W1-4, W1-5, W10-1), advisory speed plaques (W13-1P), chevrons (W1-8), and large arrows (W1-6), can reduce the frequency of RwD crashes, particularly nighttime crashes, on horizontal curves.

Chevrons, particularly, have been shown to reduce fatal and injury RwD crashes by 16 percent and crashes of all severity by 25 percent.[8] Figure 10 shows two horizontal curves with curve signs and chevrons. The MUTCD provides guidance for when these signs shall, should, or may be used on horizontal curves.[9] It is important for SCDOT and local partners to be compliant with MUTCD curve warning signs and to make sure vegetation does not impede visibility of signage. Figure 11 shows the requirements for curve signing for arterials and collectors with traffic volume greater than 1,000 based on differences between the speed limit and advisory speed.

**Figure 10**. **Horizontal Curves with Signs and Chevrons**

**Table 2C-5. Horizontal Alignment Sign Selection**

| Type of Horizontal Alignment Sign | Difference Between Speed Limit and Advisory Speed | | | | |
|---|---|---|---|---|---|
| | 5 mph | 10 mph | 15 mph | 20 mph | 25 mph or more |
| Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and Combination Horizontal Alignment/Intersection (W10-1) (see Section 2C.07 to determine which sign to use) | Recommended | Required | Required | Required | Required |
| Advisory Speed Plaque (W13-1P) | Recommended | Required | Required | Required | Required |
| Chevrons (W1-8) and/or One Direction Large Arrow (W1-6) | Optional | Recommended | Required | Required | Required |
| Exit Speed (W13-2) and Ramp Speed (W13-3) on exit ramp | Optional | Optional | Recommended | Required | Required |

**Figure 11**. **Curve Signing Requirements for Arterials/Collectors with AADT>1,000**[9]

These signs can also be enhanced to improve effectiveness. Potential enhancements include increasing the size of the sign, doubling-up signage, using fluorescent yellow prismatic sheeting, using overhead sign placement, providing "Wig-Wag" style flashers, including reflectorized posts, installing speed feedback signs, and upgrading to sequential flashing chevrons. Increased retroreflectivity has been found to reduce head-on, run-off-road, and sideswipe crashes by 34 percent, sequential chevrons have been shown to reduce crashes of all severity by 44 percent and fatal and injury crashes by 60 percent, and dynamic speed feedback signs have been shown to reduce all and single-vehicle crashes by 5 to 7 percent.[8,10,11]

Table 18 indicates the CMFs used in this Plan, along with their applicable crash types, applicable crash severities, and sources. Sources specifically refer to a CMF ID for FHWA's CMF Clearinghouse.

**Table 18. CMFs for Curve Signing**

| Treatment | CMF | Crash Type | Severity | Source |
|---|---|---|---|---|
| Advance curve warning sign | 0.70 | All | Injury | 71 |
| Advance curve warning sign | 0.92 | All | PDO | 72 |
| Enhanced curve delineation | 0.73 | All | All | 10613 |
| Chevrons | 0.84 | All | Injury | 2438 |

Static curve signing suggested implementation is as follows:

1. The placement of static curve warning signs should be targeted for locations where the curve radius, roadway superelevation, posted speed, advisory speed, and/or roadside environment may be configured in such a way that a driver is surprised by the road geometry or has a challenge navigating the corridor. The data used to identify potential locations included some, but not all, of these potential contributing factors. Consequently, a first step in implementing this treatment is for SCDOT and local partners to conduct field evaluations using the prioritized list of sites to confirm the need for these curve warning signs.

2. At locations where a driver needs additional warning, enhanced curve warning systems are recommended. Often, an agency deploys static curve warning signs and then ultimately add enhanced features such as flashing beacons or larger signs if the problem persists. For this reason, implementation of the static curve warning signs and the enhanced curve warnings systems should be assessed together and only one initial treatment deployed per location. SCDOT and local partners should consider prioritizing those locations deemed to be highest risk for enhanced curve signing.

### PAVEMENT MARKINGS AND MARKERS

Pavement markings are used to delineate the edges of the traveled way. Pavement markings are a visual countermeasure to communicate information to the driver, particularly during nighttime conditions. Pavement markings address head-on crashes, sideswipe-opposite direction crashes, curve crashes, and RwD crashes at night. The MUTCD indicates that centerline markings shall be placed on all paved urban arterials and collectors with a traveled way of at least 20 feet and an average daily traffic of at least 6,000 vehicles per day, while they should be placed on rural arterials and collectors with a traveled way width of at least 18 feet and an average daily traffic of at least 3,000 vehicles per day. Additionally, edge line markings shall be placed on rural arterials with a traveled way width of at least 20 feet and an average daily traffic of at least 6,000 vehicles per day, while they should be placed if the traveled way width is at least 20 feet and the average daily traffic is at least 3,000 vehicles per day. SCDOT and local partners should consider adding pavement markings on lower volume roads that may not meet these warrants where risk factors exist.

Research has shown pavement markings have safety benefits, with centerlines and edge lines combined reducing crashes on rural roads by 24 percent, edge lines where centerlines already exist reducing crashes by 15 percent on rural lane roads with less than 22 feet of pavement width, and edge lines reducing crashes by 26 percent on rural two-lane curves with lane widths of 11 feet or narrower.[12,13,14]

Widening edge lines, say from 4 inches to 6 inches, has been shown to reduce fatal and injury crashes on rural two-lane roads by 36.5 percent and crashes of all severity by 17.5 percent (Figure 12).[15] SCDOT can consider expanding the use of wider edge lines to additional contexts, such as horizontal curves. Additionally, wider edge lines will help in the future as autonomous and semi-autonomous vehicles increasingly rely on the visibility of edge line markings.


**Figure 12. 4-Inch (Left) and 6-Inch (Right) Edge Lines in Rural Two-Lane Roads**

Standard water-based pavement markings achieve retro-reflectivity through glass beads which reflect light from the headlight back to the driver. The performance of standard pavement markings suffers under wet road conditions. When water interferes with the ability of the markings to reflect light. Wet-reflective pavement markings counteract this issue by including both glass beads and ceramics to achieve light reflection.[16] These markings can be installed on high-risk segments with a history of drainage issues, weather or wet road-related crashes, or nighttime crashes.

Raised reflective pavement markers (RRPMs) can supplement traditional longitudinal pavement markings. The color of RRPMs reflected in the direction of traffic matches the color of the longitudinal marking, while reflecting red to opposing vehicles if used on a divided facility. RRPMs are most useful at night, increasing the delineation of the roadway.

Table 19 indicates the CMFs used in this Plan, along with their applicable crash types, applicable crash severities, and sources. Sources specifically refer to a CMF ID for FHWA's CMF Clearinghouse. Further, this plan assumes a CMF of 0.81 for RPMs, based on research conducted in Louisiana. [17]

**Table 19. CMFs for Pavement Markings and Markers**

| Treatment | CMF | Crash Type | Severity | Source |
|---|---|---|---|---|
| Install standard centerline | 0.99 | All | Injury | 87 |
| Install standard edge line | 0.85 | All | All | 10243 |
| Install centerline and edge line | 0.76 | All | Injury | 101 |
| Replace standard with wider edge line | 0.63 | All | Injury | 4737 |
| Install RRPMs | 0.81 | All | All | 5496 |

Suggested implementation is as follows:

1. This section highlighted the MUTCD requirements for centerline and edge line pavement marking installation. However, SCDOT and local partners can install pavement markings on roadways with lower volumes to support reducing the risk of RwD crashes.

2. The Plan assumes that some additional benefit can be achieved through widening standard pavement markings to wider pavement markings. Prior to initiating improvement projects, SCDOT and local partners should inspect the candidate sites and confirm that the sites are viable options for this treatment.

3. Information about locations with centerline raised pavement markings already present was not available at the time of Plan development. The Plan assumes that these pavement markings are already present for 50 percent of roadway segments. Prior to initiating improvement projects, SCDOT and local partners should inspect the candidate sites and confirm that the sites are viable options for this treatment.

### DELINEATORS

Pavement markings can also be supplemented with delineators, which are typically mounted on a flexible post or on a roadside barrier (Figure 13). Delineators are especially effective at night and during adverse weather conditions, remaining visible when the road is wet or covered in snow. The MUTCD provides guidance for the usage and characteristics of delineators.[9]

**Figure 13. Barrier Mounted and Post Mounted Delineators**

Installing delineators, centerlines, and edge lines in combination is expected to result in a 45 percent reduction in injury crashes (CMF ID 102). This Plan assumes a CMF of 0.81, consistent with the CMF for RRPMs, providing delineation on horizontal curves.

### FRICTION TREATMENTS

Some parts of roadways, particularly horizontal curves, have increased friction demand. Additionally, some of those sites may have reduced friction availability, in some cases due to polished pavement surfaces and in other cases during wet pavement conditions. FHWA has documented various methods to improve pavement friction, including:[18]

- Thin Hot Mix Asphalt Overlay – An up to a 2-inch overlay that is not considered a structural layer. This can be done through a mill-and-fill.

- Open Graded Friction Course – A course that uses open-graded or porous mixture that allows water to draw away quickly.

- Ultra-Thin Bonded Wearing Course – A ½ to ¾-inch thick non-structural course that seals and protects the underlying pavement. Installed after the application of an emulsion layer.
- Slurry Seal – A mixture of emulsified asphalt, water, fine aggregate, and mineral filler mixed into a slurry and applied in a thin layer that fills surfaces cracks and voids, improves friction and appearance, and prevents water infiltration.
- Microsurfacing – A treatment that mitigates raveling and oxidation and improves the friction and appearance of the pavement surface. It is a mixture of polymer-modified asphalt emulsion, water, fine aggregate, and mineral filler that is mixed into a slurry and applied in a thin layer, like slurry seal but more durable.
- Chip Seal and Seal Coats – A bituminous membrane of polymer-modified asphalt emulsion followed by a layer of aggregate, sometimes called "chips". It is not a structural layer, but it does provide a durable wearing surface. It can be applied in single, double, or triple layer treatments with variety of aggregate sizes. The treatment seals fine cracks and prevents water intrusion while sustaining and improving friction.
- High-Friction Surface Treatment (HFST) – A specialty pavement treatment used specifically to restore or enhance friction at spot locations using resin binders and polish-resistant aggregates.

HFST is an innovative pavement treatment that incorporates the application of high-quality calcined bauxite aggregate to the pavement surface using a polymer binder. This pavement treatment is an effective way to improve friction at sharp horizontal curve locations where standing water is likely to occur or where pavement friction is not suitable. HFST can be an effective alternative at locations with sharp horizontal curvature and insufficient superelevation, because HFST can be constructed in lieu of more costly alternatives like geometric changes that require a flatter horizontal curve or superelevation wedge construction. This application then results in enhanced skid resistance and helps vehicles maintain their path at critical locations. HFST can provide enhanced road surface performance for both wet and dry pavements. HFST can also provide improved friction at ramp locations with abrupt speed changes.

Recently, FHWA published a before-after evaluation of HFST on horizontal curves and ramps.[(19)] Table 20 summarizes the results of that study. HFST was found to produce significant reductions in crash frequency for both horizontal curves and ramps for many crash types. Additionally, the benefit-cost ratios showed that these reductions in crashes produce a notable return on investment. HFST has a relatively medium cost – between $25,000 and $50,000 per location.

Additionally, Merritt et al. published an extensive collection of CMFs for various friction treatments – the CMFs are available on the CMF Clearinghouse. [18] For each pavement treatment, the authors estimated CMFs for combinations of all-severity crashes and fatal and injury crashes, as well as all crashes, dry weather crashes, wet road crashes, and run off road crashes.

**Table 20. Summary of HFST CMFs and Benefit-Cost Ratio[16]**

| Crash Type | Horizontal Curve CMF | Ramp CMF |
|---|---|---|
| All Crashes | 0.430 | 0.212 |
| Injury Crashes | 0.515 | 0.365 |
| Run-Off-Road Crashes | 0.279 | 0.202 |
| Wet-Road Crashes | 0.168 | 0.079 |

Suggested implementation is as follows:

1. The placement of HFST should be targeted for locations where the road surface friction is not sufficient for vehicles to adequately maintain their path, particularly during wet weather conditions. HFST should only be used at locations where the existing pavement surface is in good condition. For this application, "good condition" refers to where there is not any evidence of pavement deficiencies that would indicate compromised integrity of the pavement structure. Common applications of HFST are at curve locations where the pavement surface does not always maintain proper drainage.
2. The data used to identify potential locations is based on horizontal curve radius and does not consider the site-specific characteristics or contributing factors on curves with similar features. Prior to implementing this treatment, it would be advisable for SCDOT and local partners to conduct field evaluations to confirm site suitability and priority.

### RUMBLE STRIPS

Rumble strips (or rumble stripes) are modifications to the pavement to provide audible and tactile feedback to drivers who cross them. These are typically installed on the centerline and shoulders to warn drivers they are leaving the roadway. Centerline rumble stripes / strips are effective treatments for rural undivided highway locations where any noise generated by these treatments will not be disruptive to the surrounding community. Edge line or shoulder rumble stripes or strips can effectively alert a driver who inadvertently exits his or her travel lane. These treatments are appropriate for non-curbed (typically rural) roadways. Figure 14 is an example of a road with centerline markings, edge line markings, centerline rumble strips, and shoulder rumble strips.

**Figure 14. Two-Lane Highway with Centerline and Shoulder Rumble Strips**

Table 20 summarizes the CMFs from the most comprehensive national study to date, with results focusing on rural two-lane highways, respectively.[20]

**Table 21. CMFs for Rumble Strips on Rural Two-Lane Highways[20]**

| Rumble Strip Location | All Severity Crashes | Fatal and Injury Crashes |
|---|---|---|
| Shoulder (SVROR) | 10 Percent Reduction | 17 Percent Reduction |
| Centerline | 4 Percent Reduction | 9 Percent Reduction |

Suggested implementation is as follows:

1. A statewide database for existing centerline or shoulder/edge line rumble strips is not available. Consequently, the Plan assumes that centerline rumble strips are not present and edge line rumble strips are present on most facilities. Prior to initiating improvement projects, SCDOT and local partners should inspect the candidate sites and confirm that the sites are viable options for this treatment. As part of the field evaluation, SCDOT and local partners should confirm the minimum pavement width. This value should include the roadway and the shoulder widths.

### ROADWAY LIGHTING

The strategic positioning of streetlights at critical locations, such as intersections or sharp horizontal curves (as depicted in Figure 15), can help to enhance roadway visibility and therefore reduce nighttime collisions. Transportation agencies often install lighting at locations with a pattern of nighttime RwD crashes or conditions where this type of crash is likely. For rural areas, an agency can encounter challenges deploying lighting if electrical service is not available at more remote locations. As the number of lanes, access points, changes in horizontal or vertical alignment, or parking increases, the demand for lighting increases. Roadway lighting has been found to reduce injury crashes by 28 percent and PDO crashes by 17 percent. [12]

**Figure 15. Horizontal Curve Lighting**

Suggested implementation is as follows:

1. The basis for the Plan recommendation to install lighting improvements is to reduce nighttime RwD crashes. Because lighting may require supplemental power, a first step towards implementation is to determine if and where lighting can be supported by solar power versus hardwired electrical power. For rural locations that require physical electrical wiring, SCDOT and local partners should inspect the sites to determine how or if this service can be provided. Prior to initiating improvement projects, staff should inspect the candidate sites and confirm that the sites are viable options for this treatment.
2. A common strategy for adding lighting is to share poles with other utilities so that the department can minimize the number of roadside fixed objects. If, for example, electrical service is available it may also be practical to coordinate with the power company or owner of the existing poles to mount lighting standards on their poles. SCDOT and local partners should explore if this option is acceptable and, if deemed appropriate, coordinate with regional utility companies to determine common locations identified during the ranking process that correspond to identified share pole locations.
3. If solar powered lights are determined to be practical, SCDOT and local partners should finalize specifications for the lights and determine suitable locations based on priority segments SCDOT has identified as candidates for curve lighting.

### SHOULDERS

Shoulders are critical to provide a paved area for drivers to recover. Roadways with minimal shoulder widths do not provide space for errant vehicles that exit their travel lane to correct their path (while still on a paved surface). Shoulders also provide a benefit for disabled vehicles to safely exit the active travel lanes. Consequently, providing wider shoulders can be an effective safety treatment. Shoulders are especially useful on horizontal curves, where drivers may fail to change their alignment with the curve and where large vehicles may require the extra pavement for wheel tracking.

Figure 16 shows a horizontal curve with an outside shoulder to provide forgiveness for vehicles which depart the traveled way. The wide shoulder is a countermeasure to reduce the potential for a RwD crash, while the shoulder rumble strips, pavement markings, post-mounted delineators, and chevrons help keep drivers on the roadway.


**Figure 16. Horizontal Curve with Widened Outside Shoulder**

There are numerous studies in FHWA's CMF Clearinghouse and AASHTO's *Highway Safety Manual* (HSM) which show that widening paved shoulder width is correlated with a reduction in RwD crashes.(21) Table 22 provides an overview of shoulder CMFs found in the.

**Table 22. Shoulder CMFs**

| Treatment | CMF | Crash Type | Severity | Source |
|---|---|---|---|---|
| Add 2-foot paved shoulder | 0.87 | All | All | HSM* |
| Add 4-foot paved shoulder | 0.77 | All | All | HSM* |
| Add 6-foot paved shoulder | 0.67 | All | All | HSM* |
| Add 8-foot paved shoulder | 0.58 | All | All | HSM* |

*Converted HSM shoulder widening adjustment factor to total crashes for roadways with at least 2,000 vehicles per day.

Suggested implementation is as follows:

- For this Plan, candidate locations that would benefit from shoulder widening are included in the priority segments. Prior to initiating an improvement project, SCDOT and local partners should examine the individual sites and determine feasibility of improvement and assess the need for drainage grading improvements.

### SAFETY EDGE

Pavement edge drop offs can occur as result of resurfacing, settling, erosion, and even tire wear. Significant pavement drop-offs make it difficult for drivers to return to the traveled way and can increase the risk of tripping or complete loss of control. Safety Edge includes shaping the edge of pavement into a 30-degree shape (Figure 17). This provides stability for vehicles that are recovering from a RwD.

**Figure 17. Safety Edge**

Table 23 presents CMFs for providing a Safety Edge for several different crash types.[22]

**Table 23. Safety Edge CMFs [22]**

| Treatment | CMF | Crash Type | Severity | Source |
|---|---|---|---|---|
| Provide Safety Edge | 0.65 | Drop-off | All | 9671 |
| Provide Safety Edge | 0.79 | Run-off-road | All | 9661 |
| Provide Safety Edge | 0.81 | Head-on | All | 9662 |
| Provide Safety Edge | 0.89 | All | Injury | 9660 |

Suggested implementation is as follows:

1. Safety Edge can be implemented systematically, on all resurfacing projects, or targeted based on higher risk locations for pavement drop-off-related crashes. This Plan provides priority locations based on risk for RwD crashes. Prior to initiating an improvement project, SCDOT and local partners should examine the individual sites and determine feasibility of improvement and assess the need for Safety Edge.

### CENTERLINE BUFFER AREA

Undivided roadways are at-risk for head-on and opposite direction sideswipe crashes. Providing centerline rumble strips can reduce the likelihood of a vehicle crossing the centerline; however, vehicles may still encroach the opposite lane before making a corrective action. A centerline buffer, as shown in Figure 18, can be used to provide further separation between opposing traffic. The centerline buffer can be enhanced using centerline rumble strips in the middle of the buffer or by using centerline rumble stripes corresponding to each double-yellow in the buffer area, further providing for recovery.


**Figure 18. Centerline Buffer.**

Centerline buffer areas have been shown to be effective in reducing opposite direction crashes on rural, two-lane roadways as shown in Figure 19. As shown, a 4-foot buffer is expected to reduce opposite direction crashes by up to 60 percent and a 6-foot buffer by as much as 80 percent.[23] Consideration should be given to narrowing the shoulders to create a centerline buffer. Research did not find a corresponding RwD crash increase when installing a centerline buffer area, but the risk of right-side RwD crash frequency and severity should be considered when considering a centerline buffer.

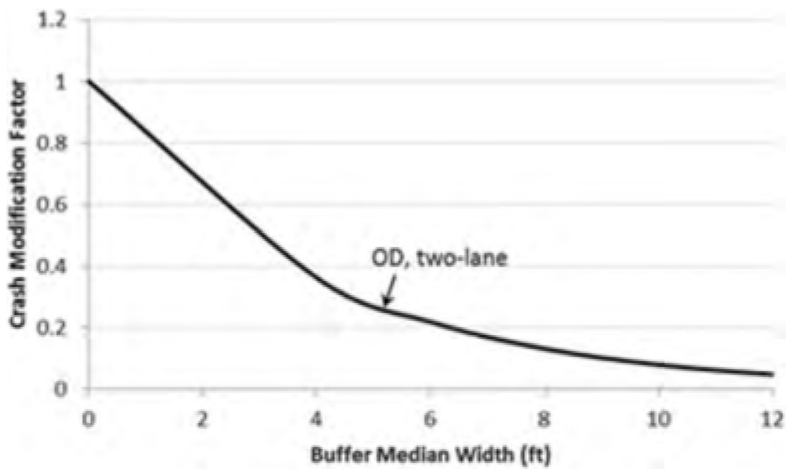


**Figure 19. Crash Modification Factor for Centerline Buffer [23]**

Suggested implementation is as follows:

1. The centerline buffer area can be implemented based on higher risk locations for head-on or cross-centerline crashes. Providing a centerline buffer area may require additional pavement or can be done within existing pavement by narrowing existing shoulders. This Plan provides priority locations based on risk for RwD crashes. Prior to initiating an improvement project, SCDOT and local partners should examine the individual sites and determine feasibility of improvement and assess the need for a centerline buffer area.

### CLEAR ZONES AND ROADSIDE SLOPES

FHWA defines a clear zone as “an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway”. [24] The width of the clear zone is the distance between the edge of the travel lanes and any fixed objects or non-traversable slopes. Notably, this width includes the shoulder. At locations where fixed objects are located on the roadside, an errant vehicle that inadvertently exits the roadway may impact these trees or fixed objects if they are positioned too close to the active travel way. When feasible, an agency should completely remove these fixed objects. As shown in Figure 20, the close lateral placement of utility poles near active traffic can result in severe RwD crashes. This treatment can be challenging when the fixed object is a pole and is in the right-of-way where multiple users share the pole. In many cases, however, the object may be a large number of trees and removal is simply not practical. For these locations, the agency should shield the trees that cannot be removed.

**Figure 20. Candidate Relocation for Utility Pole (Urban Environment)**

The AASHTO *Roadside Design Guide* has a six-step hierarchy for addressing obstacles and hazard in the clear zone that the SCDOT and its local partners can follow to address clear zone safety issues:

1. Remove the obstacle.
2. Redesign the obstacle to be traversable.
3. Relocate the obstacle to where it is less likely to be struck.
4. Reduce the severity of impact with that obstacle by using a breakaway device.
5. Shield the obstacle with a longitudinal barrier or a crash cushion.
6. Delineate the obstacle.

Federal Lands Highway's (FLH) Barrier Guide for Low Volume and Low Speed Roads includes guidance for calculating the recommended clear zone width on low-speed roads based on traffic volume, design speed, and roadside foreslopes and back slopes.(25) The AASHTO Roadside Design Guide provides recommended clear zone widths based on the same features for higher-speed, higher-volume roadways.(26) Note that increases in speed, traffic volume, and steepness of slope are associated with wider clear zone recommendations, and these values change with the presence of curvature.

For roadways in fill sections, it is important to provide a recoverable slope, which is a slope flat enough for drivers to counter-steer, maintain control of the car, and return to the roadway. If unable to provide a recoverable slope, the fill slope should at least be traversable, which is flat enough for a vehicle to safely traverse without a high probability of overturning. If a slope is not traversable or recoverable, it is considered critical. Slopes at 1V:4H or flatter are recoverable, 1V:3H to 1V:4H are traversable (Figure 21), and steeper than 1V:3H are critical. Roadside barriers should be used to protect vehicles when the roadside slope is critical.

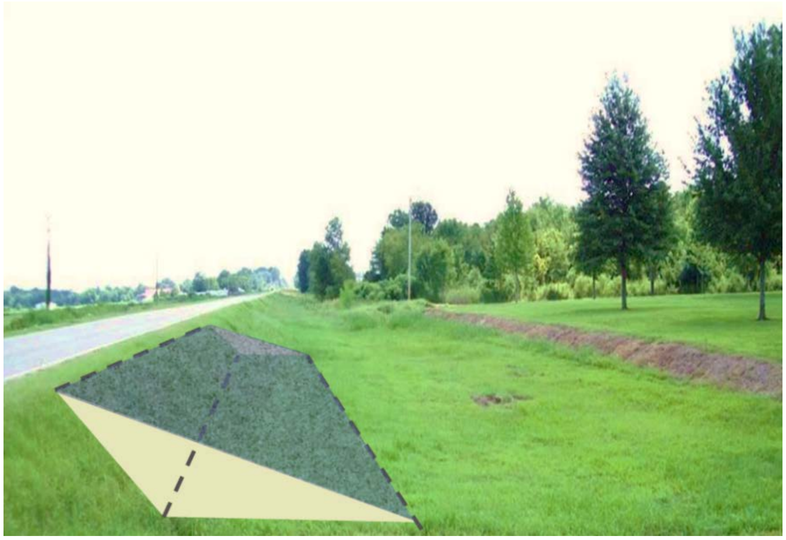

**Figure 21. Traversable Slope**

Research has shown that widening the clear zone from 3.3 feet to 16.7 feet reduces crashes by 22 percent, while widening from 16.7 feet to 30 feet reduces crashes by 44 percent**Error! Bookmark not defined.**.(12) Another study found that removing utility poles or relocating beyond 50 feet from the paved shoulder resulted in a 34 percent decrease in fatal and injury crashes.(27) The costs to widen the clear zone can vary widely depending on the work required, with removal of one or two fixed objects having a low relative cost compared to the removal of dense fixed objects.

Table 24 summarizes the CMFs for single-vehicle crashes associated with sideslope flattening, as documented in the HSM.(21)

**Table 24. CMFs for Single-Vehicle Crashes after Flattening Sideslopes(21)**

| Before Sideslope | After Sideslope | | |
|---|---|---|---|
| | 1V:4H | 1V:5H | 1V:6H |
| **1V:2H** | 0.90 | 0.85 | 0.79 |
| **1V:3H** | 0.92 | 0.86 | 0.81 |
| **1V:4H** | - | 0.94 | 0.88 |
| **1V:5H** | - | - | 0.94 |

### BREAKAWAY DEVICES

Breakaway supports for signs and other roadside devices are designed to bend, shear, or otherwise breakaway after being struck by a vehicle. By yielding, this allows the vehicle to continue past the fixed object, slowing the vehicle but not forcing the vehicle to stop suddenly, as sudden decelerations increase the probability of severe injury to vehicle occupants. Designers should consider potential impact directions and choose between omnidirectional and unidirectional options.

### BARRIERS

Locations with steep roadside terrain or heavily wooded land are often shielded by roadside barriers. Roadside barriers are designed to redirect and slow vehicles while shielding them from obstacles likely to result in a more severe crash, such as rigid fixed objects, steep slopes, or bodies of water. Contextually, it is important to use the correct barrier as different barrier systems require different roadside conditions and are designed to contain varying levels of impact energy. Additionally, barriers should be mounted at the correct height and with sufficient soil support. Finally, guiderail terminals should be used to reduce the potential severity of collisions with barrier ends.

In many cases, barriers are constructed and remain in place for many years. In other cases, barriers are frequently impacted and SCDOT and local partners are required to maintain the barrier. In addition, over time the design of an effective barrier may change. These design modifications could require barrier reconstruction or improvement. Recently, the United States began a transition from NCHRP 350 barrier crash criteria to the 2016 AASHTO Manual for Assessing Safety Hardware. For this treatment to improve barrier, the improvements should be designed for the current criteria for the location. Figure 22 is an example of an improved barrier to current standards.

**Figure 22. Improve Barrier to Current Standards**

Safety studies for barriers often show increases in total crashes due to the introduction of a fixed object closer to the traveled way, which is compared against a decrease in target, more severe crash outcome. For instance, one study showed that the installation of cable median barrier resulted in a 604 percent increase in fixed object crashes while decreasing cross median crashes by 97 percent on rural principal arterial freeways and expressways.(28) Meanwhile, new guiderail installations on embankments have been found to reduce RwD injury crashes by 47 percent.(12) A recent study found that installing guardrail at sites with lateral offsets to utility poles less than 20 feet and side slopes flatter than 1 vertical to 6 horizontal resulted in a 48 percent reduction in fatal and injury crashes and a 57 percent reduction in fatal and injury crashes when the lateral offset is greater than 20 feet.(27)

### EDUCATION AND ENFORCEMENT COUNTERMEASURES

The following sections describe what countermeasures can be used to address common behavioral contributing factors for severe RwD crashes. These countermeasures are selected from the NHTSA's *Countermeasures That Work*.(29) SCDOT, local partners, and other agencies can work together to develop strategies which address these issues.

#### Speeding

Speeding increases the probability of a crash occurring by reducing the available time for drivers to react to changes in geometry or hazards. It also increases the probability of a crash resulting in a severe injury, as crashes at higher speeds involve more energy transferred to occupants. Table 25 summarizes countermeasures which can address speeding.

**Table 25. Summary of Education and Enforcement Countermeasures to Address Speeding**

| Countermeasure | Description |
|---|---|
| Aggressive Driving Laws | SC does not currently have a law prohibiting aggressive driving, though some aggressive driving behaviors can be labelled "reckless driving" or otherwise captured in speed limit violations. Though there is no evidence suggesting aggressive driving laws or increased penalties for these behaviors reduces aggressive driving crashes, they may reduce the probability of this behavior, especially for potential repeat behaviors. |
| Automated Enforcement | Automated enforcement can be used to supplement enforcement strategies by targeting speeding in high-risk locations, such as work zones or school zones. Automated enforcement can be useful in the USCOG due to the limited resources available for traffic enforcement. |
| High-Visibility Enforcement | High-visibility enforcement typically includes an increase in aggressive driving patrols targeting areas with a history of aggressive driving crashes and/or violations. Though there are mixed results with regards to the effectiveness of these campaigns on crashes, they are still a useful tool to raise awareness of the potential dangers of aggressive driving behaviors. |
| Communications and Outreach to Support Enforcement | Media campaigns can be used to raise awareness of aggressive driving enforcement programs. These programs should notify the public of where the program is occurring, why it is occurring, expected safety benefits, and the consequences of receiving a violation. |

**Impaired Driving**

Driving while impaired, either under the influence of alcohol, illicit drugs, or any other substance, is hazardous as it dulls the processing and decision-making ability of drivers, significantly increasing the probability of a severe crash.

Table 26 summarizes some education and enforcement countermeasures from NHTSA's *Countermeasures that Work* that SCDOT and local partners can use to address impaired driving.[29]

**Table 26. Summary of Education and Enforcement Countermeasures to Address Impaired Driving**

| Countermeasure | Description |
|---|---|
| Sobriety Checkpoints | Sobriety checkpoints at high-risk locations can be effective at reducing impaired driving crashes. The checkpoints should be highly visible to drivers and should be supported by a media campaign which informs the public when the checkpoints are taking place, where, and the expected benefit of the checkpoints. Sobriety checkpoints can be publicized through variable messaging signs. |
| High-Visibility Saturation Patrols | A saturation patrol, consisting of numerous law enforcement officers, can be targeted for locations and times with a history of impaired driving citations or crashes. The large number of officers should deter impaired driving as well as increase the likelihood of finding impaired drivers. As with sobriety checkpoints, saturation patrols should be publicized beforehand with a media campaign and should be used regularly. |
| Media Campaigns | Media campaigns can also be used to raise awareness of the dangers of impaired driving. These programs should notify the public of where the program is occurring, why it is occurring, expected safety benefits, and the consequences of receiving a violation. |
| Alternative Transportation | Alternative transportation includes providing transportation options for impaired people to get where they want to go without having to drive. In some cases, a government agency will subsidize public transportation, taxis, or rideshares on days with a high frequency of drinking to provide safe transportation for its citizens. |
| Enforcement of Drug-Impaired Driving | Law enforcement should check for drug impairment when a driver is exhibiting impaired driving behavior but has a low or no blood alcohol content. Law enforcement agencies can employ drug recognition experts and provide Advanced Roadside Impaired Driving Enforcement training to its officers. Drug-impaired driving efforts can be integrated into alcohol saturation patrols and sobriety checkpoints. |

**Fatigued and Distracted Driving**

Fatigued (drowsy) and distracted driving can be just as dangerous as impaired driving. Just like impaired driving, a driver's ability to react is limited due to inattention, whether the inattention is coming from a physical distraction such as a cell phone or a mental distraction such as exhaustion. Table 27 summarizes behavioral countermeasures which can be used to reduce the frequency and severity of fatigued and distracted driving crashes which may result in RwD crashes. [29]

**Table 27. Summary of Education and Enforcement Countermeasures to Address Fatigued and Distracted Driving**

| Countermeasure | Description |
|---|---|
| Distracted Driving Enforcement | Distracted driving laws make the use of portable electronic devices a primary offense, meaning law enforcement officers can pull over and cite drivers if they are seen using a portable electronic device, such as a cell phone, while driving |
| Distracted Driving Outreach | Every April is National "Distracted Driver Awareness Month", which includes campaigns to make drivers aware of the dangers and consequences of distracted driving. Distracted driving outreach can be used in concert with target distracted driving patrols to reduce distracted driving behaviors and crashes. |
| Drowsy Driving Outreach | Drowsy driving prevention focuses on raising awareness of and reducing drowsy driving risks through outreach and education activities targeting high-risk groups. SCDOT and local partners can use variable message signage and other methods including radio ads, television public service announcements, and social media campaigns to warn drivers of the dangers of drowsy driving. |

**Occupant Protection**

Abundant research has shown that correctly using an appropriate child restraint or seat belt is the single most effective way to save lives and reduce injuries in crashes. Lap and shoulder combination seat belts, when used, reduce the risk of fatal injury to front-seat passenger car occupants by 45 percent and the risk of moderate-to-critical injury by 50 percent.[30] For light truck occupants, seat belts reduce the risk of fatal injury by 60 percent and moderate-to-critical injury by 65 percent. NHTSA estimates that correctly used child restraints are even more effective than seat belts in reducing fatalities among children. [29] Table 28 summarizes behavioral countermeasures which can be used to reduce the frequency and severity of unrestrained driver and occupant RwD crashes.

**Table 28. Summary of Education and Enforcement Countermeasures to Address Unrestrained Drivers and Occupants**

| Countermeasure | Description |
|---|---|
| Seat Belt Use Laws | According to South Carolina Department of Public Safety's "SC Safety belt law" (section 56-5-6520), "The driver and every occupant of a motor vehicle, when it is being operated on the public streets and highways of this State, must wear a fastened safety belt which complies with all provisions of federal law for its use. The driver is charged with the responsibility of requiring each occupant seventeen years of age or younger to wear a safety belt or be secured in a child restraint system. However, a driver is not responsible for an occupant seventeen years of age or younger who has a driver's license, special restricted license, or beginner's permit and who is not wearing a seat belt; such occupant is in violation of this article and must be fined (in accordance with Section 56-5-6540)." (7) |
| Seat Belt Law Enforcement | Law enforcement in the USCOG should actively enforce relevant seat belt laws. |
| Communication and Outreach | Media campaigns can be used to raise awareness of enforcement programs that aim to increase the use of occupant protection. Campaigns can include earned media (news stories), paid advertising as well as social media. |

## PROJECT DEVELOPMENT

As outlined in the action plan, SCDOT and local partners will prioritize locations for systemic treatment based on the level of risk for focus crashes on focus facilities. For locations with higher risk, the sites should be reviewed for contributing factors and the decision to treat should be made based on engineering judgment, contributing factors, and the expected benefits of proposed countermeasures. Countermeasure enhancements should be prioritized to those locations at greatest risk, or those locations having a history of RwD crashes if basic countermeasures are already in place.

SCDOT and local partners can utilize a benefit-cost analysis to determine the potential impacts of systemic deployment or for location-based deployment when consideration is given using a hot-spot based approach. Caution should be exercised when focusing on benefit-cost ratio for systemic treatments at individual locations. Some locations at high risk for future crashes may not have recently had crashes, leading to a low benefit-cost ratio. Utilization of HSM-based methods, such as the Empirical Bayes analysis will provide a better estimate of expected safety benefits; however, systemic treatment of RwD crashes using low-cost countermeasures has been shown to have high benefit-cost ratios when considered in aggregate.

To further reduce the implementation cost for countermeasure deployment, SCDOT and its local partners should consider nearby locations at high-risk and bundle those locations together for countermeasure deployment. Project bundling will allow SCDOT and its partners to address many projects with similar needs using standard and cost-effective procedures for deployment. The resulting economy of scale increases efficiency and creates the potential for cost and time savings. Additionally, SCDOT and its partners can include consideration of high-risk locations when conducting other improvements, such as pavement resurfacing, to address locations while onsite doing other work.

## FUNDING SOURCES

Since this Plan aligns closely with the existing efforts from the SHSP, it can utilize existing State funding sources for implementation efforts. Based on the five-year update cycle required for state SHSPs, it is anticipated that SCDOT's SHSP will be updated in 2025. It is important that the USCOG Plan continues to align with the SHSP to leverage safety resources. USCOG and SCDOT may choose to update this Plan in conjunction with priorities (i.e., new strategies and actions) identified with each update of the SHSP. Another consideration is aligning the timing of the update of this Plan with that of SCDOT's Long Range Transportation Plan and USCOG's Transportation Improvement Program. Aligning the timing provides an opportunity to integrate this Plan's strategies and action items into Transportation Improvement Program projects, ultimately advancing the implementation of the Plan.

### HSIP

The HSIP is a core Federal-aid program tasked with achieving a significant reduction in fatalities and serious injuries on all public roads. This data-driven program supports the SHSP by funding projects that demonstrate a high potential for return on investment, benefit-cost ratio. SCDOT administers the HSIP program for State-maintained roadways only.

### SS4A

The 2021 Bipartisan Infrastructure Law (BIL) established the SS4A Grant Program. This new discretionary program provides $5-6 billion in grants between 2022 and 2026 to support regional, local, and Tribal initiatives through grants to prevent roadway deaths and serious injuries. This Plan satisfies many of the eligibility criteria for acquiring project implementation SS4A funds and can be used as a starting point for local partners to apply for SS4A grants:

**Required Criteria**

- Does the Action Plan include all of the following?
  - Analysis of existing conditions and historical trends to baseline the level of crashes involving fatalities and serious injuries across a jurisdiction, locality, Tribe, or region.
  - Analysis of the location(s) where there are crashes, the severity, as well as contributing factors and crash types.
  - Analysis of systemic and specific safety needs is also performed, as needed (e.g., high risk road features, specific safety needs of relevant road users.
  - A geospatial identification (geographic or locational data using maps) of higher risk locations.
- Does the plan identify a comprehensive set of projects and strategies to address the safety problems identified in the Action Plan, time ranges when the strategies and projects will be deployed, and explain project prioritization criteria?
- Was the plan finalized and/or last updated between 2017 and 2022?

**Optional Criteria (4 out of 6 Elements Required)**

- Are both of the following true:
  - Did a high-ranking official and/or governing body in the jurisdiction publicly commit to an eventual goal of zero roadway fatalities and serious injuries?
  - Did the commitment include either setting a target date to reach zero, OR setting one or more targets to achieve significant declines in roadway fatalities and serious injuries by a specific date?

- To develop the Action Plan, was a committee, task force, implementation group, or similar body established and charged with the plan's development, implementation, and monitoring?
- Did the Action Plan development include all of the following activities?
  - Engagement with the public and relevant stakeholders, including the private sector and community groups.
  - Incorporation of information received from the engagement and collaboration into the plan.
  - Coordination that included inter- and intragovernmental cooperation and collaboration, as appropriate.
- Did the Action Plan development include all of the following?
  - Considerations of equity using inclusive and representative processes.
  - The identification of underserved communities through data.
  - Equity analysis, in collaboration with appropriate partners, focused on initial equity impact assessments of the proposed projects and strategies, and population characteristics.
- Are both of the following true?
  - The plan development included an assessment of current policies, plans, guidelines, and/or standards to identify opportunities to improve how processes prioritize safety; and
  - The plan discusses implementation through the adoption of revised or new policies, guidelines, and/or standards.
- Does the plan include all of the following?
  - A description of how progress will be measured over time that includes, at a minimum, outcome data.
  - The plan is posted publicly online.

### RURAL SURFACE TRANSPORTATION GRANT PROGRAM

The Rural Surface Transportation Grant Program supports projects that improve and expand the surface transportation infrastructure in rural areas. Like other BIL-related programs, this competitive funding source is intended to increase connectivity, improve the safety and reliability of the movement of people and freight, and generate regional economic growth and improve quality of life. This program will allocate $2 billion in funding over fiscal years 2022 through 2026. BIL specifies funding for rural RwD-related improvements through this program; SC is an eligible States through this program.

### REBUILDING AMERICA'S INFRASTRUCTURE WITH SUSTAINABILITY AND EQUITY (RAISE) DISCRETIONARY GRANTS

RAISE is the latest iteration of the Better Utilizing Investments to Leverage Development (BUILD) and Transportation Investment Generating Economic Recovery programs. Like SS4A, this competitive funding source supports surface transportation projects of local and/or regional significance. These projects consider:

- Safety.
- Environmental sustainability.
- Quality of life.
- Economic competitiveness and opportunity.
- Partnership and collaboration.
- Innovation.
- State of good repair.
- Mobility and community connectivity.

USDOT allocates RAISE grant funds equally between urban and rural areas.

### SURFACE TRANSPORTATION BLOCK GRANT (STBG) PROGRAM

Formally known as the Surface Transportation Program, the STBG program delivers funds designed to be flexible in their application. States and localities can use these grants for projects on any Federal-Aid eligible highway, on bridge projects for any public road, on paths for non-motorized users, or on transit capital projects. States and localities are responsible for a 20 percent share of project costs funded through this program. Systemic improvements lend themselves to incorporation as components of larger improvements. STBG-funded projects can incorporate safety elements as part of broader roadway enhancements.

### FEDERAL NHTSA GRANT FUNDING

The highway safety office in each State manages NHTSA grant funding to support enforcement, education, and emergency response activities. The purpose of this funding is to improve driver behavior and reduce deaths and injuries from motor vehicle-related crashes. State highway safety offices receive grant applications annually in early spring and NHTSA typically provides approval in July.

## EVALUATION

After installing applicable countermeasures at priority locations, it is important for USCOG and SCDOT to evaluate the effectiveness of the Plan and decision-making processes. This can be accomplished through tracking projects, measuring performance, and evaluating project and program effectiveness. The following sections provide a brief overview of each step of the process.

## PROJECT TRACKING

In order to track effectiveness, USCOG and SCDOT should track locations that have been funded and countermeasure installations that have been completed. Project documentation should include the following:

- Roadway data. This information should include the roadway characteristics, including project start and end locations and other pertinent site identification details.
- Installation details. This should include the time period when project work began and when project work was completed. This time period should be excluded from performance analysis and used as the breaking point for before and after data.
- Crash data. Three to five years of crash data for the site should be captured before installation and three to five years of crash data should be captured after installation.
- Traffic volume. Traffic volumes before and after installation should be captured to help account for changing exposure from the before to the after period.
- Site ranking criteria. Criteria used to rank the site should be captured to detail the level of risk assigned to the location. This will help support decision-making based on where the countermeasure is more or less effective.
- A short list of strategies considered, including details on how and why countermeasures were chosen or dismissed from further consideration.
- Final project cost. This detail will support economic analysis for systemic analysis and location-based analysis on the cost effectiveness of the countermeasure or safety strategy.

Projects can be grouped by countermeasure type to evaluate countermeasure effectiveness (including where it is and is not effective). Additionally, USCOG and SCDOT can combine data from countermeasures for conducting program-level evaluation on the effectiveness of safety strategies and decision-making.

## PERFORMANCE MEASURES

Using the data in the previous section, USCOG and SCDOT can track project and program implementation for the Plan. USCOG and SCDOT can track program implementation using the following measures:

- Amount of RwD safety projects completed.
- Amount of dedicated funding for RwD safety projects.
- Number of curves treated with RwD countermeasures.
- Miles of corridors treated with RwD countermeasures.
- Amount of funding dedicated to RwD education or enforcement campaigns.
- Number of RwD education or enforcement campaigns implemented.

Further, USCOG and SCDOT can track performance in terms of safety outcomes, including the following:

- Number of RwD crashes, fatalities and serious injuries by year.
- Number of fatal and serious injury wet-road or nighttime RwD crashes on corridors or curves.
- Number of fatal and serious injury head-on or opposite direction sideswipe crashes.
- Number of fatal and serious injuries related to impairment, distraction, speeding, or unbelted status.
- Change in crash frequency at countermeasure installation locations.
- Change in fatal and serious injury crash frequency at countermeasure installation locations.
- Change in crash frequency or fatal and injury crash frequency for countermeasures by specific features (e.g., AADT or horizontal curve radius).

Finally, USCOG and SCDOT can track progress through the performance tracking of safety evaluations, including the following:

- Number of simple post-implementation evaluations (such as naïve before-after analysis) performed for RwD countermeasures.
- Number of rigorous post-implementation evaluations (such as using a comparison group or empirical Bayes before-after methods) performed for RwD countermeasures.
- Number of crash modification factors developed for RwD countermeasures.

## EVALUATION METHODS

The primary method for evaluating countermeasure and program effectiveness is conducting naïve before-after evaluations for individual locations or for groups of similar countermeasures. This methodology is the most basic, does not require larger crash sample sizes, and does not require collection of comparison of reference sites for comparative analysis. Due to the systemic approach to addressing safety, regression-to-the-mean bias should be minimized (this is most commonly a concern when evaluating the effects of countermeasures installed at locations due to a recent history of high crash counts). The naïve before-after analysis can still use the change in traffic volume to adjust for differences in exposure from the before to the after period.

For countermeasures with more installation locations, USCOG and SCDOT can consider employing more rigorous before-after analysis with comparison sites or using the empirical Bayes approach. While more rigorous, these methods have been found to be more reliable for estimating the effectiveness of safety treatments to support identifying to what extent the countermeasures are effective and for which circumstances they are the most effective.

The HSM provides more details on using these methods for conducting safety effectiveness evaluations. The results of these analysis can be used to inform future decisions, such as for which circumstances countermeasures should be considered or which countermeasures may not be as effective as first thought. These analyses should be conducted periodically and continually used to update processes and decision-making procedures.

## SUMMARY

Due to recent economic improvements in the United States, the number of crashes has continued to increase. Over the last decade, the transportation profession has continued to learn more about the effectiveness of individual safety treatments and their associated effectiveness. With this added knowledge about how these countermeasures can contribute to crash reductions, this implementation Plan is intended to assist USCOG and SCDOT with determining how to target valuable safety resources in an effort to further reduce the number and severity of RwD crashes. This Plan specifically focuses on lower cost treatments that USCOG and SCDOT can deploy at numerous sites where RwD crashes are likely.

The focus of this plan is on identification of candidate countermeasures, deployment levels, and costs that collectively result in an estimated 57 annual fatal and injury crashes reduced with a corresponding 161 prevented crashes.

# REFERENCES


1. South Carolina of Transportation. *South Carolina Strategic Highway Safety Plan: Target Zero, 2020 – 2024.* South Carolina Department of Transportation. December 2020.

2. South Carolina Department of Transportation. *2022 South Carolina Highway Safety Improvement Program Annual Report*. South Carolina Department of Transportation. 2022.

3. South Carolina Department of Transportation. *Engineering Directive: Roadway Departure Mitigation Project Prioritization Process*. SCDOT Traffic Engineering. April 2017.

4. Satterfield, C., and A. Eigen. *Federal Highway Administration Focus Area Data Definitions*. Report No. FHWA-HRT-14-062, FHWA, U.S. Department of Transportation, Washington, D.C., 2014.

5. Griffith, M. Memorandum Subject: Information: Revised Data Definitions for FHWA Safety Focus Areas. Memorandum to Safety Field, FHWA, U.S. Department of Transportation, Washington, D.C., 2014.

6. South Carolina Department of Public Safety. *Distracted Driving Law*. SC DPS. 2023. Accessed at: https://scdps.sc.gov/ohsjp/DrivinginSC/distracted-driving-law#:~:text=When%20driving%3A,Section%2056%2D5%2D3890.

7. South Carolina Department of Public Safety. SC Safety Belt Law. SC DPS. 2023. Accessed at: https://scdps.sc.gov/buckleupsc/safety_belt_law#:~:text=Mandatory%20use%20of%20seat%20belt,federal%20law%20for%20its%20use.

8. Srinivasan, R., J. Baek, D. Carter, B. Persaud, C. Lyon, K. Eccles, F. Gross, and N. Lefler. *Safety Evaluation of Improved Curve Delineation*. Report No. FHWA-HRT-09-045. Federal Highway Administration, Washington, D.C., 2009.

9. Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition Including Revision 1 dated May 2012 and Revision dated May 2012*. Federal Highway Administration, Washington, D.C., 2012.

10. Smadi, O., N. Hawkins, S. Knickerbocker, S. Hallmark, and A. Pike. *Evaluation of the Sequential Dynamic Curve Warning System – Final Report*. Report No. FHWA-15-CAI-012-B. Federal Highway Administration, Washington, D.C., 2015.

11. Hallmark, S., N. Hawkins, and O. Smadi. *Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project*. Report No. FHWA-HRT-14-020. Federal Highway Administration, Washington, D.C., 2015.

12. Elvik, R. and T. Vaa. *Handbook of Road Safety Measures*. Elsevier, Oxford, United Kingdom, 2004.

13. Sun, X. and S. Das. *Safety Improvement from Edge Lines on Rural Two-Lane Highways*. Report No. FHWA/LA.11/487. Louisiana Department of Transportation, Baton Rouge, LA. 2011.

14. Tsyganov, A., R. Machemehl, N. Warrenchuck. *Safety Impact of Edge Lines on Rural Two-Lane Highways*. Report No. FHWA/TX-05/0-5090-1. Texas Department of Transportation, Austin, TX. 2005.

15. Park, E., P. Carlson, R. Porter, and C. Anderson. Safety Effects of Wider Edge Lines on Rural, Two-Lane Highways. *Accident Analysis and Prevention*. Vol. 48, 2012.

16. Lyon, C., B. Persaud, and K. Eccles. *Safety Evaluation of Wet-Reflective Pavement Markings*. Report No. FHWA-HRT-15-065. Federal Highway Administration, Washington, D.C., 2016.

17. Sun, X., and S. Das. *Developing Louisiana Crash Reduction Factors*. Report No. FHWA/LA.12/506. Louisiana Department of Transportation. Baton Rouge, LA, 2012.

18. Merritt, D., C. Lyon, and B. Persaud. *Evaluation of Pavement Safety Performance*. Report No. FHWA-HRT-14-065. Washington, D.C., 2015.

19. Merritt, D., C. Lyon, B. Persaud, and H. Torres. *Developing Crash-Modification Factors for High-Friction Surface Treatments*. Report No. FHWA-HRT-20-061. Federal Highway Administration, Washington, D.C., 2020.

20. Torbic, D., J. Hutton, C. Bokenkroger, K. Bauer, D. Harwood, D. Gilmore, J. Dunn, J. Ronchetto, E. Donnell, H. Sommer, P. Garvey, B. Persaud, and C. Lyon. N*CHRP Report 641: Guidance on the Design and Application of Shoulder and Centerline Rumble Strips.* NCHRP Report 641. Transportation Research Board, Washington, D.C., 2009.

21. American Association of State Highway and Transportation Officials. *Highway Safety Manual*. AASHTO, Washington, D.C., 2010.

22. Lyon, C., B. Persaud, and E. Donnell. Safety Evaluation of the SafetyEdge Treatment for Pavement Edge Drop-Offs on Two-Lane Rural Roads. *Presented at the 97$^{th}$ Annual*

*Meeting of the Transportation Research Board*, Paper No. 18-0673, Washington, D.C., 2018.

23. Dixon, K., E. Park, M. Brewer, L. Wu S. Geedipally, R. Srinivasan, B. Lan, C. Zegeer, S. Das, and E. Rista. *NCHRP Report 995: Guidelines for Treatments to Mitigate Opposite Direction Crashes*. Transportation Research Board, Washington, D.C., 2022.

24. FHWA. Clear Zones. FHWA. June, 2023. Accessed at: https://highways.dot.gov/safety/rwd/provide-safe-recovery/clear-zones/clear-zones

25. Stephens, L. *Barrier Guide for Low Volume and Low Speed Roads*. Report No. FHWA-CFL/TD-05-009. Federal Highway Administration Central Federal Lands Highway Division. Lakewood, CO. 2005.

26. American Association of State Highway and Transportation Officials. *Roadside Design Guide, 4th Edition*. AASHTO, Washington, D.C., 2011.

27. Avelar, R., S. Ashraf, K. Dixon, and A. Jhamb. *Developing Crash Modification Factors for Guardrails, Utility Poles, and Side-Slope Improvements*. Report No. FHWA-HRT-21-076. Federal Highway Administration. McLean, VA. 2021.

28. Graham, J., D. Harwood, K. Richard, M. O'Laughlin, E. Donnell, and S. Brennan. *NCHRP Report 794: Median Cross-Section Design for Rural Divided Highways.* NCHRP Report 794. Transportation Research Board, Washington, D.C., 2014.

29. Venkatraman, V., C. Richard, K. Magee, Batelle Memorial Institute, and K. Johnson. *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices, 10th Edition*. Report No. DOT HS 813 097. National Highway Traffic Safety Administration. Washington, D.C., 2021.

30. Kahane, C. Lives saved by vehicle safety technologies and associated Federal Motor Vehicle Safety Standards, 1960 – 2012 – Passenger cars and LTVs – With reviews of 26 FMVSS and the effectiveness of their associated safety technologies in reducing fatalities, injuries, and crashes. Report No. DOT HS 812 069. National Highway Traffic Safety Administration. Washington, D.C., 2015.