WEST VIRGINIA ROADWAY DEPARTURE SAFETY IMPLEMENTATION PLAN

Draft Plan

April 2018

Safe Roads for a Safer Future

Investment in roadway safety saves lives

Disclaimer

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The Federal Highway Administration (FHWA) and its contractor 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 of severity of roadway departure crashes and is not a directive from FHWA or the final recommendation. The countermeasures noted in the report represent one set of recommendations for West Virginia 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
AASHTO	American Association of State Highway and Transportation Officials
CMF	Crash Modification Factor / Function
FARS	Fatal Fatality Analysis Reporting System
FHWA	Federal Highway Administration
HARP	Home Access Route Program
HFST	High Friction Surface Treatment
NHTSA	National Highway Traffic Safety Administration
RwD	Roadway Departure (crash)
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
SVROR	Single Vehicle Run-off-road (crash)
WVDOT	West Virginia Department of Transportation

EXECUTIVE SUMMARY

From 2009 to 2015, roadway departure crashes in West Virginia accounted for approximately 79 percent of statewide fatal crashes, yet the percent of total crashes that occurred due to roadway departures ranged from 42 to 47 percent. In an effort to address these disproportionately high fatal crashes, the State of West Virginia initiated aggressive safety enhancement efforts. As an example, West Virginia adopted the following goal in their 2017-2021 Strategic Highway Safety Plan:

> *"To achieve a 50 percent reduction in fatalities by 2030 and a 66 percent reduction in serious injuries by 2030."*

Currently, West Virginia's five-year roadway departure goal is to continue identifying and deploying safety countermeasures that collectively will help them reach this 50 percent fatal crash reduction goal. As part of this initiative, this W*est Virginia Roadway Departure Safety Implementation Plan*, referred to as the Plan in this document, includes data analysis and recommendations for improvements targeted at reducing these severe roadway departure crashes.

The Federal Highway Administration (FHWA) and its contractor developed a data analysis package that incorporates an evaluation of the observed West Virginia roadway departure crashes and unique road characteristics that may contribute to the crashes. This Plan focuses on low cost countermeasures suitable for widespread deployment. In 2017, FHWA and critical staff from the West Virginia DOT participated a workshop where collectively the attendees helped to refine candidate safety countermeasures. Resulting from this workshop was a list of 15 prospective treatments that are the focus of this Plan.

Based on this analysis, this plan proposes treatments that collectively should result in a reduction of approximately 11 fatal crashes per year and almost 750 total crashes per year for a five-year period. The analysis used for this assessment blended predictive methods with observed crash analysis methods. The following enhancements are critical components needed to achieve this crash reduction goal:

- The traditional approach of primarily relying on major improvements at high-crash roadway departure locations should be complimented with the systematic deployment of proven lower cost treatments.
- The treatments evaluated as part of this Plan focused on roadway departure crashes. An additional way to reduce the number and severity of crashes on West Virginia highways is to similarly assess candidate countermeasures for other crash types.
- The following fifteen roadway departure countermeasures should be deployed based on a prioritization approach that optimizes construction with ongoing work efforts and

emphasizes deployment at locations where there are greater opportunities to reduce crashes:

- Center rumble stripes / strips.
- Edgeline rumble stripes / strips.
- Six-inch wide centerline pavement markings.
- Six-inch wide edgeline pavement markings.
- Lighting improvements.
- High friction surface treatments.
- Static curve warning signs (standard).
- Enhanced curve warning system.
- Utility pole relocation.
- Remove or shield tree or fixed objects.
- Culvert and ditch improvement.
- Flattening median sideslopes.
- Add barrier.
- Improve barrier.
- Install median barrier with mow strip.

This plan provides recommendations on how these safety enhancement strategies can be effectively implemented. An annual reduction of 11 fatal crashes per year requires an annual investment of more than $25 million for each of the next five years. Following deployment and maintenance of these treatments, the number of lives saved due to roadway departure crashes will continue to increase for West Virginia highways.

For additional information about the FHWA Roadway Departure Focus State Initiative, contact Joseph Cheung, FHWA Office of Safety, at joseph.cheung@dot.gov.

ROADWAY DEPARTURE SAFETY GOAL

BACKGROUND

West Virginia roadway departure (RwD) fatal crashes account for more than 79 percent of all roadway fatal crashes within the State. Total and fatal West Virginia crashes that are related to roadway departure generally account for 42 to 47 percent of the total roadway crashes (see Table 1), yet they make up from 73 to 83 percent of the total fatal crashes. In addition, data from the National Highway Traffic Safety Administration (NHTSA) 2013 Fatality Analysis Reporting System (FARS) reveals that the majority (64 percent) of fatal crashes in West Virginia are single vehicle crashes, and 73 percent of these fatal crashes involve roadway departures. Approximately 39 percent of fatal crashes also involve speeding. The rate (2.15) of rural fatal crashes per 100 million vehicle miles driven is almost twice the rate (1.13) of urban fatal crashes per 100 million vehicle miles driven. Some of the causes for these crashes include a failure to maintain control, speed, impairment, and failure to obey traffic control devices. (1)

Table 1. Total, RwD, and Fatal Crashes by Year

Year	Total Crashes			Fatal Crashes		
	RwD Crashes	Total Crashes	Percent of Annual Total (%)	Fatal RwD Crashes	Total Fatal Crashes	Percent of Annual Total (%)
2009	14,966	32,178	47	216	265	82
2010	14,522	31,994	45	203	244	83
2011	13,601	29,892	46	192	247	78
2012	11,665	26,514	44	189	242	78
2013	10,882	24,538	44	148	191	77
2014	11,382	25,285	45	138	178	78
2015	10,591	25,290	42	143	197	73
Total	**87,609**	**195,691**	**45**	**1229**	**1564**	**79**

To reduce crashes and save lives, West Virginia adopted the following goal in their 2017-2021 Strategic Highway Safety Plan (SHSP): (2)

> *"To achieve a 50 percent reduction in fatalities by 2030 and a 66 percent reduction in serious injuries by 2030."*

West Virginia's five-year RwD goal is to continue to reduce RwD fatalities by 50 percent for the target year of 2030. From 2009 to 2015, West Virginia RwD fatal crashes reduced from 216 to 143 fatal RwD crashes per year (a 34 percent reduction in RwD fatal crashes).

DEFINITION OF RWD CRASHES

A recently published Federal Highway Administration (FHWA) report titled *Federal Highway Administration Focus Area Data Definitions* provides an overview of the FHWA definition of RwD crashes.(3) 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 crashes as a single vehicle run-off-road (SVROR) crash. These agencies expanded this definition for multiple-vehicle crashes as the following collision types:

- Front-to-front.
- Front-to-side, opposite direction.
- Sideswipe, opposite direction.

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." [(4)] The single change to the coding is to remove the intersection filter. FARS defines the vast majority of RwD events as those classified with a first harmful event for any involved vehicle as:

- Ran-off-road -- right (FARs code 63),
- Ran-off-road -- left (FARs code 64),
- Cross median (FARS code 65), or
- Cross centerline (FARS code 68).

The definition further includes a number of fixed object codes based on the idea that a vehicle must depart a roadway in order to collide with an object. These first harmful event codes are represented as the FARS fixed object codes 17, 19–43, 46, 52, 53, 57, and 59).[(5)] Finally, the RwD identification definition includes three additional event codes deemed to most likely be indicative of a RwD crash:

- Vehicle went airborne (FARS code 67),
- Re-entering roadway (FARS code 69), and
- End Departure (FARS code 71).

For this effort, the West Virginia definition for RwD crashes is:

- All single vehicle non-pedestrian, non-bicycle crashes.
- Head-on crashes and sideswipe crashes where one vehicle was traveling east and another west or one vehicle was traveling north and another south.

- All other multi-vehicle crashes with a fixed object noted for Crash Event 1-3.
- No intersection crashes.
- No pedestrian or bicycle related crashes.

The basis for the West Virginia crash information included in this document is data for the seven-year period extending from 2009 to 2015. The data summarized in this report represents crashes identified as RwD events as included in the West Virginia crash database.

Approach

The goal of this Plan is to help reduce statewide RwD fatal and serious injury crashes in the State of West Virginia. 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 enhance roadway safety at locations where RwD crashes may be expected. This Plan blends traditional high-crash analysis techniques with state-of-practice predictive procedures to help identify locations where the deployment of safety treatments will provide the best opportunity to reduce these severe crashes in West Virginia.

These data driven analysis approaches use historic (observed) crash data as a key element when evaluating safety performance. The companion Data package document provides detailed information about the steps used to develop the recommended treatments included in the Plan. The procedures use the observed crash data and, where sufficient data is available, predicted crashes to estimate the opportunity to reduce crashes at target locations. The Plan documents the potential impact of these improvements in terms of reducing total RwD crashes, severe injury crashes (fatal and incapacitating crashes or "KA" collisions), and fatal (or "K").

In addition to the deployment of targeted safety treatments, West Virginia will benefit from developing additional system-wide applications as well as prioritizing effective treatments as a routine part of facility maintenance and construction.

Distribution of Roadway Departure Crashes

A review of RwD crash and injury severity data for West Virginia can help to identify insights into the distribution and characteristics of these observed crashes. As a starting point, Table 2 summarizes the individual roadway jurisdictions for West Virginia roads. The system includes a large number of low volume access roads referred to as the Home Access Route Program (HARP). These HARP facilities were not included in the data used to develop the predictive method and companion safety performance functions (SPFs) used for the detailed safety performance analysis.

Table 2. Ownership of West Virginia Roads (2016 Public Certified Mileage)

Ownership	Length (miles)
State owned highways	34,691
State owned Interstate highways	555
Federally owned roads	835
Municipal / HARP roads	3244
West Virginia Turnpike	87
National Highway System	1988

Source: http://www.transportation.wv.gov/highways/Pages/default.aspx

West Virginia road ownership includes state and federally owned or maintained facilities, municipally owned roads, and those owned and operated by the West Virginia Turnpike authority. The West Virginia road types include rural or urban facilities. Figure 1 illustrates the distribution of the roadway lengths by these three facility types. A noteworthy observation is that 86 percent of the West Virginia roads are located in rural areas. For the summary information, this Plan combines the urban cluster (population of 5,000 to 49,999) with urbanized facility types (population 50,000 and above) into one "urban" facility type. This results in analysis based on the following two facility type designations:

- West Virginia Department of Transportation (WVDOT) Rural Roadways.
- WVDOT Urban Roadways.

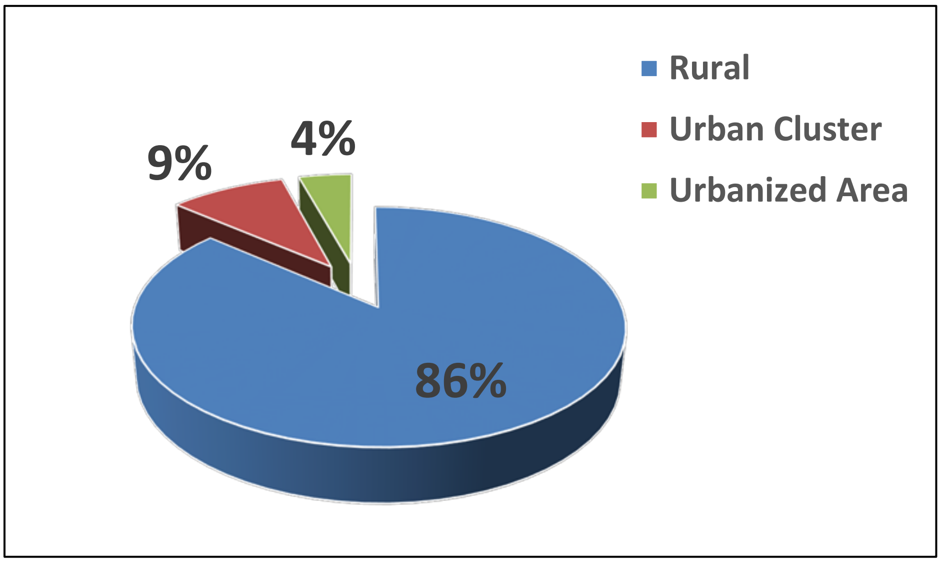

Figure 1. Distribution of Roadway Lengths by Roadway Facility Types

Table 3 summarizes the number of observed RwD crashes, by route and region type, recorded from 2009 to 2015. During this seven-year period, 36,012 of the total 87,609 RwD crashes occurred at locations identified as 'other' (referring to roads that are not Interstate, US highway system, or state routes). Of these crashes, 460 involved at least one fatal injury. The companion Data Package document contains detailed RwD crash statistics.

Table 3. RwD Crashes by Route and Region Type (2009-2015)

Route	Region Type	RwD Crashes		Fatal RwD Crashes	
		Number	Percent of Annual Total (%)	Number	Percent of Annual Total (%)
Interstate	Rural	3,667	71	39	65
	Urban	3,441	50	29	69
	Unknown	1,131	39	4	50
	Total	8,239	55	72	65
US Route	Rural	12,563	39	217	74
	Urban	3,863	28	52	55
	Unknown	1,557	39	18	69
	Total	17,983	36	287	69
State Route	Rural	18,693	46	328	83
	Urban	5,249	37	63	77
	Unknown	1,433	37	19	59
	Total	25,375	43	410	81
Others	Rural	19,841	80	307	92
	Urban	10,381	60	86	93
	Unknown	5,790	19	67	63
	Total	36,012	50	460	86
Total		**87,609**	**45**	**1229**	**79**

Note: Urban / Urbanized = population 5,000 and above.

Table 4 summarizes the collision types for RwD and total crashes by collision type. Head-on crashes made up 20 percent of the total RwD fatal crashes while 77 percent of the fatal crashes were single vehicle collisions. For additional detailed information regarding different collision types, refer to the companion Data Package document.

Table 4. RwD and Total Crashes by Collision Type (2009-2015)

Collision Type	All Crashes				Fatal Crashes			
	RwD Crashes	Total Crashes	Percent of Annual Total (%)	Percent of Total RwD Crashes (%)	Fatal RwD Crashes	Total Fatal Crashes	Percent of Annual Total (%)	Percent of Total RwD Fatal Crashes (%)
Single Vehicle Crash	72,689	77,583	94	83	946	990	96	77
Sideswipe Opposite Direction	8,451	9,203	92	10	26	26	100	2
Sideswipe Same Direction	80	12,727	1	0	0	22	0	0
Head-On	5,893	6,371	92	7	246	248	99	20
Other	496	89,807	1	1	11	278	4	1
Total	**87,609**	**195,691**	**45**	**100**	**1229**	**1564**	**79**	**100**

Note: Urban / Urbanized = population 5,000 and above.

Table 5 further identifies the crash data based on the first harmful event. Common first harmful events included hitting another motor vehicle in transport, overturning, impacting a tree, and hitting a utility pole. The first harmful event can be particularly useful when selecting candidate countermeasures, as it will help identify treatments that, if deployed, explicitly target these key conditions. The companion Data Package document contains detailed statistics regarding the first harmful event.

Table 5. RwD Crashes by First Harmful Event (2009-2015)

First Harmful Event	Region Type	Total RwD Crashes	Percent of Total Crashes (%)	Fatal RwD Crashes	Percent of Total Fatal Crashes (%)
Motor vehicle in transport	Rural	8,641	16	192	53
	Urban / Urbanized	3,641	12	44	41
	Unknown	1,706	6	21	41
	Total	13,988	13	257	50
Overturn	Rural	5,872	99	162	97
	Urban / Urbanized	1,697	98	34	94
	Unknown	894	78	17	77
	Total	8,463	96	213	95
Tree	Rural	4,417	100	149	100
	Urban / Urbanized	1,487	100	28	100
	Unknown	743	77	15	71
	Total	6,647	97	192	97
Utility pole	Rural	2,950	100	38	100
	Urban / Urbanized	1,485	100	17	100
	Unknown	583	48	5	83
	Total	5,018	89	60	98
Other	Rural	32,884	91	350	95
	Urban / Urbanized	14,624	90	107	88
	Unknown	5,985	58	50	68
	Total	53,493	85	507	90
Total		**87,609**	**45**	**1229**	**79**

Note: Urban / Urbanized = population 5,000 and above.

The presence of street lighting can help reduce the number of nighttime crashes. Table 6 depicts the distribution of RwD crashes based on lighting conditions. As shown, approximately 59 percent of the RwD crashes occurred during daytime conditions.

Table 6. RwD Crashes by Lighting Condition (2009-2015)

Lighting Condition	All Crashes				Fatal Crashes			
	RwD Crashes	Total Crashes	Percent of Annual Total (%)	Percent of Total RwD Crashes (%)	Fatal RwD Crashes	Total Fatal Crashes	Percent of Annual Total (%)	Percent of Total RwD Fatal Crashes (%)
Daylight	51,567	139,025	37	59	647	865	75	53
Dark (No Lighting)	27,458	35,284	78	31	480	559	86	39
Dark (Lighting)	4,565	14,205	32	5	52	76	68	4
Dawn	2,344	3,605	65	3	22	29	76	2
Dusk	1,618	3,437	47	2	21	28	75	2
Unknown	57	135	42	0	7	7	100	1
Total	**87,609**	**195,691**	**45**	**100**	**1229**	**1564**	**79**	**100**

As shown in Table 7, 60 percent of the total RwD crashes occurred on West Virginia roads from 2009 to 2015 when the pavement surface was dry. In fact, on average approximately 24 percent of total RwD crashes and 16 percent of fatal RwD crashes occurred during wet pavement conditions.

Table 7. RwD Crashes by Pavement Surface Condition (2009-2015)

Surface Condition	All Crashes				Fatal Crashes			
	RwD Crashes	Total Crashes	Percent of Annual Total (%)	Percent of Total RwD Crashes (%)	Fatal RwD Crashes	Total Fatal Crashes	Percent of Annual Total (%)	Percent of Total RwD Fatal Crashes (%)
Dry	52,558	135,447	39	60	963	1,222	79	78
Wet	20,726	40,166	52	24	194	250	78	16
Snow	6,319	9,143	69	7	17	22	77	1
Ice/Frost	5,466	7,121	77	6	28	33	85	2
Other	2,540	3,814	67	3	27	37	73	2
Total	**87,609**	**195,691**	**45**	**100**	**1229**	**1564**	**79**	**100**

SUMMARY OF RWD CRASH STATISTICS

Based on a review of the RwD crashes that occurred in West Virginia during a seven-year period, the following items directly influenced the recommended key components of this RwD Implementation Plan:

- The majority of RwD crashes occurred in rural regions (see Table 3).

- Single vehicle and head-on collision crash types made up the majority of fatal RwD crashes in West Virginia at approximately 97 percent of the total RwD fatal crashes (see Table 4).
- The first harmful events common to RwD crashes in West Virginia include hitting another motor vehicle in transport, overturning, colliding with a tree, and hitting a utility pole (see Table 5).
- More than 50 percent of the observed RwD crashes occurred during daytime conditions (see Table 6).
- On average, about 24 percent of total RwD crashes and 16 percent of fatal RwD crashes occurred during wet pavement conditions (see Table 7).

SUMMARY OF RWD COUNTERMEASURE DEPLOYMENTS

The WVDOT 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. Table 8 summarizes these recommended countermeasures and their associated costs. The information contained in this table represents a summary strategy matrix that identifies the individual candidate countermeasures, reviews the associated costs expected for each treatment, and summarizes the annual estimated reduction in crashes for total RwD, K, and KA collisions. Finally, Table 8 identifies the individual cost (in millions of dollars) requires to save one life each year. The intent of this strategy matrix is to identify prospective treatments to program as part of a five-year initiative.

As noted in the strategy matrix, saving 11additional lives per year will require an approximate investment of $126.3 million over the next five-year period. This is equivalent to approximately $25.3 million per year for each of the five implementation years.

Table 8. RwD Countermeasure Strategy Matrix – Five-Year Summary

Countermeasure	Unit Cost	Estimated Number of Improve-ments (Length or Unit)	Associated Cost ($ Million)	Annual Targeted RwD Crash Reduction	Annual Estimated Fatality Reduction	($ Million) Required to save one life annually
Rural Roadways						
Center rumble stripes / strips	$0.50/ft	1104	$0.75	58.34	0.93	$0.80
Edgeline rumble stripes/strips	$0.30/ft	3708	$1.59	84.75	1.38	$1.15
6" wide centerline pavement markings	$600/mi	258	$0.04	1.11	0.03	$1.51
6" wide edgeline pavement markings	$500/mi/ edge	171	$0.04	4.16	0.07	$0.61
Lighting improvements	$10,000/ unit	4270	$5.49	122.00	2.33	$2.35
High friction surface treatment	$35/sy	94.4	$16.52	33.93	0.42	$39.02
Static curve warning sign (standard)	$750/ location	142	$0.16	55.71	0.91	$0.18
Enhanced curve warning system	$3,000/ location	51.5	$0.16	12.18	0.20	$0.82
Utility pole relocation	$3,000/ unit	505	$0.50	20.91	0.27	$1.84
Remove or shield tree or fixed objects	$3,000/ location	962	$1.15	68.71	1.83	$0.63
Culvert and ditch improvement	$1,000/ location	1015	$0.33	72.51	0.44	$0.75
Flattening median sideslopes	$150/ft	14	$3.28	0.86	0.02	$137.69
Add barrier	$700,000/ mi	172	$36.02	3.92	0.10	$344.92
Improve barrier	$700,000/ mi	102	$11.25	4.80	0.03	$352.25
Install median barrier with a mow strip	$700,100/ mi	18	$3.63	1.67	0.05	$78.65
Subtotal for Rural Roads (5 year cost)			**$80.90**	--	--	--
Subtotal for Rural Roads (yearly cost)			**$16.18**	**109.12**	**1.80**	**$8.98**
Urban Roadways						
6" wide centerline pavement markings	$600/mi	6894	$0.54	29.55	0.39	$1.36
6" wide edgeline pavement markings	$500/mi/ edge	4990	$0.24	121.19	1.22	$0.20
Lighting improvements	$10,000/ unit	248	$2.48	7.07	0.10	$24.93
High friction surface treatment	$35/sy	70.8	$12.39	25.78	0.20	$60.81
Utility pole relocation	$3,000/ unit	63	$0.25	2.62	0.03	$8.44

Table 8. RwD Countermeasure Strategy Matrix – Five-Year Summary (continued)

Countermeasure	Unit Cost	Estimated Number of Improve-ments (Length or Unit)	Associated Cost ($ Million)	Annual Targeted RwD Crash Reduction	Annual Estimated Fatality Reduction	($ Million) Required to save one life annually
Remove or shield tree or fixed objects	$3,000/ location	107	$0.50	7.64	0.09	$5.50
Culvert and ditch improvement	$1,000/ location	90	$0.14	6.46	0.02	$5.99
Add barrier	$700,000/ mi	17	$18.23	0.38	0.00	$4,066.58
Improve barrier	$700,000/ mi	16	$10.65	0.76	0.00	$6,114.11
Subtotal for Urban Roads (5 year cost)			**$45.42**	**--**	**--**	**--**
Subtotal for Urban Roads (yearly cost)			**$9.08**	**40.29**	**0.41**	**$22.02**
Grand Total for Rural and Urban Roads (5 year cost)			**$126.31**	**747.02**	--	--
Grand Total for Rural and Urban Roads (yearly cost)			**$25.26**	**149.40**	**2.21**	**$2.28**

The companion Data Analysis package (see Appendix A) documents the development of the countermeasure recommendations as presented in the Strategy Matrix. The Data Analysis package also includes information related to the development of the West Virginia safety performance functions for rural and urban two-lane roadways. Appendix B is an Excel file that summarizes and ranks the individual highway sections suitable for countermeasure deployment.

First Key Actions

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 Implementation Plan should be presented to the West Virginia DOT leadership including representatives from the District Offices, Maintenance Division, Engineering Division, Traffic Engineering Division, Materials Control Soils and Testing Division, Planning Division, and Programming Division. 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.
- 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, the DOT should identify and program safety treatments typically deployed as part of maintenance, design, and operations activities.
- Due to the large number of RwD crashes occurring on rural roads, a successful implementation of RwD safety treatments should consider some systemic applications of safety treatments for these facilities. Though the Plan identified candidate locations for centerline and edgeline rumble strips, as an example, consideration should be given to widescale deployment of these and similar countermeasures that will provide uninterrupted treatments along entire corridors.
- In order to assess Plan effectiveness, West Virginia should explore ways to track performance before and after treatment deployment. This approach will enable identification of additional future cost effective treatments with known safety performance.

Components of Plan for Selecting Treatment Types and Thresholds

Where feasible, methods that collectively consider road types and their unique characteristics provide more reliable results than techniques that limit the analysis only to observed crashes at select locations. Consequently, this Plan recommends the following analysis methods to help West Virginia enhance their aggressive ongoing safety initiatives:

- Predictive safety assessment method for facilities where a RwD safety performance function is available. For the West Virginia Plan, the RwD crash data is sufficient for the development of a total RwD safety performance function to develop predictive equations for rural two-lane and urban two-lane roadways. The resulting predictive approach enables an analysis that weights the observed crashes with statistically developed predicted crashes for an overall expected crash number. This expected number of crashes (before deployment of a treatment) can then be used, in conjunction with industry developed crash modification factors specifically focused on RwD crashes, to calculate the estimated reduction in the total number of RwD crashes (after treatment).
- For locations where RwD safety performance functions are not feasible or where a suitable CMF for RwD crashes is not available, the Plan incorporates traditional safety assessment techniques that rely on observed crashes at known high-crash locations.
- Many opportunities exist for the system-wide deployment of safety treatments. For example, the systemic construction of a SafetyEdge treatment may occur as part of a resurfacing or shoulder improvement project. The estimated RwD safety benefits included in this Plan do not directly address West Virginia systemic treatments commonly deployed as a matter of policy.

Review of Low-Cost Countermeasures for WVDOT 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 West Virginia. This initiative involves the identification of several potential low-cost, effective countermeasures targeted for the reduction of RwD crashes along West Virginia highway 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. These treatments evaluated in this Plan are as follows:

- Keep Vehicles on Roadway
    - Center rumble stripes / strips.
    - Edgeline rumble stripes / strips.

- Six-inch wide centerline pavement markings.
    - Six-inch wide edgeline pavement markings.
    - Lighting improvements.
    - High friction surface treatments.
    - Static curve warning signs (standard).
    - Enhanced curve warning system.
- Provide for a Safe Recovery Area
    - Utility pole relocation.
    - Remove or shield tree or fixed objects.
    - Culvert and ditch improvement.
    - Flattening median sideslopes.
- Reduce Crash Severity
    - Add barrier.
    - Improve barrier.
    - Install median barrier with mow strip.

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 recent extensive safety initiatives in West Virginia, the WVDOT may have constructed safety treatments at some of the identified locations. Consequently, this Plan further notes that WVDOT personnel 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.

The analysis summarized in this Plan assesses roadways divided into two-mile segments. In many cases, the roadway section exceeds two miles in length. For these locations, the analysis included in this Plan further divided these study corridor section. Similarly, many roadway segments are considerably shorter than the targeted two-mile threshold. Study segments, for the purposes of this analysis, represent corridor lengths that are greater than or equal to 0.1 miles in length and up to and including two-mile roadway sections. Though the Plan may identify a segment as a high crash corridor while excluding an adjacent study location, it is recommended that WVDOT personnel **assess upstream and downstream locations during the site visit** to determine if the limits of the countermeasure application should be extended based on similar road conditions at these adjacent locations.

Overview of Individual Countermeasure Analysis

Table 9 provides an overview of the individual countermeasures and associated assessment techniques used for the safety analysis included in this Plan. The road types represented in the analysis include:

- Rural two-lane highways.
- Rural multilane highways.
- Urban two-lane highways.
- Urban multilane highways.

A West Virginia RwD safety performance function is available for the rural and urban two-lane highways. The multilane highways did not have sufficient traffic volume or RwD crashes for the development of stable, statistically reliable RwD safety performance functions. For these facilities, the Plan uses observe crash data exclusively.

Also as shown in Table 9, some facility types are not candidates for a specific treatment. For example, the placement of rumble strips in urban areas is generally discouraged due to the additional noise generated by these treatments. The toolbox of potential treatments, included in Chapter 3 of this Plan, further identifies these treatment constraints where applicable.

For the two-lane roadways where the safety performance functions are available, the Plan uses safety performance functions for total RwD crashes and then weights them with the observed crashes to estimate the expected number of RwD crashes prior to the application of a treatment. This method is more reliable than the traditional approach that only uses observed crashes, as the safety performance function considers all similar road types in the evaluation. This number of expected crashes represents the "before" condition. For the multilane highways where safety performance functions are not available, the number of observed crashes only is used to represent the "before" condition. These "before" values can then be adjusted with a crash modification factor to estimate the "after" treatment condition number of crashes. A description of this analysis approach is included in more detail in the companion Data Package document for this Plan. Table 9 depicts the more reliable predictive method analyses with a "P" indicator. The table further identifies assessments based solely on observed crashes by an "O" indicator.

In some cases, a crash modification factor may not be applicable for the total RwD crash condition. For these treatments, the observed crash assessment method may also be used. As an example, the crash modification factor for improving lighting relies on nighttime-only conditions rather than the total RwD value. The companion Data Package provides additional detail about the safety performance functions and their use for the underlying safety assessment.

Table 9. List of Assessment Techniques Used

No.	Countermeasure Strategy	Rural Two-Lane	Rural Multilane	Urban Two-Lane	Urban Multilane
1	Center Rumble Stripes/Strips	P	O [undivided only]	NA	NA
2	Edgeline Rumble Stripes/Strips	P	O	NA	NA
3	6” Wide Centerline Pavement Markings	P	NA	P	NA
4	6” Wide Edgeline Pavement Markings	P	NA	P	NA
5	Lighting Improvements	O [dark – not lighted]	O [dark – not lighted]	O [dark – not lighted]	O [dark – not lighted]
6	High Friction Surface Treatment	P	O	P	O
7	Static Curve Warning Sign (Standard)	P	O	NA	NA
8	Enhanced Curve Warning System	P	O	NA	NA
9	Utility Pole	O [pole crashes only]	O [pole crashes only]	O [pole crashes only]	O [pole crashes only]
10	Remove or shield tree or fixed objects	O [fixed object crashes only]	O [fixed object crashes only]	O [fixed object crashes only]	O [fixed object crashes only]
11	Culvert and Ditch Improvement	O [culvert and ditch crashes only]	O [culvert and ditch crashes only]	O [culvert and ditch crashes only]	O [culvert and ditch crashes only]
12	Flattening Median Sideslopes	NA	O [overturn and no barrier in median]	NA	O [overturn and no barrier in median]
13	Add Barrier	O [no barrier and fixed object crash]	O [no barrier and fixed object crash]	O [no barrier and fixed object crash]	O [no barrier and fixed object crash]
14	Improve Barrier	O [barrier present]	O [barrier present]	O [barrier present and fixed object crash]	O [barrier present and fixed object crash]
15	Install Median Barrier with a mow strip	NA	O [overturn and no median barrier	NA	NA

P = predictive method (weights observed crashes and predicted crashes for an expected number of crashes)
O = based on observed crashes
NA = not applicable for road type considered

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 West Virginia highways. For the purposes of this Plan, the data supports the countermeasures presented in this chapter. The recommended countermeasures include proven treatments and treatments actively deployed on West Virginia highways during recent safety initiatives during the spring of 2017. The exact locations of these safety treatments, at the time of Plan development, were unknown. Consequently, the Plan recommends that WVDOT first assess the individual ranked sites to identify and remove locations that were the focus of recent safety enhancement projects.

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 WVDOT representatives will need to make additional refinements based on unique field conditions. The following summaries review each potential safety treatment as it relates to West Virginia applications.

Centerline Rumble Stripes / Strips

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. Figure 2 shows an example of a rumble stripe where the placement of the pavement marking occurs directly on the rumble strip (making it a rumble stripe). Table 10 provides a typical value for a crash modification factor for head-on and sideswipe crashes based on the application of centerline rumble stripes/strips for rural two-lane highways. The study included data from Minnesota, Pennsylvania, and Washington as documented in NCHRP Report 641.

Figure 2. Centerline Rumble Stripe

Table 10. Centerline Rumble Stripes/Strips CMF Values

Facility Type:	Rural two-lane highway	Crash Severity:	All
Crash Type:	Head-on & Sideswipe	CMF:	0.63
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=3355 *Note: A CMF for rural multilane undivided facilities is not available, so the 0.63 value applied to rural multilane facilities as well.*			

In West Virginia, the centerline rumble stripes/strips can be applied to rural two-lane as well as rural undivided multilane highways. The placement of a milled centerline rumble stripe/strip requires full depth pavement so that the construction of the treatment does not undermine the integrity of the roadway. Raised profile treatments, though effective, do not typically perform well during snow removal activities and may not be optimal for West Virginia roadways. Centerline rumble stripes/strips can only be considered for West Virginia facilities if the **overall pavement width is 16 feet or greater**. The placement of a centerline rumble stripe is dependent on the presence of centerline pavement marking.

The application of a centerline rumble strip is not recommended for highways with pavement widths less than 16 feet; therefore, the analysis used to identify candidate sites excluded very narrow roads, only included undivided roads, and excluded urban facilities. The Appendix B spreadsheet summarizes potential sites where a centerline rumble strip may be considered. The Plan ranks the sites based on how much the observed number of crashes exceeded the expected number of crashes for each location based on the predictive method.

Table 11 summarizes the approximate length of improvements, associated treatment costs, and anticipated reduction in crashes estimated to result from the placement of centerline rumble stripes/strips. The Plan for deploying recommended centerline rumble stripe/strip applications is expected to reduce total crashes by approximately 58 crashes per year. This crash reduction also equates to approximately seven to eight serious injury or fatal crashes each year. Prior to deployment of this treatment, WVDOT personnel should conduct a site inspection to confirm that this treatment is suitable and is not already present at the subject location.

Table 11. Estimated Crash Reductions for Centerline Rumble Strips at Undivided Facilities

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Type K per 100 Crashes	Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	79.3	$0.21	2.72	12.53	16.8	0.45	2.11
Rural multi-lane	203.2	$0.54	2.72	12.53	41.6	1.13	5.21
Total	282.5	$0.75	-	-	58.4	1.58	7.32

Notes:

- For installing centerline rumble strips at locations with opposite direction sideswipe and head-on crashes, assumes improvement of 50% of identified locations.
- Cost estimates based on $0.50/ft.
- CMF value of 0.63 used for installing centerline rumble strips.
- For two-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes (using predictive analysis). For rural multilane facilities, the analysis utilized a crash level threshold of four crashes due to rollover/overturn within a 7-year period.

Suggested implementation is as follows:

1. A statewide database for existing centerline rumble stripes/strips is not available. Consequently, the Plan assumes that these rumble strips are not present. Prior to initiating improvement projects, WVDOT staff should inspect the candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes that only 50 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption. As part of the field evaluation, WVDOT should confirm the minimum pavement width of 16 ft for each site.

2. The recommended application for centerline rumble stripes/strips is restricted to undivided roadways at rural locations only; however, it is possible that facilities classified as urban could be potential candidates for future centerline rumble stripes/strips. The rural locations are ranked in the Appendix B spreadsheet and should be used as a starting point for programming future improvement sites. WVDOT staff may want to explore the potential for deploying this treatment at select urban locations where the noise generated by the rumble stripes/strips will not adversely impact the property owners along the corridor.

EDGELINE RUMBLE STRIPES / STRIPS

Edgeline 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 3 depicts roadways with example edgeline/shoulder rumble stripe/strip applications. Table 12 summarizes known safety performance for edgeline rumble stripes/strips.

Edgeline Rumble Stripe

Edgeline/Shoulder Rumble Strip

Figure 3. Edgeline Rumble Stripe/Strip

Table 12. Edgeline Rumble Stripes/Strips CMF Values

Facility Type:	Rural two-lane highway	Crash Severity:	All severity levels
Crash Type:	Run-off-road	CMF:	0.84
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=3442#commentanchor *Note: A CMF=0.84 assumed for rural multilane highways applications as well.*			

This treatment is appropriate for rural West Virginia two-lane highways with a **pavement width of 18 ft or greater or for rural multilane highways**. To be effective, the placement of milled edgeline rumble stripes/strips requires full depth pavement so that the construction of the treatment does not undermine the integrity of the roadway. Raised profile treatments, though effective, do not typically perform well during snow removal activities and may not be optimal for West Virginia. The WVDOT Standard Detail PVT 2 contains additional information about the application of edgeline rumble strips.

West Virginia currently does not have an available safety performance function for rural multilane RwD crashes. Consequently, the site identification conducted for this effort utilized blended safety assessment methods. For rural two-lane locations, the Plan used predictive safety assessment methods to identify candidate sites where the number of observed crashes exceeds the expected number of crashes for each site. For the rural multilane locations (where the safety performance function is not available), the analysis is based on crash history (i.e. observed crashes) only. Candidate sites for the observed crash assessment approach include sites with applicable crash types and ranks these sites from most crashes to fewest crashes. This information is expanded upon in the Appendix A summary. Table 13 summarizes a proposed improvement plan for edgeline rumble stripe/strip application. The Plan for deploying the recommended edgeline rumble stripe/strip applications is expected to reduce total crashes by approximately 85 crashes per year. This crash reduction also equates to approximately seven serious injury or fatal crashes each year. Prior to deployment of this treatment WVDOT personnel should conduct a site inspection to confirm that this treatment is suitable and is not already present at the subject location.

Table 13. Estimated Crash Reductions for Edgeline Rumble Stripes/Strips at Rural Locations

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment: Annual Targeted Crash Reduction	After Treatment: Annual Estimated K Crash Reduction	After Treatment: Annual Estimated KA Crash Reduction
Rural 2-lane	3.4	$0.01	1.63	7.90	0.37	0.01	0.03
Rural divided multilane	212.3	$1.35	1.63	7.90	55.53	0.90	4.39
Rural undivided multilane	74.6	$0.24	1.63	7.90	28.86	0.47	2.28
Total	290.3	$1.59	-	-	84.75	1.38	6.69

Notes:

- For installing edgeline rumble stripes/strips at locations with RwD crashes, assumes improvement of 50% of identified locations.
- Cost estimates based on $0.30 per ft. Edgeline rumble strips assumed to have four applications at divided locations and only two applications at undivided locations. Assuming a cost of $0.30 per ft this is equivalent to $3168 per mi for rural 2-lane and rural undivided multilane highways and a cost equivalent to $6336 per mi for rural divided multilane highways.
- CMF value of 0.84 used for installing edgeline rumble stripes/strips.
- For two-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes (using predictive analysis). For rural multilane facilities, analysis based on a crash level threshold of four related RwD crashes within a 7-year period.

Suggested implementation is as follows:

1. A statewide database for existing edgeline rumble stripes/strips is not available. Consequently, the Plan assumes that these rumble strips are not present. Prior to initiating improvement projects, WVDOT should inspect the candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes that only 50 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption. As part of the field evaluation, WVDOT staff should confirm the minimum pavement width of 18 ft for each site.

2. The recommended application for edgeline rumble stripes/strips is restricted to roadways at rural locations only; however, it is possible that facilities classified as urban could be potential candidates for future centerline rumble stripes/strips. The rural locations are ranked in the Appendix B spreadsheet and should be used as a starting point for programming future improvement sites. WVDOT staff may want to explore the potential

for deploying this treatment at select urban locations where the noise generated by the rumble stripes/strips will not adversely impact the property owners along the corridor.

SIX-INCH WIDE CENTERLINE PAVEMENT MARKINGS

The application of standard as well as wider pavement marking can help to provide positive guidance to the driver so that he or she does not deviate from the active travel lane. This treatment can be constructed individually (just a centerline) or in conjunction with wider edgeline pavement markings (resulting in centerline and edgeline pavement markings). The application can occur at rural as well as urban locations.

Figure 4. Six-inch Centerline Pavement Markings

Table 14 demonstrates that the use of a wider centerline pavement marking does marginally reduce crashes (by approximately three percent). The treatment, however, in conjunction with companion pavement marking, is likely to help further reduce the number of crashes. The available CMF values primarily target all crashes on rural two-lane highways.

Table 14. Six-Inch Wide Centerline Pavement Marking CMF Values

Facility Type:	Rural two-lane highway	Crash Severity:	All severity levels
Crash Type:	All	CMF:	0.97
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=83# *Note: A CMF for RwD crashes or for Urban roads is not available, so the 0.97 CMF is used.*			

West Virginia applies centerline pavement marking routinely at locations where the roads are 22 ft or wider. For roads that are narrower than 16 ft, West Virginia does not typically install a centerline stripe. Consequently, West Virginia, as part of routine maintenance activities, can program a systemic application of wider centerline pavement markings at these existing locations with that currently have centerline pavement marking. Due to these boundary conditions, the recommended West Virginia highway locations that are suitable candidates for this treatment as part of this Plan are facilities with **pavement widths greater than or equal to 16 ft but less than 22 ft**.

The Appendix B spreadsheet summarizes potential sites where a wider centerline pavement marking may be considered. The Plan ranks the sites based on how much the observed number of crashes exceeded the expected number of crashes for each location using the predictive safety assessment approach. This information is expanded upon in Appendix A. Table 15 summarizes the proposed improvement plan for six-inch centerline pavement marking applications. The Plan for deploying the recommended six-inch centerline pavement marking is expected to reduce total crashes by approximately 31 crashes per year. This crash reduction also equates to a reduction of two to three serious injury or fatal crashes each year.

Table 15. Estimated Crash Reductions for Six-Inch Wide Centerline Pavement Markings at Rural Locations

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment: Annual Targeted Crash Reduction	After Treatment: Annual Estimated K Crash Reduction	After Treatment: Annual Estimated KA Crash Reduction
Rural 2-lane	63.0	$0.04	2.26	9.44	1.11	0.03	0.10
Urban 2-lane	349.0	$0.21	1.33	7.67	29.55	0.39	2.26
Total	412.0	$0.25	-	-	30.65	0.42	2.37

Notes:

- Rural and urban 2-lane roadways considered for this evaluation must have a pavement width of 16 ft up to but not including 22 ft. Facilities equal to or wider than 22 ft should maintain centerline pavement marking as a standard maintenance activity.
- For installing 6” wide centerline pavement markings at identified locations, the Plan assumes improvement of 50% of identified locations.
- Cost estimates based on $600 per mi.
- CMF value of 0.97 used for installing 6” wide centerline stripes.
- For these 2-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes during the most recent seven year period (using predictive analysis).

Suggested implementation is as follows:

1. The recommended application for the six-inch wide centerline marking is assumed to apply to existing roads with pavement widths greater than or equal to 16 ft but less than 22 ft. The identified sites are based on the assumption that these narrower roads do not currently include similar centerline pavement marking. Prior to initiating improvement projects, WVDOT staff should inspect the candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes that only 50 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption.

2. The recommended application for wide centerline pavement marking will be applied to undivided highways. Because West Virginia routinely stripes roads with a width of 22 ft or greater, the WVDOT may want to consider expediting this treatment by linking this task to the routine maintenance activity. For locations subject to routine maintenance, the striping of these narrower roads could be scheduled sequentially or concurrently while

the equipment is in the region. The recommended (ranked) sites are included in the Appendix B spreadsheet and should be used as a starting point for programming future improvement sites.

Six-inch Wide Edgeline Pavement Markings

The goal of an edgeline is to help delineate the edge of the roadway and ultimately minimize or reduce RwD crashes. The use of six-inch wide edge lines will further emphasize the edges of the travel area. Edgelines are appropriate at locations that also have centerline marking if the width of the road is sufficient to support motor vehicle travel in two directions. The application of edgelines can occur at rural as well as urban locations, though engineers often design urban roadways with raised curb so that the curb line is used for roadway edge delineation in lieu of an edgeline pavement marking.

Figure 5. Six-inch wider Edgeline Pavement Markings

Table 16 demonstrates that the use of a wider edgeline pavement marking helps to reduce single vehicle crashes by approximately 17 percent. The available CMF values primarily target all single vehicle crash types, though most of the related research has focused on rural two-lane highways.

Table 16. Six-Inch Wide Edgeline Pavement Marking CMF Values

Facility Type:	Rural two-lane highway	Crash Severity:	All severity levels
Crash Type:	Single Vehicle	CMF:	0.83
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=4736# and http://www.cmfclearinghouse.org/detail.cfm?facid=4737# *Note: A CMF for RwD crashes or for Urban roads is not available, so the CMF=0.83 (RwD crashes) has been used for these facilities. This CMF value estimates a 17 percent reduction in crashes following application of the edgeline treatment.*			

West Virginia routinely positions edgeline pavement marking for roads that are 22 ft or wider. Consequently, this proposed countermeasure targets two-lane highways in West Virginia for which the **pavement width is greater than or equal to 18 ft but less than 22 ft**.

The Appendix B spreadsheet summarizes potential sites where a wider edgeline pavement marking may be considered. The Plan ranks the sites based on how much the observed number of crashes exceeded the expected number of crashes for each location using the predictive safety assessment approach. This information is expanded upon in the Appendix A summary. Table 17 summarizes a proposed improvement plan for six-inch edgeline pavement marking applications. The Plan for deploying the recommended six-inch edgeline pavement marking is expected to reduce total crashes by approximately 125 crashes per year. This crash reduction also equates to a reduction of approximately eight serious injury or fatal crashes each year.

Table 17. Six-Inch Wide Edgelines at Two-Lane Road Locations – Based on Expected Number of RwD Crashes (18’ ≤ Pavement Width < 22’)

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	41.0	$0.04	1.63	7.90	4.16	0.07	0.33
Urban 2-lane	239.5	$0.24	1.00	5.93	121.19	1.22	7.19
Total	280.5	$0.28	-	-	125.35	1.28	7.52

Notes:

- Rural and urban 2-lane roadways considered for this evaluation must have a pavement width of 18 ft up to but not including 22 ft. Facilities wider than 22 ft should maintain edgeline pavement marking as a standard maintenance activity.
- For installing 6” wide edgeline pavement markings at locations with RwD crashes, assumes improvement of 50% of identified locations.
- Cost estimates based on $500 per mile per edge. For edgelines there are two edges and so the cost per mile of $500 should be doubled if the line is positioned on both sides (i.e. resulting in $1000 per mile).
- CMF value of 0.83 used for installing 6” wide centerline stripes.
- For these two-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes during the most recent seven year period (using predictive analysis).

Suggested implementation is as follows:

1. The recommended application for the six-inch wide edgeline marking is assumed to apply to existing roads with pavement widths greater than or equal to 18 ft but less than 22 ft. The identified sites are based on the assumption that these narrower roads do not currently include similar edgeline pavement marking. Prior to initiating improvement projects, WVDOT staff should inspect the candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes

that only 50 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption.

2. If West Virginia staff elect to stripe centerline markings (as recommended in the previous treatment summary), the agency should consider combining the centerline and edgeline pavement marking treatments at selected locations to elevate safety performance of these combined treatments.

3. Because West Virginia routinely stripes roads with a width of 22 ft or greater, the WVDOT may also want to consider expediting this treatment by linking this task to the routine maintenance activity. For locations subject to routine maintenance, the striping of these narrower roads could be scheduled sequentially or concurrently while the equipment is in the region. The recommended (ranked) sites are included in the Appendix B spreadsheet and should be used as a starting point for programming future improvement sites.

LIGHTING IMPROVEMENTS

The strategic positioning of streetlights at critical locations, such as intersections or sharp horizontal curves (as depicted in Figure 6), 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.

Figure 6. Adding Lighting Improvements at Key Isolated Locations

Table 18 demonstrates that the addition of lighting improvements reduces nighttime crashes by approximately 17 to 28 percent. The available CMF values primarily target nighttime crashes for all roadway facilities.

Table 18. CMF Values for Lighting Improvements

Facility Type: All	Crash Severity: ABC and O
Crash Type: Nighttime	CMF: 0.72 (ABC Severity) 0.83 (O Severity) [Used a CMF value of 0.80]
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=192 and http://www.cmfclearinghouse.org/detail.cfm?facid=193 *Note: An overall CMF for all severity levels of nighttime crashes is not available, so a combined CMF=0.80 is assumed for this purpose. In addition, the CMF is applicable to nighttime crashes only and not intended for all RwD crashes.*	

The Appendix B spreadsheet summarizes potential sites where lighting improvements may be considered. The Plan ranked sites based on the frequency of observed crashes during nighttime conditions where supplemental lighting was not available. This information is expanded upon in the Appendix A summary. Table 19 summarizes a proposed plan for lighting improvements. The Plan for deploying supplemental lights is expected to reduce nighttime crashes by approximately 129 crashes per year. This crash reduction also equates to a reduction of approximately nine to ten serious injury or fatal crashes each year.

Table 19. Lighting Improvements – RwD Nighttime Crashes with No Lighting

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	709.3	$4.52	1.91	7.39	100.46	1.92	7.42
Rural multi-lane	133.3	$0.97	1.91	7.39	21.54	0.41	1.59
Urban 2-lane	264.5	$1.84	1.40	6.19	5.25	0.07	0.32
Urban multi-lane	76.8	$0.64	1.40	6.19	1.83	0.03	0.11
Total	1183.9	$7.96	-	-	129.07	2.43	9.45

Notes:

- For lighting installation or improvements, assumes improvement of 40% of identified locations.
- Cost estimates based on $10,000 per location and assume a typical section has a length on average of 1.5 miles.
- CMF value of 0.80 used for lighting improvements.
- Based on a crash level threshold of 4 crashes into a utility pole or light support within a 7-year period.

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 it to determine if and where lighting can be supported by solar power versus hardwired electrical power. For rural locations that require physical electrical wiring, WVDOT should inspect the sites to determine how or if this service can be provided. Prior to initiating improvement projects, WVDOT staff should inspect the candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes that only 40 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption.

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. WVDOT 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, WVDOT should finalize specifications for the lights and determine suitable locations based on the ranked sites included in the Appendix B spreadsheet.

HIGH FRICTION SURFACE TREATMENTS

High Friction Surface Treatment 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 intersection and sharp horizontal curve locations where standing water is likely to occur. This application then results in enhanced skid resistance and helps vehicles maintain their path at critical locations.

Figure 7. High Friction Surface Treatment

Table 20 notes that High Friction Surface Treatments have shown impressive safety-related results; however, a mature and fully vetted crash modification factor still needs to be developed. Consequently, the observed crash reductions that range from 57 up to 90 percent conservatively support a crash modification value of 0.70.

Table 20. CMF Values for High Friction Surface Treatments

Facility Type:	All	Crash Severity:	All
Crash Type:	All crashes at high risk locations (see discussion below)	CMF:	0.70
Additional Information: https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/high_friction/ *Note: An overall CMF for high friction surface treatment is preliminary. This relatively new treatment type has already proven to be effective, but studies are currently underway to better quantify the safety effectiveness. By its nature, the typical application of a high friction surface treatment is at a high crash location (often one characterized by horizontal curve geometry and marginal surface drainage). Studies report remarkable results including crash reductions by as much as 57 to 90 percent. One cited study at the FHWA link above notes that this treatment can reduce crashes by approximately 31 percent. Consequently, this Plan uses a conservative value of CMF=0.70.*			

West Virginia currently does not have an available safety performance function for rural multilane RwD crashes. Consequently, the site identification conducted for this effort utilized blended safety assessment methods to identify candidate sites where the number of observed crashes exceeds the expected number of crashes for each site. For the rural multilane locations (where the safety performance function is not available), the analysis is based on crash history (i.e. observed crashes) only. Candidate sites for the observed crash assessment approach include sites with applicable crash types and ranks these sites from most crashes to fewest crashes. These ranked sites are included in the Appendix B spreadsheet. Appendix A expands upon this information.

Table 21 summarizes a proposed improvement plan for High Friction Surface Treatment applications for West Virginia facilities. The Plan for deploying the recommended High Friction Surface Treatment applications is expected to reduce total crashes by approximately 60 crashes per year. This crash reduction also equates to approximately three to four serious injury or fatal crashes each year.

Table 21. High Friction Surface Treatment – Based on Predicted (Two-lane roads) and Observed (Multilane roads) RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	37.6	$4.83	1.25	6.28	11.37	0.14	0.71
Rural multi-lane	54.0	$11.69	1.25	6.28	22.56	0.28	1.42
Urban 2-lane	25.2	$3.78	0.79	4.44	8.60	0.07	0.38
Urban multi-lane	46.5	$8.61	0.79	4.44	17.18	0.14	0.76
Total	163.3	$28.91	-	-	59.71	0.63	3.28

Notes:

- For the installation of high friction surface treatments, assumes improvement of 40% of identified locations.
- Cost estimates based on $35 per square yard with an assumed typical application that is 30 feet wide and 1500 feet long. Only one application assumed per location.
- CMF value of 0.70 used for high friction surface treatment improvements.
- For two-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes (using predictive analysis). For rural multilane locations, the analysis is based on observed crashes and assumed a crash level threshold of 3 crashes due to RwD crashes that occurred during wet conditions at horizontal curves within a 7-year period.

Suggested implementation is as follows:

1. The application of a High Friction Surface Treatment, as identified in this Plan, focuses on locations with sharp horizontal curvature where drainage and geometry may adversely influence roadway friction. This pavement treatment is only a viable option at locations where the existing pavement surface is in good condition and will function as a stable surface for application of the associated binder and high quality calcined bauxite aggregate treatment. The sites included in the Appendix B recommendations are based on locations with sharp horizontal curvature that are likely to be subject to standing water. WVDOT staff should examine additional information about the existing pavement surface condition and associated friction measurements prior to refining the list of candidate locations. Prior to initiating improvement projects, WVDOT should inspect the

candidate sites and confirm that the sites are viable options for this treatment. To overcome this potential limitation, the Plan assumes that only 40 percent of the identified locations can be addressed. Following the site inspections, WVDOT may elect to adjust this assumption. As part of the field evaluation, WVDOT staff should confirm the existing pavement surface is in good condition and can support this pavement treatment application.

2. The recommended application for high friction surface treatments includes rural and urban facilities; however, as WVDOT prioritizes improvements it is important to consider the approach speed and available friction at a facility. WVDOT staff should further consider these thresholds when prioritizing sites for improvements and this assessment may ultimately provide greater emphasis on isolated high-speed rural locations. The candidate rural and urban locations are ranked in the Appendix B spreadsheet based on crash history and/or horizontal curvature and should be used as a starting point for programming future improvement sites.

STATIC CURVE WARNING SIGN (STANDARD)

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.

Figure 8. Application of Curve Warning Signs

Table 22 indicates that deployment of static curve warning signs reduce crashes from 30 up to 44 percent. For conservative applications that encompass rural two-lane highways, the Plan analysis used a crash modification factor of 0.70.

Table 22. CMF Values for Static Curve Warning Signs

<table>
<tr><td>Facility Type:</td><td>Not specified</td><td>Crash Severity:</td><td>ABC</td></tr>
<tr><td>Crash Type:</td><td>Varies</td><td>CMF:</td><td>Varies ranging from 0.56 (run off road) up to 0.70</td></tr>
<tr><td colspan="4">Additional Information:
http://www.cmfclearinghouse.org/detail.cfm?facid=71
and
http://www.cmfclearinghouse.org/detail.cfm?facid=1910

Note: The CMF=0.56 study is based on principal arterials, freeways, and expressways. Though these facilities are important, a large number of candidate sites for this treatment are rural 2-lane highways. Consequently, the more conservative value of CMF = 0.70 has been used for this analysis.</td></tr>
</table>

The Appendix B spreadsheet summarizes potential sites where static curve warning signs may be considered. The Plan ranks the sites based on observed crash information for rural roadways associated with RwD crashes at horizontal curve locations.

West Virginia currently does not have an available safety performance function for rural multilane RwD crashes. Consequently, the site identification conducted for this effort utilized blended safety assessment methods. For rural two-lane locations, the Plan used predictive safety assessment methods to identify candidate sites where the number of observed crashes exceeded the expected number of crashes for each site. For the rural multilane locations (where the safety performance function is not available, the analysis is based on crash history (i.e. observed crashes) only. Candidate sites for the observed crash assessment approach include sites with applicable crash types and ranks these sites from most crashes to fewest crashes. Appendix A expands on this information.

Table 23 summarizes a proposed improvement plan for deploying a static curve warning sign treatment. The Plan for deploying these static curve warning signs is expected to reduce rural crashes at horizontal curve locations by approximately 56 crashes per year. This crash reduction also equates to a reduction of approximately four to five serious injury or fatal crashes each year.

Table 23. Static Curve Warning Signs – Based on Observed Number of RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	67.5	$0.10	1.63	7.90	11.11	0.18	0.88
Rural divided multi-lane	46.7	$0.04	1.63	7.90	25.33	0.41	2.00
Rural undivided multi-lane	22.4	$0.02	1.63	7.90	19.26	0.31	1.52
Total	136.6	$0.16	-	-	55.71	0.91	4.40

Notes:

- For the installation of static horizontal curve signage, installation assumed to only occur at rural locations (Urban locations assumed to have more mature signage and less open areas for this type of treatment).
- Cost estimates based on $750 per location (assumed to be one application at, on average, one mile segment).
- CMF value of 0.70 used for static horizontal curve sign improvements.
- For two-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes (using predictive analysis). For rural multilane facilities, a crash level threshold of four crashes due to RwD crashes that occurred within a 7-year period.

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 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 WVDOT staff to conduct field evaluations using the prioritized list of sites included in Appendix B to confirm the need for these supplemental curve warning signs.

2. At locations where a driver needs additional warning, enhanced curve warning systems are recommended (see the next treatment in this Plan). Often, an agency deploys static curve warning signs and then ultimately adds enhanced features such as flashing beacons or larger signs if the problem persist. 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.

ENHANCED CURVE WARNING SYSTEM

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.

Figure 9. Enhanced Curve Warning Systems

Table 24 notes that crash modification factors vary for the enhanced curve warning sigh treatment; however, a conservative value assumes an approximate 30 percent reduction in RwD crashes. This equates to a crash modification factor of 0.70.

Table 24. CMF Values for Enhanced Curve Warning Signs

Facility Type:	Varies	Crash Severity:	All
Crash Type:	Run off road	CMF:	Varies but in range of 0.59 up to 0.73 (Conservative value of CMF = 0.70 used)
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=1856 and http://www.cmfclearinghouse.org/detail.cfm?facid=1874 *Note: Facility type referenced in CMF studies had 4 lanes and was a principal arterial or freeway and was based on conditions in Italy in the early 2000s. For this analysis, assumed value of 0.70 for CMF that is conservatively applied to all facility types including rural 2-lane highways.*			

The Appendix B spreadsheet summarizes potential sites where enhanced curve warning system configurations may be considered. The Plan ranks the sites based on a blend of predicted crashes (for 2-lane rural highways) and observed crash information associated with rural multilane highway locations. The analysis focused on RwD crashes at horizontal curve locations.

The Plan ranked sites based on the frequency of observed crashes at curve locations on rural West Virginia facilities where the **sharpest horizontal curve has a radius of 1000 ft or sharper**. This crash identification information is expanded upon in the Appendix A summary. Table 25 summarizes a proposed improvement plan for deploying enhanced curve warning signs. The Plan for deploying this suite of warning signs is expected to reduce rural crashes at sharp horizontal curve locations by approximately 12 crashes per year. This crash reduction also equates to a reduction of approximately one serious injury or fatal crash each year.

Table 25. Enhanced Curve Warning Signs – Based on Observed Number of RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	52.1	$0.31	1.63	7.90	8.43	0.14	0.67
Rural divided multi-lane	1.8	$0.01	1.63	7.90	0.69	0.01	0.05
Rural undivided multi-lane	3.0	$0.01	1.63	7.90	3.06	0.05	0.24
Total	56.9	$0.33	-	-	12.18	0.20	0.96

Notes:

- For the installation of enhanced horizontal curve signage, installation assumed to only occur at rural locations (Urban locations assumed to have more mature signage and less open areas for this type of treatment). Assumed that 50% of target sites can be addressed.
- Cost estimates based on $3000 per one location.
- CMF value of 0.70 used for enhanced curve warning sign applications.
- For 2-lane facilities, analysis based on locations where the observed number of crashes exceeded the expected number of crashes (using predictive analysis). For rural multilane facilities, a crash level threshold of 4 crashes due to RwD crashes that occurred within a 7-year period.

Suggested implementation is as follows:

1. The placement of enhanced curve warning signs should be targeted for locations where the curve radius, roadway superelevation, posted speed, advisory speed, and/or roadside environment are configured in such a way that that a driver is surprised by the road geometry or has a challenge navigating the corridor. The data used to identify potential locations for this Plan only considered rural locations with a horizontal curve radius of 1000 ft or less (per the Manual on Uniform Traffic Control Devices Table 3F-1). A first step in implementing this treatment is for WVDOT staff to conduct field evaluations using the prioritized list of sites included in Appendix B to confirm the need for these supplemental curve warning signs.

2. At locations where a driver needs additional warning but where the location may not warrant extra signage or illumination, the use of static curve warning signs may be

sufficient (see previous treatment). Often, an agency deploys static curve warning signs and then ultimately adds enhanced features such as flashing beacons or larger signs if the problem persist. For this reason, WVDOT staff should assess the implementation of the enhanced curve warning systems and the static curve warnings signs at the same time and only deploy one initial treatment per location.

UTILITY POLE RELOCATION

As shown in Figure 10, the close lateral placement of utility poles near active traffic can result in severe roadway departure crashes. The only way to eliminate these potential hazards is to relocate the utility poles to locations where they no longer create a risk. This treatment can be challenging when the pole is located in the right-of-way where multiple users share the pole. Where feasible, relocation of the poles laterally can help to reduce the frequency and severity of crashes. Table 26 identifies source information for potential crash modification factors for utility pole relocation. Due to significant variability in pole positions prior to relocation, the estimated safety implications vary. The Plan assigned crash reductions of approximately 29 percent.

Figure 10. Candidate Relocation for Utility Pole (Urban Environment)

Table 26. CMF Values for Utility Pole Relocation

Facility Type:	Rural Undivided	Crash Severity:	Not specified
Crash Type:	Fixed Object Crashes	CMF:	0.71
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=5240# and https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec47.cfm *Note: CMF values vary dramatically. This is likely due to the variability of the "before" condition. For an assumed increase in lateral offset of 5' to 10', CMF values range from 0.63 (37 percent crash reduction) to 0.40 (60 percent crash reduction) when applied to fixed object crashes. A conservative CMF of 0.71 (29 percent crash reduction) is suggested as part of the HSIP manual.*			

The Appendix B spreadsheet summarizes potential sites where utility pole relocation may be considered. The Plan ranks the sites based on observed crash information associated with RwD crashes into utility poles. This information is expanded upon in the Appendix A summary. Table 27 summarizes a proposed improvement plan for utility pole relocations. The Plan for relocating utility poles is expected to reduce pole crashes by approximately 24 crashes per year. This crash reduction also equates to a reduction of approximately one to two serious injury or fatal crashes each year.

Table 27. Utility Pole Relocation – Based on Observed Number of RwD Crashes

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural roadways	165.1	$0.50	1.29	6.75	20.91	0.27	1.41
Urban roadways	84.3	$0.25	1.14	6.80	2.62	0.03	0.18
Total	249.4	$0.75	-	-	23.53	0.30	1.59

Note:

- For utility pole relocation, assumes improvement of 40% of identified locations.
- Cost estimates based on $3000 per location and assume 5 or fewer pole relocations per site
- CMF value of 0.71 used for the utility pole analysis.
- Based on a crash level threshold of 3 crashes into a utility pole or light support within a 7-year period.

Suggested implementation is as follows:

1. Utility poles located in close proximity to the roadway can also behave as fixed objects subject to RwD crashes if their placement is not carefully considered. For many locations, existing utility poles preceded agency management. In other instances, the utility poles have been located as far from the roadway as practical for the surrounding terrain. Consequently, the lateral relocation of utility poles may not always be practical and an agency should consider shielding them. The ownership of a utility pole can also vary and more than one utility, including lighting, may depend on the specific utility pole placement. To determine feasibility of relocation, therefore, WVDOT staff should first identify the pole owners and agencies sharing the pole and assess potential for relocation of these fixed objects. For this Plan, the identified locations are based on sites with a history of RwD crashes into utility poles (see list in Appendix B spreadsheet).

2. Often crashes into a single utility pole shift upstream and downstream over time. This trend suggests the likelihood that there are multiple poles collectively located too close to the road. When this trend is observed, the WVDOT staff should consider initiating a project to relocate (or shield) all of the utility poles along a corridor. During field visits, inspectors can identify these issues by inspecting poles upstream and downstream of the identified corridor locations. Strong indications of this trend would be indications on the

poles where a vehicle has scrubbed against the pole and left a scar. WVDOT should consider prioritized these utility pole corridors for improvement projects.

REMOVE OR SHIELD TREE OR FIXED OBJECTS

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. In many cases, however, the objects 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.

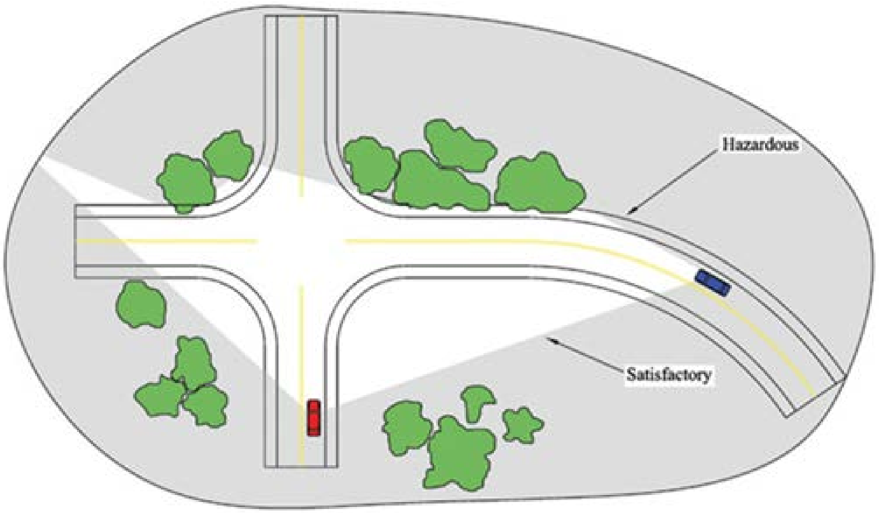

Figure 11. Remove or Shield Trees or Fixed Objects

Table 28 summarizes the safety performance resulting from removing or shielding trees or fixed objects. As shown, the published research varies substantially about the expected reduction in crashes, but a conservative expectation is an approximate reduction of 50 percent for fixed object crashes.

Table 28. CMF Values for Remove or Shield Trees or Fixed Objects

Facility Type: All	Crash Severity: All
Crash Type: Fixed Object, All	CMF: 0.5 (Fixed Objects)
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=2724 http://www.cmfclearinghouse.org/detail.cfm?facid=1044 https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec47.cfm#s47j *Note: CMF values vary dramatically. Studies report CMF values of 0.03 (when applied only to fixed object crashes) and 0.62 (all crashes.) A conservative CMF of 0.71 (29 percent crash*	

reduction) is suggested as part of the HSIP manual. For this analysis, the Plan utilizes a CMF value of 0.5 as applied to fixed object crashes.

The Appendix B spreadsheet summarizes potential sites where removing or shielding trees or fixed objects may be considered. The Plan ranks the sites based on observed crash information associated with RwD crashes into utility poles. This information is expanded upon in the Appendix A summary. Table 29 summarizes a proposed improvement plan for removing or shielding these roadside objects. The Plan for removing or shielding trees or fixed objects is expected to reduce fixed object crashes by approximately 45 crashes per year. This crash reduction also equates to a reduction of approximately five serious injury or fatal crashes each year.

Table 29. Removed or Shield Trees or Fixed Objects – Based on Observed Number Fixed Object RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	168.0	$0.50	2.66	11.52	40.18	1.07	4.63
Rural multi-lane	3.5	$0.01	2.66	11.52	0.68	0.02	0.08
Urban 2-lane	85.3	$0.26	1.19	7.06	3.86	0.05	0.27
Urban multi-lane	1.5	$0.00	1.19	7.06	0.07	0.00	0.01
Total	258.3	$0.78	-	-	44.79	1.13	4.98

Notes:

- For removal or shielding of trees or fixed objects, assumes improvement of 50% of identified locations.
- Cost estimates based on $3000 per location.
- CMF value of 0.50 used for the tree/fixed object tree analysis.
- Based on a crash level threshold of 3 crashes into a tree or fixed object within a 7-year period.

Suggested implementation is as follows:

1. The placement of fixed objects in the clear recovery zone can result in an increase in the number of fixed object crashes. For isolated fixed objects, removal of the item is recommended; however, in many cases there are a series of objects and it is not practical to remove all of the objects. In this scenario, it may be appropriate to shield them. This Plan identified sites where recurring fixed object crashes persist for rural and urban locations. As a first implementation step, WVDOT staff should review the prioritized sites included in the Appendix B spreadsheet and determine if any of these locations overlap with proposed improvement or safety enhancement projects. For any of these overlapping sites, the removal or shielding of the fixed object should be addressed as part of these projects. If overlapping projects are not identified, the WVDOT should

systematically being to address these sites by initiating projects to relocate (or shield) these fixed objects.

2. This Plan also included a countermeasure to relocate utility poles (see previous treatment) and a variety of treatments to add or improve barriers. WVDOT staff can explore these treatments collectively and one or more may potentially be considered for a given site; therefore, the WVDOT should assess this treatment at the same time as these other treatments so that safety initiatives can be combined and duplication of efforts can be minimized.

CULVERT AND DITCH IMPROVEMENT

A preferred drainage treatment is to locate culverts and drainage ditches so that they are not located immediately adjacent to active travel lanes and, consequently do not pose treats to roadway users. In many cases, however, the available right-of-way constrains the placement of these drainage features. When this occurs, transportation professionals should design culvert end treatments and associated drainage ditches that are located in close proximity to a road so that they are traversable.

Source: FHWA at https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec47.cfm

Figure 12. Roadside Culvert and Treatment and Associated Ditch Improvement

Table 30 summarizes published resources associated with the safety of culvert and ditch improvements; however, this proven treatment does not have a designated crash modification factor. For this reason, this Plan uses an estimated assumption that 50 percent of crashes related to culverts and ditches will be eliminated if these treatments are improved so that they are traversable or shifted laterally so that they no longer pose a threat to drivers of errant vehicles.

Table 30. CMF Values for Culvert and Ditch Improvement

Facility Type:	Not Specified	Crash Severity:	All
Crash Type:	Culvert and ditch RwD crashes	CMF:	None documented – since proven treatment assume CMF=0.50 (culvert and ditch related crashes)
Additional Information: https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec47.cfm and http://www.cmfclearinghouse.org/detail.cfm?facid=6914			

The Appendix B spreadsheet summarizes potential sites where improving culvert end treatments and associated ditch sideslopes may be considered. The Plan ranks the sites based on observed crash information associated with RwD crashes into culverts or ditches. Appendix A expands on this information. Table 31 summarizes a proposed improvement plan for minimizing culvert or ditch related RwD crashes. The Plan for this treatment is expected to reduce RwD crashes by approximately 79 crashes per year. This crash reduction also equates to a reduction of approximately four to five serious injury or fatal crashes each year.

Table 31. Culvert and Ditch Improvement – Based on Observed Culvert or Ditch Related RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment: Annual Targeted Crash Reduction	After Treatment: Annual Estimated K Crash Reduction	After Treatment: Annual Estimated KA Crash Reduction
Rural 2-lane	301.8	$0.30	0.61	5.47	66.51	0.40	3.64
Rural multi-lane	30.4	$0.03	0.61	5.47	6.00	0.04	0.33
Urban 2-lane	126.3	$0.13	0.36	4.77	5.89	0.02	0.28
Urban multi-lane	13.0	$0.01	0.36	4.77	0.57	0.00	0.03
Total	471.5	$0.47	-	-	78.97	0.46	4.27

Notes:

- For culvert or ditch improvement, assumes improvement of 40% of identified locations.
- Cost estimates based on $1000 per location.
- CMF value of 0.50 used for the culvert and ditch analysis.
- Based on a crash level threshold of 3 crashes into a culvert end treatment or ditch within a 7-year period.

Suggested implementation is as follows:

1. The placement of culverts is common at driveway locations where the culvert aligns with the roadside ditch. In addition, often a culvert positioned laterally across the road. The common issue associated with these treatments is that the orientation of the culvert

treatments or the slopes associated with the roadside ditches have the potential to become roadside hazards. For this Plan, candidate locations where culvert and ditch-related crashes occur are priorities in the Appendix B spreadsheet. Prior to initiating an improvement project, WVDOT staff should examine the individual sites and determine feasibility of improvement. The relocation of a roadside ditch, for example, may not be feasible and a site evaluation can help make this determination. Where possible, however, culvert end treatments should be modified to be traversable, shielded, or outside of the roadside clear zone.

2. For locations where the relocation of the roadside ditch is not feasible or where a culvert cannot be modified or extended, an alternative option may be to shield the roadside areas with a barrier. For this reason, WVDOT should explore this culvert and ditch improvement implementation plan at the same time as the add barrier treatment option.

FLATTENING MEDIAN SIDESLOPES

In some instances, such as extreme terrain locations, an errant vehicle cannot safely traverse the adjacent median sideslope. This trend tends to occur when the ratio of vertical to horizontal slopes is steeper than one foot vertically for every three feet horizontally. If this steeper grade is sustained, an errant vehicle may not be able to recover and could overturn. Table 32 demonstrates that flattening median sideslopes can result in a reduction of approximately 42 percent of overturn crashes.

Table 32. CMF Values for Flattening Median Sideslopes

Facility Type:	Divided roadway	Crash Severity:	All
Crash Type:	Overturn / Rollover	CMF:	0.58
Additional Information: https://safety.fhwa.dot.gov/hsip/hrrr/manual/sec47.cfm *Note: Flattening sideslopes is a potential treatment for the roadside slope adjacent to the paved surface. The FHWA reference above notes that this type of improvement is appropriate at horizontal curve locations or where the roadside sideslopes exceed values of a 1 (Vertical):3 (Horizontal) slope. For the West Virginia application, this treatment focuses only on median sideslopes locations.*			

The Appendix B spreadsheet summarizes potential sites where flattening median sideslopes at locations that do not have median barrier may be considered. The Plan focuses on rural divided multilane highways and ranks the sites based on observed crash information associated with rollover RwD crashes at these locations. Appendix A expands on this information. Table 33 summarizes a proposed improvement plan for minimizing crashes that occur at these steep median sideslope locations. The number of candidate sites is limited to approximately four miles. This equates to an expected reduction in rollover crashes of approximately one crash per year.

This crash reduction also equates to a reduction of approximately one serious injury or fatal crashes every nine years.

Table 33. Flattening Median Sideslopes – Based on Observed Number of RwD Rollover/Overturn Crashes

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment: Annual Targeted Crash Reduction	After Treatment: Annual Estimated K Crash Reduction	After Treatment: Annual Estimated KA Crash Reduction
Rural Divided Roadway	4.1	$3.28	2.76	12.84	0.86	0.02	0.11
Total	4.1	$3.28	-	-	0.86	0.02	0.11

Notes:
- For flattening median sideslopes, assumes improvement of 40% of identified locations.
- Cost estimates based on $150 per foot.
- CMF value of 0.58 used for flattening median sideslope analysis.
- Based on a crash level threshold of 3 crashes due to rollover/overturn within a 7-year period.

Suggested implementation is as follows:

1. The identification of candidate improvement locations included in this Plan is based on locations that are rural divided highways where currently median barrier is not present and where rollover crashes occur. Prior to initiating these improvement efforts, WVDOT staff should examine the identified locations (consisting collectively of 4.1 miles) to determine the feasibility of flattening the sideslopes. The Appendix B spreadsheet identifies these candidate sites, but this Plan is based on an assumption that ultimately only 40 percent of the sites can be improved. WVDOT staff may want to asses this assumption and modify it following this field inspection step.

2. Flattening the sideslope for an existing median can introduce additional issues including drainage modification, removal of existing fixed objects, and substantial import of suitable soil material. Consequently, the WVDOT staff should consider evaluation of the treatment in conjunction with that of adding median barrier to minimize redundant assessments. It may also be appropriate to consider only one of the treatment options, and this joint assessment will help to identify the optimal solution.

ADD BARRIER

In the event that roadway improvements cannot prevent a vehicle from inadvertently exiting the roadway, a transportation agency should design the roadside environment to minimize crash severity. One common way to reduce crash severity is to install roadside barriers. Table 34 notes that the addition of a barrier can result in an approximate 16 percent reduction in run-off-road crashes.

Table 34. CMF Values for Adding Barrier

Facility Type: Varies (2 to 5 lanes)	Crash Severity: KABC
Crash Type: Run-off-road	CMF: 0.84

Additional Information:

http://www.cmfclearinghouse.org/detail.cfm?facid=8348#commentanchor

Note: The CMF Clearinghouse includes a variety of "add barrier" studies and the associated CMF values differ substantially for the varying studies. Consequently, the CMF=0.84 value is used because it is from a United States evaluation and developed using reliable statistical procedures.

The Appendix B spreadsheet summarizes potential sites where the potential addition of roadside barrier is expected to help minimize crashes. The Plan ranks the sites based on observed crash information associated with rural and urban locations associated with RwD crashes at locations where barrier is not currently present. Appendix A expands on this information. Table 35 summarizes a proposed improvement plan for adding barrier at locations with run-off-road crashes where barrier is not currently present. The Plan for deploying barrier is expected to reduce rural crashes by approximately four or five crashes per year. This crash reduction also equates to a reduction of approximately one serious injury or fatal crash every two years.

Table 35. Adding Barrier – Based on Observed Number of RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	50.4	$35.29	2.66	11.52	3.86	0.10	0.44
Rural multi-lane	1.1	$0.74	2.66	11.52	0.07	0.00	0.01
Urban 2-lane	25.6	$17.91	1.19	7.06	0.37	0.00	0.03
Urban multi-lane	0.5	$0.32	1.19	7.06	0.01	0.00	0.00
Total	77.5	$54.25	-	-	4.30	0.11	0.48

Notes:

- For adding barrier at locations with crashes into trees, poles, or other fixed objects, assumes improvement of 15% of identified locations.
- Cost estimates based on $700,000 per mile.
- CMF value of 0.84 used for adding barrier.
- Based on a crash level threshold of 4 crashes due to rollover/overturn within a 7-year period.

Suggested implementation is as follows:

1. This Plan identified potential locations where the addition of a barrier may be suitable based on crash history into trees, poles, or other barriers at locations where barriers are

not present. To make this determination, the Plan used the WVDOT guardrail database from 2017. During that same year, WVDOT implemented an aggressive safety campaign that likely included some additional barrier that may not have been incorporated into the database. For this reason, the recommended segment candidates are based on the assumption that only 15 percent of the identified sites can be practically treated. Consequently, a first step towards implementation is to confirm that roadside barrier is not currently present at this list of prioritized locations (see the Appendix B spreadsheet).

2. Several of the treatments included in this Plan recommend removal, reconfiguration, or shielding of roadside conditions. For this reason, assessment and ultimate implementation of this "Add Barrier" treatment should occur concurrent to that of these other treatments (i.e. lighting improvements, utility pole relocation, remove or shield tree or fixed object, or culvert and ditch improvement).

Improve Barrier

Locations with steep roadside terrain or heavily wooded land are often shielded by roadside barrier. In many cases, barrier is constructed and remains in place for many years. In other cases, barrier is frequently impacted and the department of transportation is required to maintain the barrier. In addition, over time the design of effective barrier may change. These design modifications could require barrier reconstruction or improvement. Table 36 notes that improving barrier to current standards can be estimated to reduce run-off-road crashes by approximately 33 percent.

Figure 13. Improve Barrier to Current Standards

Table 36. CMF Values for Improving Barrier to Current Standards

Facility Type: Not specified	Crash Severity: ABC, KABC
Crash Type: Run-off-road	CMF: 0.67 to 0.68 (used 0.67)
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=41 and http://www.cmfclearinghouse.org/detail.cfm?facid=5551 *Note: Studies included general sites (0.67) as well as rural multilane divided locations (0.68). This Plan utilized the slightly more conservative value of 0.68.*	

The Appendix B spreadsheet summarizes potential sites where barrier is present but continues to be a location with barrier-related crashes. The Plan ranks the sites based on observed crash information associated with rural and urban locations associated with RwD crashes at locations where barrier is not currently present. Appendix A expands on this information.

Table 37 summarizes a proposed improvement plan for improving barrier at locations with run-off-road crashes into existing barrier. The Plan for improving barrier at these locations is expected to reduce rural crashes by approximately five to six crashes per year. This crash reduction also equates to a reduction of approximately one serious injury or fatal crash every four years.

Table 37. Improving Barrier – Based on Observed Number of RwD Crashes

Facility Type	Estimated Length of Improve-ments (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural 2-lane	0.8	$0.59	0.66	4.86	0.14	0.00	0.01
Rural multi-lane	15.2	$10.65	0.66	4.86	4.66	0.03	0.23
Urban 2-lane	0.5	$0.37	0.23	3.45	0.02	0.00	0.00
Urban multi-lane	14.7	$10.28	0.23	3.45	0.74	0.00	0.03
Total	31.3	$21.90	-	-	5.56	0.03	0.26

Notes:

- For improving barrier at locations with crashes into existing barrier treatments, assumes improvement of 15% of identified locations.
- Cost estimates based on $700,000 per mile.
- CMF value of 0.67 used for improving barrier.
- Based on a crash level threshold of 4 crashes due to rollover/overturn within a 7-year period.

Suggested implementation is as follows:

The repair of damaged or deficient barrier treatments may be incorporated into standard maintenance activities; however, recent modifications to the design of barriers are likely to justify barrier improvement projects that exclusively focus on these enhancements. This Plan identified locations with recurring crashes into guardrail, cable, and concrete barrier treatments. Prior to initiating barrier improvement plans, these sites should be inspected to determine if the recurring crashes are due to barrier issues or other site conditions. Consequently, this Plan assumes barrier improvements will only occur at approximately 15 percent of the prioritized sites included in the Appendix B spreadsheet. Following a more detailed inspection, the WVDOT may elect to change this threshold.

Install Median Barrier with a Mow Strip

The installation of a median barrier is a reasonable treatment at locations where the maintaining agency cannot practically flatten the median sideslope or relocate fixed objects outside of the median area. West Virginia requires construction of a mow strip as part of the median barrier installation (per current standards). Table 38 notes that an approximate reduction of 65 percent for cross median crashes at locations with median barrier installations.

Table 38. CMF Values for Installing Median Barrier with a Mow Strip

Facility Type:	Divided	Crash Severity:	All
Crash Type:	Cross median RwD	CMF:	0.31 to 0.35 (varies) [Used 0.35]
Additional Information: http://www.cmfclearinghouse.org/detail.cfm?facid=5445# and http://www.cmfclearinghouse.org/detail.cfm?facid=7091# *Note: The CMF Clearinghouse includes a variety of studies with a broad range of results. The higher quality studies cited above have a CMF value that ranges from 0.31 to 0.35. Consequently, the Plan utilizes the more conservative value of 0.35.*			

The Appendix B spreadsheet summarizes potential sites where a median barrier is not currently present but where overturn/rollover crashes continue to occur. These identified rural multilane divided highway locations collectively have a length of approximately 5.2 miles. The Plan ranks the sites based on observed crash information associated with rural divided highway locations subject to rollover crashes. Appendix A expands on this information.

Table 39 summarizes a proposed improvement plan for installing median barrier (and a companion mow strip). The Plan for median barrier installation at these locations is expected to reduce rural divided highway crashes by approximately two rollover crashes per year. This crash reduction also equates to a reduction of approximately one serious injury or fatal rollover crash every five years.

Table 39. Installing Median Barrier with a Mow Strip – Based on Observed Number of Rural RwD Overturn/Rollover Crashes

Facility Type	Estimated Length of Improvements (mi)	Construction Cost ($ Million)	Annual Average Type K per 100 Crashes	Annual Average Type KA per 100 Crashes	After Treatment		
					Annual Targeted Crash Reduction	Annual Estimated K Crash Reduction	Annual Estimated KA Crash Reduction
Rural Divided Roadway	5.2	$3.63	2.76	12.84	1.67	0.05	0.21
Total	5.2	$3.63	2.76	12.84	1.67	0.05	0.21

Notes:

- For installing median barrier with a mow strip at locations that currently do not have existing barrier treatments, assumes improvement of 50% of identified locations.
- Cost estimates based on $700,100 per mile.
- CMF value of 0.35 used for adding barrier.
- Based on a crash level threshold of 3 crashes due to rollover/overturn within a 7-year period.

Suggested implementation is as follows:

1. This Plan identifies candidate improvement locations for installing a median barrier based on locations that are rural divided highways where currently median barrier is not present and where rollover crashes occur. Prior to initiating these improvement efforts, WVDOT staff should examine the identified locations (consisting collectively of 5.2 miles) to determine the feasibility of installing a median barrier, with its companion mowing strip, at these locations. The Appendix B spreadsheet identifies these candidate sites, but this Plan is based on an assumption that ultimately only 50 percent of the sites can be improved. WVDOT staff may want to asses this assumption and modify it following this field inspection step.

2. One potential alternative to installing a median barrier is to determine if another treatment may be more suitable. For example, if the justification for the barrier is to help prevent rollover crashes, then flattening the sideslope may be a preferred treatment. Consequently, the WVDOT staff should consider evaluation of the treatment in conjunction with that of flattening the median sideslope to minimize redundant assessments. It may also be appropriate to consider only one of the treatment options, and this joint assessment will help to identify the optimal solution.

PERFORMANCE MEASURES

As the implementation of safety treatments occurs over time, assessing performance measures is an effective way to assess ongoing success with the Plan. This observation can then help WVDOT refine future proven safety treatments. Two types of performance measures may be considered:

1. Production performance measures that track the implementation of treatments can be used to assess the quantity of efforts expended toward reaching future safety goals.

2. Effectiveness performance measures that evaluate the effectiveness of the individual treatments can compare the estimated to actual safety metrics.

Table 40 provides an example format for evaluating production performance measures. The measures shown would be updated based on the individual treatment implementation activities. Table 41 provides one example template that could be used for tracking the effectiveness performance measures that are specifically targeted at reducing crashes.

Table 40. Example Production Performance Measures Table

Treatment	Measure	Target Initiation Timeline	Annual Completion
Center Rumble Stripes/Strips	282 rural miles	TBD	Actual results
Edgeline Rumble Stripes/Strips	290 rural miles	TBD	Actual results
6” Wide Centerline Pavement Markings	63 rural miles, 349 urban miles	TBD	Actual results
6” Wide Edgeline Pavement Markings	41 rural miles, 240 urban miles	TBD	Actual results
Lighting Improvements	549 rural locations, 248 urban locations	TBD	Actual results
High Friction Surface Treatment	94 rural locations, 70 urban locations	TBD	Actual results
Static Curve Warning Sign (Standard)	142 rural locations	TBD	Actual results
Enhanced Curve Warning System	51 rural locations	TBD	Actual results
Utility Pole	505 rural locations, 63 urban locations	TBD	Actual results
Remove or shield tree or fixed objects	381 rural miles, 166 urban miles	TBD	Actual results
Culvert and Ditch Improvement	330 rural miles, 139 urban miles	TBD	Actual results
Flattening Median Sideslopes	4 rural miles	TBD	Actual results
Add Barrier	41 rural miles, 26 urban miles	TBD	Actual results
Improve Barrier	16 rural miles, 15 urban miles	TBD	Actual results
Install Median Barrier with a mow strip	5.2 rural miles	TBD	Actual results
TBD = To Be Determined			

Table 41. Example Effectiveness Performance Measures Table

Countermeasure	Year Improvements Implemented	Year Evaluation Plan Developed	Year Evaluation Completed	Estimated Crash Reduction	Actual Crash Reduction
Center Rumble Stripes/Strips					
Edgeline Rumble Stripes/Strips					
6” Wide Centerline Pavement Markings					
6” Wide Edgeline Pavement Markings					
Lighting Improvements					
High Friction Surface Treatment					
Static Curve Warning Sign (Standard)					
Enhanced Curve Warning System					
Utility Pole					
Remove or shield tree or fixed objects					
Culvert and Ditch Improvement					
Flattening Median Sideslopes					
Add Barrier					
Improve Barrier					
Install Median Barrier with a mow strip					

SUMMARY

Due to recent economic improvements in the United States, the number of crashes has continued to increase. The State of West Virginia, however, has seen relatively stable RwD crash numbers since 2012. At the same time, 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 the WVDOT 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 the WVDOT 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 11 lives saved with a corresponding 747 prevented RwD crashes (see Table 8).

References

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4. 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.

5. National Highway Traffic Administration. *Fatality Analysis Reporting System (FARS) Analytical User's Manual 1975-2016.* Report No. DOT HS 812 447, NHTSA, U.S. Department of Transportation, Washington, D.C., 2017.

6. Preston, H., R. Storm, J.D. Bennett, and B. Wemple. *Systemic Safety Project Selection Tool*. Report No. FHWA-SA-019, FHWA, U.S. Department of Transportation, Washington, D.C., 2013.

7. American Association of State Highway and Transportation Officials (AASHTO). *Highway Safety Manual.* AASHTO, 2010.

APPENDIX A

Appendix A is a separate PDF document that contains the West Virginia crash data analysis for the period extending from 2009 to 2015. This Roadway Departure Implementation Plan is based on this analysis.

APPENDIX B

Appendix B is a separate Microsoft Excel file that provides information on individual highway locations for the various countermeasures. The individual sites are further identified by a ranking for application of a treatment based on the analysis summarized in the Appendix A document.