Oregon Roadway Departure Implementation Plan Update

2009-2015

Final Report

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EXECUTIVE SUMMARY

In the 7-year period from 2009 to 2015, Oregon experienced 2,476 highway fatalities, 55 percent of which were the result of roadway departures (RwD). This statistic is commensurate with the entire United States, for which the latest crash statistics indicate 54 percent of all the traffic fatalities are RwD-related. Nationwide, there is an annual average of 18,275 fatal RwD crashes[1], about one percent of which occur in Oregon.

The Federal Highway Administration (FHWA) defines a RwD crash as one that "occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way."[2] The above data suggests that these particular crashes are not overrepresented in the State of Oregon. In fact, there has been a generally decreasing trend in the State's RwD crashes over the past seven years. But even more improvement can be made. Updated analysis of Oregon's RwD crashes, and potential for expanded countermeasure implementation, indicate that an additional 48 lives may be saved annually over the next several years through further investment in this strategy.

The systemic approach to traffic safety continued in this plan begins with a system-wide analysis of RwD crash types. Once investigators identify the most prevalent crash types and contributing circumstances (e.g., navigating horizontal curves, crossing the center line, driving impaired), they match these crashes to applicable, cost-effective RwD countermeasures. Each countermeasure can be strategically deployed over the portion of the highway system that exhibits an overrepresentation of targeted-type crashes. The result is a State-tailored, systemic-focused implementation plan designed to reduce RwD crashes, severe injuries, and fatalities in Oregon.

Investigators and analysts developed a data analysis package that was merged with a set of RwD safety strategies to identify a set of countermeasures, deployment levels, and funds needed to achieve a substantial annual reduction in RwD fatalities and serious injuries. The project team conducted a workshop with Oregon Department of Transportation (ODOT) project management, and other transportation stakeholders in May, 2017 to discuss and fine-tune the analysis; and draft implementation recommendations.

Through these efforts, the project team identified the countermeasures showing the greatest potential to significantly reduce RwD fatalities and severe injuries. Those selected for additional consideration and deployment are:

- Curve signing and marking
- Center line rumble strips
- Edge rumble strips
- Delineation
- High friction surface treatments

[1] FHWA, Office of Safety Program, "Roadway Departure Safety," last modified: April 3, 2017. Available at: https://safety.fhwa.dot.gov/roadway_dept/.
[2] Ibid.

- Tree management
- Shoulder Widening

ODOT should also consider the idea that education and highly visible enforcement activities are considered strategies for improving safety on selected corridors with an over-represented RwD crash history associated with unsafe driving characteristics, according to the annual NHTSA-administered safety program. This Roadway Departure Safety Implementation Plan identifies sections of highway that have high frequencies of alcohol and drug, and speed-related RwD crashes.

This plan provides recommendations on where these additions to the current safety practices can be implemented effectively. Saving the estimated 48 additional lives per year will take an investment of approximately $31 million in total over the next 5 years to implement infrastructure improvements and education/enforcement initiatives, or about $6.2 million annually.

With implementation of the full recommendations and deployment levels, an estimated reduction of nearly 10,000 RwD crashes can be realized, and 480 lives saved over the next 10-year period.

For additional information about this implementation plan, contact Douglas Bish, P.E.in the ODOT Traffic-Roadway Section at (503) 986-3594 or douglas.w.bish@odot.state.or.us.

PURPOSE

The purpose of this report is to identify additional areas in which RwD safety can be increased, since the comprehensive analysis performed in 2010. This report is not intended to recommend the methods with which ODOT implements the countermeasures; that procedure—as developed in 2010—is already in place in the State and progressing effectively. The product of this effort is merely an identification of the locations, deployment levels, and expected safety benefits of systemic implementation of RwD countermeasures, as revealed by the State's most recent crash data.

BACKGROUND

In 2007 ODOT began to focus efforts and funds towards reducing RwD crashes. The original RwD Implementation Plan in 2010 contained crash analyses from 2002-2008. These crashes accounted for approximately 66 percent of all fatalities in Oregon: an annual average of just over 300 RwD fatalities per year. Implementation of mitigations has continued through the present day.

From 2009 through 2015, fatal crashes involving roadway departures (RwD) accounted for 55 percent of all highway fatalities in the State of Oregon: an annual average of just under 200 RwD fatalities per year. Crashes of this nature typically fluctuate from year to year, but have—until 2015—displayed a general downward trend, as indicated in Table 1.

Table 1: Total and RwD Crashes and Fatalities by Year

Year	Crashes			Fatalities		
	Total	RwD	Percent	Total	RwD	Percent
2009	41,271	8,851	21%	377	233	62%
2010	44,093	8,674	20%	317	183	58%
2011	49,052	10,464	21%	331	191	58%
2012	49,798	10,268	21%	337	186	55%
2013	49,510	10,106	20%	313	159	51%
2014	51,245	9,984	19%	356	188	53%
2015 (K Only)	29,057	5,294	18%	445	221	50%
Total	**314,026**	**63,641**	**20%**	**2,476**	**1,361**	**55%**

Using the RwD flag developed by ODOT's Crash Analysis and Reporting (CAR) Unit, the research team isolated a subset of crashes using the following criteria and data field codes:

```
-- table joins
CRASH.crash_id = CRASH_CAUSE_EVNT.crash_id
-- matches "crash" & "crash events" to the same crash
and CRASH.crash_id = VHCL.crash_id
-- matches "crash" & "vehicles" to the same crash
```

```
and VHCL.crash_id = VHCL_CAUSE_EVNT.crash_id
-- matches "vehicles" & "vehicle events" to the same crash
and VHCL.vhcl_id = VHCL_CAUSE_EVNT.vhcl_id
-- matches "vehicles" & "vehicle events" to the same vehicle
and VHCL.crash_id = PARTIC.crash_id
-- matches "vehicles" and "participants" to the same crash
and VHCL.vhcl_id = PARTIC.vhcl_id
-- matches "vehicles" and "participants" to the same vehicle
and PARTIC.crash_id = PARTIC_CAUSE_ERR_EVNT.crash_id
-- matches participants & errors to the same crash
and PARTIC.partic_id = PARTIC_CAUSE_ERR_EVNT.partic_id
-- matches "participants”  to their errors

-- crash is not intersectional nor intersection-related
        and CRASH.RD_CHAR_CD <> '1'
        and CRASH.ISECT_REL_FLG <> 1

-- participant is a driver
        and PARTIC.partic_typ_cd = '1'

-- crash is off road or involved a lane departure as specified below
   and (CRASH.OFF_RDWY_FLG = 1

  -- struck vehicle on other roadway
or CRASH.CRASH_TYP_CD = '1'

  -- fixed object crashes (excluding pavement irregularities, expansion joint, overhead
structures, vegetation, or other overhead objects, wire cables, or slides struck on-road)
or (CRASH.CRASH_TYP_CD = '8'
        and VHCL_CAUSE_EVNT.vhcl_evnt_1_cd not in
            ('049','063','064','067','073','074','118','127')
        and VHCL_CAUSE_EVNT.vhcl_evnt_2_cd not in
            ('049','063','064','067','073','074','118','127')
        and VHCL_CAUSE_EVNT.vhcl_evnt_3_cd not in
            ('049','063','064','067','073','074','118','127')
        and CRASH_CAUSE_EVNT.crash_evnt_1_cd not in
            ('049','063','064','067','073','074','118','127')
        and CRASH_CAUSE_EVNT.crash_evnt_2_cd not in
            ('049','063','064','067','073','074','118','127')
        and CRASH_CAUSE_EVNT.crash_evnt_3_cd not in
            ('049','063','064','067','073','074','118','127')  )

 -- collision = sideswipe meeting
or  CRASH.COLLIS_TYP_CD =  '4'

  -- collision type = "head on" when the vehicle crossed a median
or (CRASH.COLLIS_TYP_CD = '2' and (VHCL.actn_cd = '029' OR VHCL.actn_cd =
'033'))

 -- error = “failed to maintain lane” or “ran off road”
or (PARTIC_CAUSE_ERR_EVNT.partic_err_1_cd in ('080', '081')
```

```
or PARTIC_CAUSE_ERR_EVNT.partic_err_2_cd in ('080', '081')
or PARTIC_CAUSE_ERR_EVNT.partic_err_3_cd in ('080', '081')))
```

As this report is an update to the 2010 plan (itself containing data analyses from 2002 to 2008), investigators evaluated data from 2009 to 2015. Only fatal crashes were available in the 2015 data, so this information was used *only* to establish fatal crash severities—the ratio of fatal crashes to all crashes—for the predictive analysis. As such, 2015 occurrences of fatal and severe injury crashes for specific roadway segments were omitted from analysis identifying overrepresentation of target crash types.

APPROACH

To help reduce statewide RwD fatalities, this plan recommends the following to complement the traditional approach of improving safety at specific high-crash locations:

- Systemic application of low-cost countermeasures at locations that have a moderate or high number of RwD crashes above a specified crash frequency by subtype. This approach is based on FHWA's Strategic Approach to RwD Safety, which will be described in greater depth on page 10 in this report.
- Comprehensive application of education and enforcement initiatives targeted at corridors that exhibit a RwD crash history associated with unsafe driving characteristics (e.g., alcohol and drugs, and speed).

The systemic approach to safety involves widely implemented improvements based on high-risk highway features correlated with specific severe crash types. The approach provides a more comprehensive method for safety planning and implementation that supplements and complements traditional site analysis.

The comprehensive (education and enforcement) initiatives are targeted at reducing unsafe driving behaviors on corridors that have an over-represented RwD crash history associated with these characteristics.

Both approaches are driven by RwD crash data. The systemic approach identifies crash types that specific countermeasures are designed to address, and selects clusters of locations that have targeted crashes at or above a designated threshold level. The total number of targeted crashes in these clusters is then coupled with a predicted crash modification factor (CMF) to estimate the total number of crashes that could be reduced, should the countermeasure be implemented at each of the locations deemed feasible.

The impact of these improvements, in terms of crash severity reduction, is determined by multiplying these targeted crash reductions by severe injuries per 100 crashes, and fatalities per 100 crashes, for targeted crashes in the environment of the clusters identified. Statewide ratios are used rather than the previous history at individual sites to produce a more reliable estimate of system-wide severity impact.

Distribution of Roadway Departure Fatalities

RwD crash and injury severity data for Oregon were analyzed to gain insight into the distribution and characteristics of the RwD crash experience. Key information derived from the total crash and RwD crash data analysis is shown in Table 2 and Table 3.

Table 2: Total Crashes and Fatalities by Locality

Locality	Crashes		Fatalities	
	Total	Percent	Total	Percent
State Rural	43,877	14%	978	39%
State Urban	85,527	27%	371	15%
State Total	129,404	41%	1,349	54%
Non-State Rural	29,016	9%	663	27%
Non-State Urban	155,606	50%	464	19%
Non-State Total	184,622	59%	1,127	46%
Grand Total	**314,026**	**100%**	**2,476**	**100%**

Table 3: Roadway Departure Crashes and Fatalities by Locality

Locality	Crashes		Fatalities	
	Total	Percent	Total	Percent
State Rural	22,079	35%	637	47%
State Urban	7,408	12%	84	6%
State Total	29,487	46%	721	53%
Non-State Rural	16,118	25%	486	36%
Non-State Urban	18,036	28%	154	11%
Non-State Total	34,154	54%	640	47%
Grand Total	**63,641**	**100%**	**1,361**	**100%**

Summary of Roadway Departure Crash Findings

This data supports a few important conclusions for Oregon:

- As shown in Table 1, RwD fatalities decreased 19.3 percent during the study period (2009-2014), far more dramatically than overall fatal crashes which only decreased 5.6 percent.
- While the majority (54 percent) of fatal RwD crashes occurred on the ODOT system, a significant 46 percent occurred off-system.

Summary of Roadway Departure Countermeasure Deployments

The next portion of this plan describes techniques to reduce the occurrence and severity of RwD crashes, for State and Non-state roadways. A summary of the countermeasures, deployment levels, costs, and estimated lives saved is provided in Table 4.

Table 4: Strategy Matrix Summary

Countermeasure	Threshold Crash Level (6 Years)	Number of Crashes in 6 Years (2009-14)	Estimated Number of Improvements	Construction Costs ($ Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved ($ Million)
State								
Curve treatment - Level 2	3	6,810	842	$10.53	238.35	7.72	19.58	$1.36
Curve treatment - Level 3	16	861	18	$1.80	29.06	0.94	2.39	$1.91
Center Line Rumble Strips	3	2,366	249	$0.45	86.75	18.78	35.27	$0.02
Edge Rumble Strips	3	10,664	654	$1.96	191.95	6.06	14.53	$0.32
Delineation	5	1,346	164	$1.23	46.66	1.20	2.53	$1.02
High Friction Surface Treatment	11	386	12	$0.98	24.13	0.56	1.53	$1.75
Wider Shoulders (2 ft.)	10	1,395	25	$0.86	4.07	0.13	0.31	$6.62
Tree Management	4	507	21	$0.26	8.45	0.54	0.92	$0.48
Alcohol Enforcement - Rural	5	15	1	$0.02	0.20	0.05	0.05	$0.53
Alcohol Enforcement - Urban	6	25	2	$0.03	0.33	0.03	0.04	$1.05
Speed Enforcement - Rural	18	414	8	$0.15	4.14	0.09	0.23	$1.67
			State Total	**$18.27**	**634**	**36**	**77**	**$16.73**
Non-State								
Curve treatment - Level 1	3	4,748	619	$6.19	142.44	5.15	12.73	$1.20
Curve treatment - Level 2	5	2,343	215	$2.15	82.01	2.97	7.33	$0.72
Curve treatment - Level 3	19	275	8	$0.77	12.99	0.47	1.16	$1.64
Center Line Rumble Strips	3	2,260	206	$0.74	66.29	1.52	5.39	$0.49
Edge Rumble Strips	4	3,151	56	$0.34	18.91	0.76	2.04	$0.44
Delineation - Rural	7	450	37	$0.55	15.60	0.45	1.27	$1.22
High Friction Surface Treatment	5	236	16	$1.36	14.75	0.31	1.10	$4.34
Tree Management	3	147	5	$0.12	1.23	0.08	0.16	$1.46
Alcohol Enforcement - Rural	4	38	3	$0.06	0.51	0.08	0.14	$0.81
Alcohol Enforcement - Urban	5	128	9	$0.18	1.71	0.07	0.14	$2.76
Speed Enforcement - Rural	11	183	5	$0.10	1.83	0.05	0.16	$1.78
			Non-State Total	$12.55	358	12	32	$16.86
			Grand Total	**$30.82**	**992**	**48**	**109**	**$33.60**

Saving 48 additional lives per year will take an investment of approximately $31 million over the next 5 years to implement the infrastructure and comprehensive improvements, or about $6.2 million per year for 5 years of implementation.

The data analysis package the research team used for the initial ODOT review, and that supports the information in the Strategy Matrix, is included as Appendix A of this document. The matrix shown above has been modified—as a result of the on-site workshop in Oregon—to reflect the final set of countermeasures, deployment levels, costs, and safety impacts that are in the body of this report. In addition, Appendix B includes an Excel file that provides information for each of the highway sections on which the countermeasures in Table 4 are recommended to be deployed. Appendix C details the rationale behind the saturation (feasible deployment levels) and crash modification factors assumed for developing this plan. Appendix D is a stand-alone guide describing the process of updating an existing RwD Implementation plan.

In addition to the countermeasure deployment strategies recommended above, there are a number of treatment scenarios that analysts and ODOT officials deemed inappropriate for inclusion in this update of the plan. Some of these applications are simply a different setting (rural vs. urban) of a solution recommended elsewhere in this plan, others are traditional solutions not normally considered in a RwD plan, and still others are innovative solutions brainstormed during the workshop with Oregon safety stakeholders. These applications and the rationale behind their omission are shown below:

- Curve-Level 1: State: Rural - Each curve on the ODOT system is either in compliance with MUTCD minimums, or part of a program that will bring it into compliance by 2019.
- Delineation: State and Non-State: Urban – The data did not reveal an overrepresentation of dark RwD crashes within the urban setting.
- Wider Shoulders: Non-State: Rural - The data did not reveal an overrepresentation of failure-to-maintain-lane crashes on the non-State system.
- Utility Pole Management: State and Non-State: Rural and Urban- The data did not reveal an overrepresentation of fixed object (utility pole) crashes in any system or setting in the State.
- Speed Education and Enforcement: State and Non-State: Urban - The data did not reveal an overrepresentation of speed involved crashes in the urban setting.
- Cable Median Barriers - ODOT currently has a nearly fully executed cable median barrier deployment plan.
- Animal warnings – No CMF exists to accurately predict the safety benefit of placing animal warning signs, or providing animal crossings.
- Variable (weather-related) Speed Limits - No CMF exists to accurately predict the safety benefit of deploying variable, weather-related, speed zones.

Even though these countermeasures were not recommended for systemic deployment as described below, they could still be appropriate as solutions in individual areas. ODOT officials should remain aware of locations where target crash types seem overrepresented. If these areas are examined in greater depth, an engineering study may reveal the applicability of the above-listed countermeasures.

MAJOR COMPONENTS OF THE PLAN

The remaining sections of this plan provide a detailed description of key approaches to achieving increased RwD safety. As previously stated, these efforts are broadly classified into two approaches: Systemic and Comprehensive.

This systemic approach involves the installation of several sets of cost-effective countermeasures at locations with previously targeted crash histories in an effort to significantly decrease the potential for future crashes. Each countermeasure within this approach can be classified according to FHWA's Strategic Approach to RwD Safety[3], shown here in priority order:

1. Keep vehicles on the roadway, in their appropriate directional lane,
    - Curve Treatments
    - Centerline Rumble Strips
    - Edge Rumble Strips
    - Delineation
    - High Friction Surface Treatment
2. Reduce the potential for crashes when vehicles do leave the roadway or cross into opposing traffic lanes
    - Wider Shoulders
3. Minimize the severity of crashes that do occur.
    - Tree Management

The comprehensive approach introduces human behavior considerations—specifically unsafe driving behaviors—into the plan. The focus areas within the comprehensive approach are:

- Alcohol and Drug Education and Enforcement
- Speed Education and Enforcement

The methodology to identify sections of highway with crashes meeting a defined minimum threshold involves dividing the corridor into consecutive segments of a discrete length (e.g., 0.5 miles) and counting the number of targeted crashes in each segment to develop a frequency distribution. Considering sections instead of individual spot locations decreases the uncertainty in locating and coding crashes. A data analyst then investigates the crashes to identify sections with a number of targeted crash types that equal or exceed the defined threshold. The list of roadway sections that equal or exceed the crash thresholds for each of the above countermeasures is provided in Appendix B.

The output from this process, however, requires additional evaluation based upon field conditions or overall route characteristics. As an example, a single curve could span two adjoining sections. Thus, curve crashes on either side of a section identified as a targeted crash curve section should be reviewed to determine if there are any additional crashes that occurred on the same curve, but in the adjoining section. As another example, a rural highway may be 10 miles in length and 75 percent of the sections on the route meet the crash threshold for edge

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[3] FHWA, Office of Safety Program, "Strategic Approach to Roadway Departure Safety," last modified: February 16, 2017 . https://safety.fhwa.dot.gov/roadway_dept/strat_approach/.

line rumble strips. For routes with multiple clusters above the threshold, providing rumble strips on the entire route rather than just on those sections that meet the threshold may be an appropriate decision. This may be determined by reviewing the information in Appendix B, along with the associated segments on GIS maps, to determine priority locations to conduct field reviews.

Enhanced Signing and Friction to Reduce Roadway Departures on Curves

Curves are one of the most common roadway attributes in RwD crashes. Researchers have identified a number of treatments that can reduce crashes on curves and classified them as described below:

- Level 1- Minimum treatment specified by Section 2C-07 of the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD)
- Level 2- Level 1 treatments plus any combination of oversize warning signs, left and right warning sign placement, advisory speed plaques, chevron signs (as recommended in MUTCD Section 2C-09), and fluorescent reflectorized sleeves on posts
- Level 3- Level 2 treatments plus high-friction surface treatment (HFST) throughout curve, or flashing beacons on curve approaches

ODOT Route Implementation

Curves on rural ODOT highways with related crashes at or above threshold levels and considered for sign enhancements are summarized in Table 5. Since every curve on the ODOT system already complies, or will comply with MUTCD minimums by 2019; only the additional enhancements provided by curve countermeasure levels 2 and 3 are considered.

Table 5: Curve - Level 2: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	1,203	6,810	842	$10.53	238.35	7.72	19.58	$1.36

Notes:

1. Assume 70% of identified curves can be improved.
2. Assume average cost of $12,500 per 0.5-mile section. This includes preliminary engineering which is required for all improvements in Oregon.
3. Assume CMF of 0.7.

Within the rural curves identified in Table 5, curves with higher crash levels—in which the addition of an improved friction surface or enhanced curve warning signs should be considered—are provided in Table 6.

Table 6: Curve - Level 3: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
16	36	861	18	$1.80	29.06	0.94	2.39	$1.91

Notes:

1. Assume 50% of identified curves can be improved.
2. Assume average cost of $100,000 per 0.5-mile section.
3. Assume CMF of 0.595.

Non-ODOT Route Implementation

The high number of RwD crashes on curves not maintained by ODOT provides an opportunity for a non-State road curve program to return significant safety benefits. Crashes on non-State routes in Oregon are not recorded with a linear reference, although the data does provide the latitude, longitude, route name, and segment identification associated with each crash. For this reason, investigators analyzed the non-State system by individual areas measuring 1 minute of latitude by 1 minute of longitude. In the state of Oregon, this area equates to approximately 1 square mile. The units used for non-State discussions throughout this report will be “minutes.” Table 7 shows the recommended deployment level and benefits for installing curve countermeasures on non-State roads in Oregon.

Table 7: Curve - Level 1: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	1,031	4,748	619	$6.19	142.44	5.15	12.73	$1.20

Notes:

1. Assume 60% of identified curves can be improved.
2. Assume average cost of $10,000 per 1-minute area.
3. Assume CMF of 0.7.

Within the rural curves identified in Table 7, curves with higher crash levels were considered for Level 2 countermeasures. Those results are summarized in Table 8.

Table 8: Curve - Level 2: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
5	307	2,343	215	$2.15	82.01	2.97	7.33	$0.72

Notes:

1. Assume 70% of identified curves can be improved.
2. Assume average cost of $10,000 per 1-minute area.
3. Assume CMF of 0.7.

Within the rural curves identified in Table 7 and Table 8 are curves with still higher crash levels. These were considered for Level 3 countermeasures and summarized in Table 9.

Table 9: Curve - Level 3: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
19	11	275	8	$0.77	12.99	0.47	1.16	$1.64

Notes:

1. Assume 70% of identified curves can be improved.
2. Assume average cost of $100,000 per 1-minute area.
3. Assume CMF of 0.595
4. Assume only one candidate curve will exist within a 1-minute area.

Center Line Rumble Strips to Reduce Opposite Direction and Ran-off-roadway-left Crashes

Rumble strips are of a pattern of controlled depressions—milled into the roadway surface—that alert drivers to a potential lane departure by causing the vehicle's wheels to vibrate noisily. As such, the warning is both tactile and audible, giving the errant driver a chance to correct the vehicle's direction. When rumble strips are installed on the center line of two-lane, two-way roads, they have proven to decrease the occurrence of opposite direction and ran-off-road-left crashes.

In addition to producing noise within the vehicle cabin, rumble strips also produce significant ambient noise. This, coupled with the complications of increased driveway densities in urban areas, constrict the implementation of this countermeasure to rural settings only.

ODOT Route Implementation

ODOT rural undivided highways should be considered for center line rumble strips if they meet or exceed the crash thresholds shown in Table 10.

Table 10: Center Line Rumble Strips: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	498	2,366	249	$0.45	86.75	18.78	35.27	$0.02

Notes:

1. Assume 50% of identified segments can be improved.
2. Assume average cost of $1,800 per 0.5-mile segment.
3. Assume CMF of 0.56.

Non-ODOT Route Implementation

There are opposite direction and run-off-roadway-left crashes on non-State rural roads in Oregon that should be addressed. Table 11 includes recommended deployment levels and benefits for installing center line rumble strips on non-ODOT road segments.

Table 11: Center Line Rumble Strips: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	515	2,260	206	$0.74	66.29	1.52	5.39	$0.49

Notes:

1. Assume 40% of identified areas can be improved.
2. Assume average cost of $3,600 per 1-minute area.
3. Assume CMF of 0.56.

Edge Rumble Strips to Reduce Failure-to-maintain-lane (Ran-off-roadway-right) Crashes

Edge line or shoulder rumble strips function in the same manner as the center line rumble strips described above. The notable difference is the type of crash targeted for reduction. Edge line rumble strips have proven effective in reducing ran-off-roadway-right crashes: in Oregon reported as failure-to-maintain-lane.

Depending on facility type, ODOT generally installs rumble strips on the shoulder (rural divided), or the edge line (rural undivided). For purposes of this report, the CMF for either installation is considered the same, and the countermeasure is generically referred to as “Edge Rumble Strips.” The actual deployment will conform to State policy, as appropriate, for the facility type encountered.

ODOT Route Implementation

Systemic deployment of edge rumble strips will be considered on highways meeting the crash threshold presented in Table 12. Per ODOT policy, individual installations are subject to the limitations of the roadway segments for which they were identified (e.g., insufficient width, insufficient barrier clearance, truck climbing lanes, proximity to noise-sensitive residences, etc.).

Table 12: Edge Rumble Strip: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	2,181	10,664	654	$1.96	191.95	6.06	14.53	$0.32

Notes:

1. Assume 30% of identified segments can be improved.
2. Assume average cost of $3,000 per 0.5-mile segment.
3. Assume CMF of 0.64.

Non-ODOT Route Implementation

There are single vehicle RwD crashes on non-State roads in Oregon, which are important in addressing local safety needs. Table 13 provides recommended deployment levels and benefits for installing edge rumble strip on non-State road segments.

Table 13: Edge Rumble Strip: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
4	560	3,151	56	$0.34	18.91	0.76	2.04	$0.44

Notes:

1. Assume 10% of identified areas can be improved.
2. Assume average cost of $6,000 per 1-minute area.
3. Assume CMF of 0.64.

Alignment Delineation to Reduce Dark RwD Crashes

Alignment delineation for night driving is generally considered on those sections of highway that have high incidences and proportions of dim or dark crashes. Although wet crashes were not considered for this countermeasure, enhanced delineation also improves driver guidance during inclement weather (poor visibility) at any time.

There is a distinct difference between crashes that occur *because* of dark conditions, and those that merely occur *during* dark conditions. In an attempt to segregate the former, analysts first discarded from the dataset all dark crashes believed to have occurred for reasons other than limited visibility. To accomplish this estimation, they compared the ratios of dark:total crashes for each segment to the dark:total crash ratio for the entire state. Only locations where the individual ratios were significantly higher than the statewide ratio were considered for analysis. Significance, in this case, is defined as 5 percent (approximately 1 standard deviation) higher than the statewide average.

The specific countermeasures considered for the State of Oregon are post-mounted delineators and raised pavement markers. Both devices clearly delineate boundaries in low-light conditions.

ODOT Route Implementation

Table 14 shows the number of ODOT road sections for systemic deployment of enhanced roadway delineation.

Table 14: Delineation: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
5	205	1,346	164	$1.23	46.66	1.20	2.53	$1.02

Notes:

1. Assume 80% of identified segments can be improved.
2. Assume average cost of $7,500 per 0.5-mile segment.
3. Assume CMF of 0.74.

Non-ODOT Route Implementation

There are single vehicle dark RwD crashes on non-State roads in Oregon, which are important in addressing local safety needs. Table 15 provides recommended deployment levels and benefits for installing enhanced delineation on non-State road segments.

Table 15: Delineation: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
7	46	450	37	$0.55	15.60	0.45	1.27	$1.22

Notes:

1. Assume 80% of identified areas can be improved.
2. Assume average cost of $15,000 per 1-minute area.
3. Assume CMF of 0.74.

High Friction Surface Treatment to Reduce Wet RwD Crashes

Wet road surfaces can lead to decreased friction and consequently, RwD crashes resulting from hydroplaning, sliding, or skidding. Improvements to pavement friction have proven to decrease the occurrence of crashes in wet conditions. There are a number of treatments that can accomplish this improvement—each with its own appropriate use—, but high friction surface treatment (HFST) is arguably the most effective.

HFST consists of a thin layer of durable, angular aggregates bonded in a polymer resin. Currently, calcined bauxite is the aggregate shown to have the longest-lasting skid resistance. As discussed earlier in this report, HFST can also decrease the occurrence of RwD crashes in geometrically inadequate curves.

ODOT wet crash data was parsed in the same manner (described earlier in this report) as the dark crash data. As a result, analysts only considered crashes that happened as a result of wet pavements rather than those that occurred in wet conditions, but for a different reason.

ODOT Route Implementation

HFST should be considered on those sections of highway—irrespective of alignment—that meet the threshold levels shown in Table 16.

Table 16: High Friction Surface Treatment: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
11	23	386	12	$0.98	24.13	0.56	1.53	$1.75

Notes:

1. Assume 50% of identified segments can be improved.
2. Assume average cost of $85,000 per 0.5-mile segment.
3. Assume CMF of 0.25.
4. 0.5-mile segments are identified for improvement locations, but the improvement will only be a 1,500 foot section, which assumes an average curve length including 300 feet on each approach.

Non-ODOT Route Implementation

There are single vehicle wet RwD crashes on non-State roads in Oregon, which are important in addressing local safety needs. Table 17 provides recommended deployment levels and benefits for installing HFST on non-State road segments.

Table 17: High Friction Surface Treatment: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
5	32	236	16	$1.36	14.75	0.31	1.10	$4.34

Notes:

1. Assume 50% of identified segments can be improved.
2. Assume average cost of $85,000 per 0.5-mile segment.
3. Assume CMF of 0.25.
4. 0.5-mile segments are identified for improvement locations, but the improvement will only be a 1,500 foot section, which assumes an average curve length including 300 feet on each approach.

Wider Shoulders to Reduce Failure-to-maintain-lane (Ran-off-roadway-right) Crashes

The addition of shoulders—or the widening of existing shoulders—increases safety by providing an opportunity for an errant vehicle to regain the roadway. Table 18 details the crash thresholds at which adding a 2-ft. shoulder or widening existing shoulders by 2 ft. will cost-effectively decrease crashes.

Table 18: Wider Shoulders: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
10	98	1,395	25	$0.86	4.07	0.13	0.31	$6.62

Notes:

1. Assume 25% of identified segments can be improved.
2. Assume average cost of $35,000 per 0.5-mile segment.
3. Assume CMF of 0.93.

Tree Management to Reduce RwD Fixed Object (tree) Crashes

Nationwide, crashes involving roadside trees are among the most prevalent fatal RwD Crashes. Nevertheless, these particular fixed objects remain among the least treated. This is due, in part, to the fact that trees are often protected under strict environmental regulations, have cultural or historic significance, or exist on private property. There are however, a number of successful—immediately deployable—tree countermeasures currently practiced across the United States. These range from complex, expensive contract solutions to in-house efforts that can be accomplished with minimal resources. Solutions that align with the concept of cost-effective systemic safety follow:[4]

- Shield trees that cannot be removed
- Reestablish clear zones during 3 or 4R work
- Clear only the clear zone width instead of entire right of way
- Negotiate tree removal with private property owners (replacing their trees elsewhere or providing them the harvested firewood)
- Remove diseased trees eliminating wind fall hazards
- Remove dead or dying trees eliminating ice fall hazards
- Thin trees for additional solar gain in snow and ice conditions
- Delineate critical trees that cannot be removed

ODOT Route Implementation

Tree management should be considered in those locations that meet the threshold levels shown in Table 19.

[4] Jones, J.G., *Noteworthy Practices: Roadside Tree and Utility Pole Management*, FHWA-SA-16-043 (Washington, DC: U.S. Department of Transportation (FHWA), October 2016).

Table 19: Tree Management: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
4	103	507	21	$0.26	8.45	0.54	0.92	$0.48

Notes:

4. Assume 20% of identified segments can be improved.
5. Assume average cost of $12,500 per 0.5-mile segment.
6. Assume CMF of 0.50.

Non-ODOT Route Implementation

Tree management is complicated for routes off the ODOT system since their rights of way are often easements granted by the adjacent property owners. There are however, some critical sites for tree crashes on the non-State system that should be considered for tree management. These are shown in Table 20.

Table 20: Tree Management: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
3	46	147	5	$0.12	1.23	0.08	0.16	$1.46

Notes:

1. Assume 10% of identified areas can be improved.
2. Assume average cost of $25,000 per 1-minute area.
3. Assume CMF of 0.50.

Education and Enforcement Corridor Initiatives

This initiative combines education and enforcement actions on corridors that have high concentrations of RwD crashes involving alcohol and speeding. While enforcement activities do not necessarily occur in a linear fashion by location, analysts used the same discreet segment/area analysis to identify general locations that could benefit from the initiative.

ODOT Route Implementation

Table 21, Table 22, and Table 23 include recommended deployment levels and benefits for conducting alcohol and speed enforcement and education activities.

Table 21: Alcohol and Drug Education and Enforcement: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
5	3	15	1	$0.02	0.20	0.05	0.05	$0.53

Notes:

1. Assume 40% of identified segments can be improved.
2. Assume average cost of $20,000 per 0.5-mile segment.
3. Assume CMF of 0.80.

Table 22: Alcohol and Drug Education and Enforcement: State: Urban

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
6	4	25	2	$0.03	0.33	0.03	0.04	$1.05

Notes:

1. Assume 40% of identified segments can be improved.
2. Assume average cost of $20,000 per 0.5-mile segment.
3. Assume CMF of 0.80.

Table 23: Speed Education and Enforcement: State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
18	19	414	8	$0.15	4.14	0.09	0.23	$1.67

Notes:

1. Assume 40% of identified segments can be improved.
2. Assume average cost of $20,000 per 0.5-mile segment.
3. Assume CMF of 0.85.

Non-ODOT Route Implementation

Table 24, Table 25, and Table 26 include recommended deployment levels and benefits for conducting alcohol and speed enforcement and education activities on the non-State system.

Table 24: Alcohol and Drug Education and Enforcement: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
4	8	38	3	$0.06	0.51	0.08	0.14	$0.81

Notes:

4. Assume 40% of identified areas can be improved.
5. Assume average cost of $20,000 per 1-minute area.
6. Assume CMF of 0.80.

Table 25: Alcohol and Drug Education and Enforcement: Non-State: Urban

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
5	23	128	9	$0.18	1.71	0.07	0.14	$2.76

Notes:

4. Assume 40% of identified area can be improved.
5. Assume average cost of $20,000 per 1-minute area.
6. Assume CMF of 0.80.

Table 26: Speed Education and Enforcement: Non-State: Rural

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improve-ments	Construction Costs (Million)	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	Cost/Life Saved (Million)
11	12	183	5	$0.10	1.83	0.05	0.16	$1.78

Notes:

4. Assume 40% of identified area can be improved.
5. Assume average cost of $20,000 per 1-minute area.
6. Assume CMF of 0.85.

Summary

The State of Oregon has experienced a general decrease in the number of fatal RwD crashes that seems to parallel the effort to increase safety in that area, beginning in 2010. With implementation of the countermeasures recommended by this update to that plan, fatalities and severe injuries within the State can continue to decline measurably over the next several years. Specifically targeted actions can increase the rate of RwD fatality reductions and save an estimated 48 additional lives per year. Transportation officials in Oregon should continue to supplement traditional safety practice with the systemic deployment of cost-effective countermeasures and the use of a coordinated enforcement and education approach on corridors that have a high number of RwD fatalities.

The countermeasures, deployment levels, costs, and estimated 48 lives saved annually are shown in Table 4. Of course, the actual number of lives saved per year will vary and is dependent upon the timing of this plan's full implementation. While this represents a rigorous undertaking, the expected outcome – annually preventing an additional 992 crashes, 109 severe injuries, and 48 fatalities on Oregon's highways – is a worthwhile investment.

APPENDIX A: CRASH DATA ANALYSIS

Appendix A consists of the following documentation:

- A separate PDF document titled *Appendix A-Initial Data Analysis* that contains the Oregon crash data (2009 to 2014) analysis used to develop this update: pre-workshop.
- A separate MS-Excel Spreadsheet titled *Appendix A-Final Data Analysis* that contains the Oregon crash data (2009 to 2014) analysis used to refine this update: post-workshop.
- The following matrix documenting the comments and subsequent actions resulting from the workshop.

  Note: Although this table generally documents the evolution between the initial and final data analyses, some changes occurred between the two iterations that are not represented herein (e.g., data error corrections, countermeasure name changes, etc.). Also of note, the contents of this table are the author's raw notes: largely unedited.

Element	Locality	Setting	Workshop Discussion	Action	Note
Curve: Level 1	Non-State	Rural	Use MUTCD minimum, *minus* plaques	Edit description	It is difficult for local agencies to stock and maintain such a varied sign inventory.
Curve: Level 1	Non-State	Rural	Delete Item	Delete Item	All non-State curves have already been treated to MUTCD minimum, or will be by 2019.
Curve: Level 2	State	Rural	Description should read: "…plate, MUTCD recommended chevrons," and "…fluorescent reflectorized sleeves on posts."	Edit description	ODOT wishes to draw a distinction between reflectorized post sleeves and PMDs.
Curve: Level 2	State	Rural	Cost should be $12,500 per 1/2 mile	Change cost	ODOT is required to do preliminary engineering on any action, even maintenance activities. This accounts for the higher cost.
Curve: Level 2	Non-State	Rural	Description should read: "…plate, MUTCD recommended chevrons," and "…fluorescent reflectorized sleeves on posts."	Edit description	ODOT wishes to draw a distinction between reflectorized post sleeves and PMDs.

Element	Locality	Setting	Workshop Discussion	Action	Note
Center Line Rumble Strips	State	Rural	Saturation should be 0.5	Change saturation	Lower saturation is based on ambient noise restrictions, pavement types, lift thickness seams, and locations already treated.
Center Line Rumble Strips	State	Rural	Remove note concerning "fail to maintain lane"	Delete note	"Failed to maintain lane" means "ran off road right" 99% of the time. This is more appropriate for shoulder analysis.
Center Line Rumble Strips	Non-State	Rural	Remove note concerning "fail to maintain lane"	Delete note	"Failed to maintain lane" means "ran off road right" 99% of the time. This is more appropriate for shoulder analysis.
Center Line Rumble Strips	Non-State	Rural	Add note about width restrictions	Add note	Lower saturation is based on additional width restrictions on the non-State system.
Center Line Rumble Strips	State	Rural	Remove "failed to maintain lane" from query.	Re-query	"Failed to maintain lane" means "ran off road right" 99% of the time. This is more appropriate for shoulder analysis.
Curve: Level 2	Non-State	Rural	Cost should be $10,000 per minute	Change cost	ODOT is required to do preliminary engineering on any action, even maintenance activities. This accounts for the higher cost.
Edge Rumble Strips	State	Rural	Saturation should be 0.3	Change saturation	Lower saturation due to significant restrictions in Oregon, including lack of shoulders.
Edge Rumble Strips	State	Rural	Remove note concerning the potential need for shoulder widening.	Change saturation	This has been accounted for under the low saturation.
Edge Rumble Strips	Non-State	Rural	Saturation should be 0.1	Change saturation	Lower saturation due to even more significant restrictions on Oregon's local system than with the State system: primarily width.

Element	Locality	Setting	Workshop Discussion	Action	Note
Edge Rumble Strips	Non-State	Rural	Remove note concerning the potential need for shoulder widening.	Change saturation	This has been accounted for under the low saturation.
Edge Rumble Strips	State	Rural	Crash types should include "failed to maintain lane," "overturn," and "fixed object."	Re-query	Non-collision crash types are almost always ran off road.
Edge Rumble Strips	Non-State	Rural	Crash types should include "failed to maintain lane," "overturn," and "fixed object."	Re-query	Non-collision crash types are almost always ran off road.
Curve: Level 3	State	Rural	Saturation should be 0.5	Change saturation	
Curve: Level 3	State	Rural	Cost should be $100,000 per 1/2 mile	Change cost	Dynamic flashers alone are $90K.
Curve: Level 3	Non-State	Rural	Cost should be $100,000 per 1/2 mile	Change cost	Dynamic flashers alone are $90K.
Delineation	Non-State	Rural	Add RPMs and compound CMF	Change CMF	RPMs will require new CMF
Delineation	Non-State	Rural	Cost may need to be adjusted	Check Cost	RPMs will require cost adjustment
Delineation	Non-State	Rural	Edit note explaining the weighting process for filtering dark-caused crashes. Specifically that data was parsed first…then clustered.	Add note	
Delineation	Non-State	Urban	Add RPMs and compound CMF	Change CMF	RPMs will require new CMF
Delineation	Non-State	Urban	Cost may need to be adjusted	Check Cost	RPMs will require cost adjustment
Delineation	Non-State	Urban	Edit note explaining the weighting process for filtering dark-caused crashes. Specifically that data was parsed first…then clustered.	Add note	
Delineation	Non-State	Urban	Crash threshold should be 9	Change threshold	This countermeasure is very likely infeasible, but ODOT wants to keep it to draw attention to the problem of dark urban crashes.
Delineation	State	Rural	Add RPMs and compound CMF	Change CMF	RPMs will require new CMF

Element	Locality	Setting	Workshop Discussion	Action	Note
Delineation	State	Rural	Cost may need to be adjusted	Check Cost	RPMs will require cost adjustment
Delineation	State	Rural	Edit note explaining the weighting process for filtering dark-caused crashes. Specifically that data was parsed first…then clustered.	Add note	
Delineation	State	Urban	Add RPMs and compound CMF	Change CMF	RPMs will require new CMF
Delineation	State	Urban	Cost may need to be adjusted	Check Cost	RPMs will require cost adjustment
Delineation	State	Urban	Edit note explaining the weighting process for filtering dark-caused crashes. Specifically that data was parsed first…then clustered.	Add note	
Delineation	State	Urban	Crash threshold should be 5	Change threshold	This countermeasure is very likely infeasible, but ODOT wants to keep it to draw attention to the problem of dark urban crashes.
Delineation	Non-State	Urban	Check crash numbers	Re-query	Query results seem inordinately high for an urban setting.
High Friction Surface Treatment	Non-State	Rural	Analyze	Query	Local agencies at workshop enthusiastically supported HFST.
Wider Shoulders	State	Rural	Analyze	Query	Assume 2 ft., whether new or expanding existing
Wider Shoulders	Non-State	Rural	Analyze	Query	Assume 2 ft., whether new or expanding existing
Tree Management	State	Rural	Saturation should be 0.2	Change saturation	It is very difficult to cut a tree, much less clear cut, in Oregon.
Tree Management	Non-State	Rural	Saturation should be 0.1	Change saturation	The general difficulty in tree-cutting is compounded on the non-State system because property owners own the R/W. All non-state roads are on easement.

Element	Locality	Setting	Workshop Discussion	Action	Note
Tree Management	Non-State	Rural	Verify crash numbers.	Re-query	The number of RWD tree crashes seems inordinately low. Verify query with ODOT Crash Analysis and Reporting (CAR) unit.
Alcohol Education & Enforcement	Non-State	Urban	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system
Alcohol Education & Enforcement	Non-State	Rural	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system
Alcohol Education & Enforcement	State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Alcohol Education & Enforcement	State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Alcohol Education & Enforcement	Non-State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Alcohol Education & Enforcement	Non-State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Speed Education & Enforcement	Non-State	Urban	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system
Speed Education & Enforcement	Non-State	Rural	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system

Element	Locality	Setting	Workshop Discussion	Action	Note
Speed Education & Enforcement	State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Speed Education & Enforcement	State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Speed Education & Enforcement	Non-State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Speed Education & Enforcement	Non-State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface; however units may need to remain as they are to successfully locate the work for Appendix B. Further analysis needed.
Utility Pole Management	State	Rural	Verify crash numbers.	Re-query	The number of RWD pole crashes seems inordinately low. Verify query with ODOT Crash Analysis and Reporting (CAR) unit.
Utility Pole Management	State	Urban	Verify crash numbers.	Re-query	The number of RWD pole crashes seems inordinately low. Verify query with ODOT Crash Analysis and Reporting (CAR) unit.
Utility Pole Management	Non-State	Rural	Verify crash numbers.	Re-query	The number of RWD pole crashes seems inordinately low. Verify query with ODOT Crash Analysis and Reporting (CAR) unit.

Element	Locality	Setting	Workshop Discussion	Action	Note
Utility Pole Management	Non-State	Urban	Verify crash numbers.	Re-query	The number of RWD pole crashes seems inordinately low. Verify query with ODOT Crash Analysis and Reporting (CAR) unit.
Utility Pole Management	State	Rural	Remove from Summary	Leave in discussion	Even though the cost per life saved is inordinately high, ODOT believes there should be a discussion of this CM.
Utility Pole Management	State	Urban	Remove from Summary	Leave in discussion	Even though the cost per life saved is inordinately high, ODOT believes there should be a discussion of this CM.
Utility Pole Management	Non-State	Rural	Remove from Summary	Leave in discussion	Even though the cost per life saved is inordinately high, ODOT believes there should be a discussion of this CM.
Utility Pole Management	Non-State	Urban	Remove from Summary	Leave in discussion	Even though the cost per life saved is inordinately high, ODOT believes there should be a discussion of this countermeasure.
Cable Median Barrier	State	Rural	Analyze	Query	Freeway medians are already shielded by state policy. Check expressways only if that information exists in the OR data. There is no way of discerning expressway vs. freeway.
Animal crashes	All	All	Analyze	Query	Not recommended. No CMF exists for animal control countermeasures.
Variable Speed Limits	State	Rural	Analyze	Query	Not recommended. No CMF exists for weather-based variable speed limits.

APPENDIX B: COUNTERMEASURE DEPLOYMENT LOCATIONS

Appendix B consists of the following documentation:

- A separate, GIS-compatible MS-Excel Spreadsheet titled *Appendix B-Deployment Locations* that lists all the segments or areas where crashes exceed the thresholds defined in the data analysis.
- A separate MS-Excel Spreadsheet titled *Appendix B-Segment Marker Year* that lists all the segment marker IDs used in the database along with their latest year of use. This data will allow GIS analysts to mitigate potential conflicts with the evolution of segment names.

APPENDIX C: COUNTERMEASURE DEPLOYMENT LEVELS AND ASSOCIATED ASSUMPTIONS

Appendix C contains backup data and assumptions that investigators used to predict the severe and fatal crash reductions shown in this report. Specifically, it contains:

- The assumptions used to estimate feasible countermeasure deployment levels.
- The sources of the CMFs used to predict crash reductions.

Deployment levels

Countermeasure	Ownership	Locality	Deployment Level	Assumption
Curve - Level 1 Curve - Level 2 Curve - Level 2	Non-State State Non-State	Rural Rural Rural	60% 70% 70%	Signing is both inexpensive and non-intrusive; and with several options and combinations available, it is adaptable to the agency's capabilities and site limitations.
Curve - Level 3	State	Rural	50%	HFST has strict requirements for the existing pavement to which it can be bonded; it would likely not be an acceptable option for all sites.
Curve - Level 3	Non-State	Rural	70%	While the requirements for HFST substrates are likely to be even more critical on the non-state system, the number of areas meeting the elevated crash threshold is so small that a more aggressive saturation can be considered.
Center Line Rumble Stripes	State	Rural	50%	The existing pavement must be of a sufficient quality, width, depth, and orientation (seam placement) to install and maintain rumble strips. These elements will likely be insufficient in some locations. There are further complications with ambient noise generation.
Center Line Rumble Stripes	Non-State	Rural	40%	The same pavement limitations evident on the State system are likely to be present on the non-State system, with pavement quality and width being even more acute. This is due to many non-State pavements having evolved from multiple cold-mix applications.

Countermeasure	Ownership	Locality	Deployment Level	Assumption
Edge Rumble Strips	State	Rural	30%	The existing pavement must be of a sufficient quality and width to install and maintain edge rumble strips. These elements are insufficient in some locations. There are further complications with ambient noise generation, absence of shoulders, and bicycle traffic.
Edge Rumble Strips	Non-State	Rural	10%	The same pavement limitations evident on the State system are likely to be present on the non-State system, with pavement quality and width being even more acute
Delineation	State Non-State	Rural	80%	Delineation countermeasures are generally inexpensive, straightforward, and non-intrusive to install.
High Friction Surface Treatment (HFST)	State Non-State	Rural	50%	HFST has strict requirements for the existing pavement to which it can be bonded; it would likely not be an acceptable option for all sites. The treatment is also relatively new and the State may be unfamiliar with its use.
Wider Shoulders (2 ft.)	State Non-State	Rural	25%	Shoulder widening is complicated given the inherent restrictions (e.g., existing R/W, drainage, fill material, etc.) present on the system.
Tree Management	State	Rural	20%	Public perception and opposition can make tree removal difficult if not impossible.
Tree Management	Non-State	Rural	10%	Public perception and opposition can make tree removal difficult if not impossible. This is further complicated on the non-State system where most rights of way are merely easements granted by adjacent property owners.

Countermeasure	Ownership	Locality	Deployment Level	Assumption
Alcohol and Drug Education and Enforcement	State Non-State	All	40%	By statute, Oregon cannot use enforcement checkpoints. Some of the segments targeted for enforcement activities lack the proper geometrics to safely detain motorists.
Speed Education and Enforcement	State Non-State	Rural	40%	By statute, Oregon cannot use enforcement checkpoints. Some of the segments targeted for enforcement activities lack the proper geometrics to safely detain motorists.

Crash Modification Factor Sources, Values, and Justification

Countermeasure	Identified CMF and Source	CMF chosen for RwD Implementation Plans	Justification
Curve - Level 1 Curve - Level 2	Chevrons: 0.71 (mean of 6 4-star studies in CMF Clearinghouse) Speed Plates: 0.78 (mean of 2 3-star studies in CMF Clearinghouse) Basic Advanced Warning Signs: 0.69 (NCHRP 500, Objective 17.1 E1)	0.70	Base condition is no curve signing. Conservative estimate for the combination of these treatments.
Curve - Level 3	0.607 HFST on Curve (Clearinghouse – Merritt et al., 2015) 0.95 Dynamic Flashers, Sequential Flashers, or Speed Feedback Signs (Clearinghouse – Hallmark et al., 2015)	0.595	Engineering estimate of the potential treatment(s) to be implemented, compounded with the Level 1 or 2 curve-focused CMF above.
Center Line Rumble Stripes	0.56 (NCHRP 641) Head on and opp. sideswipe Fatal and Injury crashes.	0.56	The Implementation Plan is focused on reducing fatal/injury crashes as the Plan's benefit. FHWA reviewed NCHRP 641 and chose the most appropriate CMFs for this purpose (0.56).
Edge Rumble Strips	0.67 and 0.61 (Clearinghouse – Torbic et al., 2009)	0.64	Average of two highest rated, applicable CMFs in clearinghouse.
Delineation	Range 0.76 to 1.16 nighttime crashes for delineation installation: Choose 0.85. (NCHRP 518, 2004) 0.867 average of three highest-rated nighttime RPM (Sun and Das, 2013) and nighttime SRPM (Bahar, 2004)	0.74	Initial CMF of 0.85 was compounded with the average of three highest-rated nighttime RPM (0.867), yielding a combined CMF of 0.74. This seems commensurate with the average of three nighttime CMFs for combined striping and RPM (0.74) (Sun and Das, 2013).

High Friction Surfaces	0.139 (Clearinghouse – Merritt et al., 2015)	0.25	Merritt CMF tempered with naïve observations from PA, KY, and MO.
Wider Shoulders (2 ft.)	Change shoulder width from X to Y (in feet) $\boldsymbol{CMF = e^{(-0.0321(Y-X))}}$ (Clearinghouse – Labi, 2011)	0.93	Used verbatim.
Tree Management	0.024 (fixed object crashes) Remove or relocate fixed objects outside of clear zone. (Ogle, "Support for the Elimination of Roadside Hazards," 2009) 0.62 Remove or relocate fixed objects outside the clear zone. (Hovey and Chowdhury, "Development of Crash Reduction Factors," 2005) 0.43 Clear trees an additional 10' from the current location. (NCHRP 440) 0.45 Remove tree from 8' off roadway to 20' off roadway. Note that other combinations are available in this study. (Ogle, "Support for the Elimination of Roadside Hazards," 2009)	0.50	Accommodation for widely varying studies
Alcohol and Drug Education and Enforcement	NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices.	0.80	Estimated based upon cited reduction range of 10-35 percent (.65 to .90 CMF)

Speed Education and Enforcement	NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices.	0.85	Estimated based upon cited CMF range of .57 to .96. Supported by Queensland, Australia observed CMF of .85

APPENDIX D: RWD IMPLEMENTATION PLAN UPDATE PROCESS

1. Data Analysis

1.1. Obtain Data. The RwD safety improvement process performed for the State of Oregon, and its periodic updates, are built on data. In fact, the quality and effectiveness of the safety analysis and implementation plan are only as good as the accuracy of the ODOT crash data. For this reason, the investigator, data analyst, ODOT project manager, and ODOT Crash Analysis and Reporting (CAR) representative must carefully coordinate with each other to identify and extract quality data.

1.1.1. Complete Data Elements Checklist. Prior to data analysis efforts, the investigator should provide a Data Elements Checklist (Exhibit A) to the CAR unit to identify the available data elements with their specific formats, the level of confidence and valid percentages for each, their sources, and how to find or extract the specified data. The information obtained through this checklist, especially data availability and quality, will shape the data analysis approach, indicating which elements should be used with which method. An incomplete checklist could cost money and time to the project as it is performed. Selecting appropriate analyses based on the quality of the available data should be a decision that the investigator and data analyst make together.

1.1.2. Develop list of critical data. Upon discussion and approval of the data elements checklist, the investigator and data analyst should identify the critical data elements required for the analyses, along with additional or optional elements that would bring the highest accuracy and benefit to the plan. This list will serve as a check for data providers to ensure they deliver the requested data.

The critical datasets will include crash and roadway data at a minimum. The investigator should clearly determine the data elements that are necessary or significantly beneficial to identify any of the crash types. These elements will provide direction to the data analyst to extract data for each crash type and analyze it individually.

Another critical element in this process is the data for location identification. This is critical for properly identifying crash locations, and accurately locating roadway characteristics to determine the most effective (crash-reducing) projects. The RwD safety team should include ODOT GIS personnel in such discussions to maximize the benefit of any available data the State possesses.

1.1.3. Request data package. After determining the critical data elements, the RwD team should reach consensus on the data package specifics. This will include the years for which data is requested, data format for each element and dataset, data package maximum or preferred size, data transfer method, and passwords if necessary. Requesting the data according to these directions will accelerate the data analysis process by eliminating extra data formatting and management efforts.

1.2. Analyze Data

Once the data package is received, the data analyst and investigator should follow a strategic framework to efficiently analyze the data. The framework will consist of three starting steps that are further explained in following sections of this document:

1. Define and query specific crash types,
2. Develop clusters to reveal the density of specific crash types at each location, and
3. Separately calculate the severity of each crash type within the network.

Conducting the data analysis with Microsoft Access is recommended to keep the data analysis efforts clear and understandable for engineers with no data analysis experience. The design of tables, links between tables, and queries will depend on the format in which the data package was received.

1.2.1. Query Data. As discussed in section 1.1.2, having the critical data elements in the data set will allow the team to identify and analyze different crash types in detail. The investigator should examine the data elements, and provide a matrix to the analyst detailing the codes necessary to extract the data for each crash type. Not only will this matrix aid the investigator's consideration of appropriate countermeasures, but it will also serve as a dictionary for the data analyst, providing the definitions for each sub-group of crashes. Figure 1 displays an example matrix, indicating which query elements should be used to identify crashes that would be addressed by specific countermeasures.

Element	Locality	Setting		Crash Level												Participant Level					
			Median Type	Crash Type	Other Crash Type	Collision Type	Crash Severity	Weather Condition	Road Surface Condition	Light Condition	Traffic Control Device	Crash Level Events	Crash Level Cause	Vehicle Level Event	Injury Severity	Error	Participant Level Cause	Blood Alcohol Content (BAC) Test Results	Alcohol Use Reported	Drug Use Reported
Wider Shoulders	State	Rural			8,&	9						10, 100		10, 100		80,81				
Wider Shoulders	Non-State	Rural			8,&	9						10, 100		10, 100		80,81				
HFST	Non-State	Rural							2											
CLRS	State	Rural	0			2,4							5			2, 39, 44				
ELRS	State	Rural			8,&	9						10, 100		10, 100		16,80, 81	16, 27			
ELRS	Non-State	Rural			8,&	9						10, 100		10, 100		16,80, 81	16, 27			
Delineaton	Non-State	Urban								3,4,5										
Tree Removal/Shielding	State	Rural			8,9	9						62		62						
Tree Removal/Shielding	Non-State	Rural			8,9	9						62		62						
Utility Pole Removal/Shielding	State	Rural			8,9	9						52,53,9 5		52,53,9 5						
Utility Pole Removal/Shielding	State	Urban			8,9	9						52,53,9 5		52,53,9 5						
Utility Pole Removal/Shielding	Non-State	Rural			8,9	9						52,53,9 5		52,53,9 5						
Utility Pole Removal/Shielding	Non-State	Urban			8,9	9						52,53,9 5		52,53,9 5						

Figure 1. Example crash data query matrix

The data analyst and investigator should work together to ensure the AND and OR statements that are used in queries to determine joint properties of crash types, are selected correctly. Then the data analyst should run the queries to list the crashes that fall into each category. The lists can be further broken down by rural/urban roads, functional classifications, and road ownership.

1.2.1.1. Example.

To run a query for a specific crash type, the analyst should start with the description in the crash data query matrix. This example will query the roadway departure crashes on non-state urban roads (as shown in Figure 1) that call for delineation.

Based on the requirements in the matrix and with the help of the Crash Code Manual, the analyst can develop this query following the steps below:

1. From the crash database, identify the fields that will be used in the query either to be listed, counted, or to be assigned a criterion.

   In this example, use crash ID no (CRASH_ID) as the unique identifier of each crash to be listed, and add Roadway Departure Crash Flag (LANE_RDWY_DPRT_CRASH_FLG), Roadway Number (RDWY_NO), Functional Classification (FC_CD), and Light condition (LGT_COND_CD) to be assigned with appropriate criteria to narrow the crashes down into the desired subset.

2. Assign the appropriate criteria to each data field and combine them with an "AND" statement to ensure narrowing down the result of the query to crashes that meet all of the criteria at the same time:

   a. To select roadway departure crashes out of the entire data set, select crashes that are coded as "Y" for LANE_RDWY_DPRT_CRASH_FLG field.

   b. To select crashes occurred on the non-state system, see the relevant section of the Crash Code Manual as in Figure 1. This section states that roads not on the state highway system are coded blank. Accordingly, select the crashes with a blank RDWY_NO field.

ROADWAY NUMBER

Format: 1 char

Code	Description
Blank	Not on state highway system
1	Undivided highway, or add-mileage alignment of divided hwy *(exception: I-5 "non-add" mileage)*
2	Non-add mileage alignment of a divided highway or couplet *(exception: I-5 "add" mileage)*
5	Mileage on alignment not yet built or mileage on a non-state owned roadway and considered "located".

Figure 2. "Roadway Number" section of the Crash Code Manual

c. To select crashes that occurred on urban roads, see the functional classification section of the Crash Code Manual as shown in Figure 3. This section states that urban roads are coded 11, 12, 14, 16, 17, or 19. Accordingly, select crashes with any of these numbers coded in their FC_CD field. The search for such crashes should be with a criterion listing each code with "OR" statements in between.

FUNCTIONAL CLASSIFICATION

Format: 2 char

Code	Description
01	Rural Interstate
02	Other Rural Principal Arterial
06	Rural Minor Arterial
07	Rural Major Collector
08	Rural Minor Collector
09	Rural Local
11	Urban Interstate
12	Other Urban Freeways and Expressways
14	Other Urban Principal Arterial
16	Urban Minor Arterial
17	Urban Collector
19	Urban Local

Figure 3. "Functional Classification" section of the Crash Code Manual

d. To select crashes that occurred during low-light conditions, see the relevant section of the Crash Code Manual as in Figure 4, and the crash data query matrix. This section states that crashes occurring in low-light conditions are coded 3, 4, or 5. Select crashes with any one of these numbers coded in their LGT_COND_CD field. The search for such crashes should be with a criterion listing each code with "OR" statements in between.

LIGHT CONDITION

Format: 1 char

Code	Description
0	Unknown
1	Daylight
2	Darkness – with street lights
3	Darkness – no street lights
4	Dawn (Twilight)
5	Dusk (Twilight)

Figure 4. "Light Condition" section of the Crash Code Manual

3. Run the query to see all the roadway departure crashes that occurred on non-state urban roads under low-light conditions. Note the total number of crashes. Also, save the query to carry it over for the next steps of the data analysis.

1.2.2. Develop Crash Clusters. Once the crashes are grouped by types based on specific characteristics, the analyst should identify the number of each crash type for each road section with a specific or approximate length. The length of the sections will depend on the availability of location data. The goal should be to keep the sections short and detailed enough to develop tailored solutions to the problems and find such locations quickly when field-checking; but still provide enough length for each section to have a statistically significant number of crashes from which reasonable inferences can be drawn.

In Oregon, the State Road database allows using the "Mile Post" field of each crash to develop accurate clusters, by crash type, with any desired section length. The recommended section length for such analysis is approximately one half mile, although the investigator may prefer to analyze the crashes using shorter or longer road sections.

In addition to the crash types, clusters are also separated by setting (rural vs. urban) and ownership (State vs. non-State). The currently available database for non-state roads in Oregon does not provide accurate mile post information for all crashes. It does however; provide location information by latitude and longitude for each crash. This data can be used to limit each section as the part of a specific roadway contained by an area of one minute latitude by one minute longitude. Given the geography (i.e., degree of latitude) of Oregon, such a section approximates 1-mile in length. Figure 9 shows an example of a crash cluster table.

Clustering crashes of known cause is a fairly straightforward process. The exception is crashes associated with environmental conditions: usually dark- and wet-related. There is a distinct difference between crashes that occur because of dark and wet conditions, and those that merely occur *during* these conditions. In an attempt to segregate the former, a statistical method can be applied to normalize the data and eliminate outliers. This method consists of four main steps (shown here for dark crashes):

1. Calculate Dark crashes vs. Total crashes ratio for the entire state;
2. Calculate the ratios of Dark crashes vs. Total crashes for each segment;
3. Compare the ratios of Dark crashes vs. Total crashes for each segment to the Dark crashes vs. Total crashes ratio for the entire state. Only locations where the individual ratios are significantly higher than the statewide ratio should be considered for analysis. Significance, in this case, is defined as 5 percent (approximately 1 standard deviation) higher than the statewide average.
4. Discard from the dataset all dark crashes believed to have occurred for reasons other than limited visibility.

The exact same steps should be applied for the other exceptional category: usually wet crashes.

1.2.2.1. Example.

The example in Section 1.2.1.1 identified all the roadway departure crashes that occurred on non-state urban roads under low-light conditions (warranting delineation). The next step is to cluster these crashes by location to determine those with high crash frequencies.

To start the data clustering, the analyst should develop a query, following the steps below:

1. Join the main crash database with the query (run and saved in Example 1.2.1.1) in the query window, to select only the roadway departure crashes that occurred on non-state urban roads under low-light conditions.
2. Add into the query the necessary fields that will help to group the crashes by 1-minute areas on non-state roads.
    a. Add FC_SHORT_DESC field, which will group the crashes by the functional class of the roads.
    b. Add County Name (CNTY_NM) field, which will group the crashes based on the county.
    c. Add City Section Name (CITY_SECT_NM) field, which will group the crashes based on the city section.

   d. Add Full Street Name (ST_FULL_NM) field, which will group the crashes by the full street name.
3. Add CRASH_ID field to the query design, to count the number of crashes occurred on each section.
   a. Count the total number of entries in CRASH_ID column for each location identified by grouped data.
   b. List them in descending order.

1.2.3. Calculate Severities. The severity of a specific crash type is the ratio of the fatalities or serious injuries to the total number of crashes of the same type. Crash severity information is necessary and important to prioritizing location, crash types addressed, and countermeasures implemented. The query matrix described in step 1.2.1 will also guide the severity calculations by described each crash type to be queried for all crashes, and then separately for fatal crashes and for serious injury crashes. The same level of decomposition (such as setting or ownership) that was used in previous steps should be kept for severity calculation queries as well. Using the results of these queries, the investigator will know the fatal and severe injury rate of each crash type, for each owner, in each setting.

1.2.3.1. Example. Building on Examples 1.2.1.1 and 1.2.2.1 of this document, the analyst can calculate the severity of roadway departure crashes that occurred on non-state urban roads, under low-light conditions, by following the steps below:

1. Join the main crash database with the query (run and saved in Example 1.2.1.1), in the query window to select only the roadway departure crashes that occurred on non-state urban roads under low-light conditions.
2. Add CRASH_ID field to the query design, to count the number of crashes that occurred.
3. Count the total number of entries in CRASH_ID column.
4. Add Total Fatality Count (TOT_FATAL_CNT) field to the query design, to count the number of fatalities occurred.
5. Sum the values in the TOT_FATAL_CNT column.
6. Add Total Level A Injury Count (TOT_INJ_LVL_A_CNT) field to the query design, to count the number of capacitating injuries that occurred.
7. Sum the values in the TOT_INJ_LVL_A_CNT column.
8. Summarize the query results as shown in Figure 5.

Severity Calculation		
CountOfCRASH_ID	SumOfTOT_FATAL_CNT	SumOfTOT_INJ_LVL_A_CNT
4256	39	171

Figure 5. Summary of Severity Query Results

9. By copying and pasting the query results into an Excel Spreadsheet, calculate the fatal and serious injury severities separately as shown in Figure 6.

Roadway Departure - Delineation - Non-State - Urban		
CountOfCRASH_ID	**SumOfTOT_FATAL_CNT**	**SumOfTOT_INJ_LVL_A_CNT**
4256	39	171
Severity	=39/4256	=171/4256
Severity as percentage	1%	4%

Figure 6. Severity Calculation Spreadsheet

1.2.4. Deliver Data. Upon completion of all the steps within section 1 of this document, the data analyst will be able to develop and deliver a complete data analysis package to the investigator. Preferably, the data will be in Excel Spreadsheet format for the ease of use. The workbook should have separate tabs for each cluster analysis and severities for all the crash types in all the settings and ownerships. The workbook should also include an overview tab that displays the general trends of the crash data in the State.

This data package will serve as the scientific basis to develop and include data-driven safety solutions in the plan.

2. Perform Safety Analysis

2.1. Determine Countermeasures. The RwD implementation model described in this document, while crash-focused, is truly systemic. That is to say countermeasures are deployed across the entire system, but placed in areas that show the greatest potential to benefit. As such, the countermeasures chosen must be within the agencies' ability to deploy, and be appropriate to counter the overrepresented crash types.

Prior to analyzing the data, investigators should meet with State and local safety personnel to review the RwD countermeasures previously deployed in the state and determine any emerging innovations that they may be considering, or indeed, piloting.

In addition, the investigator should gauge the state of the RwD industry nationwide and note new products, practices, and research that may help to decrease the fatal and serious injury RwD crashes.

2.2. Develop Workbook. Once the appropriate countermeasures have been determined, investigators can begin to pair them with targeted crash types. This will involve working with the data analyst to query, cluster, and determine crash severities as described above.

2.2.1. Import Data. The analyst should provide the data as spreadsheet output that can be easily imported and incorporated into the project workbook. The workbook itself (reproduced in hardcopy in Appendix A) is merely the set of calculations used to determine the appropriate level of countermeasure deployment, its cost, and the expected safety benefit. Figure 7 shows a screenshot of a typical workbook sheet with an individual tab for each countermeasure being considered. The data imported from the analyst is hilighted.

Information	
Countermeasure	Curve Treatment
Subtitle	Level 2
Description	MUTCD minimum plus oversize warning signs, warning sign doubled up-left and right, advisory speed plate, MUTCD-recommended chevrons, and fluorescent relfectorized sleeves on posts
Ownership	State
Setting	Rural
Crash Type Targeted	RwD on curved alignment OR failed to negotiate curve
Total RwD Crashes	11,180
Severity (Fatal)	0.03239
Severity (Severe Injury)	0.08213
Segment Size	0.5 mile
Saturation	0.7
Cost	$12,500
Cost Unit	0.5 mile
CMF	0.7
Note 1	
Note 2	
Note 3	

Strategy Matrix

Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improvements	Construction Costs ($ Million)	Fatalities per 100 Crashes	Severe Injuries per 100 Crashes	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	$ Million/Life Saved
3	1344	7673	941	$11.76	3.24	8.21	268.56	8.70	22.06	$1.35

Crash Cluster Summary

Crashes per Section	Number of Sections	Cumulative		Cumulative	
		Sections	Percent	Crashes	Percent
> 50	-	-	-	-	-
30 - 49	11	11	0%	396	4%
20 - 29	14	25	1%	733	7%
10-19	124	149	4%	2,273	20%
5-9	465	614	15%	5,207	47%
4	276	890	22%	6,311	56%
3	454	1,344	34%	7,673	69%
2	864	2,208	55%	9,401	84%
1	1,779	3,987	100%	11,180	100%
Total	**3,987**	**3,987**	**100%**	**11,180**	**100%**

Crash Cluster Detail

Crashes per Section	Number of Sections	Cumulative		Cumulative	
		Sections	Percent	Crashes	Percent
44	1	1	0.03%	44	0.39%
43	1	2	0.05%	87	0.78%
42	-	2	0.05%	87	0.78%
41	-	2	0.05%	87	0.78%
40	1	3	0.08%	127	1.14%
39	-	3	0.08%	127	1.14%
38	1	4	0.10%	165	1.48%
37	2	6	0.15%	239	2.14%
36	-	6	0.15%	239	2.14%
35	-	6	0.15%	239	2.14%
34	-	6	0.15%	239	2.14%
33	1	7	0.18%	272	2.43%
32	1	8	0.20%	304	2.72%
31	2	10	0.25%	366	3.27%
30	1	11	0.28%	396	3.54%
29	1	12	0.30%	425	3.80%
28	2	14	0.35%	481	4.30%
27	1	15	0.38%	508	4.54%
26	1	16	0.40%	534	4.78%
25	1	17	0.43%	559	5.00%
24	1	18	0.45%	583	5.21%
23	1	19	0.48%	606	5.42%
22	3	22	0.55%	672	6.01%
21	1	23	0.58%	693	6.20%

Summary | S-Curve 2 | S-Curve 3 | S-CLRS | S-ELRS | S-Deln.-Rural | S-Deln.-Urban | S-Tree | S-Pole-Rural | S-Pole-Urban | S-HFST | S-V

Figure 7. Typical calculation sheet in workbook

2.2.2. Hypothesize Saturations. The saturation of any countermeasure considered is the percentage of candidate roadway segments upon which that solution can reasonably be expected to be applied. For example, ODOT cannot expect edge line rumble strips to be installed on 100 percent of the roadway segments identified as candidates. Factors such as thin pavements, narrow lanes, lack of shoulders, and high driveway densities will almost certainly prevent the use of this countermeasure in a certain percentage of locations. The investigator should estimate the saturation based on prior work of a similar nature, the experience of similar states, or intrinsic knowledge of the ODOT system. At this point in the analysis, a hypothesis is accurate enough. Later in the process, multidisciplinary safety stakeholders from across the organization will review and fine-tune each saturation. ODOT saturation levels and their rationale are detailed in Appendix C of this report.

The saturation should be entered into the “saturation” cell of the appropriate workbook sheet as shown in Figure 8.

Information	
Countermeasure	Edge Line Rumble Strip(e)s
Subtitle	
Description	Pattern of controlled depressions—milled into the roadway surface—that alert drivers to a potential lane departure by causing the vehicle’s wheels to vibrate noisily. As such, the warning is both tactile and audible, giving the errant driver a chance to correct the vehicle’s direction.
Ownership	State
Setting	Rural
Crash Type Targeted	Ran off road
Total RwD Crashes	16,388
Severity (Fatal)	0.031573
Severity (Severe Injury)	0.075698
Segment Size	0.5 mile
Saturation	0.3
Cost	$3,000
Cost Unit	0.5 mile
CMF	0.64
Note 1	Assume "ran off road" means "ran off road right."
Note 2	
Note 3	

Figure 8. Saturation, cost, and CMF cells

2.2.3. Determine Cost. Costs per unit installation are usually available from an agency’s contracts unit. Anecdotal costs from maintenance or traffic personnel can also be useful, as can historic costs from previous implementation plans.

The cost should be entered into the “cost” cell of the appropriate workbook sheet as shown in Figure 8.

2.2.4. Determine CMF. The crash modification factor (CMF) for any countermeasure is the effect that its installation can be expected to have on crashes. For instance, a CMF of 0.7 indicates that the post-installation crash counts will be 70% of the pre-installation levels. CMF are well-documented—most notably—in the Crash Modification Clearinghouse maintained by FHWA: http://www.cmfclearinghouse.org/. The CMF can also be based on legitimate research outside of the clearinghouse, including in-house research and observations at ODOT.

The CMF should be entered into the “CMF” cell of the appropriate workbook sheet as shown in Figure 8.

2.2.5. Populate Other Information. There is other information, critical to the plan development process, but less subjective than the three preceding items. The items and a brief explanation of each are shown below:

- Ownership – Enter “State” or “non-State”
- Setting – Enter “urban” or “rural”
- Crash Type targeted – Enter code or descriptions of crash types targeted for the current countermeasure
- Segment Size – Enter “0.5 mile” for State roadways; “1 minute Lat/Lon” for non-State
- Cost Unit – Enter “0.5 mile” for State roadways; “1 minute Lat/Lon” for non-State
- Notes – Enter any assumptions or supporting information that will be critical to recall at a later time.

2.2.6. Determine Crash Thresholds. After all of the critical supporting information has been entered into the workbook, the investigator must select the appropriate crash threshold at which to deploy a given countermeasure. This step is the most subjective aspect of the RwD implementation plan development process, but there are a few rules that guide the selection.

Crash Cluster Detail					
Crashes per Section	Number of Sections	Cumulative		Cumulative	
		Sections	Percent	Crashes	Percent
26	1	1	0.09%	26	0.76%
25		1	0.09%	26	0.76%
24	-	1	0.09%	26	0.76%
23	-	1	0.09%	26	0.76%
22	-	1	0.09%	26	0.76%
21	-	1	0.09%	26	0.76%
20	1	2	0.18%	46	1.35%
19		2	0.18%	46	1.35%
18	-	2	0.18%	46	1.35%
17		2	0.18%	46	1.35%
16	2	4	0.37%	78	2.29%
15		4	0.37%	78	2.29%
14	2	6	0.55%	106	3.11%
13	2	8	0.73%	132	3.88%
12	4	12	1.10%	180	5.29%
11	6	18	1.65%	246	7.23%
10	10	28	2.56%	346	10.17%
9	10	38	3.48%	436	12.81%
8	17	55	5.04%	572	16.81%
7	19	74	6.78%	705	20.72%
6	40	114	10.44%	945	27.77%
5	74	188	17.22%	1,315	38.64%
4	121	309	28.30%	1,799	52.87%
3	189	498	45.60%	2,366	69.53%
2	443	941	86.17%	3,252	95.56%
1	151	1,092	100.00%	3,403	100.00%
Total	1,092	1,092	100.00%	3,403	100.00%

Figure 9. Example cluster table

Given the level of subjectivity inherent in the crash threshold process, it is critical that the safety stakeholders discuss and, if necessary, adjust each threshold during the workshop.

2.2.6.1. Rule of Three. Generally speaking, roadway segments with one or two crashes over the study period are not considered indicative of any particular RwD cause. Even though the data query validly returned them as the targeted crash type, their true cause may be something other than that being studied. For example, a curve exhibiting 1 or 2 two crashes in a 5-year period may not be indicative of a substandard or hazardous curve. Perhaps pavement condition or animal avoidance was the cause. Conversely, a segment exhibiting three or more crashes generally indicates that the cause of the crash is tied to the roadway characteristic being considered. Except in rare circumstances, investigators should begin countermeasure deployment considerations at segments exhibiting three or more crashes over the study period.

2.2.6.2. Level of Effort. In choosing the appropriate crash threshold, the investigator should compare the level of effort in deploying the countermeasures, with the expected benefit of the deployment. This process is similar to calculating a benefit:cost ratio. For instance, the crash clusters shown in Figure 9 indicate that if locations with a single crash (100 percent of locations) were treated, then 100 percent of the problem would be expected to be solved. Similarly, treating locations with 2 crashes (86.17 percent of locations) would theoretically solve 95.56 percent of the crash problem. As discussed above, locations with one or two crashes generally aren't considered, so consider the same example with a threshold of 3 crashes. In this case treating fewer than half (45.6 percent) of locations could be expected to alleviate over two thirds (69.53 percent) of the crash problem. At a crash threshold of 4, the level of effort drops to nearly one quarter (28.3 percent) while over half (52.87 percent) of the crash burden is mitigated.

In this example, a threshold of either three or four is likely a reasonable crash threshold at which to recommend countermeasures. The level of effort is low (conserving valuable resources), while the safety improvement remains relatively high.

2.2.6.3. Cost per Life Saved. No traffic fatality can be considered acceptable, and no emotional or personal value of a life can be calculated. In an actuarial sense however, the statistical value of a life can be determined. If the crash threshold chosen yields a cost per life saved that exceeds this value, the investigator should consider adjusting the threshold to yield a more reasonable cost. This may result in fewer lives saved for a particular crash type, but will allow funding to be redirected to mitigate other crash types where—in aggregate—even more lives may be saved.

2.2.6.4. Lives Saved per Year. The investigator should consider the number of lives saved per year, predicted by a given crash threshold. The inverse is also true; the number of years required to save a single life is an important consideration. If the crash threshold being considered yields a time period to save a single life that approaches, equals, or exceeds the useful life of the countermeasure, the investigator should consider a different threshold.

2.2.7. Perform Calculations. The following sections describe the calculations necessary to define the information presented in the strategy matrix shown in Figure 10.

Strategy Matrix										
Threshold Crash Level (6 Years)	Number of Sections	Number of Crashes in 6 Years (2009-2014)	Estimated Number of Improvements	Construction Costs ($ Million)	Fatalities per 100 Crashes	Severe Injuries per 100 Crashes	Annual Targeted Crash Reduction	Annual Estimated Fatality Reduction	Annual Estimated Severe Injury Reduction	$ Million/Life Saved
3	498	2,366	249	$0.45	21.64	40.65	86.75	18.78	35.27	$0.02

Figure 10. Example strategy matrix

2.2.7.1. Threshold Crash Level. Determined as discussed in Section 2.2.6 above.

2.2.7.2. Number of Sections. Value taken from the “cumulative sections” column of the crash clusters table, in the row that corresponds to the selected threshold.

2.2.7.3. Number of Crashes. Value taken from the “cumulative crashes” column of the crash clusters table, in the row that corresponds to the selected threshold.

2.2.7.4. Estimated Number of Improvements. The number of improvements ODOT can reasonably expect to construct is calculated by:

$$Est. No. of\ Improvements = No.\ of\ Sections\ \times Saturation$$

2.2.7.5. Construction Costs. The cost (in millions of dollars) of deploying the countermeasures at the calculated level is given by:

$$Construction\ Cost = \frac{(Est. No. of\ Improvements\ \times Cost)}{1{,}000{,}000}$$

The cost value is taken from the “Cost” cell of the information table.

2.2.7.6. Fatalities per 100 Crashes. Taken from the “Severity (Fatal)” cell of the information table.

2.2.7.7. Severe Injuries per 100 Crashes. Taken from the “Severity (Severe Injury)” cell of the information table.

2.2.7.8. Annual Targeted Crash Reduction. The annual targeted RwD crash reduction (of any severity) is calculated by:

$$Annual\ Crash\ Reduction_{total} = \left(\frac{No. of\ Crashes}{Study\ Period\ (yr.s)}\right) \times Saturation\ \times (1 - CMF)$$

2.2.7.9. Annual Estimated Fatality Reduction. The annual estimated fatality reduction is calculated by:

$$Annual\ Fatality\ Reduction = Annual\ Crash\ Reduction_{total} \times Severity_{fatal}$$

2.2.7.10. Annual Estimated Severe Injury Reduction. The annual estimated severe injury reduction is calculated by:

$$Annual\ Severe\ Injury\ Reduction = Annual\ Crash\ Reduction_{total} \times Severity_{sev.\ inj.}$$

2.2.7.11. Cost per Life Saved. The cost (in millions of dollars) of each estimated life saved is calculated by:

$$Cost\ per\ Life\ Saved = \frac{Construction\ Cost}{Annual\ Fatality\ Reduction}$$

2.3. Review the Workbook. The workbook calculations (and eventually the implementation plan) performed by the investigator are only as accurate as the estimations and assumptions that individual uses. To increase the accuracy and validity of the work, the investigator and data analyst should convene a live, facilitated workshop to review and refine the workbook. The workshop participants should be safety stakeholders from key positions and divisions within ODOT, and from non-State agencies such as cities and counties.

2.3.1. Conduct Workshop. The investigator should schedule, manage logistics for, and facilitate a 1-day (8-hour) workshop attended by, but not limited to, the following safety stakeholders.

- State DOT Safety Engineer
- State DOT Traffic Operations Engineer
- Governors' Highway Safety Office Representative
- NHTSA Regional Office Representative
- FHWA Division Safety Engineer
- State DOT Local Roads Coordinator
- State DOT District/Region Traffic Engineers
- City Traffic Engineers
- Rural County Engineers
- LTAP Safety Engineer
- MPO/RPC representatives
- State and Local Police Representatives
- State DOT Pavement Design Engineer
- State DOT Maintenance Engineer
- State DOT Design Engineer
- State DOT Pedestrian/Bicycle Coordinator
- State DOT Environmental Specialist

The general format of the workshop is described in the following sections.

2.3.1.1. Introductory Content. The Investigator should begin the meeting by introducing the attendees and clearly articulating the goals of the workshop. The investigator should then present information on the following topics such that the entire audience—not just the most experienced practitioners—can achieve a functional understanding of the following concepts and methods:

- Importance of RwD safety
- Overview of RwD data in Oregon
- Concept of systemic safety as compared to traditional methods
- FHWA's strategic approach to RwD safety
- Analytical method (described above) driving the ODOT implementation plan update

2.3.1.2. Safety analysis refinement. The heart of the workshop must be dedicated to refining the plan: fine-tuning the assumptions according to the first-hand knowledge inherent in the carefully selected audience. Specifically, the Investigator should examine each countermeasure (State and non-State) to ensure the estimates and assumptions for each reflect the Oregon status quo as accurately as possible. All aspects of each countermeasure should be open to discussion and revision, specifically as follow:

- Countermeasure Description – Workshop participants may have additional insight into new technologies, methods, or products not considered by the investigator.

- Targeted Crashes – Often, participants closer to or more familiar with the data are able to challenge the crash types and codes upon which the data analysis is conducted.
- Setting – Certain countermeasures are appropriate for only either rural or urban applications. There are circumstances however, in which those participants closer to the everyday operation of the system can make a case for an unconventional countermeasure deployment.
- Cost – Cost assumptions are frequently changed given the expertise of those stakeholders who frequently develop and estimate construction contracts, or who frequently purchase materials or services from vendors.
- Review Saturation-Like costs, saturation levels are frequently changed by those practitioners closest to the day-to-day system operation and who know the practical limitations of countermeasure deployment.
- CMF-CMFs should remain open to discussion, but considering that their most frequent source is the FHWA-vetted clearinghouse, they seldom change.
- Threshold – The stakeholders in the workshop can most accurately confirm or recommend changes to the crash thresholds used to determine deployment levels. As discussed above, appropriate threshold-setting is the most subjective step in the implementation plan process and should therefore benefit most from the stakeholders' expertise. A calculations spreadsheet constructed as described above (included in Appendix A) is very helpful in the threshold-setting discussion as it can accommodate changes and display safety impacts in real time.

2.3.2. Incorporate Changes. Following the workshop, the investigator and the analyst should compare their notes and develop a change matrix: a sort of checklist that helps ensure their information is accurate and that every change agreed upon in the workshop gets incorporated into the plan. An example matrix is shown in Figure 11.

Certain changes identified in the workshop will require new data queries and analyses. The investigator should request these of the analyst who will follow the procedures described in Part 1 of this document.

Upon receipt of the newly analyzed data and the adjustment of the critical calculation information, the investigator should recalculate the output for each countermeasure to arrive at the new summary matrix. This matrix should represent a very close approximation of crash conditions within Oregon, and the safety impact of strategically placed countermeasures across the system.

Element	Locality	Setting	Change	Action	Note	Responsibil
Alchohol Enforcement	Non-State	Rural	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system	Joe
Alchohol Enforcement	State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface, however units may need to stay as are to successfully locate the work for Appendix B. Further analysis needed.	Joe
Alchohol Enforcement	Non-State	Rural	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface, however units may need to stay as are to successfully locate the work for Appendix B. Further analysis needed.	Joe
Alchohol Enforcement	Non-State	Urban	Saturation should be 0.4	Change saturation	0.8 is unrealistic for off-system	Joe
Alchohol Enforcement	State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface, however units may need to stay as are to successfully locate the work for Appendix B. Further analysis needed.	Joe
Alchohol Enforcement	Non-State	Urban	Linear/area units may not be appropriate	Consider changing units	This makes sense on the surface, however units may need to stay as are to successfully locate the work for Appendix B. Further analysis needed.	Joe
Animal crashes	All	All	Analyze	Query	Not recommended. No CMF exists for animal control countermeasures. **Confirm with Doug.**	Safak
Cable Median Barrier	State	Rural	Analyze	Query	Freeway medians are already shielded by state policy. Check expressways only if that information exists in the OR data. There is no way of discerning expressway vs. freeway. **Confirm with Doug.**	Safak

Figure 11. Example change matrix

3. Develop Plan.

3.1. Develop Draft. Following the final data analysis and safety analysis, the Investigator should develop the RwD Implementation plan report. This document presents and preserves the details of the safety analysis conducted on the Oregon System, and provides a summary of expected safety benefits from deploying the recommended countermeasures.

Specifically, the report should contain the following elements:

- **Executive Summary:** High-level overview of the RwD implementation plan, functioning as an abstract, and the first (and potentially only) point of contact with agencies' executive management. It should briefly state the importance of RwD safety, summarize the safety analysis process, and present the overall expected safety benefits.

- **Purpose:** A brief discussion of the reasons for conducting the update, and the outcomes of having done so. (i.e., identification of the locations, deployment levels, and expected safety benefits of systemic implementation of RwD countermeasures, as revealed by the State's most recent crash data.)
- **Background:** High-level discussion of RwD crash statistics, data conditions, and previous RwD safety efforts in Oregon.
- **Approach:** Brief discussion of the data and safety analysis detailed in this appendix, and presentation of summary matrix showing the total expected benefit of full implementation.
- **Major Components:** In-depth discussion of each countermeasure including its, place within the FHWA RwD strategy, analytical considerations (e.g., assumptions, parameters), and expected safety benefits.
- **Other Considerations:** Brief discussion of countermeasures considered but not recommended for deployment. This rationale provides a deeper understanding for future users of the plan document who may not have been part of its development.
- **Summary:** Restatement of the process and overall estimated cost and safety benefit of full implementation.
- **Appendices**: Documentation supporting the implementation plan.
    - Appendix A: Data and safety analysis package: essentially the pre- and post-workshop workbooks, along with the change matrix serving as a crosswalk between the two.
    - Appendix B: MS-Excel file (in GIS compatible format) detailing the actual roadway sections on which the countermeasures are recommended for deployment. Appendix B *cannot* be created until the entire plan has been finalized.
    - Appendix C: Rationale behind the saturation levels and crash modification factors assumed for developing the plan.

3.2. Develop Final Plan. The investigator should submit the draft plan, for review by key safety stakeholders involved in its development. Upon receipt of comments, the investigator should incorporate the changes resulting in a final RwD implementation plan. The plan should then be submitted to ODOT executive management for final approval.

3.3. Develop Remaining Appendices. Upon final approval of the plan, the analyst should create Appendix B, as follows:

After the completion of the plan, the investigator will provide the analyst with the thresholds and saturations of each countermeasure or project type for each setting and ownership. Combining these final decisions with the previously set crash type definitions in step 1.2.1 and updates provided in step 2.3; the analyst will be able to provide the list of locations for each recommended set of countermeasures.

The analyst will run the same type of queries as in step 1.2.2 to obtain the list of crash clusters with location information. Then, applying the threshold numbers and saturation ratios to this list, the analyst will be able to extract the top locations that satisfy these conditions. Based on the data availability, Mile Post or GPS latitude-longitude information will indicate the locations for recommended countermeasure deployment.

Exhibit A: Data Elements for Roadway Departure Safety Data Analysis

The following elements are requested for crash data analysis. Indicate in the columns to the right whether these elements are available and the estimated percentage of data considered valid.

	Data Element	Notes	Available (Y/N)	If Available, Data Source (Crash File or Roadway File)	Per-centage Valid
1.	Crash #		Y	Crash data	100%
2.	Year of Crash		Y	Crash data	100%
3.	Number of Vehicles		Y	Crash data	100%
4.	Crash Type		Y	Crash data	100%
5.	Manner of Collision		Y	Crash data	100%
6.	Harmful Events		Y	Crash data	100%
7.	Fixed object type		Y	Crash data	100%
8.	Highway alignment		Y	Crash data	100%
9.	Speed limit	Yes only if available in the Police Accident Report (PAR)	Y	Crash data	??
10.	State/local road ownership/maintenance		??	Crash data	100%
11.	Rural/urban area		Y	Crash data	100%
12.	County		Y	Crash data	100%
13.	City/ Municipality		Y	Crash data	100%
14.	Crash location		Y	Crash data	100%
15.	Light condition		Y	Crash data	100%
16.	Surface condition		Y	Crash data	100%
17.	Weather condition		Y	Crash data	100%
18.	AADT	Available for all state highways and some local agency roadways http://www.oregon.gov/ODOT/TD/TDATA/pages/tsm/tvt.aspx http://highway.intranet.odot.state.or.us/cf/	Y	Transportation data	??

	Data Element	Notes	Available (Y/N)	If Available, Data Source (Crash File or Roadway File)	Per-centage Valid
		highwayReports/traffic_parms.cfm			
19.	Maximum injury severity		Y	Crash data	100%
20.	Number of fatalities		Y	Crash data	100%
21.	Number of incapacitating injuries		Y	Crash data	100%
22.	Number of lanes	Total number of lanes in both directions		Crash data	100%
23.	Roadway length	??			
24.	Roadway width	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/aml_detail_parms.cfm	Y	Transportation data	??
25.	Median type		Yes	Crash data and transportation data	100%
26.	Median width	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/aml_detail_parms.cfm	Y	Transportation data	??
27.	Pavement type	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/mlpt_detail_parms.cfm	Y	Transportation data	??
28.	Year surface improved				
29.	Skid number	We can get this data from Pavement Services for State Highways only.	N		
30.	Year of skid test	We can get this data from Pavement Services for State Highways only.	N		
31.	Shoulder type	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/mlpt_detail_parms.cfm	Y	Transportation data	??
32.	Shoulder width	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/mlpt_detail_parms.cfm	Y	Transportation data	??
33.	Year shoulder improved				
34.	Divided/ undivided road	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/mlpt_detail_parms.cfm	Y	Transportation data and crash data	??
35.	Restricted/ open access road		Y	Crash data	100%
36.	Road type	Did you mean functional classification?	Y	Crash	100%

	Data Element	Notes	Available (Y/N)	If Available, Data Source (Crash File or Roadway File)	Per-centage Valid
				data and transportation data	
37.	Horizontal alignment	Available for state highways only. http://highway.intranet.odot.state.or.us/cf/highwayReports/horizontal_curves_parms.cfm	Y	Transportation data	
38.	Alcohol-related crash		Y	Crash data	100%
39.	Speed-related crash		Y	Crash data	100%
40.	Belted Unbelted		Y	Crash data	100%
41.	Crash narrative (available electronically?	Only for fatal crashes?????	Y	Crash data	??
42.	Pedestrian-involved		Y	Crash data	100%
43.	Bicycle-involved		Y	Crash data	100%
44.	Intersection identifier				

Additional Questions

- What are the required fields to properly connect the crash file to the roadway file?