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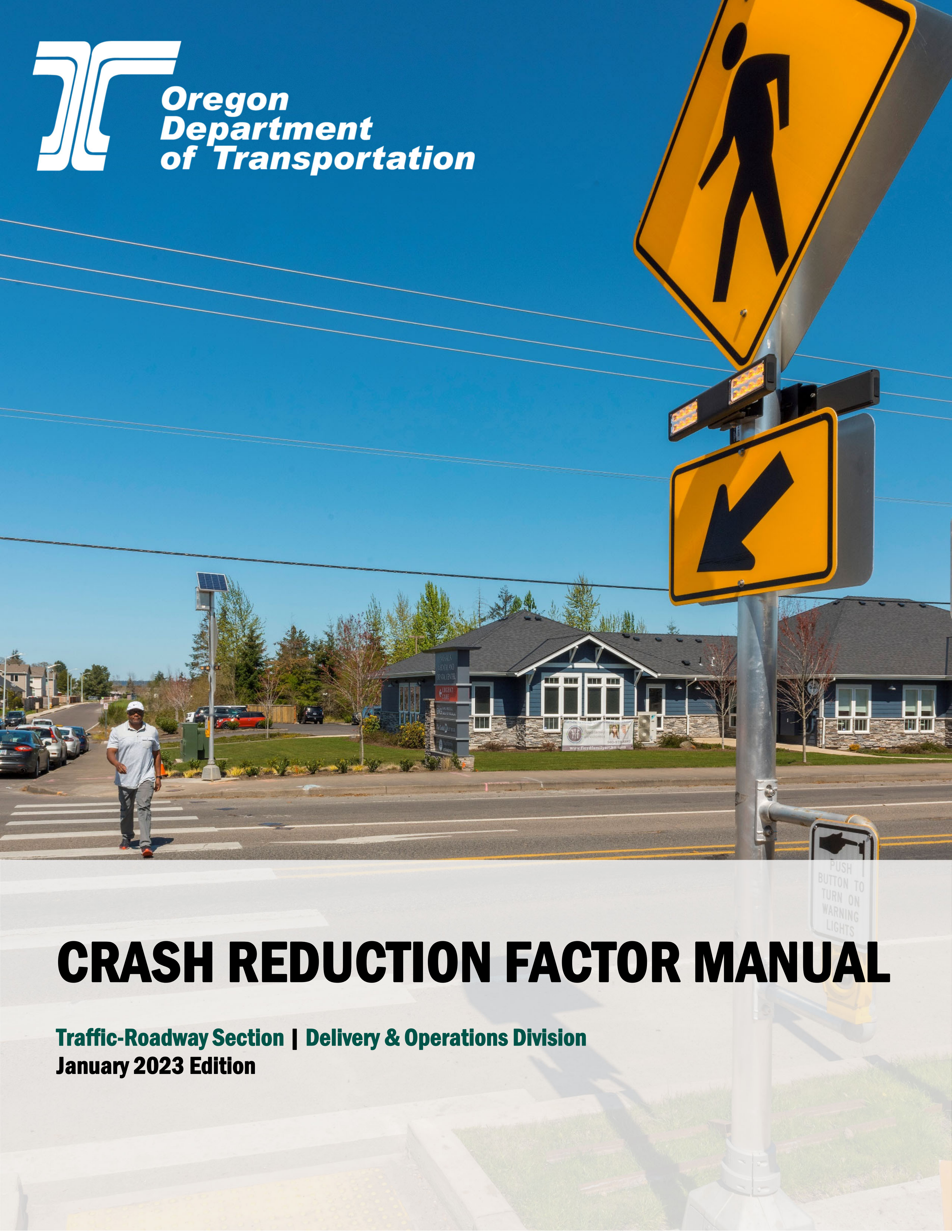

CRASH REDUCTION FACTOR MANUAL

Traffic-Roadway Section | Delivery & Operations Division

January 2023 Edition

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Acronym Glossary

ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
ARTS	All Roads Transportation Safety
CMF	Crash Modification Factor
CRF	Crash Reduction Factor
DOT	Department of Transportation
FHWA	Federal Highway Administration
FYA	Flashing Yellow Arrow
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
ITS	Intelligent Transportation System
LED	light Emitting Diodes
LPI	Leading Pedestrian Interval
MPH	Mile Per Hour
MUT	Median U-turn
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
ODOT	Oregon Department of Transportation
PDO	Property Damage Only
PHB	Pedestrian Hybrid Beacon
RHCP	Railway-Highway Crossing Program
RRFB	Rectangular Rapid Flash Beacons
SHSP	Strategic Highway Safety Plan
SV	Superelevation Value
TWLTL	Two-way Left-turn Lane

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Chapter 1 Introduction

Addressing the complex challenge of road safety demands a holistic approach that encompasses engineering, education, enforcement, and evaluation. Improving road infrastructure, promoting responsible driving behaviors, enforcing traffic regulations, and fostering public awareness all contribute to a safer transportation environment. While these measures collectively aim to reduce the risk of crashes, their effectiveness hinges on accurate assessments and informed decision-making. Some of the complex challenges in road safety include:

- Human Behavior: One of the biggest challenges in road safety is changing human behavior. Factors such as speeding, distracted driving (e.g., texting or using a phone), driving under the influence of alcohol or drugs, and not using seat belts contribute significantly to increased crash frequency and severity.
- Vulnerable Road Users: Protecting vulnerable road users such as pedestrians, cyclists, and motorcyclists presents challenges due to their limited protection in case of a crash and the difficulty of ensuring their visibility to other road users.
- Enforcement and Regulation: Effective enforcement of traffic laws and regulations is necessary to promote road safety. However, ensuring consistent enforcement and deterring violations can be challenging.
- Education and Awareness: Raising public awareness about road safety issues, including behaviors and the importance of safe driving practices, is an ongoing challenge.
- Data Collection and Analysis: Accurate and comprehensive data collection and analysis are needed for identifying trends, understanding the causes of crashes, and identifying effective safety treatments.
- Diverse Road Users: Different types of road users, such as pedestrians, cyclists, motorcyclists, and drivers of various types of vehicles, have different needs and face distinct risks, requiring tailored approaches to address safety.
- Cultural and Socioeconomic Factors: Cultural attitudes toward road safety, as well as socioeconomic factors that influence access to education, proper vehicles, and enforcement resources, can impact road safety outcomes.
- Urbanization and Population Growth: Rapid urbanization and population growth can strain existing road infrastructure and lead to increased traffic congestion, posing challenges for road safety management.

Traffic crashes are complex events that typically result from the interaction of multiple contributing factors. Understanding how these factors interact and contribute to crashes is needed for improving road safety and implementing effective countermeasures or safety treatments. It's important to note that in many cases, factors often interact and amplify each other's effects. For example, a driver who is both distracted and speeding is more likely to be involved in a crash. Similarly, adverse weather combined with unfamiliare road conditions can also increase the probability of a crash.

A comprehensive approach to analyzing and addressing these contributing factors is crucial for improving road safety. The Safe Systems Approach has been embraced by the transportation community as an effective way to address and mitigate factors inherent in our enormous and complex transportation system. It works by building and reinforcing multiple layers of protection to both prevent crashes from happening in the first place and minimize the harm caused to those involved when crashes do occur. It is a holistic and comprehensive approach that provides a guiding framework to make places safer for people.

1.1 Purpose

The *Safety Countermeasures List* is developed to provide safety practitioners, intending to use HSIP funding, with a list of effective countermeasures that are appropriate improvements to many common safety issues. The countermeasures presented in this manual are aimed at reducing crash frequency or severity on all public roads. These countermeasures represent infrastructure improvements at intersections and along roadways such as the addition of signs, signals, or markings, or a change in roadway design. ODOT uses some of the following references to develop the Crash Reduction Factor (CRF) list:

- The Crash Modification Factors (CMF) Clearinghouse
- FHWA's Proven Safety Countermeasures
- Highway Safety Manual (HSM), First Edition, 2010
- FHWA Desktop Reference for Crash Reduction Factors (CRF)
- Manual for Selecting Safety Improvements on High-Risk Rural Roads (HRRR)
- Engineering judgement

Safety Practitioners are encouraged to utilize these references to gain a deeper understanding of the listed countermeasures and the details surrounding their application. As previously noted, crashes often result from a combination of factors, it's important to recognize that any single countermeasure may not comprehensively address all contributing factors.

In order for the ARTS program applications to be evaluated fairly, use of these countermeasures is required. The countermeasures have been sorted into 2 primary categories: countermeasures eligible for Hotspot funding and countermeasures eligible for Systemic funding. Systemic funding is further divided into Roadway Departure, Intersection, and Bicycle & Pedestrian for informational use only.

ODOT recognizes that there may be countermeasures that are not included on the list where CRF's have not been established yet when this manual was published. Please use the form provided at this website to submit your suggestion for new CRF countermeasures to be added to the list.

The safety treatments in this list are those that have been in place for an extended period and/or have proven effective. As new safety research data becomes available, the list will be evaluated to update, add, or remove some safety improvement countermeasures.

ODOT is interested in any feedback and suggestions from safety practitioners on the overall countermeasure list as well as specific details of individual countermeasures. Please send all other feedback and suggestions to ODOT State Highway Safety Engineer Christina McDaniel-Wilson at christina.A.MCDANIEL-WILSON@odot.oregon.gov.

Chapter 2 Summary of Crash Reduction Factor for Safety Countermeasures

2.1 Safety Countermeasures and Crash Reduction Factors

Safety countermeasures, also known as safety treatments, are strategies, actions, technologies, or improvements implemented to reduce the likelihood and severity of crashes. They are typically based on extensive research, data analysis, and best practices to improve their effectiveness in reducing factors and improving safety outcomes. Study results for safety treatments can vary widely depending on the specific study context and the types of factors being addressed.

Examples of safety countermeasures include installing a traffic signal, increasing the width of edge lines, and installing a median barrier. In the past several decades, the federal and state agencies have developed a series of safety countermeasures to reduce crashes, especially fatal and serious injury crashes. The National Cooperative Highway Research Program (NCHRP) Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan listed many safety countermeasures for targeted crash types. Recently, the Federal Highway Administration (FHWA) has developed the Proven Safety Countermeasures for implementation by state and local agencies. This initiative is a collection of countermeasures and strategies effective in reducing roadway fatalities and serious injuries.

Crash Modification Factors (CMF) and Crash Reduction Factors (CRF) are related concepts used in transportation safety analysis to assess the effectiveness of safety countermeasures and treatments. Both are used to quantify the impact of safety improvements on reducing the frequency or severity of crashes, but they focus on different aspects of the analysis. The relationship between the two is straightforward, the CMF quantifies the change in crash experience resulting from a safety treatment, while the CRF provides a complementary measure of the crash reduction achieved by that treatment.

$$1 = CMF + CRF$$

CRFs are typically expressed as percentages, those with a positive value indicate an expected decrease in crashes, while those with a negative value indicate an expected increase in crashes.

For example, if a CRF for a new traffic signal installation at a intersection is determined to be 30%, it means that the implementation of that signal could potentially lead to a 30% reduction in the number of crashes at that intersection compared to its previous state. Similarly, if a CRF for adding reflective lane markings on a stretch of road is 20%, it implies that this measure might result in a 20% decrease in the occurrence of crashes on that road.

Because a CRF provides a direct measure of the crash reduction achieved by a safety treatment, it is used directly in our benefit cost (B/C) calculation. While CRF’s serve as valuable tools for analysts o make informed decisions about allocating resources to improve road safety and reduce the occurrence of crashes, it's important to note that they are estimations and can vary based on study factors such as the specific characteristics of the site, the effectiveness of the chosen countermeasure, and the quality of data used for the research and analysis.

2.2 Combining Safety Countermeasures

It's important to note that the hot spot safety approach and the systemic safety approach are not mutually exclusive; they can complement each other. Some analysts may use a combination of both countermeasure types to create a comprehensive and effective safety strategy that addresses both specific locations and broader systemic issues. While ODOT asks applicants to submit separate applications for hotspot and for systemic treatments, the flexibility exists to combine these approaches, provided that the application type being proposed contributes to over 50% of the projected benefits. It is important to note that a maximum of four countermeasures can be applied in one application.

2.3 Crash Reduction Factors for Hotspot Safety Countermeasures

The hot spot safety approach in refers to a strategy that focuses on identifying and addressing specific locations or areas with a disproportionately high number of crashes, injuries, or fatalities. These locations are often referred to as "hot spots" because they exhibit a concentration of safety issues. The hot spot approach is a more reactive and targeted method compared to the systemic safety approach, which aims to address broader patterns and systemic deficiencies. Hotspot countermeasures are typically more expensive than systemic countermeasures. Examples of hotspot projects include installation of left turn lane(s), installation of a new traffic signal or roundabout at an intersection, or conversion of a signalized intersection to a roundabout. To be qualified for a hotspot project in ARTS, the location must have a crash history of at least one fatal or serious injury crash within the last five years of most recent crash data.

Key aspects of the hot spot safety approach include:

- Crash Data Analysis: The hot spot approach relies heavily on the analysis of crash data to identify locations where crashes are occurring at a higher rate than expected. This helps analysts pinpoint specific areas for treatment.

- Location-Specific treatments: Once hot spots are identified, analysts implement targeted treatments and countermeasures designed to improve safety at those locations. These may include changes to road design, signage, traffic signals, speed limits, and other measures.
- Immediate Impact: The hot spot approach aims to have a direct and immediate impact on improving safety at specific locations.
- Resource Allocation: Since the hot spot approach focuses resources on specific locations, it allows analysts to allocate their budget and efforts where they are most needed, maximizing the effectiveness of safety improvements.
- Collaboration with Law Enforcement: Law enforcement agencies often play a crucial role in the hot spot approach by increasing patrols, enforcing traffic laws, and conducting targeted enforcement efforts at identified hot spot locations.
- Community Engagement: In some cases, involving local communities and stakeholders in the hot spot approach can lead to more informed decisions and successful implementation of safety measures.

Short-Term Focus: While the hot spot approach can lead to immediate improvements at specific locations, it may not necessarily address underlying contributing systemic issues. The safety countermeasures in **Table 2-1** are for crash hotspots on both roadway segments and intersections. Detailed information for those safety countermeasures is included in **Chapter 3**.

The hotspot method addresses an individual location with a history of high crash frequency and severity. These hotspot locations must have a crash history of at least one fatal or serious injury crash within the last five years. Hotspot countermeasures are typically more expensive than systemic countermeasures. Examples of hotspot projects include installation of left-turn lane(s), installation of a new traffic signal or roundabout at an intersection, or conversion of a signalized intersection to a roundabout.

A collection of countermeasures has been developed by many federal, state and local agencies to effectively reduce fatalities and serious injuries. Practitioners now have many resources and tools available to help them identify potential safety improvements and decide which ones to implement. For example, the CMF Clearinghouse is a comprehensive and searchable database of published CMFs and offers transportation professionals a central, web-based repository of crash modification factors for various safety improvement countermeasures.

To provide technical guidance for state and local agencies on how to select safety improvement countermeasures for the ARTS program, ODOT developed the safety improvement countermeasures based on results from CMF Clearinghouse, technical reports on safety countermeasures, and references from other sources. A total of 66 engineering countermeasures are discussed in detail in this chapter, including a description of the safety countermeasure, typical scenario for applying the safety countermeasure, additional factors for consideration when using the countermeasure, and special conditions for the countermeasure.

Table 2-1. Summary of Crash Reduction Factors for Hotspot Safety Countermeasures

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	Add Std. Error	Reference	ADA Trigger	
H1	Median U-Turn Intersection Treatment	All	All Injury (not including PDOs)	20	Signalized /Unsignalized	Urban/Rural	30		Synthesis of the Median U-Turn Intersection Treatment (FHWA-HRT- 07-033), FHWA Proven Safety Countermeasures		
H2	Right Turn Lane on Single Major Road Approach: Unsignalized Intersection (3- or 4-leg)	All	All	20	Unsignalized	Urban/Rural	14		HSM/CMF Clearinghouse (CMF ID: 285)	Likely	
H3	Right Turn Lane on Both Major Road Approaches: Unsignalized Intersection (3- or 4-leg)	All	All	20	Unsignalized	Urban/Rural	26		HSM/CMF Clearinghouse (CMF ID:289)	Likely	
H4	Right Turn Lane on Single Major Road Approaches: Signalized Intersection (3- or 4-leg)	All	All	20	Signalized	Urban/Rural	4		HSM/CMF Clearinghouse (CMF ID: 286)	Likely	
H5	Right Turn Lane on Both Major Road Approaches: Signalized Intersection (3- or 4-leg)	All	All	20	Signalized	Urban/Rural	8		HSM/CMF Clearinghouse (CMF ID: 290)	Likely	
H6	Channelized Right Turn Lane with Raised Median	All	All Injury (not including PDOs)	20	Signalized /Unsignalized	Urban/Rural	35		FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-07-015)	Likely	
H7	Left Turn Lane on Single Major Road Approach: Urban, Unsignalized Intersection (3-leg)	All	All	20	Unsignalized	Urban	33		HSM/CMF Clearinghouse (CMF ID: 254)	Likely	
H8	Left Turn Lane on Both Major Road Approaches: Urban, Unsignalized Intersection (4-leg)	All	All	20	Unsignalized	Urban	47		HSM/CMF Clearinghouse (CMF ID: 269)	Likely	
H9	Left Turn Lane on Single Major Road Approach: Rural, Unsignalized Intersection (3-leg)	All	All	20	Unsignalized	Rural	44		HSM/CMF Clearinghouse (CMF ID: 253)		
H10	Left Turn Lane on Both Major Road Approaches: Rural, Unsignalized Intersection (4-leg)	All	All	20	Unsignalized	Rural	48		HSM/CMF Clearinghouse (CMF ID: 268)		
H11	Left Turn Lane on Single Major Road Approach: Urban, Signalized Intersection (3-leg)	All	All	20	Signalized	Urban	7		HSM/CMF Clearinghouse (CMF ID: 4644)	Likely	
H12	Left Turn Lane on Single Major Road Approach, Urban, Signalized Intersection (4-leg)	All	All	20	Signalized	Urban	10		HSM/CMF Clearinghouse (CMF ID: 262)		
H13	Left Turn Lane on Both Major Road Approaches: Urban, Signalized Intersection (4-leg)	All	All	20	Signalized	Urban	19		HSM/CMF Clearinghouse (CMF ID: 270)	Likely	
H14	Left Turn Lane on Single Major Road Approach: Rural, Signalized Intersection (3-leg)	All	All	20	Signalized	Rural	15		HSM/CMF Clearinghouse (CMF ID: 4643)	Likely	
H15	Left Turn Lane on Single Major Road Approach, Rural, Signalized Intersection (4-leg)	All	All	20	Signalized	Rural	18		HSM		

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	Add Std. Error	Reference	ADA Trigger	
H16	Left Turn Lane on Both Major Road Approaches: Rural, Signalized Intersection (4-leg)	All	All	20	Signalized	Rural	33		HSM	Likely	
H17	Channelized Left Turn Lane with Raised Median on All Approaches (3- or 4-leg)	All	All Injury (not including PDOs)	20	Signalized /Unsignalized	Urban/Rural	27		HSM/CMF Clearinghouse (CMF ID: 249)	Likely	
H18	Install Roundabout from Minor Road Stop Control	All	All Injury (not including PDOs)	20	Unsignalized	Urban/Rural	82		HSM/CMF Clearinghouse (CMF ID: 228)	Likely	
H19	Install Roundabout from Signalized Intersection	All	All Injury (not including PDOs)	20	Signalized	Urban/Rural	78		HSM/CMF Clearinghouse (CMF ID: 226)	Likely	
H20	Convert to All-Way Stop Control (From Urban 2-Way or Yield Control)	Angle	All	10	Unsignalized	Urban	75		HSM/CMF Clearinghouse (CMF ID: 310)		
H21	Convert to All-Way Stop Control (From Rural 2-Way or Yield Control)	All	All	10	Unsignalized	Rural	48		HSM/CMF Clearinghouse (CMF ID: 315)		
H22	Install Urban Traffic Signal	Angle	All	20	Unsignalized	Urban	67		HSM/CMF Clearinghouse (CMF ID: 323)	Likely	
H23	Install Urban Traffic Signal	Rear End	All	20	Unsignalized	Urban	-143		HSM/CMF Clearinghouse (CMF ID: 324)	Likely	
H24	Install Rural Traffic Signal	Angle	All	20	Unsignalized	Rural	77		HSM/CMF Clearinghouse (CMF ID: 326)	Likely	
H25	Install Rural Traffic Signal	Rear End	All	20	Unsignalized	Rural	-58		HSM/CMF Clearinghouse (CMF ID: 328)	Likely	
H26	Convert 4-Leg Intersection to Two 3-Leg Intersections (Minor St ADT is 15-30% of Total Entering Traffic)	All	All Injury (not including PDOs)	20	Unsignalized	Urban/Rural	25		HSM/CMF Clearinghouse (CMF ID: 201)	Likely	
H27	Convert 4-Leg Intersection to Two 3-Leg Intersections (Minor St ADT is 30% + of Total Entering Traffic)	All	All Injury (not including PDOs)	20	Unsignalized	Urban/Rural	33		HSM/CMF Clearinghouse (CMF ID: 202)	Likely	
H28	Install Rural Median Acceleration Lane	All	All Injury (not including PDOs)	20	Unsignalized	Rural	45		CMF Clearinghouse (CMF ID: 2755)/NCHRP 650		
H29	Install Lighting at Intersection	Night	All Injury (not including PDOs)	20	Signalized/ Unsignalized	Urban/Rural	38		HSM/CMF Clearinghouse (CMF ID: 433)	Likely	
H30	Install Lighting on a Roadway Segment	Night	All Injury (not including PDOs)	20	None - Roadway	Urban/Rural	28		HSM/CMF Clearinghouse (CMF ID: 192)		
H31	Install Any Type of Median Barrier	All	All Injury (not	20	None - Roadway	Urban/Rural	30		HSM/CMF Clearinghouse (CMF ID: 43)	Likely	

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	Add Std. Error	Reference	ADA Trigger	
			including PDOs)								
H32	Install New Guardrail (Not Median Barrier Application)	Run off the Road	All Injury (not including PDOs)	20	None - Roadway	Urban/Rural	47		CMF Clearinghouse (CMF ID: 38)		
H33	Install Two Way Left Turn Lane on 2-Lane Road	Rear End	All	20	None - Roadway	Urban/Rural	39		CMF Clearinghouse (CMF ID: 2351)		
H34	Reduce Urban Driveways from 48 to 26 - 48 per mile	All	All Injury (not including PDOs)	20	None - Roadway	Urban	29		HSM/CMF Clearinghouse (CMF ID: 177)	Likely	
H35	Reduce Urban Driveways from 26 - 48 to 10 - 24 per mile	All	All Injury (not including PDOs)	20	None - Roadway	Urban	31		HSM/CMF Clearinghouse (CMF ID: 178)	Likely	
H36	Reduce Urban Driveways from 10 - 24 to less than 10 per mile	All	All Injury (not including PDOs)	20	None - Roadway	Urban	25		HSM/CMF Clearinghouse (CMF ID: 179)	Likely	
H37	Provide a Raised Median, Urban 2-Lane Road	All	All Injury (not including PDOs)	20	None - Roadway	Urban	39		HSM/CMF Clearinghouse (CMF ID: 21)	Likely	
H38	Provide a Raised Median, Urban Multi-Lane Road	All	All Injury (not including PDOs)	20	None - Roadway	Urban	22		HSM/CMF Clearinghouse (CMF ID: 22)	Likely	
H39	Provide a Raised Median, Rural Multi-Lane Road	All	All Injury (not including PDOs)	20	None - Roadway	Rural	12		HSM/CMF Clearinghouse (CMF ID: 24)	Likely	
H40	Install Traversable Median (4 ft. or more)	All	All	20	None - Roadway	Urban/Rural	12		ODOT Engineering Judgement	Likely	
H41	Install Passing Lane or Climbing Lane on Rural, 2-Lane Roadway	All	All Injury (not including PDOs)	20	None - Roadway	Rural	25		HSM		
H42	Widen Rural Paved Lane Width by 1 foot	All	All	20	None - Roadway	Rural	5		CMF Clearinghouse (CMF ID: 3)		
H43	Flatten Horizontal Curve (Increase Radius)	All	All	20	None - Roadway	Urban/Rural	See table		CMF Clearinghouse (CMF ID: 9270)		
H44	Flatten Crest Vertical Curve	All	All	20	None - Roadway	Urban/Rural	20		CMF Clearinghouse (CMF ID: 721)/CMF Clearinghouse (CMF ID: 721)/FHWA Desktop Reference for Crash Reductions Factors (FHWA-SA- 08-011)		
H45	Improve Superelevation Variance on Rural Curves (Between 0.01 and 0.02)	All	All	20	None - Roadway	Rural	Function of superelevation variance		HSM/CMF Clearinghouse (CMF ID: 5183)		

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	Add Std. Error	Reference	ADA Trigger	
H46	Improve Superelevation Variance on Rural Curves (More than 0.02)	All	All	20	None - Roadway	Rural	Function of superelevation variance		HSM/CMF Clearinghouse (CMF ID: 5184)		
H47	Convert from Urban Two-Way to One-Way Traffic	All	All	20	None - Roadway	Urban	47		CMF Clearinghouse (CMF ID: 5234)		
H48	Increase Pavement Friction by Installing High Friction Surface Treatment - Curves Application	Wet Road	All	10	None - Roadway	Urban/Rural	52		CMF Clearinghouse (CMF ID: 7901)		
H49	Increase Pavement Friction by Installing High Friction Surface Treatment - Ramps Application	Wet Road	All	10	None - Roadway	Urban/Rural	86		CMF Clearinghouse (CMF ID: 7899)		
H50	Install Urban Variable Speed Limit Signs	All	All	10	None - Roadway	Urban	8		CMF Clearinghouse (CMF ID: 8730)		
H51	Install Urban Variable Speed Limit Signs with Queue/Weather Warning System	All	All	10	None - Roadway	Urban	14		ODOT Engineering Judgement		
H52	Install Rural Variable Speed Limit Signs	All	All	10	None - Roadway	Rural	20		ODOT Engineering Judgement		
H53	Convert 4-Lane Roadway to 3-Lane Roadway with Center Turn Lane (Road Diet)	All	All	20	None - Roadway	Urban	29		HSM/CMF clearinghouse (CMF ID: 199)	Likely	
H54	Install Truck Escape Ramp	Truck	All	20	None - Roadway	Urban/Rural	20		FHWA Desktop Reference for Crash Reductions Factors		
H55	Install Guide Signs	All	All	20	None - Roadway	Urban/Rural	15		FHWA Desktop Reference for Crash Reductions Factors/North Carolina CMF List in CMF Clearinghouse		
H56	Provide an Auxiliary Lane Between an Entrance Ramp and Exit Ramp (Freeway Interchange)	All	All	20	None - Roadway	Urban/Rural	20		CMF Clearinghouse (CMF ID: 3898)		
H57	Extend Deceleration Lane by Approximately 100 feet (Freeway Interchange)	All	All	20	None - Roadway	Urban/Rural	7		HSM/CMF Clearinghouse (CMF ID: 475)		
H58	Extend Acceleration Lane by Approximately 100 feet (Freeway Interchange)	All	All	20	None - Roadway	Urban/Rural	11		CMF Clearinghouse (CMF ID: 474)		
H59	Add Acceleration Lane (Interchange)	All	All	20	None - Roadway	Urban/Rural	Function of acceleration lane length		HSM		
H60	Reduce Intersection Skew Angle (Minor Street Stop-Controlled Intersections Only) on 3-Leg intersection	All	All	20	Unsignalized	Rural	Function of intersection skew angle		HSM		
H61	Reduce Intersection Skew Angle (Minor Street Stop-Controlled Intersections Only) on 4-Leg intersection	All	All	20	Unsignalized	Rural	Function of intersection skew angle		HSM		
H62	Truck Priority System (Detection)	Angle and Rear-End	All	10	Signalized	Urban/Rural	9		Field Evaluation of Detection-Control System (FHWA-HRT-14-058)		

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	Add Std. Error	Reference	ADA Trigger	
H63	Dual/Double Left Turn Lanes	All	All Injury (not including PDOs)	20	Signalized	Urban/Rural	29		Signalized Intersection Informational Guide (FHWA-SA-13-027)		
H64	Convert Two-Way Left-Turn Lane to Raised Median	All	All	20	None - Roadway	Urban/Rural	47		CMF Clearinghouse (CMF ID: 7771)		
H65	Install offset (buffered) right turn lane	Angle and Turning	All	20	None - Roadway	Rural	69		CMF Clearinghouse (CMF ID: 2777)/NCHRP Report 650		
H66	Install Speed Humps/Table (not on state highways)	All	All	20	None - Roadway	Urban	50		CMF Clearinghouse (CMF ID: 134)		

2.3 Crash Reduction Factors for Systemic Safety Countermeasures

Unlike the traditional (Hot Spot) safety approaches that focus primarily on identifying and mitigating specific locations (such as intersections or segments of road with a history of crashes), the systemic safety approach takes a broader perspective. It refers to a comprehensive and proactive strategy that focuses on identifying and addressing underlying factors and systemic issues that contribute to crashes, injuries, and fatalities on roadways. Safety treatments are widely implemented based on roadway features and other factors that are correlated with crash types, rather than crash frequency and severity.

The ARTS Program consists of three emphasis areas for systemic improvements: Roadway Departure, Intersection, and Pedestrian and Bicycle. To be qualified for a Systemic project in ARTS, the location must have at least one location with a fatal or serious injury crash within the last five years of most recent crash data.

Key aspects of the systemic safety approach include:

- Identifying Patterns and Trends: Systemic safety analysis involves studying data to identify recurring patterns and trends in crashes, often at a regional or network-wide level. This allows analysts to recognize common factors that contribute to crashes, such as certain road designs, vehicle types, or specific behaviors.
- Addressing Common Factors: Once common contributing factors are identified, analysts can implement targeted treatments and countermeasures that address these factors across the entire transportation network, rather than just at specific locations.
- Designing for Safety: The systemic safety approach emphasizes proactive road design that considers potential safety issues from the outset. By incorporating safe design principles and features, such as forgiving road geometries, clear signage, and appropriate lighting, analysts aim to prevent crashes from occurring in the first place.
- Multi-Agency Collaboration: Collaboration among multiple agencies and stakeholders, including transportation departments, law enforcement, public health agencies, and community organizations supports systemic safety. This collaborative approach allows for the integration of different perspectives and expertise.
- Data-Driven Decision-Making: Data analysis plays a crucial role in the systemic safety approach. By analyzing crash data, traffic flow information, and other relevant data sources, analysts can make informed decisions about where to prioritize safety improvements.

- Long-Term Impact: The systemic safety approach seeks to have a lasting impact by systematically addressing underlying issues and making holistic improvements. This approach aims to create a safer overall transportation system rather than simply reacting to individual incidents.
- Continuous Improvement: Systemic safety is an ongoing process that involves continuous monitoring, evaluation, and adjustment of strategies based on the effectiveness of implemented measures and changing circumstances.

By focusing on systemic factors that contribute to transportation safety issues, the systemic safety approach aims to reduce the frequency and severity of crashes, making roadways safer for all users. It's important to note that the hot spot safety approach and the systemic safety approach are not mutually exclusive; they can complement each other. Some analysts may use a combination of both approaches to create a comprehensive and effective safety strategy that addresses both specific locations and broader systemic issues.

2.4 Crash Reduction Factors Intersection Safety Countermeasures

Intersections serve as points where motor vehicles and other road users intersect, representing areas with the highest potential for conflicts within the transportation network. Negotiating left turns, lane changes, and maneuvering through intersections constitutes some of the most complex traffic situations that travelers encounter. Ensuring the safety of all individuals necessitates the provision of suitable signage, traffic control apparatus, road layout, illumination, and other proactive safety treatments.

ODOT identified a total of 33 safety countermeasures that can be used at intersection to mitigate crash occurrences. Those engineering countermeasures can be classified into the following subcategories:

- Traffic signs, including regular signs and enhanced signs
- Markings and delineators, including pavement and curb markings, delineators, pavement treatment, and channelizing islands and devices
- Other traffic control devices, including traffic signals and intelligent transportation system (ITS) devices
- Geometric improvements, including intersection realignment and intersection reconfiguration measures
- Other countermeasures that do not belong to the above subcategories

A summary of those engineering countermeasures for intersection safety is summarized in **Table 2-2**. More detailed information on those safety countermeasures, including countermeasure description, application, consideration for using the safety countermeasure, CRF value and range of effectiveness, can be found in **Chapter 4**.

Table 2-2. Summary of Crash Reduction Factors for Intersection Safety Countermeasures

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
I1	Install lighting at intersection	Night	All injury (not including PDOs)	20	Signalized/ Unsignalized	Urban/Rural	38	31 - 38%	HSM/CMF Clearinghouse (CMF ID:433)		Likely
I2	Improve signal hardware: lenses, reflectorized back plates, size, and number	All	All	20	Signalized	Urban/Rural	20% for 2 countermeasures from list/25% for 3-4 countermeasures from list/30% for 5-6 countermeasures from list	0 - 46%	Oregon Intersection Safety Implementation Plan/ODOT Engineering Judgment	Backplates with Retroreflective Borders	
I3	Add 3-inch yellow retroreflective sheeting to signal backplates	All	All	10	Signalized	Urban	15	15%	CMF Clearinghouse (CMF ID: 1410)/FHWA-SA-17-051/FHWA Proven Safety Countermeasure	Backplates with Retroreflective Borders	
I4	Replace 8-inch red signal heads with 12-inch	Angle	All	10	Signalized	Urban/Rural	42	42%	CMF Clearinghouse (CMF ID: 2333)		
I5	Increase signal head quantity - additional primary head	All	All	10	Signalized	Urban	28	28%	CMF Clearinghouse (CMF ID: 1414)/ Signalized Intersection Informational Guide, Second Edition (FHWA-SA-13-027)		
I6	Replace incandescent traffic signal bulbs with light emitting diodes (LEDs)	Rear end	All	10	Signalized	Urban	17	17%	CMF Clearinghouse (CMF ID:4901)/ Safety Evaluation of Converting Traffic Signal from Incandescent to Lighting-Emitting Diodes (FHWA-HRT-13-070)		
I7	Replace night time flash with stead operation	All	All	10	Signalized	Urban/Rural	48	48%	CMF Clearinghouse (CMF ID: 4887)		
I8	Replace doghouse with flashing yellow arrow signal heads	Left turning	All	20	Signalized	Urban/Rural	25	25%	Safety Effectiveness of Flashing Yellow Arrow: Evaluation of 222 Signalized Intersections in North Carolina		
I9	Replace urban permissive or protected/permissive left turns to protected only	Left turning	All	20	Signalized	Urban	99	6 - 99%	HSM/CMF Clearinghouse (CMF ID: 333)		
I10	Protected left turn - split side street signal phasing	Left turning	All	10	Signalized	Urban/Rural	70	70%	North Carolina CMF list in CMF Clearinghouse		
I11	Replace urban permissive left turns to protected/permissive	Left turning	All Injury (not including PDOs)	20	Signalized	Urban	16	6 -99%	HSM/CMF Clearinghouse (CMF ID: 4578)		
I12	Change from permissive only to FYA - permissive only	Left turning	All	10	Signalized	Urban/Rural	50	50%	CMF Clearinghouse (CMF ID: 7700)		
I13	Install adaptive signal timing of urban traffic signals	All	All	10	Signalized	Urban	17	17%	CMF Clearinghouse (CMF ID: 6856)		
I14	Install actuated advance warning dilemma zone protection system at high speed signals (microwave detection)	All	All	10	Signalized	Urban/Rural	8	0 - 43.6%	CMF Clearinghouse (CMF ID: 4857)		
I15	Install flashing beacons as advance warning at intersections (not coordinated with signal timing)	All	All	10	Signalized/ Unsignalized	Urban/Rural	13	10.2 -13.3%	FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)		

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
I16	Install actuated or coordinated flashing beacons as advance warning for signalized intersections	Rear-end	All	10	Signalized	Urban/rural	10	10	ODOT Engineering Judgement		
I17	Increase triangle sight distance	All	All Injury (not including PDOs)	10	Signalized/ Unsignalized	Urban/Rural	48	11 - 56%	CMF Clearinghouse (CMF ID: 307)		
I18	Increase pavement friction by installing high friction surface treatment - intersection or segment application	Wet road	All	10	Signalized/ Unsignalized	Urban/Rural	57	17 - 57%	CMF Clearinghouse (CMF ID: 195)		
I19	Left turning traffic calming treatments (left turn wedge), posted speeds < 35 MPH	Left turning	All	20	Signalized	Urban	10	10%	ODOT Engineering Judgement		
I20	Left turning traffic calming treatments (hardened centerline), posted speeds <35 MPH	Left turning	All	20	Signalized	Urban	10	10%	ODOT Engineering Judgement		
I21	Improve intersection warning: stop ahead pavement markings, stop ahead signs, larger signs, additional stop signs and/or other intersection warning or regulatory signs	All	All	10	Unsignalized	Urban/Rural	20% for 1-2 countermeasures from list/25% for 3-4 countermeasures from list/30% for 5-7 countermeasures from list	11 - 55%	Oregon Intersection Safety Implementation Plan/ODOT Engineering Judgment	Systemic Application of Multiple Low-Cost Countermeasures at Stop- Controlled Intersections	
I22	Install advance warning signs (signal ahead)	Angle	All	10	Signalized	Urban	35	35%	CMF Clearinghouse (CMF ID: 1684)/FHWA Desktop Reference for Crash Reductions Factors (FHWA-SA-08-011)		
I23	Increase retroreflectivity of stop signs (reflective strips on sign post optional)	Angle	All	10	Unsignalized	Urban/Rural	7	7%	CMF Clearinghouse (CMF ID: 6048)	Systemic Application of Multiple Low-Cost Countermeasures at Stop- Controlled Intersections	
I24	Provide flashing beacons at all-way stop controlled intersections	Angle	All	10	Unsignalized	Urban/Rural	28	5 - 58%	HSM/CMF Clearinghouse (CMF ID: 454)		
I25	Provide flashing beacons at minor road stop controlled intersections	Angle	All	10	Unsignalized	Urban/Rural	13	5 - 58%	HSM/CMF Clearinghouse (CMF ID: 449)		
I26	Provide actuated flashing beacons triggered by approaching vehicles at unsignalized intersections	All	All	10	Unsignalized	Urban/Rural	27	27%	CMF Clearinghouse (CMF ID: 8441)		
I27	Install transverse rumble strips on stop controlled approach(es)	All	Fatal/serious Injury	10	Unsignalized	Urban/Rural	25	-36 - 33%	CMF Clearinghouse (CMF ID: 2705)		
I28	Install 6 feet or greater raised divider on stop approach (splitter island)	All	All	20	Unsignalized	Urban/Rural	15	15%	FHWA Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections (FHWA-SA-09-020)		
I29	Prohibit right-turn-on-red	All	All	10	Signalized	Urban/Rural	9	9%	HSM		
I30	Provide "Stop Ahead" pavement markings	All	All	10	Unsignalized	Rural	31	31%	HSM	Systemic Application of Multiple Low-Cost	

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
										Countermeasures at Stop- Controlled Intersections	
I31	Provide overhead lane-use signs	Rear end	All	10	Signalized	Urban/Rural	10	10%	Signalized Intersections: Informational Guide (FHWA_HRT-04-091)		
I32	Install wrong way driving countermeasures: signing, pavement markings, geometric modifications, and ITS technologies	All	All	20	Unsignalized	Urban/Rural	20%: for 2 countermeasures from list/30%: for 3 countermeasures from list/40%: for 4 (or more) countermeasures from list	20% - 40%	Wrong Way Driving Analysis and Recommendations		
I33	Curb extensions	All	All	20	Signalized /Unsignalized	Urban	30	30%	Michigan Intersection Crash Reduction Factors		Likely

2.5 Crash Reduction Factors for Pedestrian and Bicyclist Safety Countermeasures

Pedestrians and bicyclists are the most vulnerable road users. Approximately two-thirds of pedestrian- and bicyclist-related fatal crashes occur outside of a marked crosswalk or bicycle lane. Many serious and fatal injuries to pedestrians and bicyclists occur during dark or dusk hours. Motorist speed is one of the major factors that can mean the difference between a minor injury and a serious injury or fatality for a bicyclist or pedestrian. As speed increases, the likelihood of a crash with a bicyclist or pedestrian resulting in a fatality or serious injury also increases.

Safety countermeasures are critical for reducing pedestrian and bicyclist crashes in Oregon. In the past several decades, the federal, state and local agencies in US have developed a series of safety countermeasures for reducing fatal and serious injury crashes that involve vulnerable roadway users, including rectangular rapid flashing beacons, leading pedestrian intervals, crosswalk visibility enhancements, raised crosswalks, and pedestrian crossing and refuge islands.

This manual is intended to provide practitioners with the latest engineering countermeasures available for improving the safety of pedestrians and bicyclists. A total of 31 engineering countermeasures for pedestrian and bicyclist safety are discussed in this manual. The safety treatments selected for inclusion in this document are those that have been in place for an extended period of time and have proven effective when this document was written. New countermeasures continue to be developed, implemented, and evaluated and will be incorporated into this manual if needed when updating the manual in the next round. A brief summary of those engineering countermeasures is listed in **Table 2-3**. The practitioners are recommended to check **Chapter 5** of this manual for more detailed information on the description, application, consideration and special conditions of those safety countermeasures.

Table 2-3. Summary of Crash Reduction Factors for Pedestrian and Bicyclist Safety Countermeasures

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
BP1	Install pedestrian countdown timer(s)	Pedestrian	All	20	Signalized	Urban/Rural	70	0 - 70%	CMF Clearinghouse (CMF ID: 5272)		
BP2	Provide intersection lighting (bike & pedestrian)	Pedestrian & bicyclist night	All Injury (not including PDOs)	20	Signalized/ Unsignalized	Urban/Rural	42	42%	HSM/CMF Clearinghouse (CMF ID: 436)		Likely
BP3	Install urban leading pedestrian or bicycle interval at signalized intersection	Pedestrian & bicyclist	All	10	Signalized	Urban	37	37 - 45%	CMF Clearinghouse (CMF ID: 436)/Safety Effectiveness of Leading Pedestrian Intervals Using Empirical Bayes Method	Leading Pedestrian Intervals	
BP4	Install no pedestrian phase feature with flashing yellow arrow	Pedestrian	All	20	Signalized	Urban/Rural	43	43%	Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety (FHWA-HRT-18-044)		
BP5	Reduce right turn permissive conflicts (right turn arrow)	Pedestrian & bicyclist	All	20	Signalized	Urban/Rural	20	20%	ODOT Engineering Judgement		
BP6	Install urban green bike lanes at conflict points	Bicycle	All	10	Signalized/ Unsignalized	Urban	39	39%	CMF Clearinghouse (CMF ID: 3258)		
BP7	Install bike box at conflict points	Bicycle	All	10	Signalized	Urban/Rural	35	35%	Signalized Intersections Informational Guide, Second Edition (FHWA-SA-13-027)		
BP8	Install pedestrian refuge island	Pedestrian	All	20	None - Roadway	Urban/Rural	31	26 - 31%	CMF Clearinghouse (CMF ID: 8799)/NCHRP Report 841	Medians and Pedestrian Refuge Islands in Urban and Suburban Areas	Likely
BP9	Install rectangular rapid flashing beacon (2-lane road)	Pedestrian	All	20	None - Roadway	Urban/Rural	10	10 - 56%	NCHRP Report 841/ODOT Engineering Judgment		
BP10	Install pedestrian activated beacon at intersection	Pedestrian & bicyclist	All	20	None - Roadway	Urban	10	10%	NCHRP Report 841/ODOT Engineering Judgment		
BP11	Install rectangular rapid flashing beacon without median (3- lane or more roadway)	Pedestrian	All	20	None - Roadway	Urban/Rural	10	10 - 56%	NCHRP Report 841/ODOT Engineering Judgment		
BP12	Install rectangular rapid flashing beacon with median (3-lane or more roadway)	Pedestrian	All	20	None - Roadway	Urban/Rural	56	10 - 56%	NCHRP Report 841/ODOT Engineering Judgment	Medians and Pedestrian Refuge Islands in Urban and Suburban Areas	
BP13	Install pedestrian activated beacon midblock	Pedestrian & bicyclist	All	20	None - Roadway	Urban	10	10%	NCHRP Report 841/ODOT Engineering Judgment		
BP14	Install pedestrian activated beacon (flashing beacon in conjunction with median and stop bar)	Pedestrian & bicyclist	All	20	None - Roadway	Urban	56	56%	NCHRP Report 841/ODOT Engineering Judgment	Medians and Pedestrian Refuge Islands in Urban and Suburban Areas	
BP15	Install continental crosswalk markings and advance pedestrian warning signs at uncontrolled locations	Pedestrian	All	10	None - Roadway	Urban/Rural	15	15%	FHWA Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections (FHWA-SA-09-020)		
BP16	Install curb ramps and extensions with a marked crosswalk and pedestrian warning signs	Pedestrian	All	20	None - Roadway	Urban/Rural	37	37%	FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-07-015)		
BP17	Install advance pedestrian or bicycle warning signs	Pedestrian & bicyclist	All	10	None - Roadway	Urban/Rural	5	5 - 15%	FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-07-015)		
BP18	Install pedestrian signal	Pedestrian & bicyclist	All	20	None - Roadway	Urban/Rural	55	15 - 69%	FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-07-015)		Likely

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
BP19	Install pedestrian hybrid beacon	Pedestrian & bicyclist	All	20	None - Roadway	Urban	55	55 - 69%	CMF Clearinghouse (CMF ID: 2922)/CMF Clearinghouse (CMF ID: 9020)/NCHRP Report 926/FHWA Proven Safety Countermeasure	Pedestrian Hybrid Beacons	Likely
BP20	Convert 4-lane roadway to 3-lane roadway with center turn lane (road diet)	All	All	20	None - Roadway	Urban	29	29%	HSM/NCHRP Report 926	Road Diets (Roadway Reconfiguration)	Likely
BP21	Install bike signal	Bicycle	All	20	Signalized	Urban/Rural	45	45%	FHWA MUTCD Interim Approval for Optional Use of a Bicycle Signal Face (IA-16)		
BP22	Install bike lanes	Bicycle	All	20	None - Roadway	Urban/Rural	36	0 - 53%	FHWA Desktop Reference for Crash Reductions Factors (FHWA-SA-07-015)		
BP23	Install cycle tracks	Bicycle	All Injury (not including PDOs)	20	None - Roadway	Urban	59	59 - 74%	CMF Clearinghouse (CMF ID: 4097)/CMF Clearinghouse (CMF ID: 4102)		Likely
BP24	Install buffered bike lanes	Bicycle	All Injury (not including PDOs)	20	None - Roadway	Urban	47	N/A	ODOT Engineering Judgement		
BP25	Prohibit right-turn-on-red	Pedestrian & bicyclist	All	10	Signalized	Urban/Rural	41	26 - 44%	HSM		
BP26	Advanced yield and stop markings & signs	Pedestrian & bicyclist	All	10	None - Roadway	Urban/Rural	25	25%	CMF Clearinghouse (CMF ID: 9017)		
BP27	Install bicycle boulevard	Pedestrian & bicyclist	All	10	None - Roadway	Urban/Rural	63	63%	CMF Clearinghouse (CMF ID: 3092)		
BP28	Install raised crosswalk	Pedestrian & bicyclist	All	20	Signalized/ Unsignalized	Urban	30	30%	Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (FHWA-SA-014)		Likely
BP29	Sidewalk	Pedestrian (walking alone)	All	20	None - Roadway	Urban/Rural	20	20%	ODOT Engineering Judgement	Walkways	Likely
BP30	Install speed humps/table (not on state highways)	Pedestrian & bicyclist	All	20	None - Roadway	Urban	15	15%	CMF Clearinghouse (CMF ID: 145)		
BP31	Street trees (supports Blueprint for Urban Design)	All	All	20	None - Roadway	Urban	10	10%	ODOT Engineering Judgement		Likely

2.5 Crash Reduction Factors for Roadway Departure Safety Countermeasures

A roadway departure crash is one in which a vehicle leaves the roadway, possibly due to weaving or swerving, running off the road, wrong way driving, or overcorrecting, and collides with other vehicles, structures, trees, or other objects, or other people. Each year roadway departure crashes account for more than half of United States highway fatalities. A majority of these fatalities occur in rural areas and pertain to three general areas: overturning, opposing direction, and trees or shrubs. To reduce the number and severity of roadway departure crashes, safety practitioners focus on three objectives:

- Keep vehicles on the roadway and in their travel lane. Strategies include rumble strips, signing, delineation, and high friction surface treatments.
- Reduce the potential for severe crashes when vehicles do leave the roadway or cross into opposing traffic lanes. Strategies include shoulder installation; widen the separation between opposing direction lanes, removing fixed objects, and slope flattening.
- Minimize the severity of a roadway departure crash if it occurs. Strategies include breakaway supports, traversable drainage grates, barriers such as guard rail (or guide rail), and end treatments.

There are typically three implementation approaches to consider in reducing roadway departure crashes: the systemic approach, the spot location approach, and the comprehensive approach. These approaches may be done alone or in combination with each other. Traffic safety practitioners have developed a series of engineering countermeasures to reduce the roadway departure crashes or alleviate the crash severity, including chevrons, on-pavement markings, dynamic speed feedback signs, and longitudinal rumble strips.

To help reduce fatalities and serious injuries from roadway departure crashes, ODOT developed a series of engineering countermeasures for roadway departure crashes and included in this manual. The safety treatments selected for inclusion in this document are those that have been in place for an extended period of time and have proven effective when this document was written. New countermeasures continue to be developed, implemented, and evaluated and will be incorporated into this manual if needed when updating the manual in the next round. A brief summary of those engineering countermeasures is listed in **Table 2-4**. The practitioners are recommended to check **Chapter 6** of this manual for more detailed information on the description, application, consideration and special conditions of those safety countermeasures.

Table 2-4. Summary of Crash Reduction Factors for Roadway Departure Safety Countermeasures

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
RD1	Increase distance to rural roadside obstacle from 3 feet to 16 feet	All	All	20	None - Roadway	Rural	22	22 - 44%	HSM/CMF Clearinghouse (CMF ID: 35)	Roadside Design Improvements at Curves	
RD2	Increase distance to rural roadside obstacle from 16 feet to 30 feet	All	All	20	None - Roadway	Rural	44	22 - 44%	HSM/CMF Clearinghouse (CMF ID: 36)	Roadside Design Improvements at Curves	
RD3	Flatten rural side slopes	All	All	20	None - Roadway	Rural	See table	3 - 15%	HSM	Roadside Design Improvements at Curves	
RD4	Increase pavement friction by installing high friction surface treatment - intersection or segment application	Wet Road	All	10	None - Roadway	Urban/Rural	57	20 - 68%	CMF Clearinghouse (CMF ID: 195)	Roadside Design Improvements at Curves	
RD5	Provide safety edge for rural pavement edge drop-off	All	All	10	None - Roadway	Rural	6	5-15%	CMF Clearinghouse (CMF ID: 4311)	SafetyEdge℠	
RD6	Install recommended chevron signs on rural horizontal curves	Run Off The Road	All Injury (Excludes PDO's)	10	None - Roadway	Rural	16	4 - 25%	CMF Clearinghouse (CMF ID: 2438)	Enhanced Delineation for Horizontal Curves	
RD7	Install required chevron signs on rural horizontal curves (ballbanking and revised speed riders included)	Run Off The Road	All Injury (Excludes PDO's)	10	None - Roadway	Rural	16	16%	ODOT Engineering Judgement	Enhanced Delineation for Horizontal Curves	
RD8	Install oversized, doubled up and/or fluorescent yellow sheeting for advance curve warning signs	Run Off The Road	All	10	None - Roadway	Urban/Rural	20	20%	ODOT Engineering Judgement	Enhanced Delineation for Horizontal Curves	
RD9	Provide static combination horizontal alignment/advisory curve warning sign	All	All Injury (Excludes PDO's)	10	None - Roadway	Urban/Rural	13	13 - 29%	HSM/CMF Clearinghouse (CMF ID: 73)	Enhanced Delineation for Horizontal Curves	
RD10	Install advance curve warning flashers (curve warning signs exist)	Curve Crashes	All	10	None - Roadway	Urban/Rural	10	10%	ODOT Engineering Judgement	Enhanced Delineation for Horizontal Curves	
RD11	Install dynamic speed feedback sign for curves	All	All	10	None - Roadway	Rural	5	5%	CMF Clearinghouse (CMF ID: 6885)	Enhanced Delineation for Horizontal Curves	
RD12	Install speed feedback sign	All	All	5	None - Roadway	Urban/Rural	10	10%	ODOT Engineering Judgement		
RD13	Install raised or recessed pavement markers	Night	All	10	None - Roadway	Urban/Rural	15	15%	Oregon Roadway Departure Implementation Plan Update		

ID	Countermeasure Name	Crash Type	Crash Severity	Service Life (year)	Facility Type	Facility Context	CRF (%)	CRF Range	Reference	FHWA Proven Safety Countermeasure	ADA Trigger
RD14	Install post-mounted delineators (curve application)	Curve crashes at Night	All	10	None - Roadway	Urban/Rural	30	0 - 30%	FHWA Desktop Reference for Crash Reduction Factors (FHWA-SA-07-015)	Enhanced Delineation for Horizontal Curves	
RD15	Install edgeline striping (tangent and/or curve application)	Run off the Road	All	10	None - Roadway	Rural	11	11 - 13%	CMF Clearinghouse (CMF ID: 1943)/CMF Clearinghouse (CMF ID: 1946)	Enhanced Delineation for Horizontal Curves	
RD16	Install centerline rumble strips	All	All Injury (Excludes PDO's)	10	None - Roadway	Rural	12	9 - 45%	CMF Clearinghouse (CMF ID: 3350)/CMF Clearinghouse (CMF ID: 3362)	Longitudinal Rumble Strips and Stripes	
RD17	Install centerline rumble strips	Head On & Sideswipe Meeting	All Injury (Excludes PDO's)	10	None - Roadway	Rural	45	45%	CMF Clearinghouse (CMF ID: 3360)	Longitudinal Rumble Strips and Stripes	
RD18	Install shoulder rumble strips	Run off the Road	All	10	None - Roadway	Urban/Rural	22	16 - 42%	CMF Clearinghouse (CMF ID: 2423)	Longitudinal Rumble Strips and Stripes	
RD19	Install profiled line pavement markings	Night & Wet Road	All	5	None - Roadway	Urban/Rural	9	0 - 9%	CMF Clearinghouse (CMF ID: 9803)/Safety Evaluation of Profiled Thermoplastic Pavement Markings (FHWA-HRT-17-075)		
RD20	Install widen paved shoulder by 1 foot.	All	All	20	None - Roadway	Urban/Rural	6	3 - 6%	CMF Clearinghouse (CMF ID: 5277)	Roadside Design Improvements at Curves	
RD21	Install widen paved shoulder by 2 feet.	All	All	20	None - Roadway	Urban/Rural	13	5 - 13%	CMF Clearinghouse (CMF ID: 5279)	Roadside Design Improvements at Curves	
RD22	Install widen paved shoulder by 3 feet.	All	All	20	None - Roadway	Urban/Rural	18	6 - 18%	CMF Clearinghouse (CMF ID: 5281)	Roadside Design Improvements at Curves	
RD23	Upgrade existing markings to wet-reflective pavement markings	Wet Road	All	10	None - Roadway	Urban/Rural	14	14%	CMF Clearinghouse (CMF ID: 8137)		
RD24	Install wider edgelines (4 inches to 6 inches)	All	All	10	None - Roadway	Rural	14	17%	CMF Clearinghouse (CMF ID: 4736)/CMF Clearinghouse (CMF ID: 10128)	Enhanced Delineation for Horizontal Curves	
RD25	Install any type of median barrier	All	All Injury (Excludes PDO's)	20	None - Roadway	Urban/Rural	30	30%	HSM/CMF Clearinghouse (CMF ID: 43)	Median Barriers	
RD26	Install new guardrail (not median barrier application)	Run off the Road	All Injury (Excludes PDO's)	20	None - Roadway	Urban/Rural	47	47%	CMF Clearinghouse (CMF ID: 38)	Roadside Design Improvements at Curves	
RD27	Install seasonal wildlife warning signs	All	All	20	None - Roadway	Rural	26	26%	Wildlife Warning Signs and Animal Detection Systems		
RD28	Install wildlife detection system	Wildlife only	All	20	None - Roadway	Rural	87	87%	Advances in Wildlife Crossing Technologies (FHWA-HRT-09-006)		

Chapter 3 Safety Improvement Countermeasures for Crash Hotspots

In the traditional approach for identifying candidate sites for safety improvement, decision-makers analyze the historical crash data in order to find segments and sites with a history of high severity crashes. This methodology is called hot spot approach. Hotspot analysis along with crash data summaries can give clues to decision-makers about potential treatments at the locations with a history of crashes.

The hotspot method addresses an individual location with a history of high crash frequency and severity. These hotspot locations must have a crash history of at least one fatal or serious injury crash within the last five years. Hotspot countermeasures are typically more expensive than systemic countermeasures. Examples of hotspot projects include installation of left-turn lane(s), installation of a new traffic signal or roundabout at an intersection, or conversion of a signalized intersection to a roundabout.

A collection of countermeasures have been developed by many federal, state and local agencies to effectively reduce fatalities and serious injuries. Practitioners now have many resources and tools available to help them identify potential safety improvements and decide which ones to implement. For example, the CMF Clearinghouse is a comprehensive and searchable database of published CMFs and offers transportation professionals a central, web-based repository of crash modification factors for various safety improvement countermeasures.

To provide technical guidance for state and local agencies on how to select safety improvement countermeasures for the ARTS program, ODOT developed the safety improvement countermeasures based on results from CMF Clearinghouse, technical reports on safety countermeasures, and references from other sources. A total of 66 engineering countermeasures are discussed in details in this chapter, including a description of the safety countermeasure, typical scenario for applying the safety countermeasure, additional factors for consideration when using the countermeasure, and special conditions for the countermeasure. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period and/or have proven effective. To reflect the most recent research results, the list will be evaluated periodically to add or remove some safety improvement countermeasures. Listed below are the countermeasures recommended for hotspot currently.

- H1-Median U-turn intersection treatment
- H2-Right turn lane on single major road approach: Unsignalized intersection (3- or 4-leg)

- H3- Right turn lane on both major road approaches: Unsignalized intersection (3- or 4-leg)
- H4- Right turn lane on single major road approach: Signalized intersection (3- or 4-leg)
- H5- Right turn lane on both major road approaches: Signalized intersection (3- or 4-leg)
- H6-Channelized right turn lane with raised median
- H7-Left-turn lane on single major road approach: Urban unsignalized intersection (3-leg)
- H8- Left-turn lane on both major road approaches: Urban unsignalized intersection (4-leg)
- H9- Left-turn lane on single major road approach: Rural unsignalized intersection (3-leg)
- H10- Left-turn lane on both major road approaches: Rural unsignalized intersection (4-leg)
- H11- Left-turn lane on single major road approach: Urban signalized intersection (3-leg)
- H12- Left-turn lane on single major road approach: Urban signalized intersection (4-leg)
- H13- Left-turn lane on both major road approaches: Urban signalized intersection (4-leg)
- H14- Left-turn lane on single major road approach: Rural signalized intersection (3-leg)
- H15- Left-turn lane on single major road approach: Rural signalized intersection (4-leg)
- H16- Left-turn lane on both major road approaches: Rural signalized intersection (4-leg)
- H17-Channelized left turn lane with raised median on all approaches (3- or 4-leg)
- H18-Install roundabout from minor road stop control
- H19-Install roundabout from signalized intersection
- H20-Convert to all-way stop control (from urban 2-way or yield control)
- H21- Convert to all-way stop control (from rural 2-way or yield control)
- H22-Install urban traffic signal
- H23-Install urban traffic signal
- H24-Install rural traffic signal
- H25- Install rural traffic signal
- H26-Convert 4-leg intersection to two 3-leg intersections (minor street AADT is 15% to 30% of total entering volume)
- H27- Convert 4-leg intersection to two 3-leg intersections (minor street AADT is more than 30% of total entering volume)
- H28-Install rural median acceleration lane
- H29-Install lighting at intersection
- H30-Install lighting on a roadway segment
- H31-Install any type of median barrier
- H32-Install new guardrail (not median barrier application)
- H33-Install two way left turn lane on 2-lane road
- H34-Reduce urban driveways from 48 to 26-48 per mile

- H35- Reduce urban driveways from 26-48 to 10-24 per mile
- H36- Reduce urban driveways from 10-24 to less than 10 per mile
- H37-Provide a raised median on urban 2-lane road
- H38- Provide a raised median on urban multi-lane road
- H39- Provide a raised median on rural multi-lane road
- H40-Install traversable median (4 feet or more)
- H41-Install passing lane on rural 2-lane roadway
- H42-Widen rural paved lane width by 1 foot
- H43-Flatten horizontal curve (increase radius)
- H44-Flatten crest vertical curve
- H45- Improve superelevation variance on rural curves (between 0.01 and 0.02)
- H46-Improve superelevation variance on rural curves (more than 0.02)
- H47-Convert from urban two-way to one-way traffic
- H48- Increase pavement friction by installing high friction surface treatment – curves application
- H49-Increase pavement friction by installing high friction surface treatment – ramps application
- H50-Install urban variable speed limit signs
- H51-Install urban variable speed limit signs with queue/weather warning system
- H52-Install rural variable speed limit signs
- H53-Convert 4-lane roadway to 3-lane roadway with center turn lane (road diet)
- H54-Install truck escape ramp
- H55-Install guide signs
- H56-Provide an auxiliary lane between an entrance ramp and exit ramp (freeway interchange)
- H57-Extend deceleration lane by approximately 100 feet (freeway interchange)
- H58-Extend acceleration lane by approximately 100 feet (freeway interchange)
- H59-Add acceleration lane (interchange)
- H60-Reduce intersection skew angle (minor street stop-controlled intersection only) on 3-leg intersection
- H61-Reduce intersection skew angle (minor street stop-controlled intersection only) on 4-leg intersection
- H62-Truck priority system (detection)
- H63-Dual/double left turn lanes
- H64-Convert two-way left-turn lane to raised median
- H65-Install offset (buffered) right turn lane
- H66-Install speed humps/tables (not on state highways)

3.1 H1-Median U-turn Intersection Treatment

ODOT CRF Value
30%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
30%

Safety Effects
Reduce the number of conflict points at the intersection and preserves corridor capacity

References
Median U-turn Intersection (FHWA-HRT-09-057)
FHWA Proven Safety Countermeasures

FHWA Proven Safety Countermeasure

Description
The Median U-turn (MUT) intersection modifies direct left turns from the major approaches. Vehicles proceed through the main intersection, make a U-turn a short distance downstream, followed by a right turn at the main intersection. The U-turns can also be used for modifying the cross-street left turns.

Figure 3-1. Median U-turn Intersection Treatment

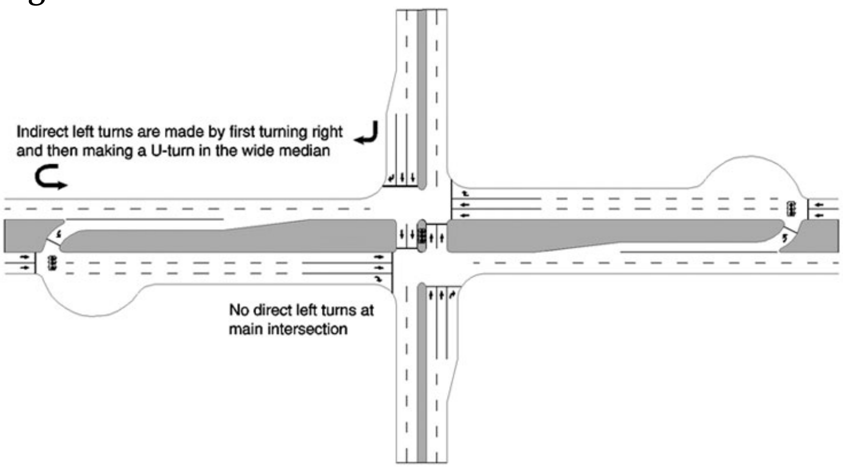


Image source: FHWA

Applications
Can be implemented for signalized or unsignalized intersections. MUT intersection treatments are typically implemented as part of a corridor treatment; however, they can also be used at isolated intersections. Unsignalized MUT intersections preserve corridor capacity and can be installed without the adverse effects of signal control. Scenarios where MUT intersections are most applicable include the followings:

- Relatively low to medium side-street through volumes and heavy left turn volumes from the major road.
- The minor road total volume to total intersection volume ratio is typically less than or equal to 0.20.
- Areas where median widths are greater than 40 feet. For narrower medians, loons or bulb-outs on the shoulders need to be constructed.

For intersections with very high left turn and through volumes from the side road approaches, the MUT intersection design is not the optimal choice.

Considerations

This countermeasure can be costly depending on right of way needs and have significant environmental and/or drainage impacts.

Special Conditions

Pair this countermeasure with turning restrictions at the intersection.

3.2 H2-Right-turn Lane on Single Major Road Approach at 3- or 4-leg Unsignalized Intersection

Description

A right-turn lane is an auxiliary lane for storage and to accommodate the decreasing speed of right-turn vehicles as they approach an intersection.

Figure 3-2. Right-turn Lane on Single Major Road Approach

Image source: FHWA and ODOT

Applications

At intersections with a high frequency of rear-end crashes resulting from conflicts between

- Vehicles turning right and following vehicles, or
- Vehicles turning right and through vehicles coming from the left on the cross street

Considerations

This countermeasure may require a significant amount of right of way. Provide enough storage length so that vehicles will not be queued in the travel lanes. For rural applications, using a buffered right-turn lane may improve safety by allowing drivers to see approaching vehicles behind the right-turning vehicles.

Special Conditions

This countermeasure CRF value can only be used for installing a right turn lane on ONE major road approach at a 3- or 4-leg UNSIGNALIZED intersection.

ODOT CRF Value

14%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness:

14%-26%

Safety Effects

Providing a right-turn lane at an intersection can reduce rear-end crashes by allowing vehicles to proceed through the intersection without having to stop or slow down for vehicles making a right turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 285)

Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

3.3 H3-Right-turn Lane on Both Major Road Approaches at 3- or 4-leg Unsignalized Intersection

Description
A right-turn lane is an auxiliary lane for storage and to accommodate the deceleration of right-turn vehicles as they approach an intersection.

Figure 3-3. Right-turn Lane on Both Major Road Approaches

Image source: Google

Applications
At intersections with a high frequency of rear-end crashes resulting from conflicts between
- Vehicles turning right and following vehicles, or
- Vehicles turning right and through vehicles coming from the left on the cross street

Considerations
This countermeasure may require a significant amount of right of way. Turns lanes shall be of adequate storage length so vehicles will not be stopped in the travel lanes. For rural applications, using a buffered right-turn lane may improve safety by allowing drivers to see approaching vehicles behind the right-turning vehicles.

Special Conditions
This countermeasure CRF value can only be used for installing right-turn lanes on BOTH major road approaches at a 3- or 4-leg UNSIGNALIZED intersection.

ODOT CRF Value
26%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
14% - 26%

Safety Effects
Providing a right-turn lane at an intersection can reduce rear-end crashes by allowing vehicles to proceed through the intersection without having to stop or slow down for vehicles making a right turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 289)
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

3.4 H4-Right-turn Lane on Single Major Road Approach at 3- or 4-leg Signalized Intersection

Description

A right-turn lane is an auxiliary lane for storage and to accommodate the deceleration of right-turn vehicles as they approach an intersection.

Figure 3-4. Right-turn Lane on Single Major Road Approach

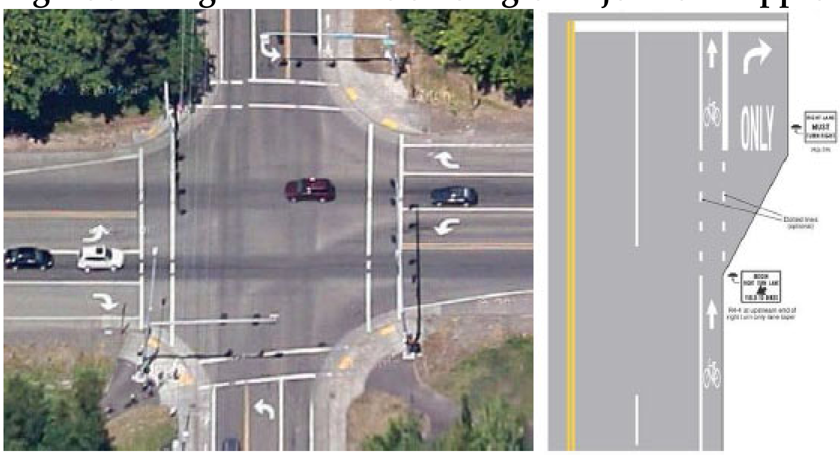


Image source: Google and FHWA

Applications

At intersections with a high frequency of rear-end crashes resulting from conflicts between

- Vehicles turning right and following vehicles, or
- Vehicles turning right and through vehicles coming from the left on the cross street

Considerations

This countermeasure may require a significant amount of right of way. Provide enough storage length so that vehicles will not be queued in the travel lanes.

Special Conditions

This countermeasure CRF value can only be used for installing a right-turn lane on ONE major road approach at a 3- or 4-leg SIGNALIZED intersection.

ODOT CRF Value

4%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

4%-9%

Safety Effects

Providing a right-turn lane at an intersection can reduce rear-end crashes by allowing vehicles to proceed through the intersection without having to stop or slow down for vehicles making a right turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 286)

Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

3.5 H5-Right-turn Lane on Both Major Road Approaches at 3- or 4-leg Signalized Intersection

Description

A right-turn lane is an auxiliary lane for storage and to accommodate the deceleration of right-turn vehicles as they approach an intersection.

Figure 3-5. Right-turn Lane on Both Majpr Road Approaches

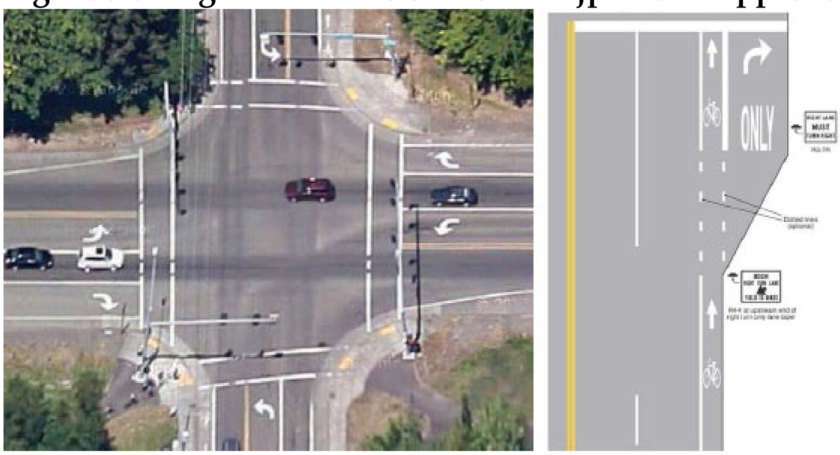


Image source: Google and FHWA

Applications

At intersections with a high frequency of rear-end crashes resulting from conflicts between

- Vehicles turning right and following vehicles, or
- Vehicles turning right and through vehicles coming from the left on the cross street

Considerations

This countermeasure may require a significant amount of right of way. Provide enough storage length so that vehicles will not be queued in the travel lanes. Providing a right-turn lane can also increase the crossing time needed for pedestrians, increasing their exposure to vehicle traffic.

Special Conditions

This countermeasure CRF value can only be used for installing right-turn lanes on BOTH major road approaches at a 3- or 4-leg SIGNALIZED intersection.

ODOT CRF Value

8%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

4%-9%

Safety Effects

Providing a right-turn lane at an intersection could reduce rear-end crashes by allowing through vehicles to proceed across the intersection without having to stop or slow down for vehicles making a right turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 290)

Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

3.6 H6-Channelized Right-turn Lane with Raised Median

Description

A right-turn lane separated from the through and left-turn lanes on the approach by a raised island and has separate traffic control from the primary intersection. The channelized right-turn lane may or may not have a deceleration lane entering it and it may have a merge or an auxiliary lane at the existing end.

Figure 3-6. Channelized Right-turn Lane

Image source: Google

Applications

Where there is a high volume of right-turning vehicles and the number of potential turning conflicts at an intersection needs to be minimized

Considerations

The countermeasure will create a wider intersection footprint and may require additional right of way.

Special Conditions

This countermeasure CRF value can be applied to BOTH signalized and unsignalized intersections. This countermeasure includes a concrete or raised island and it does NOT apply to painted islands.

ODOT CRF Value

35%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

25%-50%

Safety Effects

This countermeasure improves clarity for the minor street traffic, allowing them to identify vehicles in the through lanes on the major street and reduces the number of conflict points within an intersection. It can create a pedestrian refuge for two-stage crossings and it minimizes lane encroachment.

References

Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

3.7 H7-Left-turn Lane on Single Major Road Approach at Urban 3-leg Unsignalized Intersection

Description

A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left-turn channelization.

Figure 3-7. Left-turn Lane on Single Major Road Approach

Image source: FHWA

Applications

Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersections with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations

Provide enough storage length so that vehicles will not be queued in the travel lanes.

ODOT CRF Value

33%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

33%-55%

Safety Effects

Left-turn lanes allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 254)

Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

Special Conditions

This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at an URBAN 3-leg UNSIGNALIZED intersection.

3.8 H8-Left-turn Lane on Both Major Road Approaches at Urban 4-leg Unsignalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left-turn channelization.

Figure 3-8. Channelized Left Turn at Unsignalized 4-leg Intersection

Image source: Google

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersections with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes.

Special Conditions
This countermeasure CRF value can only be used for installing left-turn lanes on BOTH major road approaches at an URBAN 4-leg UNSIGNALIZED intersection.

ODOT CRF Value
47%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
47%-58%

Safety Effects
Left-turn lanes allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 269)
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

3.9 H9-Left-turn Lane on Single Major Road Approach at Rural 3-leg Unsignalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left-turn channelization.

Figure 3-9. Channelized Left Turn at Unsignalized 3-leg Intersection

Image source: FHWA

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersections with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations

Provide enough storage length so that vehicles will not be queued in the travel lanes. **Special Conditions**
This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at a RURAL 3-leg UNSIGNALIZED intersection.

ODOT CRF Value
44%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
33%-55%

Safety Effects
Left-turn lanes allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 253)
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

3.10 H10-Left-turn Lane on Both Major Road Approaches at Rural 4-leg Unsignalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-10. Left-turn Lane at Rural Unsignalized Intersection

Image source: FHWA

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersections with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes .

ODOT CRF Value

48%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

47%-58%

Safety Effects

Left-turn lanes allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 268)

Safety Effectiveness of Intersection Left- and Right- Turn Lanes (FHWA-RD-02-089)

FHWA Proven Safety Countermeasure

Special Conditions
This countermeasure CRF value can only be used for installing left-turn lanes on BOTH major road approaches at a RURAL 4-leg UNSIGNALIZED intersection.

3.11 H11-Left-turn Lane on Single Major Road Approach at Urban 3-leg Signalized Intersection

ODOT CRF Value

7%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

7%-15%

Safety Effects

Left-turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

[Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)]

Description

A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-11. Left Turn Channelization at Urban Signalized Intersection

Image source: Google

Applications

Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersections with high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations

Provide enough storage length so that vehicles will not be queued in the travel lanes. . Installing turn lane after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lane. Depending on left-turn volume, creating a permissive left turn would protect the adjacent pedestrian movements.

Special Conditions

This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at an URBAN 3-leg SIGNALIZED intersection.

3.12 H12-Left-turn Lane on Single Major Road Approach at Urban 4-leg Signalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-12. Left Turn Channelization at Urban 4-leg Signalized Intersection

Image source: FHWA

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersection with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

ODOT CRF Value
10%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
Left-turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 262)
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes. Installing turn lane after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lane. Consider pedestrian movements for left turn operations. Even if the left turn is permissive only, consideration of a FYA with not-pedestrian could alleviate the conflict between vehicles and pedestrians.

Special Conditions

This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at an URBAN 4-leg SIGNALIZED intersection.

3.13 H13-Left-turn Lane on Both Major Road Approaches at Urban 4-leg Signalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-13. Left Turn Channelization at 4-leg Signalized Intersection

Image source: FHWA

ODOT CRF Value
19%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
17%-48%

Safety Effects
Left turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 270)
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersection with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes. Installing turn lanes after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lane. Consider pedestrian movements for left turn operations. Even if the left turn is permissive only, consideration of a FYA with not-pedestrian could alleviate the conflict between vehicles and pedestrians.

Special Conditions

This countermeasure CRF value can only be used for installing left-turn lanes on BOTH major road approaches at a URBAN 4-leg SIGNALIZED intersection.

3.14 H14-Left-turn Lane on Single Major Road Approach at Rural 3-leg Signalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-14. Left Turn Channelization at Rural Signalized Intersection

Image source: Google

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersection with a high frequency of crash between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes. Installing turn lane after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lane.

ODOT CRF Value

15%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

7%-15%

Safety Effects

Left-turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

Special Conditions

This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at an RURAL 3-leg SIGNALIZED intersection.

3.15 H15-Left-turn Lane on Single Major Road Approach at Rural 4-leg Signalized Intersection

Description

A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-15. Left Turn Channelization at Rural 4-leg Signalized Intersection

Image source: Google

ODOT CRF Value
18%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
18%

Safety Effects
Left-turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual

Applications

Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersection with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations

Provide enough storage length so that vehicles will not be queued in the travel lanes. Installing turn lane after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lane.

Special Conditions

This countermeasure CRF value can only be used for installing a left-turn lane on ONE major road approach at an RURAL 4-leg SIGNALIZED intersection.

3.16 H16-Left-turn Lane on Both Major Road Approaches at Rural 4-leg Signalized Intersection

Description
A left-turn lane is an auxiliary lane for storage and to accommodate the deceleration of left-turn vehicles as they approach an intersection. This countermeasure is also known as left turn channelization.

Figure 3-16. Left Turn Channelization at Rural 4-leg Signalized Intersection

Image from Google

ODOT CRF Value
33%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
17%-48%

Safety Effects
Left-turn lanes could allow through vehicles to proceed across the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Safety Effectiveness of Intersection Left- and Right-turn Lanes (FHWA-RD-02-089)

Applications
Use this countermeasure where there is a high frequency of rear-end crashes resulting from the conflicts between vehicles turning left and following vehicles. Intersection with a high frequency of crashes between vehicles turning left and opposing through vehicles are also candidates for installing the left-turn lanes. Drivers feel less pressure to take insufficient gaps when they have their own lane to wait in.

Considerations
Provide enough storage length so that vehicles will not be queued in the travel lanes. Installing turn lanes after a signal has been in place may result in the need to relocate signal poles in order to accommodate the standard width of the turn lanes.

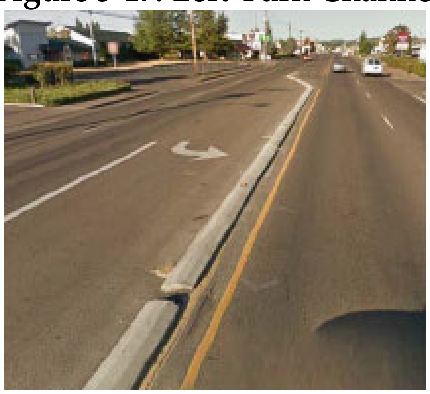
Special Conditions

This countermeasure CRF value can only be used for installing left-turn lanes on BOTH major road approaches at a RURAL 4-leg SIGNALIZED intersection.

3.17 H17-Channelized Left-turn Lane at 3- or 4-leg Intersection with Raised Median on All Approaches

Description
Channelized left-turn lanes provide a median separation between the designated left-turn lane and opposing through lanes at an intersection. This treatment is a basic curb separator that can also include a positive offset where sufficient median widths exist.

Figure 3-17. Left Turn Channelization with Raised Median



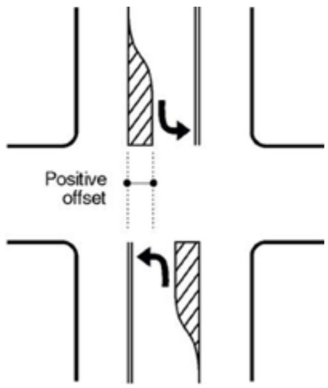


Image source: Google and FHWA

Applications
This countermeasure can be applied to locations where
- There is a high frequency of intersection crashes between vehicles turning left and opposing through vehicles, and/or
- There is a high frequency of turning movements from adjacent business accesses conflicting with intersection movements

Considerations
This countermeasure needs sufficient pavement width. It also have the potential impacts on adjacent business accesses.

Special Conditions
This countermeasure CRF can be applied to signalized and unsignalized intersections. It includes a concrete or raised median and is NOT applicable for painted medians.

ODOT CRF Value

27%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

4%-27%

Safety Effects

Channelized left-turn lanes provide the left-turning motorist a line of sight to opposing through vehicles, allowing them to see oncoming traffic. This counter-measure can also serve to protect the designated left-turn lane from vehicles turning into and out of adjacent business accesses.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 249)

3.18 H18-Convert Minor Road Stop Controlled Intersection into Roundabout

Description

A modern roundabout is a type of circular intersection defined by the basic operational principle that entering traffic yields to vehicles on the circular roadway.

Figure 3-18. Roundabout at Unsignalized Intersection

Image source: FHWA

Applications

Consider roundabouts for all existing unsignalized intersections that have been identified as needing major safety or operational improvements. Typical crash patterns that could be resolved with a roundabout are crashes related with higher than expected speed, angle and/or turning crashes.

Considerations

Roundabouts require a significant amount of public outreach and education in addition to requiring a larger geometric footprint than a typical intersection.

Special Conditions

Map-21 Legislation declares a national focus to reduce fatal and serious injury (A-injury) crashes on public roadways. Roundabouts are one of the primary tools that can be used to reduce crash severity and meet this national goal.

ODOT CRF Value

82%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness:

19%-82%

Safety Effects

Roundabouts eliminate up to 75% of vehicle conflict points typically associated with traditional intersections. They also enhance safety by reducing vehicle speeds (more typical in rural settings) both in and through the intersection and by changing the crash type from angle to sideswipe, which typically results in less severe crashes.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 228)

FHWA Proven Safety Countermeasure

3.19 H19-Convert Signalized Intersection into Roundabout

Description
A modern roundabout is a type of circular intersection defined by the basic operational principle that entering traffic yields to vehicles on the circular roadway.

Figure 3-19. Roundabout at Previously Signalized Intersection

Image source: FHWA

Applications
Consider roundabouts for all existing signalized intersections that have been identified as needing major safety or operational improvements that cannot be resolved by modifications for signalized intersection. Typical crash patterns that could be resolved with a roundabout are crashes related with high speed, angle and/or turning crashes.

Considerations
Roundabouts require a significant amount of public outreach and education in addition to requiring a larger geometric footprint than a typical signalized intersection.

Special Conditions
Map-21 Legislation declares a national focus to reduce fatal and serious injury (A-injury) crashes on public roadways. Roundabouts are one of the primary tools that can be used to reduce crash severity and meet this national goal.

ODOT CRF Value:
78%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
48%-78%

Safety Effects
Roundabouts eliminate up to 75% of vehicle conflict points typically associated with traditional intersections. They also enhance safety by reducing vehicle speeds (more typical in rural settings) both in and through the intersection and by changing the crash type from angle to sideswipe, which typically results in less severe crashes.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 226)

FHWA Proven Safety Countermeasure

3.20 H20-Convert Urban 2-way or Yield Control to All-way Stop Control

Description
Modify an intersection with minor road stop or yield control to an intersection where the major legs have to stop in addition to the minor legs.

Figure 3-20. All-way Stop Controlled Intersection in Urban

Image source: FHWA

Applications
Unsignalized 2-way stop or yield controlled intersections with a pattern of right-angle and turning crashes and relatively balanced volumes on the intersection approaches.

Considerations
Identify moderate volume situations where all-way stop control will operate efficiently without substantially more delay than a signalized intersection. Not every two-way stop-controlled intersection is as a candidate for all-way stop control. Use this countermeasure selectively, recognizing traffic volumes and patterns and potentially adverse reaction by the driving population to being stopped for no apparent reason. If drivers encounter substantial delays, they may become impatient and act irrationally, which can lead to crash patterns of the type that the strategy is intended to correct.

ODOT CRF Value
75%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
18%-75%

Safety Effects
All-way stop control can reduce right-angle and turning collisions at unsignalized intersections by providing more orderly movement at an intersection, reducing through and turning speeds, and minimizing the safety impacts of any sight distance restrictions that may be present.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 310)
The Safety Effect of Conversion to All-Way Stop Control (TRR 1068)

Special Conditions

This CRF value is for URBAN intersections ONLY. The Manual on Uniform Traffic Control Devices (MUTCD) lists guidance for the placement of all-way (multi-way) stop sign applications, which should be reviewed as installation of this treatment is considered.

3.21 H21-Convert Rural 2-way or Yield Control to All-way Stop Control

Description
Modify an intersection with minor road stop or yield control to an intersection where the major legs have to stop in addition to the minor legs.

Figure 3-21. All-way Stop Control in Rural

Image source: FHWA

Applications
Unsignalized 2-way stop or yield controlled intersections with a pattern of right-angle and turning crashes and relatively balanced volumes on the intersection approaches.

Considerations
Identify moderate volume situations where all-way stop control will operate efficiently without substantially more delay than a signalized intersection. Not every two-way stop-controlled intersection is a candidate for all-way stop controlled intersection. Use this countermeasure selectively, recognizing traffic volumes and patterns and potentially adverse reaction by the driving population to being stopped for no apparent reason. If drivers encounter substantial delays, they may become impatient and act irrationally, which can lead to crash patterns of the type that the strategy is intended to correct.

ODOT CRF Value
48%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness:
18%-75%

Safety Effects
All-way stop control can reduce right-angle and turning collisions at unsignalized intersections by providing more orderly movement at an intersection, reducing through and turning speeds, and minimizing the safety impacts of any sight distance restrictions that may be present.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 315)
The Safety Effect of Conversion to All-Way Stop Control (TRR 1068)

Special Conditions

This CRF value is for RURAL intersections ONLY. The MUTCD lists guidance for the placement of all-way (multi-way) stop sign applications, which should be reviewed as installation of this treatment is considered.

3.22 H22-Install Traffic Signal at Urban Intersection

Description

Traffic signal is a traffic control device positioned on roadways to efficiently control and manage competing flows of traffic (vehicles, pedestrians, and/or bicycles).

Figure 3-22. Traffic Signal at Urban Intersection

Image source: Google

Applications

Where an unsignalized intersection is experiencing a high frequency of right-angle crashes with adequate sight distance to that intersection from all approaches.

Considerations

It is important that the existing intersection crash patterns are related to failing to yield to right of way as opposed to failing to yield to slowing traffic as a signal installation will likely increase the latter.

ODOT CRF Value

67%

Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness

57%-77%

Safety Effects

Traffic signals help assign right of way to traffic movements, which helps reduce right-angle crashes at intersections.

References:

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 323)

Special Conditions

While signals decrease the potential for angle crashes, simultaneously they increase the potential for rear-end crashes. It is also important to note that rear-end crashes in high speed corridors typically result in more severe crashes than in lower speed corridors. Benefit/cost analysis using this countermeasure include CRF values listed in Section 3.22 and 3.23, one for decreasing angle crashes and the other for increasing rear-end crashes, to best represent the expected changes in safety with installation. The MUTCD lists nine warrants for the placement of traffic signals, which should be reviewed as installation of this treatment is considered. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

3.23 H23-Install Traffic Signal at Urban Intersection

ODOT CRF Value
-143%
Reduction in **rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness
-205%--81%

Safety Effects
Traffic signals help assign right of way to traffic movements which helps increase rear-end crashes at intersections.

References
Highway Safety Manual
[Crash Modification Factors Clearinghouse (CMF ID: 324)]

Description
Traffic signal is a traffic control device positioned on roadways to efficiently control and manage competing flows of traffic (vehicles, pedestrians, and/or bicycles).

Figure 3-23. Traffic Signal at Urban Intersection

Image source: Google

Applications
Where an unsignalized intersection is experiencing a high frequency of right-angle crashes with adequate sight distance to that intersection from all approaches.

Considerations
It is important that the existing intersection crash patterns are related to failing to yield to right of way as opposed to failing to yield to slowing traffic as a signal installation will likely increase the latter.

Special Conditions
While signals decrease the potential for angle crashes, simultaneously they increase the potential for rear-end crashes. It is also important to note that rear-end crashes in high-speed corridors typically result in more severe crashes than in lower-speed corridors. Benefit/cost analysis using this countermeasure include the CRF values listed in Section 3.22 and 3.23, one for decreasing angle crashes and the other for increasing rear-end crashes, to best represent the expected changes in safety with installation. The MUTCD lists nine warrants for the placement of traffic signals, which should be reviewed as installation of this treatment is considered. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

3.24 H24-Install Traffic Signal at Rural Intersection

Description
Traffic signal is a traffic control device positioned on roadways to efficiently control and manage competing flows of traffic (vehicles, pedestrians and/or bicycles).

Figure 3-24. Traffic Signal at Rural Intersection

Image source: Google

Applications
Where an intersection is experiencing a high frequency of right-angle crashes with adequate sight distance to that intersection from all approaches.

Considerations
It is important that the existing intersection crash patterns are related to failing to yield to right of way as opposed to failing to yield to slowing traffic as a signal installation will likely increase the latter.

ODOT CRF Value
77%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
73%-81%

Safety Effects
Traffic signals help assign right of way to traffic movements, which helps reduce right-angle crashes at intersections.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 326)

Special Conditions
While signals decrease the potential for angle crashes, simultaneously they increase the potential for rear-end crashes. It is also important to note that rear-end crashes in high-speed corridors typically result in more severe crashes than in lower-speed corridors. Benefit/cost analysis using this countermeasure include CRF values listed in Section 3.24 and 3.25, one for decreasing angle crashes and the other for increasing rear-end crashes, to best represent the expected changes in safety with installation. Meanwhile, the MUTCD lists nine warrants for the placement of traffic signals, which should be reviewed as installation of this treatment is considered. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

3.25 H25-Install Traffic Signal at Rural Intersection

ODOT CRF Value

-58%

Reduction in **rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness

-30--86%%

Safety Effects

Traffic signals help assign right of way to traffic movements, which helps reduce right-angle crashes at intersections.

References:

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 328)

Description

Traffic signal is a traffic control device positioned on roadways to efficiently control and manage competing flows of traffic (vehicles, pedestrians and/or bicycles).

Figure 3-25. Traffic Signal at Rural Intersection

Image source: Google

Applications

Where an intersection is experiencing a high frequency of right-angle crashes with adequate sight distance to that intersection from all approaches.

Considerations

It is important that the existing intersection crash patterns are related to failing to yield to right of way as opposed to failing to yield to slowing traffic as a signal installation will likely increase the latter.

Special Conditions

While signals decrease the potential for angle crashes, simultaneously they increase the potential for rear-end crashes. It is also important to note that rear-end crashes in high-speed corridors typically result in more severe crashes than in lower-speed corridors. Benefit/cost analysis using this countermeasure include CRF values listed in Section 3.24 and 3.25, one for decreasing angle crashes and the other for increasing rear-end crashes, to best represent the expected changes in safety with installation. Meanwhile, the MUTCD lists nine warrants for the placement of traffic signals, which should be reviewed as installation of this treatment is considered. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

3.26 H26-Convert 4-leg Intersection to Two 3-leg Intersections when Minor Road ADT is between 15 and 30 Percent of Total Entering Volume

Description
Realignment of a 4-leg intersection to two 3-leg intersections in an appreciable distance along the major street.

Figure 3-26. Convert 4-leg Intersection into Two 3-leg Intersections

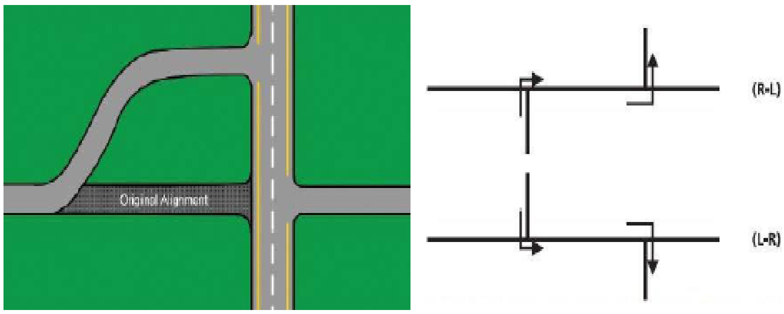


Image source: FHWA and HSM

Applications
Where an intersection is experiencing a high frequency and/or severity of right-angle and/or turning crashes and the minor street volumes are relatively low compared to the major street. This is only applicable to unsignalized intersections when a signal or roundabout is not feasible.

Considerations
If the intersections are not spaced far enough apart, the following can occur:

- There may not be enough storage length for the left-turning vehicles between the intersections;
- The operations of the intersections may interfere with one another.

In addition, this countermeasure usually requires a significant amount of right of way to build an entire new roadbed.

Special Conditions
Per HSM Guidance, this countermeasure is specifically for intersections with the minor street average daily traffic (ADT) being 15-30% of the total entering traffic. The two intersections can be right-left staggered (see the R-L image above) or left-right staggered (see the L-R image above).

ODOT CRF Value

25%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

10%-33%

Safety Effects

Less conflict points after converting a single, 4-leg intersection into two 3-leg intersections

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 201)

3.27 H27-Convert 4-leg Intersection to Two 3-leg Intersections when Minor Road ADT is More Than 30% of Total Entering Traffic

Description

Realignment of a 4-leg intersection to two 3-leg intersections in an appreciable distance along the major street.

Figure 3-27. Convert 4-leg Intersection into Two 3-leg Intersections

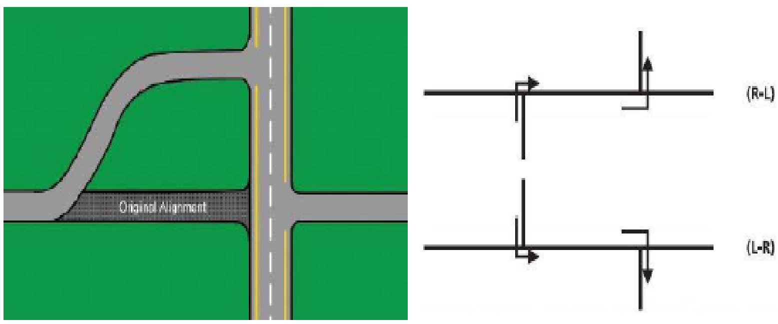


Image source: FHWA and HSM

ODOT CRF Value

33%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

10%-33%

Safety Effects

Less conflict points after converting a single, 4-leg intersection into two 3-leg intersections

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 202)

Applications

Where an intersection is experiencing a high frequency and/or severity of right-angle and/or turning crashes and the minor street volumes are relatively low compared to the major street. Consider this countermeasure in areas where a signal or roundabout is not feasible.

Considerations

If the intersections are not spaced far enough apart, the following can occur:

- There may not be enough storage length for the left-turning vehicles between the intersections;
- The operations of the intersections may interfere with one another.

In addition, this countermeasure usually requires a significant amount of right of way to build an entire new roadbed.

Special Conditions

Per HSM Guidance, this countermeasure is specifically for intersection with minor street ADT being 30% or more of the total entering traffic. The two intersections can be right-left staggered (see the R-L image above) or left-right staggered (see the L-R image above).

3.28 H28-Install Rural Median Acceleration Lane

Description
A left-turn auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds before entering the through traffic lanes of a roadway.

Figure 3-28. Median Acceleration Lane

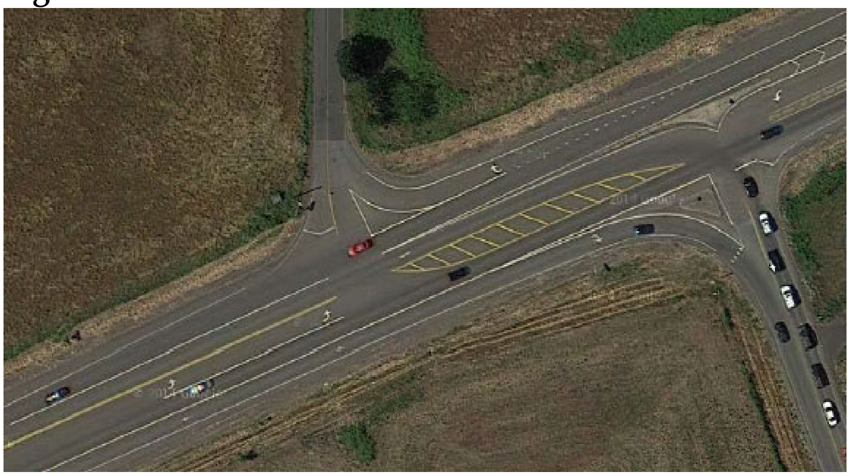


Image source: Google

Applications
At unsignalized intersections that are experiencing a high proportion of crashes related to speed differential caused by vehicles turning left onto the highway. They may also be used where intersection sight distance is limited, or where there are high volumes of trucks entering from the minor road onto the major road. Typically, they are used on divided roadways, but successes have also be seen on undivided roadways when paired with concrete lane separators.

Considerations
Acceleration lanes should be of sufficient length to permit adjustments in speeds for both through and entering vehicles so that the driver of the entering vehicle can safely maneuver into a gap before reaching the end of the acceleration lane. Acceleration lanes can establish an add lane that does not require merging, when feasible. I

Special Conditions

ODOT CRF Value

45%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

20%-79%

Safety Effects

Drivers turning onto a roadway accelerate until the desired highway speed is reached. When acceleration by entering traffic takes place directly on the traveled way, it may disrupt the flow of through traffic and create potential conflicts. Median acceleration lanes can help minimize this operational challenges at rural intersections.

References

Crash Modification Factors Clearinghouse (CMF ID: 2755)

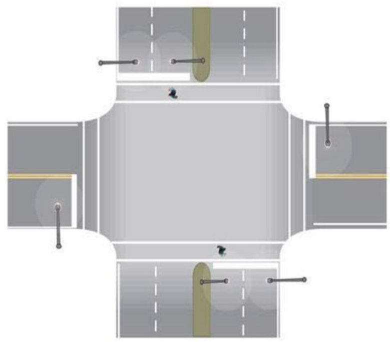
Median Intersection Design for Rural High-speed Divided Highways (NCHRP Report 650)

This countermeasure can only be applied to rural areas. Verify that acceleration lanes are operationally warranted by relatively high left-turn volumes. Design the median opening area appropriately to minimize conflicts between vehicles entering the left-turn acceleration lane and other turning vehicles using the median opening.

3.29 H29-Install Lighting at Intersection

Description
A permanent source of artificial light installed at an intersection that provides greater visibility of the intersection.

Figure 3-29. Lighting at Intersection



Images source: FHWA

Applications
Intersections that are experiencing a high instance of dark or nighttime crashes. Particularly for unsignalized intersections, rear-end, right-angle, or turning crashes on the major road approaches may indicate that approaching drivers are unaware of the presence of the intersection.

Considerations
In rural areas it may be difficult to locate a power source. In addition, it is important to determine, upfront, the jurisdiction responsible for paying the ongoing utility costs.

Special Conditions
This countermeasure is for new lighting only, not to replace existing, substandard lighting. This CRF value can be applied to signalized and unsignalized intersections. Refer to the ODOT *Lighting Policy and Guidelines* for further guidance on lighting warrants for ODOT highways.

ODOT CRF Value
38%
Reduction in **night crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
31%-38%

Safety Effects
Intersection lighting allows for greater visibility of the intersection, making signs and markings more visible and helping drivers determine a safe path through the intersection. This can be especially helpful at rural intersections where the only source of lighting for the roadway is often provided by vehicle headlights.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 433)

3.30 H30-Install Lighting on a Roadway Segment

Description

A permanent source of artificial light installed on a segment of roadway that provides greater visibility of the roadway.

Figure 3-30. Lighting on Roadway Segment

Image Source: Google and American Electric Lighting

Applications

Segments of roadway that are experiencing a high instance of dark or nighttime crashes, particularly crashes related to missed visual roadway cues.

Considerations

In rural areas it may be difficult to locate a power source. In addition, it is important to determine, upfront, the jurisdiction responsible for paying the ongoing utility costs.

Special Conditions

This countermeasure is for new lighting, not to replace existing, substandard lighting. This CRF value applies to roadway segments only. For ODOT highways, refer to the ODOT *Lighting Policy and Guidelines* for further guidance on lighting warrants.

ODOT CRF Value

28%

Reduction in **night crashes** at **all injury severities** (not including fatal and PDOs)

Range of Effectiveness

17%-29%

Safety Effects

Segment lighting allows for greater visibility of the roadway and the visual cues that help drivers determine a safe path along the roadway. This can be especially helpful in rural areas where the only source of lighting for the roadway is often provided by vehicle headlights.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 192)

3.31 H31-Install Any Type of Median Barrier

Description
Median barriers are longitudinal barriers most commonly used to separate opposing directions of traffic on a divided highway.

Figure 3-31. Median Barrier

Images source: FHWA

Applications
On divided highways with high speeds and high volumes and/or on divided highways with a high frequency of fatal or serious injury median crossover crashes.

Considerations
Ease and costs of maintenance and repair for these barrier systems is an important consideration.

Special Conditions
There are three basic categories of median barriers that each have their own set of pros and cons: rigid barrier systems, semi-rigid barrier systems and flexible barrier systems. Vehicle types, roadway geometry and potential severity of median crossover crashes must be considered when choosing a median barrier type.

- Rigid barriers (i.e. concrete barrier) have a high installation cost but a low life-cycle cost.
- Semi-Rigid barriers (i.e. guardrail) are most suitable for use in traversable medians having no or little change in grade and cross slope. Initial cost is lower than rigid barriers but it generally has a higher life cycle cost due to repair needs. Typical installation of semi-rigid median barrier is on divided roadways with 20,000 ADT or more and medians less than 50 feet wide.

ODOT CRF Value
30%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness:
-24%-43%

Safety Effects
While these systems may not reduce the frequency of crashes due to roadway departure, they do help prevent a median crash from becoming a median crossover head-on collision which has a high chance of resulting in a fatality or severe injury.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 43)

FHWA Proven Safety Countermeasure

- Flexible barriers (i.e. cable barrier) are the most forgiving barrier systems available for reducing the severity of median crossover crashes. They generally have a lower installation cost than rigid and semi-rigid barriers, but typically have a higher life cycle cost due to repair needs. Typical installations of flexible median barriers are in medians less than 50 feet wide.

3.32 H32-Install New Guardrail (not median barrier application)

Description

A semi-rigid barrier typically consisting of connected segments of metal railing supported by posts and blocks.

Figure 3-32. Roadside Guardrail

Images source: FHWA

Applications

Install guardrails where there is evidence of the need (i.e. crash history) to shield motorists from a roadside fixed object that has a higher possibility for fatal or serious injury crashes than the guardrail itself. Potential roadside fixed objects could be point (such as a bridge pier or utility pole), medium-sized (such as roadside culverts), and long (such as steep roadside slopes).

Considerations

Guardrails themselves are roadside fixed objects that a motorist can potentially strike (subsequently creating a lot of potential maintenance costs as well), so it is important to minimize guardrail installation to locations where a motorist needs to be protected from roadside fixed objects that have a higher possibility for fatal or serious injury crashes.

Special Conditions

See NCHRP Report 638 Guidelines for Guardrail Installation for more guidance on guardrail installation.

ODOT CRF Value

47%

Reduction in **run-off road crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

44%-47%

Safety Effects

Because guardrail systems are designed to absorb energy during a crash, and the entire assembly is designed to move or deflect during an impact, guardrail systems usually minimize potential injuries in run-off road or roadway departure crashes.

References

Crash Modification Factors Clearinghouse (CMF ID: 38)

FHWA Proven Safety Countermeasure

3.33 H33-Install Two-way Left-turn Lane on 2-lane Road

Description

A type of traversable median reserved for the exclusive use of vehicles turning left from both directions.

Figure 3-33. Two-way Left-turn Lane

Image source: FHWA

Applications

On two-lane roadways where frequent accesses and a high frequency of rear-end crashes related to vehicles turning left is observed.

Considerations

If the pavement width doesn't already exist, this countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts and environmental mitigation.

Special Conditions

On arterials with higher volumes (ADT above 20,000) and frequent access, it may be advantageous to consider a non-traversable (curbed) median, rather than a two-way left-turn lane (TWLTL). On higher volume or higher speed roadways, the TWLTL loses much of its safety advantage, which the non-traversable medians retain.

ODOT CRF Value

39%

Reduction in **rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness

-5%-53.1%

Safety Effects

Reduces the need for vehicles to slow down for vehicles waiting to turn left by separating the left-turning vehicles from the through lanes. In areas with frequent accesses, this countermeasure could significantly reduce these potential conflicts along an entire corridor in addition to increasing capacity of the facility. This countermeasure can also provide vehicles with the ability to make two-stage turning maneuvers from accesses.

References

Crash Modification Factors Clearinghouse (CMF ID: 2351)

3.34 H34-Reduce Urban Driveways Density from 48 Per Mile to 26-48 Per Mile

ODOT CRF Value:
29%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness:
25%-31%

Safety Effects
Reducing driveways manages the frequency and magnitude of conflict points at driveways by altering access patterns.

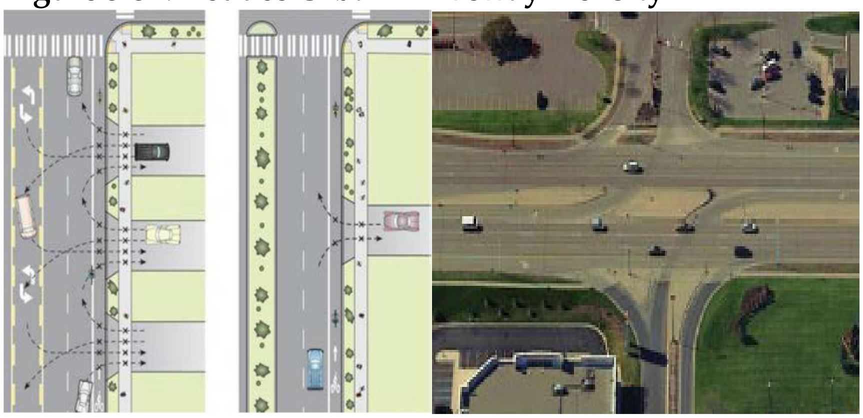
References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 177)

FHWA Proven Safety Countermeasure

Description

Driveways can be defined as private roads that provide access between public ways and activities or buildings on abutting land. Reducing the number of driveways intersecting public roadways is an access management technique, the method of control of entry and exit points along a roadway.

Figure 3-34. Reduce Urban Driveway Density



Images source: FHWA

Applications

Where a high frequency of driveway related crashes is observed on an urban corridor.

Considerations

It can be challenging to get public support and can be costly to retrofit an existing road with this access management technique.

Special Conditions

This CRF value can only be applied to reducing driveway density from 48 per mile to 26-48 per mile. Successful access management seeks to simultaneously provide accessibility while enhancing safety, preserving capacity and providing for pedestrian and bicycle needs. Refer to the HSM for more guidance.

3.35 H35-Reduce Urban Driveway Density from 26-48 Per Mile to 10-24 Per Mile

Description
Driveways can be defined as private roads that provide access between public ways and activities or buildings on abutting land. Reducing the number of driveways intersecting public roadways is an access management technique, the method of control of entry and exit points along a roadway.

Figure 3-35. Reduce Urban Driveway Density

Images source: FHWA

Applications
Where a high frequency of driveway related crashes is observed on an urban corridor.

Considerations
It can be challenging to get public support and can be costly to retrofit an existing road with this access management technique.

Special Conditions
This CRF value can only be applied to reducing driveway density from 26-48 per mile to 10-24 per mile. Successful access management seeks to simultaneously provide accessibility while enhancing safety, preserving capacity and providing for pedestrian and bicycle needs. For more guidance, refer to the HSM.

ODOT CRF Value
31%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
25%-31%

Safety Effects
Reducing driveways manages the frequency and magnitude of conflict points at driveways by altering access patterns.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 178)

FHWA Proven Safety Countermeasure

3.36 H36-Reduce Urban Driveway Density from 10-24 Per Mile to Less Than 10 Per Mile

Description

Driveways can be defined as private roads that provide access between public ways and activities or buildings on abutting land. Reducing the number of driveways intersecting public roadways is an access management technique, the method of control of entry and exit points along a roadway.

Figure 3-36. Reduce Urban Driveway Density

Images source: FHWA

Applications

Where a high frequency of driveway related crashes is observed on an urban corridor.

Considerations

It can be challenging to get public support and can be costly to retrofit an existing road with this access management technique.

ODOT CRF Value

25%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

25%-31%

Safety Effects

Reducing driveways manages the frequency and magnitude of conflict points at driveways by altering access patterns.

References

Highway Safety Manual

[Crash Modification Factors Clearinghouse (CMF ID: 179)]

FHWA Proven Safety Countermeasure

Special Conditions

This CRF value can only be applied to reducing driveway density from 10-24 per mile to less than 10 per mile. Successful access management seeks to simultaneously provide accessibility while enhancing safety, preserving capacity and providing for pedestrian and bicycle needs. For more guidance, refer to the HSM.

3.37 H37-Provide a Raised Median on Urban 2-lane Road

Description
A concrete median separation between opposing through lanes on a segment of roadway. This countermeasure can include periodic pedestrian refuges and/or designated left turn lanes at major driveways or intersections.

Figure 3-37. Raised Median on Urban 2-lane Road

Image source: PedBikeSafe

Applications
On roadways with high traffic volume and driveway density as well as a history of access-related crashes.

Considerations
On 2-lane facilities, if the pavement width doesn't already exist, this countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts, and environmental mitigation. In addition, raised medians limit property accesses, which can be perceived by business owners as deterrence to potential customers and to residents as an inconvenience. It is important to involve stakeholders as soon as possible if this countermeasure is planned for implementation. Raised medians also concentrate left turns and can increase the frequency of U-turns. It is important to accommodate and/or manage these potential movements accordingly. Lastly, medians create "pinch points" in the roadway that could prevent certain heavy vehicles from traveling through the facility. It is important that appropriate

ODOT CRF Value

39%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

39%

Safety Effects

The primary function of raised median is to manage the frequency and magnitude of conflict points at driveways and intersections by altering access patterns. Additionally, it can protect pedestrians by providing a refuge area and shorter exposed crossing distances. It can also include designated left-turn lanes to allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 21)

considerations are made for the types of heavy vehicles using the facility in order to provide them the maximum lane widths they need.

Special Conditions

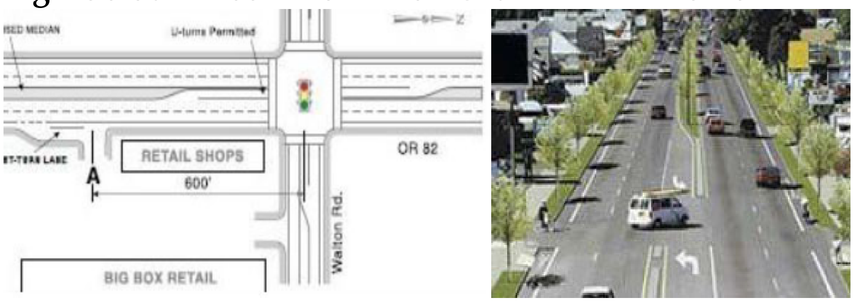
This CRF value is specifically for 2-lane urban facilities. The additional advantages for raised median are that it can reduce head-on or sideswipe crashes.

3.38 H38-Provide a Raised Median on Urban Multilane Road

Description

A concrete median separation between opposing through lanes on a segment of roadway. This countermeasure can include pedestrian refuges and/or designated left-turn lanes at major driveways or intersections.

Figure 3-38. Raised Median on Urban Multilane Road



Images source: FHWA

Applications

On roadways with high traffic volume and driveway density as well as a history of access-related crashes.

Considerations

Raised medians limit property accesses, which can be perceived by business owners as deterrence to potential customers and to residents as an inconvenience. It is important to involve stakeholders as soon as possible if this countermeasure is planned for implementation. Raised medians also concentrate left turns and can increase the frequency of U-turns. It is important to accommodate and/or manage these potential movements accordingly. In addition, medians create "pinch points" in the roadway that could prevent certain heavy vehicles from traveling through the facility. It is important that appropriate considerations are made for the types of heavy vehicles using the facility in order to provide them the maximum lane widths they need.

Special Conditions

This CRF value is specifically for multilane urban facilities. The additional advantages for raised medians are that they can prevent head-on or sideswipe meeting crashes and can provide space for landscaping and other aesthetic treatments.

ODOT CRF Value

22%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

0%-22%

Safety Effects

Raised median can manage the frequency and magnitude of conflict points at driveways and intersections by altering access patterns. It can also protect pedestrians by providing a refuge area and shorter exposed crossing distances. Raised median can include designated left-turn lanes to allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 22)

3.39 H39-Provide a Raised Median on Rural Multilane Road

Description
A concrete median separation between opposing through lanes on a roadway segment. This countermeasure can include pedestrian refuges and/or designated left-turn lanes at major driveways or intersections.

Figure 3-39. Raised Median on Rural Multilane Road

Image source: Google and FHWA

Applications
On roadways with high traffic volume and driveway density as well as a history of access-related crashes.

Considerations
Raised medians limit property accesses, which can be perceived by business owners as deterrence to potential customers and to residents as an inconvenience. It is important to involve stakeholders as soon as possible if this countermeasure is planned for implementation. Raised medians also concentrate left turns and can increase the frequency of U-turns. It is important to accommodate and/or manage these potential movements accordingly. In addition, medians create "pinch points" in the roadway that could prevent certain heavy vehicles from traveling through the facility. It is important that appropriate considerations are made for the types of heavy vehicles using the facility in order to provide them the maximum lane widths they need.

ODOT CRF Value
12%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
0%-22%

Safety Effects
Raised medians can manage the frequency and magnitude of conflict points at driveways and intersections by altering access patterns. Additionally they can protect pedestrians by providing a refuge area and shorter exposed crossing distances. Raised medians can also include designated left-turn lanes to allow vehicles to proceed through the intersection without having to stop or slow down for vehicles waiting to make a left turn.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 24)

Special Conditions

This CRF value is specifically for multilane rural facilities. Additional advantages for raised medians are that they can reduce head-on or sideswipe meeting crashes, and can provide space for landscaping and other aesthetic treatments.

3.40 H40-Install Traversable Median (four feet or more)

Description
Traversable medians provide separation between opposing flows of traffic and where wide enough, are striped to prohibit its use as a two-way left-turn lane. Traversable medians are delineated by pavement markings ONLY.

Figure 3-40. Traversable Median

Image source: East Arlington Livable Streets Coalition and Google

Applications
They can be used as an access management tool to prohibit turning movements into and out of accesses where a high frequency of access-related crashes is observed and a raised median cannot be placed. They can also be used as a buffer zone or recovery area where a high frequency of head-on or sideswipe meeting crashes is observed and can be supplemented with centerline rumble strips in rural areas.

Considerations
If the pavement width doesn't already exist, this countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts, and environmental mitigation.

ODOT CRF Value
12%
Reduction in **all crashes** at **all severities**
(not including PDOs)

Range of Effectiveness
12%-30%

Safety Effects
For access management, traversable medians manage the frequency and magnitude of conflict points at driveways and intersections by altering access patterns. For head-on and sideswipe meeting crashes, traversable medians create a larger recovery area for errant vehicles.

References
ODOT Engineering Judgement

Special Conditions
This CRF value can be used for both urban and rural areas. Compared to non-traversable medians, safety benefits of traversable medians for access management have less research available to prove their effectiveness. In addition, vehicle compliance of traversable medians is expected to be significantly lower than non-traversable medians because of the lack of physical restriction. If a traversable median contains cross-hatching stripes then it restricts left turns. The traversable median is now a highway divider as per PRS 811.430.

3.41 H41-Install Passing Lane on Rural 2-lane Roadway

Description
An auxiliary lane provided in a short segment to accommodate the passage of single-direction traffic.

Figure 3-41. Passing Lane on Rural 2-lane Roadway

Image source: FHWA and Missouri DOT

Applications
Install this countermeasure on a segment location where head-on collisions occur as a result of passing vehicles, or locations where there are crashes related to slow moving traffic.

ODOT CRF Value

25%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

25%-35%

Safety Effects

Providing passing opportunities with a climbing lane reduces the probability of increasing passing maneuvers that could lead to various lane departure crashes.

References

Highway Safety Manual

Considerations
It is important to provide optimum passing lane lengths to so that vehicles have enough distance to make a safe passing maneuver. There could also be significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts, and environmental mitigation.

Special Conditions
This countermeasure also improves overall traffic operations by breaking up traffic platoons and reducing delays caused by limited passing opportunities over substantial lengths of roadway.

3.42 H42-Widen Rural Paved Lane Width by One Foot

Description
Increasing the paved width of the travel lanes.

Figure 3-42. Rural Roadway Segment with Widen Paved Lanes

Image source: FHWA

ODOT CRF Value
5%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
5%

Safety Effects
Wider lane widths provide more recovery area for errant vehicles drifting in their lane.

References
Crash Modification Factors Clearinghouse (CMF ID: 3)

FHWA Proven Safety Countermeasure

Applications
Where a high frequency of run-off-road crashes is observed.

Considerations
There could be significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts, and environmental mitigation.

Special Conditions
Use this countermeasure at locations where the width of the travel lane is less than 12 feet.

3.43 H43-Flatten Horizontal Curve (increase radius)

Description
Increasing the radius of the horizontal curvature of the roadway.

Figure 3-43. Flatten Horizontal Curve on Roadway Segment

Image source: FHWA

Applications
On curves where a high frequency of run-off-road crashes, such as head-on or fixed object crashes, is observed.

Considerations
Many locations have minimum curve radii because of geometric restrictions, such as rock cliffs and/or steep slopes. Removing areas of rock and filling slopes can be costly in order to accommodate a realigned horizontal curve with an increased radius. Since this treatment could potentially be costly, it is important to make sure all other potential countermeasures for curve crashes have been considered, tried or proven ineffective before considering this countermeasure.

ODOT CRF Value
See Table 3-1
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
15%-78%

Safety Effects
Increased radii means an increase in sight distance, providing a more complete visual to drivers of the upcoming alignment of the roadway. Increased radii also decreases the speed differential between the approach tangent and the horizontal curve, subsequently reducing the probability of a crash.

References
Crash Modification Factors Clearinghouse (CMF ID: 9270)

Special Conditions
Use Table 3-1 to select the crash reduction factor ("percent reduction in total" column) based on existing and proposed radii.

Table 3-1. Crash Reduction Factor for Horizontal Curve Flattening

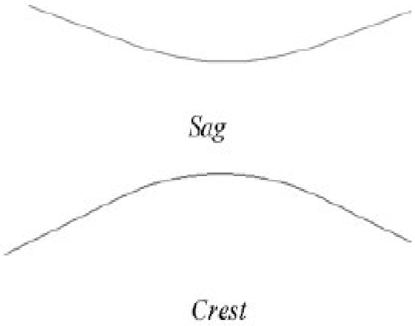
Original Degree of Curve	New Degree of Curve	Percent Reduction in Total	Original Degree of Curve	New Degree of Curve	Percent Reduction in Total
30	25	15	20	15	20
	20	31		10	41
	15	46		5	54
	10	61	15	10	24
	5	78		5	50
25	20	17		3	63
	15	35	10	5	28
	10	53		3	42
	5	72			

3.44 H44-Flatten Crest Vertical Curve

Description

Reducing the vertical curvature of the roadway either by flattening a crest curve or reducing the grade of a sag curve. When vehicles are behind slow moving vehicles ascending or descending a grade, there could be rear-end conflicts and in some cases an increase in passing maneuvers leading to head-on crashes. In a sag vertical curve, there is the possibility of vehicles descending a grade at speeds too fast for conditions, increasing the possibility of high speed rear-end crashes and potentially run-off-road crashes.

Figure 3-44. Vertical Curve on Roadway Segment



Images source: FHWA

ODOT CRF Value
51%
Reduction in **all crashes** at **all Severities** (including PDOs)

Range of Effectiveness
20%-51%

Safety Effects
Flattening a crest vertical curve provides a more complete visual to drivers of the upcoming alignment of the roadway and subsequently more stopping sight distance.

References
Crash Modification Factors Clearinghouse (CMF ID: 721)

Applications

Where a high frequency of crashes related to limited sight distance or speed-related crashes on steep grades is observed.

Considerations

Flattening crest curves could significantly impact driveway or intersection approaches to the roadway. This treatment could potentially be very costly. It is important to make sure all other potential countermeasures for vertical curve crashes have been considered, tried or proven ineffective before considering this countermeasure.

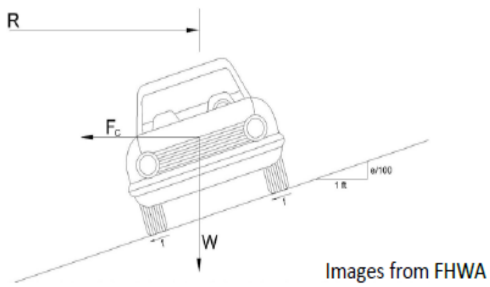
Special Conditions

This countermeasure can also be applied to unsignalized intersections with restricted sight distance due to vertical geometry and with patterns of crashes related to lack of sight distance that cannot be ameliorated by less expensive methods.

3.45 H45-Improve Superelevation Variance on Rural Curves (between 0.01 and 0.02)

Description
Superelevation is the rotation of the pavement on the approach to and through a horizontal curve. It is expressed as a decimal representing the ratio of the pavement slope to width. Typical maximum superelevations range from 0.04 to 0.12. It is intended to assist the driver in negotiating the curve by counteracting the lateral acceleration produced by tracking.

Figure 3-45. Superelevation on Rural Curve Segment



$$0.01e + f = \frac{V^2}{15R} \qquad \text{(Equation 2)}$$

Where:
e = rate of superelevation, percent;
f = side friction (demand factor);
V = vehicle speed, mph;
R = radius of curve, ft.

Images source: FHWA

ODOT CRF Value

CRF=-6x(SV-0.01)

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

N/A

Safety Effects

Superelevation offsets the horizontal sideways momentum of the approaching vehicle, minimizing the probability of a vehicle of running off the road around a curve.

References

Highway Safety Manual

[Crash Modification Factors Clearinghouse (CMF ID: 5183)]

Applications
Use at a curve where a high number of vehicle or truck crashes is observed that could be attributed to low superelevation. Low superelevation can cause vehicles to skid as they travel through a curve, potentially resulting in a run-off-road crash. Trucks and other large vehicles with high centers of mass are more likely to roll over at curves with low superelevation.

Considerations
This treatment could potentially be very costly. It is important to make sure all other potential countermeasures for curve crashes have been considered, tried or proven ineffective before considering this countermeasure.

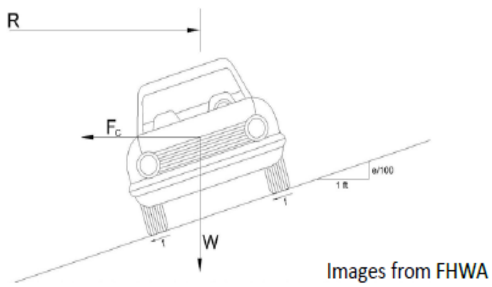
Special Conditions
The base condition is a superelevation value (SV) of less than 0.01, and the proposed reconstructed SV will be between 0.01 and 0.02. Selection of a maximum superelevation rate is based on several variables, such as climate, terrain, highway location (urban vs. rural), and frequency of very slow-moving vehicles.

3.46 H46-Improve Superelevation Variance on Rural Curves (more than 0.02)

Description

Superelevation is the rotation of the pavement on the approach to and through a horizontal curve. It is expressed as a decimal representing the ratio of the pavement slope to width. Typical maximum superelevations range from 0.04 to 0.12. It is intended to assist the driver in negotiating the curve by counteracting the lateral acceleration produced by tracking.

Figure 3-46. Superelevation on Rural Curve Segment



$$0.01e + f = \frac{V^2}{15R} \quad \text{(Equation 2)}$$

Where:
- e = rate of superelevation, percent;
- f = side friction (demand factor);
- V = vehicle speed, mph;
- R = radius of curve, ft.

Images source: FHWA

Applications

Use at a curve where a high number of vehicle or truck crashes is observed that could be attributed to low superelevation. Low superelevation can cause vehicles to skid as they travel through a curve, potentially resulting in a run-off-road crash. Trucks and other large vehicles with high centers of mass are more likely to roll over at curves with low superelevation.

ODOT CRF Value

CRF=-300xSV

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

N/A

Safety Effects

Superelevation offsets the horizontal sideways momentum of the approaching vehicle, minimizing the probability of a vehicle of running off the road around a curve.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 5184)

Considerations

This treatment could potentially be very costly. It is important to make sure all other potential countermeasures for curve crashes have been considered, tried or proven ineffective before considering this countermeasure.

Special Conditions

The base condition is a SV of less than 0.01 and the proposed reconstructed SV will be more than 0.02. Selection of a maximum superelevation rate is based on several variables, such as climate, terrain, highway location (urban vs. rural), and frequency of very slow-moving vehicles.

3.47 H47-Convert from Urban Two-way to One-way Traffic

Description
A segment of roadway that restricts vehicles to one-direction travel.

Figure 3-47. Urban One-way Street

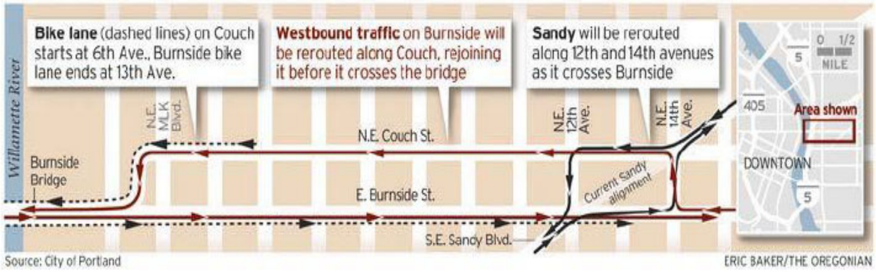


Image source: City of Portland

Applications
Preferably in a grid street system where a high frequency of intersection crashes along an urban segment, and/or crashes related to capacity limitations, is observed.

Considerations
A one-way street system often forces drivers to take out-of-direction routes to their destinations.

ODOT CRF Value
47%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
47%

Safety Effects
Reduces the number of potential conflicts at an intersection.

References
Crash Modification Factors Clearinghouse (CMF ID: 5234)

Special Conditions
One-way streets allow for a less number of signal phases, potentially increasing capacity and minimizing delay of various intersections along a segment of roadway. There are benefits to pedestrians with one-way streets too. They only need to look for traffic in one direction so there are often more gaps in traffic due to platooning.

3.48 H48-Increase Pavement Friction on Curve Segment by Installing High Friction Surface Treatment

Description

Pavement surfacing systems with exceptional skid-resistant properties not typically provided by conventional materials.

Figure 3-48. High Friction Surface Treatment for Curve Segment

Images source: FHWA

Applications

In locations where frequent crashes is observed for which insufficient friction is a contributing factor (i.e. wet weather). These are generally locations where drivers are braking frequently, for example, when going around curves or ramps, down hills or steep grades, or when approaching an intersection. The road surface can become prematurely polished, reducing the pavement friction and allowing vehicles to skid or hydroplane.

Considerations

It is costly to install and could be costly to maintain so it's important to reserve this treatment for the most needed locations. It is important to closely follow the manufacturer's installation instructions in order to reduce any chances of product failure. For more information on high friction surface treatment, refer to the FHWA website, where many informational materials are provided on the subject.

Special Conditions

Consider the pavement quality, location, posted speed, user type and crash history when selecting locations for high friction surface treatments.

ODOT CRF Value

52%

Reduction in **wet-road crashes**
at **all severities**
(including PDOs)

Range of Effectiveness

20%-68%

Safety Effects

It uses aggregates that are both polish and wear-resistant and develop channels to prevent water buildup on wet surfaces creating an exceptionally durable surface capable of withstanding extreme roadway friction demands.

References

Crash Modification Factors Clearinghouse (CMF ID: 7901)
Evaluation of Pavement Safety Performance (FHWA-HRT-14-065)

FHWA Proven Safety Countermeasure

3.49 H49-Increase Pavement Friction on Ramps by Installing High Friction Surface Treatment

Description

Pavement surfacing systems with exceptional skid-resistant properties not typically provided by conventional materials.

Figure 3-49. High Friction Surface Treatment on Ramp

Image source: Minnesota DOT

Applications

In locations where frequent crashes are observed for which insufficient friction is a contributing factor (i.e. wet weather). These are generally locations where drivers are braking frequently; for example, when going around curves or ramps, down hills or steep grades, or when approaching an intersection. The road surface can become prematurely polished, reducing the pavement friction and allowing vehicles to skid or hydroplane.

Considerations

It is costly to install and could be costly to maintain so it's important to reserve this treatment for the most needed locations. It is important to closely follow the manufacturer's installation instructions in order to reduce any chances of product failure. For more information on high friction surface treatment, refer to the FHWA website, where many informational materials are provided on the subject.

ODOT CRF Value

86%

Reduction in **wet road crashes** at **all severities** (including PDOs)

Range of Effectiveness

86%

Safety Effects

It uses aggregates that are both polish- and wear-resistant and develop channels to prevent water buildup on wet surfaces creating an exceptionally durable surface capable of withstanding extreme roadway friction demands.

References

Crash Modification Factors Clearinghouse (CMF ID: 7899)

Evaluation of Pavement Safety Performance (FHWA-HRT-14-065)

FHWA Proven Safety Countermeasure

Special Conditions

Consider the pavement quality, location, posted speed, user type and crash history when selecting locations for high friction surface treatments.

3.50 H50-Install Urban Variable Speed Limit Signs

Description
Speed limits that change based on road, traffic, and/or weather conditions.

Figure 3-50. Variable Speed Limit Sign

Image source: Oregonlive

Applications
In locations where a high frequency of crashes related to weather conditions or congestion (peak hour or incident related) is observed.

Considerations
Could be costly depending on the length of the corridor this countermeasure will be applied due to the real time data collection and communication expenses.

Special Conditions
There is still ongoing research to evaluate the effectiveness of variable speed limits through work zones. Only install black on white variable speed limit signs in combination with agreement with law enforcement to actively enforce the speed limit(s).

ODOT CRF Value
8%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
8%

Safety Effects
Increases safety by reducing the probability of a crash associated with traveling at speeds higher then what is appropriate for conditions. Variable speed limits can take into account traffic volume, operating speeds, weather information, sight distance, and roadway surface condition when posting speed limits.

References
Crash Modification Factors Clearinghouse (CMF ID: 3340)

3.51 H51-Install Urban Variable Speed Limit Signs with Queue or Weather Warning System

Description
Speed limits that change based on road, traffic, and/or weather conditions.

Figure 3-51. Variable Speed Limit Sign with Weather Warning System

Image source: Google

Applications
In locations where a high frequency of crashes related to weather conditions or congestion (peak hour or incident related) is observed.

Considerations
Could be costly depending on the length of the corridor this countermeasure will be applied due to the real time data collection and communication expenses.

ODOT CRF Value

14%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

14%

Safety Effects

Increases safety by reducing the probability of a crash associated with traveling at speeds higher then what is appropriate for conditions.. Variable speed limits can take into account traffic volume, operating speeds, weather information, sight distance, and roadway surface condition when posting speed limits.

References

ODOT Engineering Judgement

Special Conditions
There is still ongoing research to evaluate the effectiveness of variable speed limits through work zones. Only install black on white variable speed limit signs in combination with agreement with law enforcement to actively enforce the speed limit(s).

3.52 H52-Install Variable Speed Limit Signs in Rural

Description
Speed limits that change based on road, traffic, and/or weather conditions.

Figure 3-52. Variable Speed Limit Sign in Rural Area

Image source: Google

Applications
In locations where a high frequency of crashes related to weather conditions or congestion (peak hour or incident related) is observed.

Considerations
Could be costly depending on the length of the corridor this countermeasure will be applied due to the real time data collection and communication expenses.

Special Conditions
There is still ongoing research to evaluate the effectiveness of variable speed limits through work zones. Only install black on white variable speed limit signs in combination with agreement with law enforcement to actively enforce the speed limit(s).

ODOT CRF Value
20%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
20%-30%

Safety Effects
Increases safety by reducing the probability of a crash associated with traveling at speeds higher then what is appropriate for conditions. . Variable speed limits can take into account traffic volume, operating speeds, weather information, sight distance, and roadway surface condition when posting speed limits.

References
ODOT Engineering Judgement

3.53 H53-Convert 4-lane Roadway to 3-lane Roadway with Center Turn Lane (road diet)

Description

A road diet involves converting an undivided four-lane roadway into three lanes consisting of two through lanes and a center TWLTL. Reducing the number of through lanes and providing a TWLTL addresses crashes by:

- Separate left-turning traffic from through traffic;
- Reduce the number of oncoming lanes through which a left-turning driver must search for a gap, and;
- Remove the multiple-threat situation because there is no longer an adjacent lane.

Figure 3-53. Roadway Segment before and after Road Diet

Image source: FHWA

Applications

Where a high frequency of the following crash types is observed:

- Rear-end crashes from left turns;
- Sideswipe overtaking;
- Left-turning crashes, and;
- Multiple-threat pedestrian crashes from a vehicle stopped for a pedestrian, blocking the view of the driver in the adjacent lane.

Typical candidate four-lane roadways have 20,000 ADT or less.

ODOT CRF Value

29%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

29%

Safety Effects

Road diets can also decrease other incidents by providing designated spaces (sidewalks and bicycle lanes) that reduce opportunities for conflicts between motor vehicles and other road users.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 199)

FHWA Proven Safety Countermeasure

Considerations

Stakeholders represent a wide range of interests and needs within a community therefore it is important to involve them early in discussions to make sure a road diet is the right solution.

Special Conditions

The reduction of lanes in a road diet allows for the roadway to be reallocated for other uses, such as bike lanes, pedestrian crossing islands, and parking. Road diets can be low cost if planned in conjunction with reconstruction or simple overlay projects since a road diet mostly consists of restriping.

3.54 H54-Install Truck Escape Ramp

Description

An emergency area located adjacent to a downgrade roadway to provide a location for out-of-control vehicles to slow and stop away from other vehicles on the road. They are generally located near the middle or the end of long, steep downgrades. The two most common types of truck escape ramps are:

- Gravity ramps built with an upgrade to use the forces of gravity to slow a runaway vehicle; or
- Aggregate arrestor bed ramps using special sized rock in a gravel bed to slow a runaway vehicle.

These ramps may have either an upward or downward grade.

ODOT CRF Value

20%

Reduction in **truck crashes** at **all severities** (including PDOs)

Range of Effectiveness

33%-75%

Safety Effects

Truck escape ramps enable vehicles that are having braking issues to safety stop, avoiding potential run-off-road and rear-end crashes.

References

[Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)]

Figure 3-54. Truck Escape Ramp

Image source: FHWA

Applications

Where a high frequency of speed-related truck crashes is observed on steep grades.

Considerations

This countermeasure is most appropriate in rural mountainous area and may require additional right of way.

Special Conditions

This countermeasure is most appropriate in mountainous areas. The guidance listed is partially provided by Nevada DOT.

3.55 H55-Install Guide Signs

Description
Guide signs provide directional and mileage information to specific destinations. Types of roadway guide signs include:

- Interstate, US route, state, and county markers;
- Highway mile markers;
- National forest route markers;
- Hurricane evacuation route signs; and
- Exit signs.

Figure 3-55. Guide Sign

Images source: MUTCD

Applications
Along roadways where crashes occur due to drivers making errors while trying to read signs, change lanes, and decelerate as they are driving toward their destination.

Considerations
Consider sight distance and maintenance to increase visibility. Guide signs that are illuminated or retroreflective can be easily read during the day, night, and in adverse weather conditions.

Special Conditions
Refer to the MUTCD for additional guidance and standards.

ODOT CRF Value
15%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
15%

Safety Effects
Guide signs are along roadways provide drivers with information that will help them reach their destinations safely. These signs provide efficient navigation and can reduce driver slowing, stopping, and making abrupt turns or erratic maneuvers that would occur due to the absence of these signs.

References
Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

3.56 H56-Provide an Auxiliary Lane between an Entrance Ramp and Exit Ramp (freeway interchange)

Description
A designated lane between entrance and exit ramps used to allow traffic to speed up and slow down.

Figure 3-56. Auxiliary Lane on Freeway

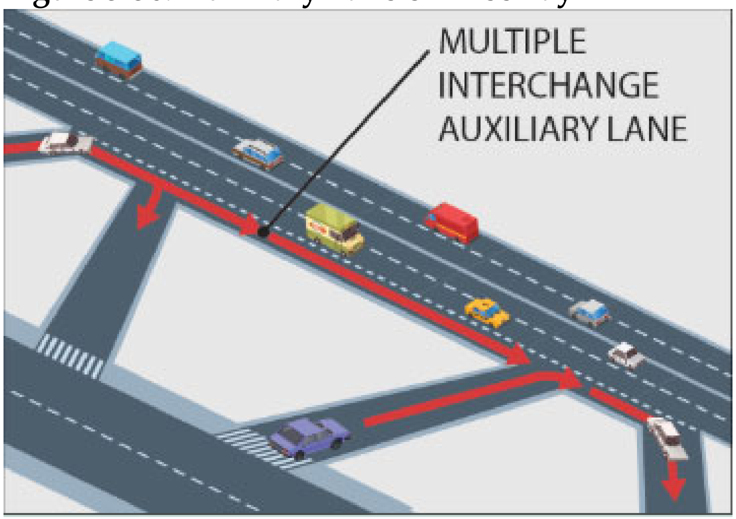


Image source: Oregon DOT

Applications
Where entrance and exit ramps are short, requiring entering traffic to merge quickly and exiting traffic to slow before exiting the main traffic lane.

Considerations
Auxiliary lanes should be of sufficient length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can safely maneuver into a gap before reaching the end of the auxiliary lane.

ODOT CRF Value

20%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

20%

Safety Effects

Reduces the conflict between exiting and entering traffic on the main lanes. Allows for efficient traffic flow at interchanges.

References

Crash Modification Factors Clearinghouse (CMF ID: 3898)

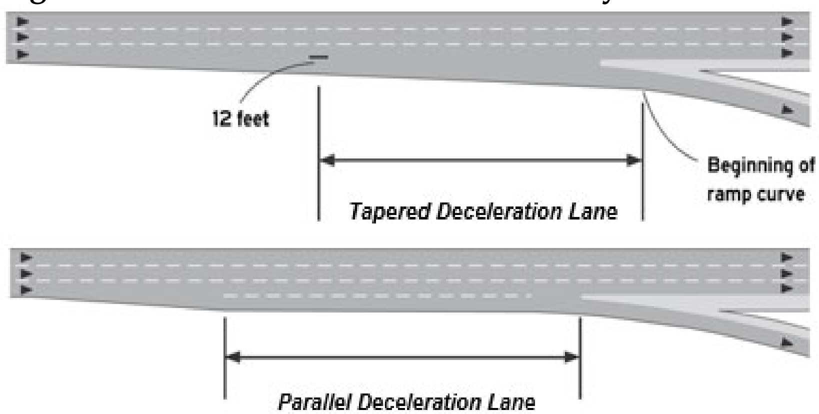
Determining Guidelines for Ramp and Interchange Spacing (NCHRP 169)

Special Conditions
This countermeasure CRF is specific to providing an auxiliary lane on freeway interchanges between entrance and exit ramps.

3.57 H57-Extend Deceleration Lane by Approximately 100 Feet (freeway interchange)

Description
A deceleration lane, also known as an auxiliary or speed-change lane, allows vehicles to slow down in a designated space not used by high-speed through traffic.

Figure 3-57. Deceleration Lane on Freeway



Images source: FHWA

Applications
At freeway off-ramps that are short, requiring exiting traffic to slow quickly before exiting the main traffic lane.

Considerations
Consider lane space when extending deceleration lanes. Converting current roadway shoulders to useable lanes may require widening and strengthening of the existing roadway pavement, leading to higher costs due to construction.

Special Conditions
This countermeasure CRF value is specific to extending deceleration lanes on freeway interchanges.

ODOT CRF Value

7%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

7%

Safety Effects

Deceleration lanes allow traffic exiting a freeway to slow down to a safer speed without affecting the main flow of traffic. Increases safety by reducing the number of conflicts between vehicles traveling at different speeds.

References

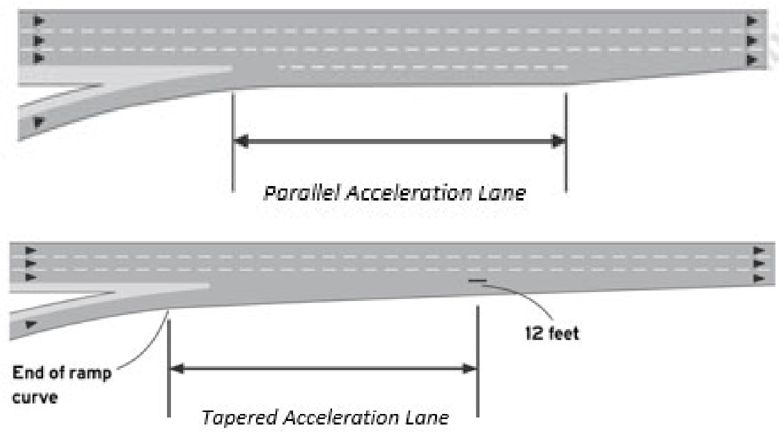
Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 475)

3.58 H58-Extend Acceleration Lane by Approximately 100 Feet (freeway interchange)

Description
An acceleration lane, also known as an auxiliary or speed-change lane, allows vehicles the opportunity to accelerate to freeway speeds in a designated space not used by high-speed through traffic.

Figure 3-58. Acceleration Lane on Freeway Interchange



Images source: FHWA

Applications
At freeway on-ramps that are relatively short, requiring entering traffic to merge quickly with main traffic lanes.

Considerations
Consider lane space when extending acceleration lanes. Converting current roadway shoulders to useable lanes may require widening and strengthening of the existing roadway pavement, leading to higher costs due to construction.

ODOT CRF Value
11%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
11%

Safety Effects
Acceleration lanes increase safety by reducing freeway congestion through creating designated areas for merging traffic to adjust to the proper speed before entering main traffic lanes.

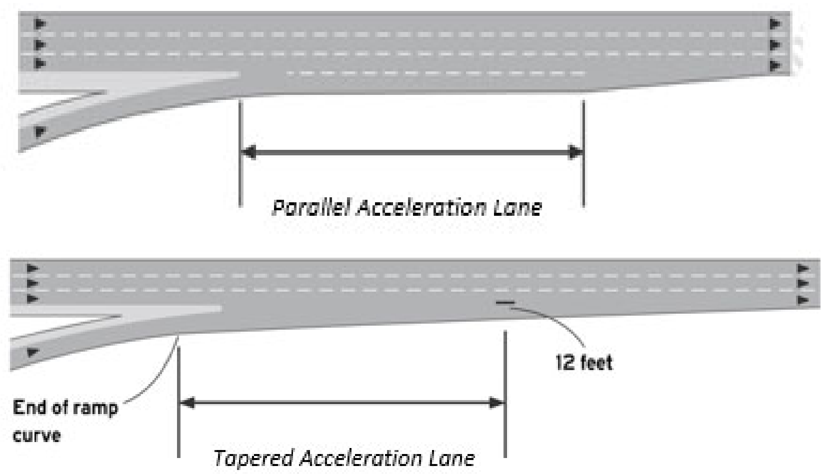
References
[Crash Modification Factors Clearinghouse (CMF ID: 474)]

Special Conditions
This countermeasure CRF value is specific to extending acceleration lanes on freeway interchanges.

3.59 H59-Add Acceleration Lane at Freeway Interchange

Description
An acceleration lane, also known as an auxiliary or speed-change lane, allows vehicles the opportunity to accelerate to freeway speeds in a designated space not used by high-speed through traffic.

Figure 3-59. Acceleration Lane at Freeway Interchange



Images source: FHWA

Applications
At freeway on-ramps with a high proportion of crashes related to speed differential caused by vehicles merging with through traffic.

ODOT CRF Value
$CRF=1-e^{-2.59xL}$
Where L is length of the acceleration lane (in miles)
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
N/A

Safety Effects
Acceleration lanes increase safety by reducing freeway congestion by creating designated areas for merging traffic to adjust to the proper speed before entering main traffic lanes.

References
Highway Safety Manual

Considerations
Acceleration lanes should be of sufficient length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can safely maneuver into a gap before reaching the end of the acceleration lane.

Special Conditions
This countermeasure CRF value is specific to adding acceleration lanes at interchanges.

3.60 H60-Reduce Intersection Skew Angle on 3-leg Minor Street Stop-controlled Intersection

Description

A skewed intersection has an angle of less than 90 degrees between intersecting streets. The skew angle for an intersection is defined as the absolute value of the deviation from an intersection angle of 90 degrees. The absolute value is used in the definition of skew angle because positive and negative skew angle are considered to have similar detrimental effect.

Figure 3-60. Intersection Skew Angle before and after the Improvement

Images source: PedBikeSafe

Applications

At intersections where there are patterns of crashes related to limited sight distance (where the driver must turn their head and neck to view approaching vehicles).

Considerations

High costs may be associated with the realignment and reduction of intersection skew angles.

Special Conditions

This countermeasure CRF value is specific to reducing intersection skew angles on 3-leg minor street stop-controlled intersections in rural areas.

ODOT CRF Value

$CRF=1-e^{0.004(\beta-\alpha)}$

Where α and β is the existing and proposed skew angle, respectively. Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

N/A

Safety Effects

Reducing the intersection skew angle results in increased sight distance for drivers and is particularly beneficial to older drivers.

References

Highway Safety Manual

3.61 H61-Reduce Intersection Skew Angle on 4-leg Minor Street Stop-controlled Intersections

Description

A skewed intersection has an angle of less than 90 degrees between intersecting streets. The skew angle for an intersection is defined as the absolute value of the deviation from an intersection angle of 90 degrees. The absolute value is used in the definition of skew angle because positive and negative skew angle are considered to have similar detrimental effect.

Figure 3-61. Intersection Skew Angle

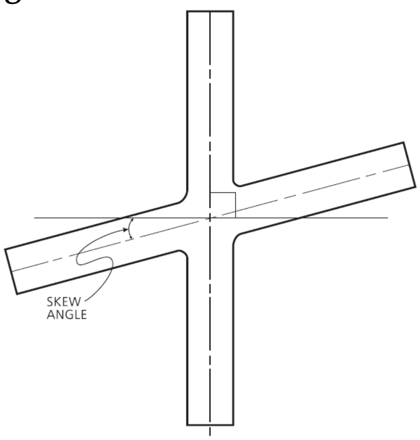


Image source: HSM

Applications

At intersections where there are patterns of crashes related to limited sight distance (where the driver must turn their head and neck to view approaching vehicles).

Considerations

High costs may be associated with the realignment and reduction of intersection skew angles.

Special Conditions

This countermeasure CRF value is specific to reducing intersection skew angles on 4-leg minor street stop-controlled intersections in rural areas.

ODOT CRF Value

$CRF=1-e^{0.0054(\beta-\alpha)}$

Where α and β is the existing and proposed skew angle, respectively. Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

N/A

Safety Effects

Reducing the intersection skew angle results in increased sight distance for drivers and is particularly beneficial to older drivers.

References

Highway Safety Manual

3.62 H62-Truck Priority Detection System

Description

A priority detection system that uses radar to measure incoming speeds and differential between trucks and cars. The system then provides an appropriate signal phase by extending the green interval for the truck within the dilemma zone (the portion of the approach where a driver must decide whether to stop safely or proceed through the intersection when faced with a yellow indication).

Figure 3-62. Truck Priority Detection System

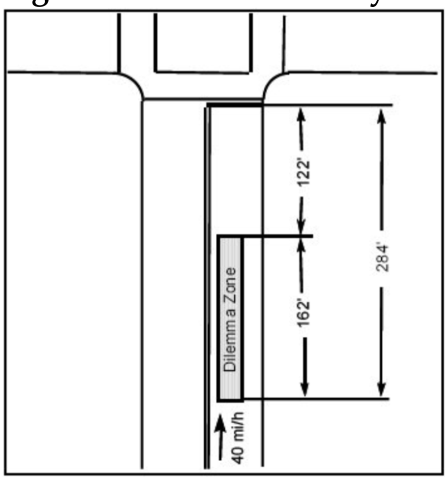


Image source: FHWA

Applications

At signalized intersections with a high frequency of angle and rear-end crashes and red-light violations associated with traffic signal phase changes. Locations with high truck traffic.

Considerations

These systems are intended for use on high speed roadways (major road approach with a posted speed limit of 45 mile per hour (MPH) or higher). It is important to consider stopping distances when implementing this countermeasure.

ODOT CRF Value

9%

Reduction in **angle and rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness

9%

Safety Effects

A priority detection system improves safety by modifying traffic control signal phasing, providing sufficient time for trucks to pass through a signalized intersection. This may reduce rear-end crashes associated with frequent stopping and angle crashes due to red-light violations.

References

Field Evaluation of Detection-control System (FHWA-HRT-14-058)

Special Conditions

Additional benefits of this treatment include reducing delay and stop frequency on the major road and maintaining or reducing overall intersection delay. In the past, loops were used to provide dilemma zone protection for this type of system, but are no longer installed unless under special circumstances.

3.63 H63-Dual or Double Left-turn Lanes

Description
Two lanes that can be used to make a turn left at a signalized intersection.

Figure 3-63. Dual Left-turn Lanes at Signalized Intersection

Image source: Google

ODOT CRF Value
29%
Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
29%

Safety Effects
Dual or Double left-turn lanes provide additional capacity at an intersection and improve intersection operation by reducing the time allocated to the signal phase for the left-turn movement.

References
[Signalized Intersections Informational Guide (FHWA-SA-13-027)]

Applications
Used at intersections with high left-turn volumes where a single left-turn lane is not sufficient.

Considerations
Consider dual left-turn lanes when volumes exceed 300 vehicles per hour (assuming moderate levels of opposing through traffic and adjacent street traffic). For double left-turn lanes, consider the following:

- Widths of receiving lanes and intersection
- Clearance between opposing left-turn movements during concurrent maneuvers
- Pavement marking and signing visibility
- Placement of stop lines for left-turning and through vehicles
- Weaving movements downstream of turn
- Potential for pedestrian conflict

Special Conditions
Benefits of dual or double left-turn lanes may include a reduced delay to left-turning vehicles, improved intersection capacity, and extra green time that can be allocated to other movements or removed to decrease cycle length. Providing positive guidance (pavement markings) along

with the implementation of dual or double left-turn lanes could help guide drivers through their designated turn lane and reduce sideswipe crashes.

3.64 H64-Convert Two-way Left-turn Lane to Raised Median

Description
Implementing a raised median in place of a TWLTL. A TWLTL is a designated lane between opposing lanes of traffic, allowing traffic to make left turns from both directions. A physical barrier separates the opposing traffic lanes when a TWLTL is replaced with a raised median.

Figure 3-64. Two-way Left-turn Lane Converted to Raised Median

Image source: FHWA

Applications
Along roadway segments where a high frequency of crashes are occurring due to vehicles using TWLTL.

Considerations
There is a potential for crashes to occur at median openings which involve vehicles turning left and making U-turns, vehicles directly hitting the median curb, and median crossover crashes.

ODOT CRF Value
47%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
47%

Safety Effects
Converting two-way left-turn lanes to raised medians can reduce head-on crashes between vehicles traveling in opposing directions. Raised medians can also provide a pedestrian refuge area and increase safety in locations where pedestrians need to cross the roadway.

References
Crash Modification Factors Clearinghouse (CMF ID: 7771)

Special Conditions
Implementing raised medians can provide pedestrian refuge islands at intersections and midblock locations, allowing for two-stage crossing. Raised medians can also prevent head-on or sideswipe crashes and provide space for landscaping and other aesthetic benefits.

3.65 H65-Install Offset or Buffered Right-turn Lane

Description
A right-turn lane that is offset by moving the lane laterally so that vehicles in right-turn lanes no longer obstruct the view of the driver on the minor road approach.

Figure 3-65. Offset Right-turn Lane at Intersection

Images source: FHWA

Applications
At locations where right-turn vehicles block drivers' views of approaching traffic and where there is a pattern of collisions between minor-road vehicles and major-road vehicles with existing right-turn lanes.

Considerations
After installing offset right-turn lanes, drivers initially may be confused by the change in traffic patterns, particularly in areas where offset right-turn lanes have not been used. This can be minimized by effective use of guide signs and pavement markings. Installation of offset right-turn lanes increase the width of the roadway, which creates a longer crossing distance for pedestrians. A possible solution would be to provide a pedestrian refuge island between the offset right-turn lane and through travel lanes.

Special Conditions
This countermeasure CRF value applies to intersections in rural areas.

ODOT CRF Value

69%

Reduction in **angle and turning crashes** at **all severities** (including PDOs)

Range of Effectiveness

69%

Safety Effects

Offset right-turn lanes can remove the sight distance obstruction created by traditional right-turn lanes and reduce the potential for crashes between vehicles turning left, turning right, or crossing from the minor road and through vehicles on the major road.

References

Median Intersection Design for Rural High-Speed Divided Highways (NCHRP Report 650)

Crash Modification Factors Clearinghouse (CMF ID: 2777)

3.66 H66-Install Speed Humps or Table on Non-state Highways

ODOT CRF Value

50%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

50%

Safety Effects

Speed humps are effective at reducing traffic speeds by forcing drivers to slow down and increase driver awareness.

References

[Crash Modification Factors Clearinghouse (CMF ID: 134)]

Description

A speed hump is a raised area (normally 3 to 4 inches in height) in the roadway pavement surface extending transversely across the roadway.

Figure 3-66. Speed Hump on Roadway

Image source: NACTO

Applications

In residential areas or on low-speed local streets where speeding increases the probability for crashes.

Considerations

Adequate signing and marking of each speed hump to warn drivers of the presence of approaching speed humps.

Special Conditions

This countermeasure CRF value is specific to installing speed humps on low-speed urban roadways.

Chapter 4 Safety Improvement Countermeasures for Intersection

Intersections are locations where two or more roads join or cross, and it is the crossing and turning maneuvers occurring at intersections that create opportunities for vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle conflicts. Thus, intersections are likely points for concentrations of traffic crashes. Although intersections constitute a very small portion of the highway system in Oregon, between 2014 and 2018, intersection-related crashes accounted for 36% of all the fatal and serious injury crashes and contributed to 440 fatalities and 3382 serious injuries. About 81% of these crashes occurred in an urban environment; and both aging drivers and younger drivers were disproportionally more involved in intersection crashes. In Oregon, intersection crashes are defined as incidents that occur at a signalized or unsignalized intersection in an urban or rural environment.

Intersection safety has been a major program at ODOT. Using crash data from the 2010 Roadway Departure Safety Implementation Plan, ODOT engaged the FHWA to develop the Oregon Intersection Safety Implementation Plan for reducing intersection crashes. The Oregon Transportation Safety Action Plan (TSAP) also listed intersection as one emphasis area and developed the following intersection action plan:

- Update the Oregon Intersection Safety Implementation Plan to reassess statewide intersection safety needs on state and local roads;
- Implement hot spot and systemic intersection safety improvements consistent with the updated Intersection Safety Implementation Plan;
- Implement intersection design treatments to reduce conflicts between all users, increase awareness, and improve compliance;
- Implement access management on high volume roads and/or around intersections to reduce the number and severity of crashes; and
- Improve the visibility of vehicles, pedestrians, and bicyclists along the corridors and at intersections with lighting and unobstructed sightlines.

FHWA developed the following proven safety countermeasures for pedestrians and bicyclists safety:

- Backplates with reflective borders
- Corridor access management
- Left- and right-turn lanes at two-way stop-controlled intersections
- Reduced left-turn conflict intersections
- Roundabouts
- Systemic application of multiple low cost countermeasures at stop-controlled intersections

- Yellow change interval

To improve intersection safety in Oregon, ODOT developed the following safety improvement countermeasures for intersections. A total of 33 engineering countermeasures are discussed in this chapter. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period of time and/or have proven effective. New countermeasures continue to be developed, implemented, and evaluated. Strategies to address intersection safety are diverse, and quite often a combination of strategies is needed to improve safety. State and local agencies can refer to the intersection safety countermeasures below when selecting the safety improvements for intersections.

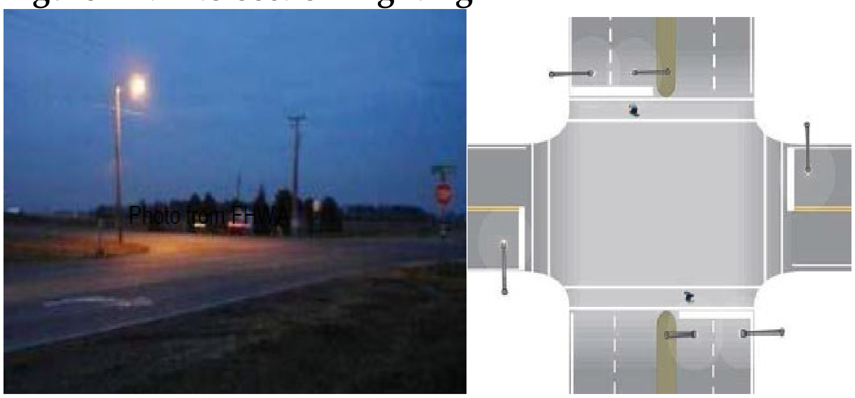
- I1-Install lighting at an intersection
- I2-Improve signal hardware: Lenses, reflectorized black plates, and number
- I3-Add 3-inch yellow retroreflective steeting to signal backplates
- I4-Replace 8-inch red signal heads with 12-inch
- I5-Increase signal head quantity: Add primary head
- I6-Replace incandescent traffic signal bulbs with light emitting diodes
- I7-Replace nighttime flash with steady operation
- I8-Replace doghouse with flashing yellow arrow signal heads
- I9-Replace urban permissive or protected/permissive left turns to protected only
- I10-Protected left turn: Split side street signal phasing
- I11-Replace urban permissive left turns to protected/permissive
- I12-Change from permissive only to flashing yellow arrow permissive only
- I13-Install coordination or adaptive signal timing of urban traffic signals
- I14-Install actuated advance warning dilemma zone protection system at high speed signals (microwave detection)
- I15-Install flashing beacons as advance warning at intersections (not coordinated with signal timing)
- I16-Install actuated or coordinated flashing beacons as advance warning for signalized intersections
- I17-Increase triangle sight distance
- I18-Increase pavement friction by installing high friction surface treatment – intersection or segment application
- I19-Left turn traffic calming treatments for posted speeds less than 35 MPH (hardened centerline and left turn wedge)
- I20- Left turn traffic calming treatments for posted speeds less than 35 MPH (hardened centerline and left turn wedge)
- I21-Improve intersection warning: Stop ahead pavement markings, stop ahead signs, larger signs, additional stop signs and/or other intersection warning or regulatory signs
- I22-Install advance warning signs (signal ahead)
- I23-Increase retroreflectivity of stop signs (reflective strips on sign post optional)

- I24-Provide flashing beacons at all-way stop controlled intersections
- I25-Provide flashing beacons at minor road stop controlled intersections
- I26-Provide actuated flashing beacons triggered by approaching vehicles at unsignalized intersections
- I27-Install transverse rumble strips on one or more stop controlled approaches
- I28-Install 6 feet or greater raised divided on stop approach (splitter island)
- I29-Prohibit right-turn-on-red
- I30-Provide “STOP AHEAD” pavement markings
- I31-Provide overhead lane-use signs
- I32-Install wrong way driving countermeasures: Signing, pavement markings, geometric modifications, and ITS technologies
- I33-Curb extensions

4.1 I1-Install Lighting at an Intersection

Description
A permanent source of artificial lighting installed at an intersection that provides greater visibility of the intersection.

Figure 4-1. Intersection Lighting



Images source: FHWA

Applications
At intersections with a high frequency of dark or nighttime crashes. Particularly for unsignalized intersections, rear-end, right-angle, or turning crashes on the major road approaches may indicate that approaching drivers are unaware of the presence of the intersection.

Considerations
In rural areas it may be difficult to locate a power source. In addition, it is important to determine, upfront, the jurisdiction responsible for paying the ongoing utility costs. For signalized intersections, retrofitting illumination onto existing signal poles could result in an entire signal rebuild.

Special Conditions
This countermeasure CRF value is for new lighting only on all corners (i.e. no lighting currently exists) and can be applied to both signalized and unsignalized intersections (both rural and urban). If the existing intersection is partially lit or partial lighting will be installed at an intersection on a state highway, refer to the ODOT *Lighting Policy and Guidelines* for further guidance on lighting warrants.

ODOT CRF Value
38%
Reduction in **night crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
31%-38%

Safety Effects
Intersection lighting allows for greater visibility of the intersection, making signs and markings more visible, and helping drivers determine a safe path through the intersection. This can be especially helpful at rural intersections where the only source of lighting for the roadway is often provided by vehicle headlights.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 433)

4.2 I2-Improve Signal Hardware: Lenses, Reflectorized Back plates, Size, and Number

Description

This countermeasure includes a set of proven, low-cost countermeasures that can be implemented at signals along a corridor. These countermeasures include the following options:

- Twelve-inch signal lenses;
- LED lenses on all signal heads;
- Reflectorized back plates on all signal heads;
- Supplemental signal heads (recommended a minimum of one traffic signal head per approach lane);
- Elimination of any late night flashing operations;
- Traffic signal yellow change interval and all red interval timing adjusted to be in accordance with the Institute of Transportation Engineers (ITE) timing standards; or
- Addition of a signal head for the right-turn lane to reduce right-turn permissive conflicts.

Figure 4-2. Signal Hardware at Intersections

Images source: FHWA

Applications

On signalized corridors with a high frequency of intersection crashes, particularly angle and turning crashes related to red light running.

Considerations

It is highly recommended that these treatments be applied systemically. Consider structural analysis to verify existing signal poles can withstand loading from additional signal heads. Switching out to 12” signal heads could create vehicle height restrictions.

ODOT CRF Value

20%

(2 countermeasures)

25%

(3-4 countermeasures)

30%

(5-6 countermeasures)

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

0%-46%

Safety Effects

All of the listed treatments are proven countermeasures that reduce intersection crashes and increase visibility of the signal and its operations.

References

California DOT Intersection Implementation Plan/ODOT Engineering Judgment

FHWA Proven Safety Countermeasure

Special Conditions

FHWA recommends that these countermeasures be used as a package so it is important to include as many of the listed countermeasures as possible. FHWA estimated the crash reduction factor for the combined basic countermeasures as 30% reduction in all crashes. This estimate was developed by an intersection safety expert panel using past effectiveness research findings for individual countermeasures combined with engineering judgment. ODOT is aware that it may not be possible to install all six countermeasures so engineering judgment has been used to adjust the crash reduction for installing less than all six countermeasures.

4.3 I3-Add 3-inch Yellow Retroreflective Sheeting to Signal Backplates

Description
A strip of yellow retroreflective sheeting placed along the perimeter edges of a backplate, providing a "frame" for the signal face.

Figure 4-3. Retroreflective Signal Backplate

Images source: FHWA

Applications
On signalized corridors with a high frequency of intersection crashes, particularly angle and turning crashes related to red light running.

Considerations
Low cost safety treatment. The retroreflective sheeting may be added to the signal head if it is in decent shape. However, the full signal head may need to be replaced. Consider backplates with retroreflective borders as a standard treatment for improving safety at signalized intersections.

Special Conditions
Backplates with retroreflective boarders enhance signal visibility, conspicuity, and benefits both older and color vision impaired drivers. This treatment reduces human error as it was designed with respect to human characteristics and limitations.

ODOT CRF Value
15%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
15%

Safety Effects
Adding Retroreflective sheeting to signals enhances the visibility of the signal during daytime and nighttime conditions. May also alert drivers to signalized intersections during periods of power outages when non-reflective signal heads and backplates would not be visible.

References
[FHWA Proven Safety Countermeasure (FHWA-SA-21-039)]
[Crash Modification Factors Clearinghouse (CMF ID: 1410)]

FHWA Proven Safety Countermeasure

4.4 I4-Replace 8-inch Red Signal Heads with 12-inch

Description
An existing 8-inch signal head replaced with a larger 12-inch head.

Figure 4-4. Signal Heads with 8-inch and 12-inch Lens

Image source: FHWA

ODOT CRF Value
42%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
42%

Safety Effects
Increasing the size of the signal head improves the visibility of the signal from a longer distance. Treatments that improve signal visibility help drivers make decisions at the intersection and alert them to the presence of a signalized intersection.

References
[Crash Modification Factors Clearinghouse (CMF ID: 2333)]

Applications
On signalized corridors with a high frequency of intersection crashes, particularly angle and turning crashes related to red light running.

Considerations
As specified in the MUTCD, 12-inch signal lens shall be used under the following conditions:

- For signal indications for approaches where road users view both traffic control and lane use control signal heads simultaneously;
- If the nearest signal face is between 120 feet and 150 feet beyond the stop line, unless a supplemental near-side signal face is provided;
- For signal faces located more than 150 feet from the stop line;
- For approaches to all signalized locations for which the minimum sight distance (specified in MUTCD) cannot be met; or
- For arrow-signal indications.

Special Conditions

This treatment may be particularly beneficial to older drivers. Additionally, MUTCD recommends the use of a 12-inch signal lens on approaches with 85^{th} percentile speeds exceeding 40 MPH and where a traffic signal might be unexpected.

4.5 I5-Increase Signal Head Quantity: Additional Primary Head

Description
An additional primary head placed on a traffic signal mast arm.

Figure 4-5. Additional Primary Signal Head

Image source: FHWA

Applications
Signalized intersections with a high frequency of crashes, particularly angle and turning crashes related to red light running.

Considerations
Consider at high-speed intersections with fewer signal heads than approach lanes. The cost of installing an additional signal head may be high if a new mast arm and pole are required. Additionally, the MUTCD standards for signal head placement need to be considered. This standard states that "a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach" An additional primary head can be added only if the MUTCD standard hasn't already been met.

Special Conditions
This countermeasure CRF value applies to urban areas.

ODOT CRF Value
28%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
28%

Safety Effects
Installing an additional signal head improves the visibility of the signal. Treatments that improve signal visibility help drivers make decisions at the intersection and alert them to the presence of a signalized intersection.

References
Crash Modification Factors Clearinghouse (CMF ID: 1414)
Signalized Intersections Informational Guide (FHWA-SA-13-027)

4.6 I6-Replace Incandescent Traffic Signal Bulbs with Light Emitting Diodes

ODOT CRF Value

17%

Reduction in **rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness

17%

Safety Effects

LEDs improve signal visibility which helps drivers make decisions at the intersection and alert them to the presence of a signalized intersection.

References

Crash Modification Factors Clearinghouse (CMF ID: 4901)

Signalized Intersections Informational Guide (FHWA-SA-13-027)

Description

Traffic signal bulbs are replaced with light emitting diodes (LEDs), which improve signal visibility, reduce energy consumption, and are expected to last much longer than conventional incandescent light bulbs in traffic signals.

Figure 4-6. Incandescent and LED Traffic Signal Head

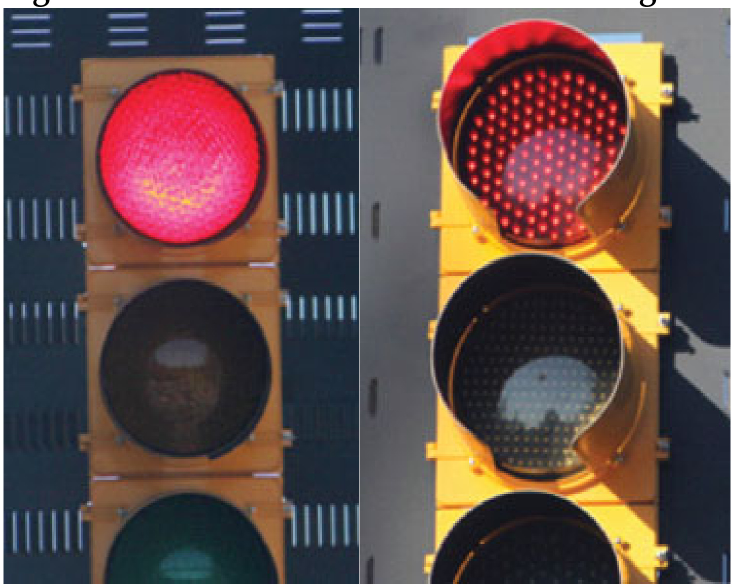


Image source: FHWA

Applications

On signalized corridors with a high frequency of intersection crashes, particularly angle and turning crashes related to red light running.

Considerations

It is important to note that studies have revealed potential limitations with LEDs, including their inability to melt snow and issues related to visual discomfort caused by glare at night.

Special Conditions

This countermeasure CRF value applies to urban areas.

4.7 I7-Replace Nighttime Flash with Steady Operation

Description

Removal of nighttime flash operations, consisting of traffic signals with red-red or red-yellow operations, to a normal steady (stop-and-go) operation. Nighttime flash is activated during nighttime and early morning conditions.

Figure 4-7. Intersection Traffic Signals Converted from Nighttime Flash Mode to Normal Steady Operation

Image source: FHWA

Applications

On signalized corridors with a high frequency of intersection crashes, particularly angle and turning crashes.

Considerations

If removal of the flashing operation is not fully actuated and responsive to traffic demand, increases in red-light running and/or complaints of long wait times at red signals may occur. Enforcement and temporary signing may be needed for a period of time after converting to the normal phasing operation.

ODOT CRF Value

48%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

48%-57%

Safety Effects

Removing a nighttime flash operation would give vehicles more time to see, respond, and yield to pedestrians and other vehicles because they would be required to stop during the red phase.

References

Safety Evaluation of Discontinuing Late-night Flash Operations at Signalized Intersections (FHWA-HRT-13-069)

Crash Modification Factors Clearinghouse (CMF ID: 4887)

Special Conditions

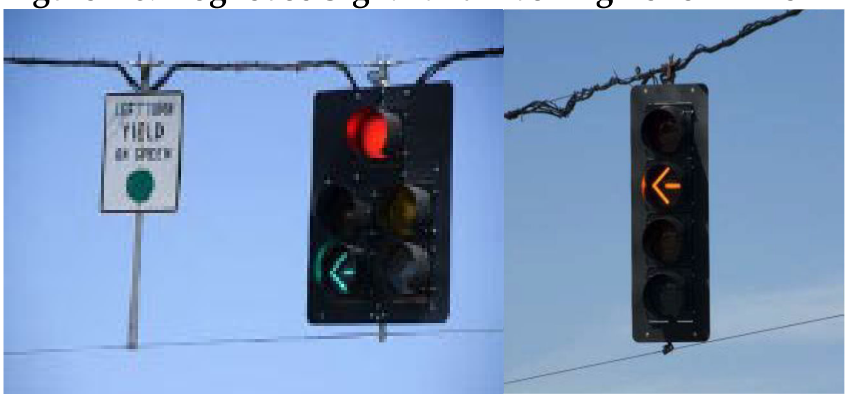
Refer to the MUTCD for additional guidance on the transition out of flash mode to steady (stop-and-go) mode.

4-8 I8-Replace Doghouse with Flashing Yellow Arrow Signal Heads

Description

Replacing the 5-section "doghouse" protected/permissive left-turn signal head with a 4- or 3-section flashing yellow arrow protected/permissive left-turn signal.

Figure 4-8. Doghouse Signal and Flashing Yellow Arrow



Images source: ODOT Photo and Video Services

Applications

Where doghouse signal heads are installed with a high frequency of left-turning crashes.

Considerations

Signal software may need to be updated in order to be compatible with the flashing yellow arrow. If a 4-section flashing yellow arrow head is used, structural limitations and height restrictions needs to be considered.

Special Conditions

This countermeasure does not apply to doghouse signal heads for right turns. In addition, be aware that the 3-section head for the flashing yellow arrow only has interim approval from FHWA (Interim Approval for Optional Use of Three-section Flashing Yellow Arrow Signal Faces (IA-17)). The flashing yellow arrow is a protected-permissive left-turn phase that allows for more flexibility of left-turn phasing throughout peak and non-peak periods.

ODOT CRF Value

25%

Reduction in **left-turning crashes** at **all severities** (including PDOs)

Range of Effectiveness

25%

Safety Effects

Previous NCHRP studies (*NCHRP Report 493* and *NCHRP Web-only Document 123*) have proven that the flashing yellow arrow is more intuitive with fewer "false positive" reactions as compared to the green ball indication on the doghouse signal head, resulting in a reduction of left-turn crashes.

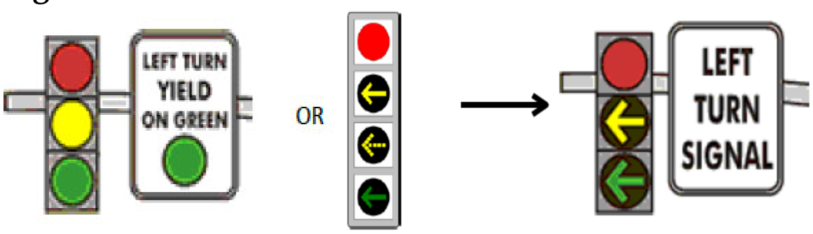
References

Safety Effectiveness of Flashing Yellow Arrow: Evaluation of 222 Signalized Intersections in North Carolina

4.9 I9-Replace Urban Permissive or Protected/Permissive Left Turns to Protected Only

Description
In a "permissive" mode, a green signal permits vehicles to turn left when an appropriate gap becomes available. In a "protected/permissive" mode, the permissive left-turn phase is immediately followed by an exclusive, protected left-turn phase, initiated by a green arrow signal indication. "Protected-only" phasing consists of providing a separate phase for left-turning traffic and allowing left turns to be made only on a green left arrow signal indication, with no pedestrian movement or vehicular traffic conflicting with the left turn. This countermeasure removes the permissive left-turn phase and provides the exclusive protected left-turn phase only.

Figure 4-9. Protected/Permissive Left Turn to Protected Only



Images source: FHWA

Applications
Where a high frequency of left-turning crashes is observed.

Considerations
Protected-only left-turn phases may reduce delay for turning vehicles but are likely to increase overall intersection delay. If the signal is within a coordinated system, it is recommended that proper analysis and timing adjustments be made to accommodate the potential impact to the corridor's capacity by implementing this countermeasure.

Special Conditions
Other factors that may warrant the use of protected-only left-turn phases include delay, visibility, and distance of the intersection.

ODOT CRF Value

99%

Reduction in **left-turning crashes** at **all severities** (including PDOs)

Range of Effectiveness

6%-99%

Safety Effects

Left-turn movements with "protected-only" phasing have fewer potential conflicts than those with "permissive-only" or "protected/permissive" phasing.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 333)

Accident Modification Factors for Traffic Engineering and ITS Improvements (NCHRP Report 617)

Safety Effects of Left-turn Phasing Schemes at High-speed Intersections

4.10 I10-Protected Left Turn: Split Side Street Signal Phasing

Description
Split phasing is the assignment of right of way to all movements of one approach, followed by all movements of the opposing approach.

Figure 4-10. Split Phasing for Side Street

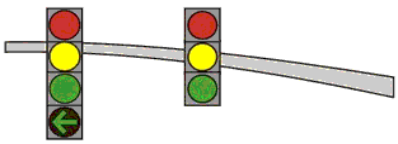


Image source: FHWA

Applications
Where a high frequency of crashes related to left-turning vehicles is observed.

Considerations
It is important to consider pedestrian crossing phases. One potential limitation related to split phasing with protected left turn displays is the potential impact on coordinated signal systems. This would require a longer cycle length to accommodate the pedestrians or would result in frequent signal out-of-coordination. Split signal phasing creates additional intersection delay and is generally less efficient than other signal phasing options. Use this countermeasure in unusual situations, determined by an engineer with signal timing expertise (see ODOT *Traffic Signal Policy and Guidelines*).

Special Conditions
Additional conditions where split phasing might be considered are:

- For a shared lane where the there isn't enough space to accommodate multiple turn lanes on one approach;
- Left-turn volumes on opposing approaches are approximately equal to through traffic volumes and total approach volumes are different for opposing approaches;
- Offset approaches where opposing left turns could not proceed simultaneously or permissive left turns could not be expected to yield to opposing through traffic;
- Angle of intersection creates paths of opposing left turns that could cause conflict;

ODOT CRF Value
70%
Reduction in **left-turning crashes**
at **all severities**
(including PDOs)

Range of Effectiveness
70%

Safety Effects
Split phasing avoids the conflict of opposing left turn vehicle paths by controlling the traffic on opposing approaches to move in separate sequences. Reduces conflicts between left turning vehicles and pedestrians.

References
North Carolina Project Development Crash Reduction Factor Information

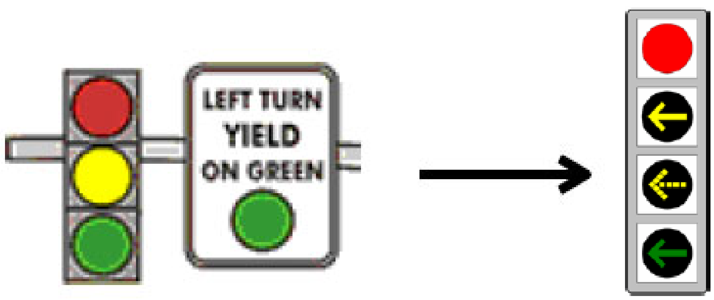
- Opposing approaches that each only have a single lane to accommodate all movements and where left-turn volumes are accommodated through a protected phase; or
- One of the opposing approaches has a heavy demand while the other approach has a minimal demand.

4.11 I11-Replace Urban Permissive Left Turns to Protected/Permissive

Description

In a "permissive" mode, a green signal permits vehicles to turn left only when an appropriate gap becomes available. While permissive-only left turn operations may reduce delay for the intersection, it may adversely affect intersection safety as motorists needs to choose acceptable gaps. In a "protected/permissive" mode, the permissive left-turn phase is immediately preceded by an exclusive, protected left-turn phase, initiated by a green arrow signal indication.

Figure 4-11. Permissve Left Turn Converted to Protected/Permissive Left Turn



Images source: FHWA

Applications

Where a high frequency of left-turning crashes is observed and protected-only phasing is not justified.

Considerations

Consider driver expectations and whether or not the signal is within a coordinated system. It is recommended that proper analysis and timing adjustments be made to accommodate the potential impact to the corridor's capacity by implementing this countermeasure.

Special Conditions

Some additional benefits to provide protected/permissive left-turn phasing:

- Average delay per left-turn vehicle is reduced;
- Protected green arrow time is reduced;
- There is potential to omit or provide an exclusive protected left-turn phase;

ODOT CRF Value

16%

Reduction in **left-turning crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

6%-99%

Safety Effects

Protected/permissive left-turn phasing provides an exclusive phase for left-turning vehicles that reduces the number of potential left-turning conflicts. Protected-permissive left-turn phases can offer a good compromise between safety and efficiency and allows for more flexibility of left-turn phasing throughout peak and non-peak periods.

References

Highway Safety Manual

CMF Clearinghouse ID: 4578

- Arterial progression can be improved, particularly when special signal head treatments are used to allow lead-lag phasing.

4.12 I12-Change from Permissive Only to FYA Permissive Only

Description
Replacing a circular green indication with a flashing yellow arrow (FYA). FYA permissive only signals have three sections: a steady red arrow, a steady yellow arrow, and a flashing yellow arrow. They are used on approaches where an exclusive left-turn phase is not present.

Figure 4-12. FYA Permissive Only Left Turn

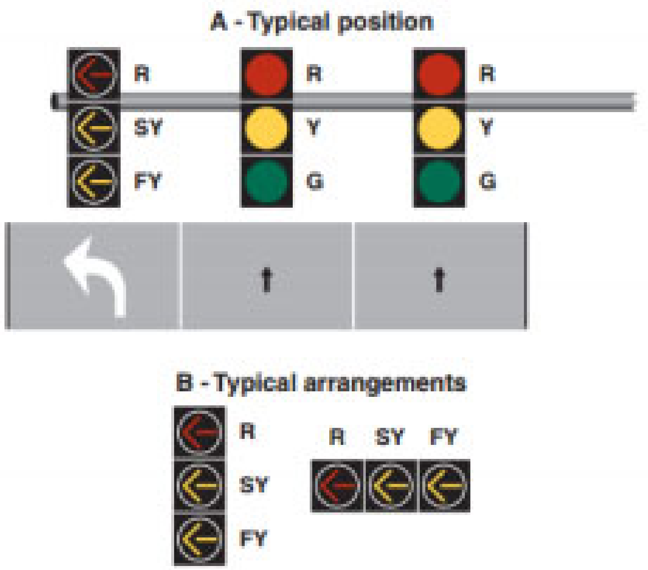


Image source: MUTCD

Applications
Where there is a high frequency of left-turn crashes at signalized intersections.

Considerations
Consider driver expectations and whether or not the signal is within a coordinated system. It is recommended that proper analysis and timing adjustments be made to accommodate the potential impact to the corridor's capacity by implementing this countermeasure.

ODOT CRF Value

50%

Reduction in **left-turning crashes**
at **all severities**
(including PDOs)

Range of Effectiveness

50%

Safety Effects

Where a circular green permissive indication is present, drivers might mistake that signal as implying they have the right of way over opposing traffic. Replacing this signal indication with a flashing yellow arrow could help eliminate confusion, and reduce collisions from left-turning movements.

References

Crash Modification Factors Clearinghouse (CMF ID: 7700)

4.13 I13-Coordination or Adaptive Signal Timing for Urban Traffic Signals

ODOT CRF Value

17%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

17%

Safety Effects

Reducing the number and frequency of required stops and maintaining constant speeds for all vehicles reduce rear-end conflicts.

References

[Crash Modification Factors Clearinghouse (CMF ID: 6856)]

Description

Coordination is the ability to synchronize multiple intersections to enhance the operation of one or more directional movements in a system. Adaptive Signal Timing is coordination that adjusts the timing of red, yellow and green lights to accommodate changing traffic patterns in real time and ease traffic congestion. Coordinated signals produce platoons of vehicles that can proceed without stopping at multiple intersections. In addition, signal coordination can improve the operation of turning movements. Drivers may have difficulty making permitted turning maneuvers because of a lack of gaps in through traffic. Crashes may occur when drivers become impatient and accept a gap that is smaller than needed. Such crashes could be reduced if longer gaps were made available.

Figure 4-13. Adaptive Signal Timing

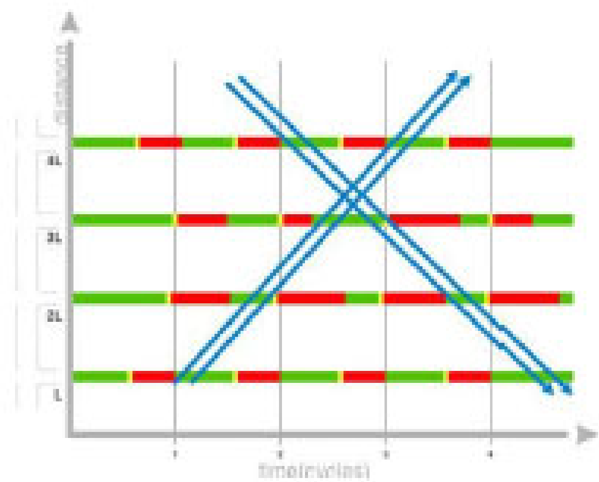


Image source: FHWA

Applications

Signalized intersections located close to each other where traffic volumes between the adjacent intersections are large. Consider on corridors with a high frequency of rear-end crashes and red light running crashes.

Considerations

Signals too close together can present challenges related to drivers focusing on a downstream signal and not noticing the signal they are approaching, or proceeding through a green signal and not being able to stop for a queue at an immediate downstream signal. Dispersion of platoons can occur if signals are spaced too far apart, resulting in inefficient use of the signal coordination. Achieving a coordinated system along a corridor may be complicated by signal requirements associated with crossing facilities, any of which may also require signal coordination. The need for long signal cycles associated with multiphase operation and long clearance intervals will dictate the cycle length on which progression will be based. Such a cycle length may produce additional delays for pedestrians and side street traffic.

Special Conditions

Consider signals, up to 3/4 mile of each other, for coordination as well as geographic boundaries, volume/capacity ratios, and characteristics of traffic flow. This countermeasure includes controllers, detection and communications. It is important to note that adaptive signal systems typically require additional detection beyond the standard. Meanwhile, for all federally funded projects, FHWA requires an Engineering Systems Document for ITS devices such as adaptive signal timing.

4.14 I14-Install Actuated Advance Warning Dilemma Zone Detection System at High-speed Signals (microwave detection)

Description

The dilemma zone is that portion of the approach where a driver suddenly facing a yellow indication must make a decision whether to stop safely or to proceed through the intersection. This countermeasure provides microwave radar that detects the speed and distance of a vehicle from the intersection and extends the green interval if the vehicle is within the dilemma zone.

Figure 4-14. Dilemma Zone Detection System

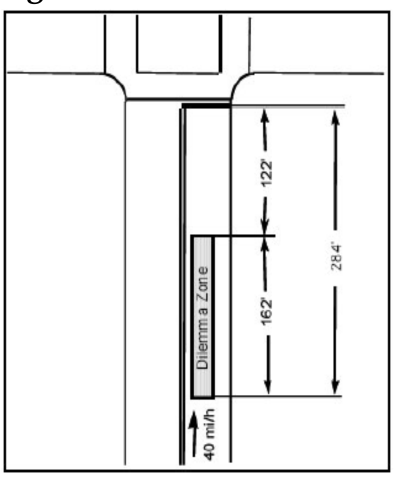


Image source: FHWA

Applications

At locations with a high frequency of crashes associated with the traffic signal phase change (e.g., rear-end and angle crashes) and high frequency of red-light violations. Consider this countermeasure at high-speed signalized intersections.

Considerations

On older signals there may be conduit capacity issues and structural issues related to where the detection system needs to be installed.

Special Conditions

This countermeasure is recommended and encouraged for use on high-speed facilities (45 MPH+). In the past, dilemma zone detection has been provided through loop and/or

ODOT CRF Value:

8%

Reduction in a**ll crashes** at **all severities** (including PDOs)

Range of Effectiveness

0%-43.6%

Safety Effects

The advance dilemma zone detection system enhances safety at signalized intersections by modifying traffic control signal timing to reduce the number of drivers that may have difficulty deciding whether to stop or proceed during a yellow phase. This may reduce rear-end crashes associated with frequent stopping and angle crashes due to illegally continuing into the intersection during the red phase.

References

Crash Modification Factors Clearinghouse (CMF ID: 4857)

camera. Microwave radar is a newer technology that more easily incorporates individual vehicle speeds in the dilemma zone detection. Additional benefits of this treatment include reducing delay and stop frequency on the major road and maintaining or reducing overall intersection delay. It is important to consider both truck and passenger vehicle stopping distances when implementing this countermeasure.

4.15 I15-Install Flashing Beacons as Advance Warning for Intersections

Description
A flashing beacon installed on a signal ahead or intersection ahead warning sign. This feature flashes at all times. For flashing beacons on signal ahead sign, it is not coordinated with signal for timing.

Figure 4-15. Flashing Beacon on Signal Ahead Sign

Image source: Google

Applications
At intersections with patterns of right-angle or turning crashes related to lack of driver awareness of the upcoming intersection (e.g. first signal upon entering an urban area, or intersection with limited sight distance).

ODOT CRF Value
13%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%-13%

Safety Effects
It helps bring more awareness to drivers of an upcoming intersection where it might not be expected.

References
[FHWA Desktop Reference for Crash Reductions Factors (FHWA-SA-08-011)]

Considerations
In rural areas, it may be difficult to find a source of power for the beacon(s).

Special Conditions
This countermeasure can include a single flashing beacon or dual flashing beacons that flash alternately ("wig-wag"). This CRF value can be applied to both signalized and unsignalized intersections.

4.16 I16- Install Actuated or Coordinated Flashing Beacons as Advance Warning for Signalized Intersections

Description

A flashing beacon on an advance warning sign for a signalized intersection that activates at a predetermined time before the end of the green interval.

Figure 4-16. Flashing Beacon for Signalized Intersection

Image source: Shari Lewis

ODOT CRF Value
10%
Reduction in **rear-end crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
It notifies drivers that the green interval is about to end to help reduce indecision and volatility in driver behavior during the yellow interval.

References
ODOT Engineering Judgement

Applications

At locations with a high frequency of crashes associated with the traffic signal phase change (e.g., rear-end and angle crashes) and high frequency of red-light violations. This countermeasure could also be used at locations with a high frequency of crashes related to limited sight distance.

Considerations

Some studies have shown that this countermeasure could inadvertently encourage some drivers to accelerate in order to make it through the green interval so use this countermeasure with caution.

Special Conditions

Additional potential benefits of this treatment include reducing delay and stop frequency on the major road and maintaining or reducing overall intersection delay.

4.17 I17-Increase Triangle Sight Distance

Description
Removal of sight distance restrictions (e.g., vegetation, parked vehicles, signs, buildings) from the sight triangles at an intersection.

Figure 4-17. Intersection Sight Triangle

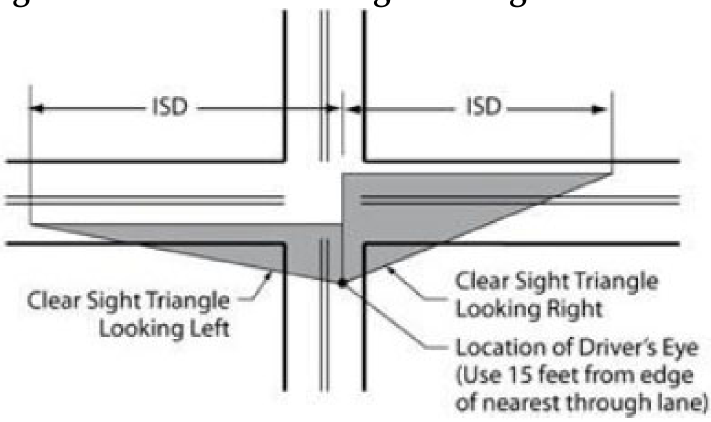


Image source: FHWA

Applications
At intersections with restricted sight distance and patterns of crashes related to lack of sight distance where sight distance can be improved by clearing roadside obstructions without major construction.

Considerations
Removing or relocating fixed objects can often be restricted and/or costly. Removing parking needs support from local community.

ODOT CRF Value

48%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

11%-56%

Safety Effects

Improvers drivers ability to see approaching vehicles on the main line without obstruction.

References

Crash Modification Factors Clearinghouse (CMF ID: 307)

Special Conditions
While countermeasure can be applied to either signalized or unsignalized intersections, it is more likely to make a significant impact at unsignalized intersections as there are more driver responses needed to judge gap sizes before deciding whether to initiate a roadway entry or a turning maneuver.

4.18 I18-Increase Pavement Friction by Installing High Friction Surface Treatment

Description
Pavement surfacing systems with exceptional skid-resistant properties not typically provided by conventional materials.

Figure 4-18. High Friction Surface Treatment

Images source: FHWA

Applications
In locations where frequent crashes are observed for which insufficient friction is a contributing factor (i.e. wet weather). These are generally locations where drivers are braking frequently; for example, curves or ramps, down hills or steep grades, or intersection. The road surface can become prematurely polished, reducing the pavement friction and allowing vehicles to skid or hydroplane.

Considerations
It is costly to install and could be costly to maintain so it's important to reserve this treatment for the most needed locations. It is important to closely follow the manufacturer's installation instructions in order to reduce any chances of product failure. For more information on high friction surface treatment, refer to the FHWA website, where many informational materials on the subject are provided.

Special Conditions
Consider the pavement quality, location, posted speed, user type and crash history when selecting locations for high friction surface treatments.

ODOT CRF Value

52%

Reduction in **wet-road crashes**
at **all severities**
(including PDOs)

Range of Effectiveness

17%-57%

Safety Effects

It uses aggregates that are both polish- and wear-resistant and develop channels to prevent water buildup on wet surfaces creating an exceptionally durable surface capable of withstanding extreme roadway friction demands.

References

Crash Modification Factors Clearinghouse (CMF ID: 195)

Evaluation of Pavement Safety Performance (FHWA-HRT-14-065)

4.19 I19-Left-turn Traffic Calming Treatments for Posted Speeds Less Than 35 MPH

ODOT CRF Value
10%
Reduction in **left-turning crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
Left-turn traffic calming treatments improve intersection safety by forcing vehicles to make a more 90-degree turn, slowing left-turn speeds. These treatments prevent corner cutting and increase crosswalk visibility, reducing conflicts between vehicles and pedestrians.

References
ODOT Engineering Judgment

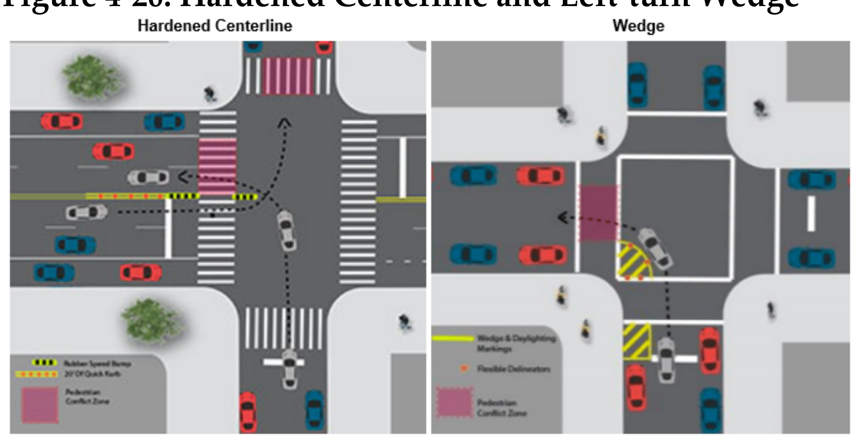
Description
Two types of left-turn traffic calming treatments:
- Hardened centerline: consists of rubber speed bumps and bollards anchored to a yellow centerline.
- Left-turn wedge: consists of a marked wedge box with rubber speed bumps or plastic flexible posts.

Figure 4-19. Left-turn Traffic Calming Treatments

Image source: PBOT

Applications
At intersections with a high frequency of left-turning crashes, for which vehicles failed to yield to pedestrians.

Figure 4-20. Hardened Centerline and Left-turn Wedge



Images source: New York City DOT

Considerations
Left-turn traffic calming treatments are low cost and require minimal installation time.

Special Conditions

This countermeasure CRF value is specific for urban areas. Hardened centerlines are installed where a one-way or two-way road meets a two-way road. Left-turn wedges are installed where a one-way road meets another one-way road.

4.20 Section Reserved

4.21 I21-Improve Intersection Warning

Description

FHWA has compiled a list of proven low-cost countermeasures that can be implemented at unsignalized intersections, as listed below:

- Doubled up (left and right), oversize advance intersection warning signs, with street name sign plaques on the through approach
- Doubled up (left and right), oversize advance "Stop Ahead" intersection warning signs
- Doubled up (left and right), oversize STOP signs
- Installation of a minimum 6-foot wide raised splitter island on the stop approach (without pavement widening)
- Properly placed stop bar
- Removal of any foliage or parking that limits sight distance
- Double arrow warning sign at stem of T-intersections

Figure 4-21. Intersection Warning Signs and Pavement Markings

Images source: FHWA

Applications

At unsignalized intersections with a high frequency of angle or turning crashes.

Considerations

If the width is not already available to place a splitter island, this countermeasure will require widening and the appropriate accommodations for adding impervious surface.

ODOT CRF Value

20%

(1-2 countermeasures)

25%

(3-4 countermeasures)

30%

(5-7 countermeasures)

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

11%-55%

Safety Effects

Increase drivers' alertness to the presence of an unsignalized intersection and reduce potential conflicts with other entering vehicles.

References

California DOT Intersection Implementation Plan/ODOT Engineering Judgment

FHWA Proven Safety Countermeasure

Special Conditions

FHWA recommends that these countermeasures be used as a package so it is important to include as many of the listed countermeasures as possible. FHWA estimated the crash reduction factor for the combined basic countermeasures as 30% reduction in all crashes. ODOT is aware that it may not be possible to install all seven countermeasures so engineering judgment has been used to adjust the crash reduction for installing less than all seven countermeasures.

4.22 I22-Install Signal Ahead Advance Warning Signs

Description
Warning signs placed before a signalized intersection to inform drivers of an approaching signal.

Figure 4-22. Signal Ahead Sign

Image source: Google

ODOT CRF Value
35%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
35%

Safety Effects
Advanced warning signs inform drivers of upcoming traffic signals and reduce potential conflicts with other vehicles present at signalized intersections.

References
Crash Modification Factors Clearinghouse (CMF ID: 1684)

Applications
At signalized intersections with patterns of angle crashes related to lack of driver awareness of the approaching signalized intersection.

Considerations
Place to provide adequate perception-reaction time for drivers. A sign placed at the wrong location may result in it being seen too late by drivers to react safely. MUTCD requires advance traffic control symbol signs such as Signal Ahead (W3-3) sign be installed to "a primary traffic-control device that is not visible for a sufficient distance to permit the road user to respond to the device."

Special Conditions
This countermeasure is specific to urban areas. Refer to the MUTCD for additional guidance on placement of these signs.

4.23 I23-Increase Retroreflectivity of Stop Signs

Description
A material applied to a stop sign that reflects a large portion of light directly back to the source. When applied to a sign, retroreflective sheeting will redirect light from the driver's headlights back to the driver's eyes making the sign more visible, which is especially during nighttime or other reduced visibility conditions. The reflective strips on sign post is optional for this treatment.

Figure 4-23. Retroreflective Stop Sign in Daylight and Nighttime Conditions

Image source: FHWA

Applications
At unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the stop sign.

Considerations
Maintenance is an important consideration so that the sign continues to serve its intended safety purpose. Service life of a retroreflective sign depends upon the type and quality of the sheeting chosen.

Special Conditions
MUTCD has standards for minimum required retro-reflectivity levels. A sign will need to be replaced if it falls below the MUTCD required levels.

ODOT CRF Value
7%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
7%

Safety Effects
Increasing the retroreflectivity increases visibility and conspicuity of the stop sign and reduces the frequency of crashes related to driver unawareness of stop controlled intersections. They may also improve safety at locations where there is a lack of nighttime visibility of intersections.

References
[Crash Modification Factors Clearinghouse (CMF ID: 6048)]

FHWA Proven Safety Countermeasure

4.24 I24-Provide Flashing Beacons at All-way Stop-controlled Intersections

Description
Red flashing beacons placed on the top of the stop signs at an all-way stop controlled intersection.

Figure 4-24. Flashing Beacons at All-way Stop Controlled Intersection

Image source: FHWA

Applications
At unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the stop sign on a stop-controlled approach.

Considerations
In rural areas, it may be difficult to find a source of power for the beacons.

ODOT CRF Value
28%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
5%-58%

Safety Effects
Flashing beacons provide a visible signal indicating the presence of an intersection and can be very effective in rural areas where there may be long stretches between intersections. They may also improve safety at locations where nighttime visibility of intersections is an issue.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 454)

Special Conditions
This countermeasure only applies to all-way stop controlled intersections.

4.25 I25-Provide Flashing Beacons at Minor-road Stop-controlled Intersections

Description
At minor road stop controlled intersections, red flashing beacons installed on top of the stop signs on the minor controlled road, and/or yellow flashing beacons installed on top of advance intersection warning signs on the major uncontrolled road.

Figure 4-25. Red Flashing Beacon at Minor-road Stop-controlled Intersection

Image source: Sebastian Chavez

Applications
At unsignalized intersections with patterns of right-angle crashes related to lack of driver awareness of the stop sign on a stop-controlled approach.

Considerations
In rural areas, it may be difficult to find a source of power for the beacons.

ODOT CRF Value
13%
Reduction in **angle crashes** at **all severities** (including PDOs)

Range of Effectiveness
5%-58%

Safety Effects
Flashing beacons provide a visible signal indicating the presence of an intersection and can be very effective in rural areas where there may be long stretches between intersections. They may also improve safety at locations where nighttime visibility of intersections is an issue.

References
Highway Safety Manual
Crash Modification Factors Clearinghouse (CMF ID: 449)

Special Conditions
This countermeasure only applies to minor-road stop-controlled intersections. The flashing beacons can be placed on the major road, minor road, or on all approaches.

4.26 I26-Provide Actuated Flashing Beacons Triggered by Approaching Vehicles at Unsignalized Intersections

ODOT CRF Value

27%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

27%

Safety Effects

These systems provide enhanced safety warning information for approaching drivers, making them aware that vehicles are or may be entering the intersection.

References

[Crash Modification Factors Clearinghouse (CMF ID: 8441)](#)

[Safety Evaluation of Intersection Conflict Warning Systems (FHWA-HRT-15-076)](#)

Description

Flashing beacons that only flash when a sensor detects a vehicle approaching the intersection. ODOT encourages the installation of the type of actuated beacon that provides enhanced warning to the through driver that there is a vehicle on a cross road stop approach that may enter the intersection. Research has shown that this actuated beacon has seen the most effectiveness.

Figure 4-26. Flashing Beacons at Unsignalized Intersection

Image source: Kevin Hass and FHWA

Applications

At unsignalized intersections that experience severe intersection-related crashes due to speed, low visibility, or insufficient gaps. Use this countermeasure where other signing enhancements have been shown to be ineffective.

Considerations

In rural areas, it may be difficult to find a source of power for the beacons. Consider potential maintenance costs and impacts when deciding between camera, loop, and radar detection. For loop detection, turning vehicles may trigger the loops if over tracking occurs. If the delay is set too high, vehicles that need to be detected won't get picked up. Consider loops, although cheaper, as a last resort with these systems.

Special Conditions

This countermeasure only applies to unsignalized intersections. FHWA requires that for all federally funded projects, an engineering systems document be provided for ITS devices such as intersection conflict warning systems. For more information, refer to the following two FHWA publications:

- Stop-controlled Intersection Safety: Through Route Activated Warning Systems (FHWA-SA-11-015)
- Safety Evaluation of Flashing Beacons at Stop-controlled Intersections (FHWA-HRT-08-044)

4.27 I27-Install Transverse Rumble Strips on Stop-controlled Approach(es)

Description

Rumble strips that are milled-in or rolled-in patterns placed across the roadway that provide both an audible warning (rumbling sound) and physical vibration to alert drivers of an upcoming intersection.

Figure 4-27. Transverse Rumble Trips

Image source: Google

Applications

Where there is a high frequency of crashes as a result of vehicles failing to stop at a stop sign (e.g. limited visibility of an approaching intersection) and where other signing enhancements have been shown to be ineffective.

Considerations

Considerations existing pavement quality and potential noise impacts to neighboring residents.

Special Conditions

Transverse rumble strips are typically installed at rural, unsignalized intersections. Consider this countermeasure when a splitter island cannot be installed.

ODOT CRF Value

25%

Reduction in **all crashes** at **fatal, A-injury and B-injury severities**

Range of Effectiveness

-36%-33%

Safety Effects

Transverse rumble strips have been proven to be effective at reducing the number of vehicles disregarding a stop sign by using an audible alert as they are approaching an intersection.

References

Crash Modification Factors Clearinghouse (CMF ID: 2705)

Safety Evaluation of Transverse Rumble Strips on Approaches to Stop-controlled Intersections in Rural Areas (FHWA-HRT-12-047)

4.28 I28-Install 6-foot or Greater Raised Divider on Stop Approach (splitter island)

Description

A channelizing island that separates traffic in opposing directions of travel at a stop approach of an unsignalized intersection and contains a left side, supplemental stop sign.

Figure 4-28. Splitter Island at Stop-controlled Intersection

Image source: FHWA

Applications

Where there is a high frequency of crashes as a result of vehicles failing to stop at a stop sign (e.g. limited visibility of an approaching intersection) and where other signing enhancements have been shown to be ineffective. The strategy is particularly appropriate for intersections where the speeds on the minor road are high and/or on approaches to skewed intersections.

ODOT CRF Value
15%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
15%

Safety Effects
The installation of splitter islands allows for the addition of a stop sign in the median to make the intersection more conspicuous.

References
[Low-cost Safety Enhancements for Stop-controlled and Signalized Intersections (FHWA-SA-09-020)]

Considerations

If the width is not already available to place a splitter island, this countermeasure will involve widening and the appropriate accommodations for adding impervious surface.

Special Conditions

Consider this countermeasure when transverse rumble strips cannot be installed.

4.29 I29-Prohibit Right Turn on Red

ODOT CRF Value
9%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
9%

Safety Effects
Prohibiting vehicles from turning right on red can improve safety at intersections with limited sight distances and could reduce conflicts from right turning vehicles.

References
Highway Safety Manual

Description
A sign indicating that a vehicle is prohibited from making a right turn when the signal is red.

Figure 4-29. No Turn on Red Sign

Image source: Google

Applications
At signalized intersections with a high pedestrian or bicycle volumes and frequency of crashes resulting from vehicles turning right.

Considerations
Low-cost treatment. Prohibiting right turn on red may lead to higher right turn on green conflicts when there are concurrent signals. Install so that sign is visible to drivers. Consider structural analysis to assess wind loading created by the addition of the sign to the signal mast arm.

Special Conditions
At intersections experiencing high pedestrian volumes, prohibiting right turn on red along with a leading pedestrian interval could provide additional safety benefits for pedestrians. Where a right turn on red restriction is needed during certain times of the day, a part-time or variable message no turn on red sign could be used.

4.30 I30-Provide "STOP AHEAD" Pavement Markings

Description
Pavement markings on a roadway surface that inform drivers of an approaching unsignalized intersection.

Figure 4-30. STOP AHEAD Pavement Marking

Image source: FHWA

Applications
Where there is a high frequency of crashes due to lack of driver awareness of upcoming, unexpected, or partially concealed stop-controlled intersections.

Considerations
Consider size and placement of the pavement markings.

Special Conditions
This countermeasure is especially useful in rural areas at unsignalized intersections with patterns of crashes which suggest that drivers may not be aware of the presence of the intersection.

ODOT CRF Value
31%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
31%

Safety Effects
STOP AHEAD pavement markings can be used to increase drivers' alertness to the presence of an unsignalized intersection and reduce potential conflicts with other entering vehicles.

References
Highway Safety Manual

FHWA Proven Safety Countermeasure

4.31 I31-Provide Overhead Lane-use Signs

ODOT CRF Value
10%
Reduction in **rear-end crashes**
at **all severities**
(including PDOs)

Range of Effectiveness
10%

Safety Effects
Enhances visibility, reducing rear-end and sideswipe crashes caused by last-minute lane changes, and other potential conflicts..

References
[Signalized Intersections Informational Guide (FHWA-SA-13-027)]

Description

Intersection lane control signs mounted overhead and placed over the lane to which it applies.

Figure 4-31. Overhead Land-use Sign at Intersection

Image source: FHWA

Applications

Where there is a high frequency of rear-end crashes at signalized intersections.

Considerations

Use of an overhead sign for one approach lane does not require installation of overhead signs for the other lanes of that approach. Consider sign support and structural analysis to reduce potential for crashes and to address wind loading created by the signs.

Special Conditions

Especially important for treatments involving indirect turning movements that may violate driver expectation.

4.32 I32-Install Wrong-way Driving Countermeasures

Description

Countermeasures that can be implemented to reduce wrong-way crashes:

- Signage: Wrong-way signs, oversized signs, lower-mounted signs, multiple signs, "Entrance Freeway" Sign at ramps
- Pavement markings: Wrong-way arrows, red raised pavement markings, stop lines, dotted lane line extensions, delineations, turn or through lane arrows, "ONLY" markings
- Geometric modifications: Channelizing islands, extended raised median or longitudinal channelizing devices, open sight distance and uniform lighting levels at ramp terminal
- ITS technologies: Sensors, traffic management center to inform law enforcement and incident responders, dynamic signs to warn drivers, LED/RRFBs illuminated wrong-way signs, changeable message signs, in-pavement warning lights

Figure 4-32. Wrong Way Driving Countermeasures

Image source: ODOT

ODOT CRF Value

20%

(2 Countermeasures)

30%

(3 Countermeasures)

40%

(4+ Countermeasures)

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

20%-40%

Safety Effects

These listed treatments can reduce crashes related to wrong-way driving.

References

Wrong Way Driving Analysis and Recommendations

Applications

Where there is a high frequency of crashes due to wrong-way driving.

Considerations

These treatments can be applied systematically.

Special Conditions

Refer to the Wrong Way Driving Analysis and Recommendations report for further guidance.

4.33 I33-Curb Extensions

ODOT CRF Value
30%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
30%

Safety Effects
Curb extensions significantly improve pedestrian crossings by reducing the pedestrian crossing distance, improving the ability of pedestrians and motorists to see each other, and reducing the time that pedestrians are in the street.

References
MDOT Intersection Crash Reduction Factors

Description
Curb extensions (also known as bulb-outs) narrow the width of the roadway by extending the curb line or sidewalk out into the parking lane.

Figure 4-33. Curb Extension

Image source: SDOT

Applications
At intersections with a high frequency of crashes that could be reduced by minimizing crossing distances and maximizing the visibility of pedestrians.

Considerations
It is important to provide sufficient pavement width to accommodate the largest size of vehicles expected to travel on the road in question. Do not extend curb line into the traveled way where bicyclists or motor vehicles may be traveling. Additionally, storm water drainage may need to be considered as curb extensions often require changing street drainage.

Special Conditions
Use curb extensions where there is a parking lane and where transit and cyclists will be traveling outside the curb edge for the length of the street.

Chapter 5 Safety Improvement Countermeasures for Pedestrian and Bicyclist Crashes

Walking is a basic human activity that has often been overlooked in the quest to build sophisticated transportation systems. Recent socio-economic and cultural trends also point to higher demands for walkable communities. Meanwhile, bicycling is an integral part of the transportation system in Oregon. Yet, with the increasing popularity of bicycling over the past several decades, the factors contributing to an increase in bicycle crashes are still evident. Creating a safer environment for the vulnerable roadway users involves more than just installing a pedestrian hybrid beacon or building a separated bicycle path. Creating a truly safe, viable walking and bicycling network involves communities and stakeholders that comprise the four E's working together to address all aspects of safety, from signage and mapping that alerts pedestrians and bicyclists to the potential conflicts with vehicular movements to the details of the design.

The safety issues with pedestrians and bicyclists can be addressed with a 5-step procedure. First, factors affecting the vulnerable roadway users safety need to be identified; in step two, analyze historical crashes to identify their pattern and contributing factors; after that, those roadway design and operation characteristics that affect pedestrian and bicyclist safety should be analyzed to understand the current safety challenges (step three); a crash-related or performance-based goal can be established in step four after the safety issues for the selected roadway site have been fully investigated; and finally, in step five, countermeasures should be selected and implemented to address the pedestrian and bicyclist safety issues.

A collection of countermeasures have been developed by many federal, state and local agencies to effectively reduce pedestrian and bicyclist fatalities and serious injuries. Practitioners now have many resources and tools available to help them identify potential safety improvements and decide which ones to implement. For example, the CMF Clearinghouse is a comprehensive and searchable database of published CMFs and offers transportation professionals a central, web-based repository of crash modification factors for various safety improvement countermeasures on pedestrian and bicyclist crashes. Meanwhile, FHWA developed the *Pedestrian Safety Guide and Countermeasure Selection System* and the *Bike Safety Guide and Countermeasure Selection System* to provide practitioners with the latest information available for improving the safety and mobility of those vulnerable roadway users. Specifically, FHWA developed a bunch of proven safety countermeasures to highlight when and where certain processes, design techniques, and safety countermeasures are the most effective at increasing pedestrian and bicyclist safety:

- Crosswalk visibility enhancements
- Bicycle lanes
- Rectangular rapid flashing beacons

- Leading pedestrian interval
- Medians and pedestrian refuge islands in urban and suburban areas
- Pedestrian hybrid beacons
- Road diets (road reconfiguration); and
- Walkways

Relevant promotional materials, best practices reports, and webinars have been developed as well to educate state and local transportation professionals about the benefits of using these proven countermeasures.

To provide technical guidance for state and local agencies on how to select safety improvement countermeasures for the ARTS program, ODOT developed the safety improvement countermeasures based on results from CMF Clearinghouse, technical reports on pedestrian and bicycle safety, and references from other sources. A total of 31 engineering countermeasures are discussed in details in this chapter, including a description of the safety countermeasure, typical scenario for applying the safety countermeasure, additional factors for consideration when using the countermeasure, and special conditions for the countermeasure. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period of time and/or have proven effective. To reflect the most recent research results on pedestrian and bicyclist safety, the list will be evaluated periodically to add or remove some safety improvement countermeasures. Listed below are the countermeasures recommended for addressing the pedestrian and bicyclist safety currently:

- BP1-Install pedestrian countdown timer(s)
- BP2-Provide intersection illumination for bicyclists and pedestrians
- BP3-Install urban leading pedestrian or bicycle interval at signalized intersections
- BP4-Install NO PEDESTRIAN phase feature with flashing yellow arrow
- BP5-Reduce right turn permissive conflict (right turn arrow)
- BP6-Install urban green bike lanes at conflict points
- BP7-Install bike box at conflict points
- BP8-Install pedestrian refuge islands
- BP9-Install rectangular rapid flashing beacon (2-lane road)
- BP10-Install rectangular rapid flashing beacon without median (3-lane or more roadway)
- BP11- Install rectangular rapid flashing beacon with median (3-lane or more roadway)
- BP12-Install pedestrian activated beacon at intersection
- BP13-Install pedestrian activated beacon midblock
- BP14-Install pedestrian activated beacon (with median and stop bar)
- BP15-Install continental crosswalk markings and advance pedestrian warning signs at uncontrolled locations
- BP16-Install curb ramps and extensions with a marked crosswalk and pedestrian warning signs

- BP17-Install advance pedestrian or bicycle warning signs
- BP18-Install pedestrian signal
- BP19-Install pedestrian hybrid beacon
- BP20-Convert 4-lane roadway to 3-lane roadway with center turn lane (road diet)
- BP21-Install bike signal
- BP22-Install bike lanes
- BP23-Install cycle tracks
- BP24-Install buffered bike lanes
- BP25-Prohibit right-turn-on-red
- BP26-Advance yield or stop markings and signs
- BP27-Install bicycle boulevard
- BP28-Install raised crosswalk
- BP29-Add sidewalk
- BP30-Install speed humps/table (not on state highways)
- BP31-Add street trees (supports Blueprint for Urban Design)

5.1 BP1-Install Pedestrian Countdown Timer(s)

Description
Pedestrian signal heads are traffic signal indications exclusively intended for controlling pedestrian traffic. They consist of the illuminated symbols of a walking person (symbolizing WALK) and an upraised hand (symbolizing DON’T WALK). Pedestrian countdown timers are pedestrian signal heads that include a countdown during the flashing DON'T WALK phase that provides pedestrians with the remaining seconds available before the pedestrian phase ends.

Figure 5-1. Pedestrian Countdown Timer

Image source: FHWA

Applications
Where there is a high frequency of pedestrian crashes at signalized intersections.

ODOT CRF Value:
70%
Reduction in **pedestrian crashes**
at **all severities**
(including PDOs)

Range of Effectiveness
0%-70%

Safety Effects
Enables pedestrians to make informed decisions on when to safely cross the road, effectively reducing the exposure of pedestrians to vehicular traffic at a signalized intersection.

References
Crash Modification Factors Clearinghouse (CMF ID: 5272)

Considerations
Depending on the age of the signal, the entire pedestrian signal head (as opposed to just the LED module) may need to be replaced, which could increase the installation costs. 90% of the time this will trigger Americans with Disabilities Act (ADA) for ODOT to meet reach and landing. This then leads to rebuilding ramps, which could be very costly.

Special Conditions

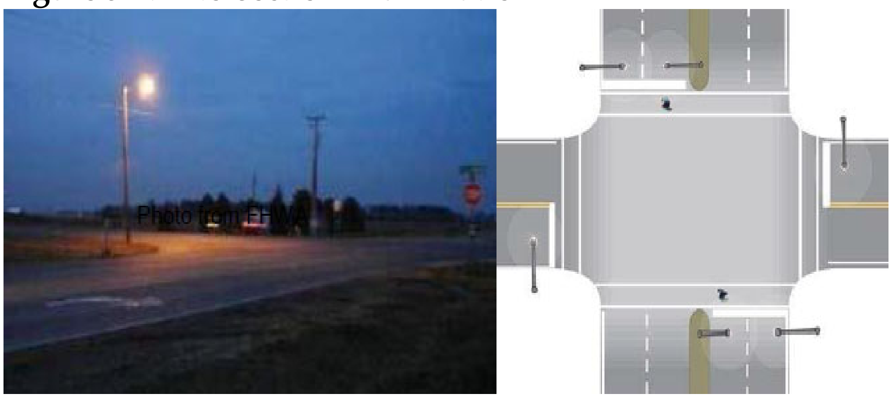
This type of pedestrian signal head is the 2009 MUTCD standard and shall be installed at all new signal installations if flashing don't walk time is 7 seconds or more. It is encouraged that this countermeasure be applied systemically along a signalized corridor to create consistency for the pedestrians as they travel along the corridor. This countermeasure may be included in an application for a Signalized Intersection Systemic project.

5.2 BP2-Provide Intersection Illumination (Bicycle and Pedestrian)

Description

A permanent source of artificial light installed at an intersection that provides greater visibility of the intersection and its potential multi-modal users. This can be especially helpful at rural intersections where the only source of lighting for the roadway is often provided by vehicle headlights.

Figure 5-2. Intersection Illumination



Images source: FHWA

Applications

At intersections where there is a high frequency of bicycle and pedestrian crashes at night.

Considerations

In rural areas it may be difficult to locate a power source. In addition, it is important to determine, upfront, the jurisdiction responsible for paying the ongoing utility costs. For signalized intersections, retrofitting illumination onto existing signal poles could result in an entire signal rebuild.

Special Conditions

This countermeasure may be used at a midblock pedestrian crossing location. This countermeasure is for new lighting only, not to replace existing, substandard lighting. This CRF value can be applied to both signalized and unsignalized intersections. For ODOT Highways, refer to the ODOT *Lighting Policy and Guidelines* for further guidance on lighting warrants.

ODOT CRF Value

42%

Reduction in **nighttime pedestrian and bicycle crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

42%

Safety Effects

Intersection lighting allows for greater visibility of the intersection. Roadway users and features are more visible and help all users determine a safe path through the intersection.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 436)

5.3 BP3-Install Leading Pedestrian Interval at Urban Signalized Intersections

Description

Leading pedestrian interval (LPI) gives pedestrians and bicycles using the marked crosswalk an advance walk signal before the motorists get a green indication, giving the pedestrian or bicyclist several seconds to start crossing before vehicles start proceeding through the intersection.

Figure 5-3. Leading Pedestrian Interval

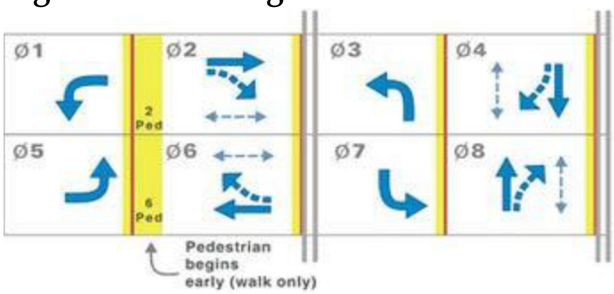


Image source: FHWA

Applications

Where there is a high frequency of motorized users failing to yield to the right of way of non-motorized users at a signalized intersection.

Considerations

It is important to consider the potential intersection capacity and delay impacts to implementing this countermeasure. MUTCD recommends audible pedestrian pushbuttons for visually impaired pedestrians when using this feature, as they may miss the start of the walk signal because there isn't the vehicle sound to queue that it has begun early. This feature could also be considered for use by time of day to account for specific pedestrian surges, such as school or shift releases. Consider lighting conditions specifically in rural or suburban fringe areas where pedestrians may not be expected at all times of the day.

Special Conditions

This treatment could also be beneficial in areas where there is a high number of older pedestrians who tend to be slower to start into the intersection. It could also be particularly effective where there is a dual lane turning movements. If a

ODOT CRF Value

37%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

37%-45%

Safety Effects

Alerts drivers to the presence of pedestrian or bicyclists in the roadway/crosswalk for permissive left-turning or right-turning drivers. It makes non-motorized users more visible to motorized users and motorized users more likely to yield to them.

References

Safety Effectiveness of Leading Pedestrian Intervals using Empirical Bayes Method

Crash Modification Factors Clearinghouse

FHWA Proven Safety Countermeasure

LPI is implemented on the side street phases 4 & 8, it will reduce left-turn and right-turn pedestrian crashes from the side street if the left turns are permissive. If the left turns are protected, this will only reduce right-turning pedestrian crashes from the side street. This countermeasure may be included in an application for a signalized intersection systemic project.

5.4 BP4-Install No-pedestrian Phase Feature with Flashing Yellow Arrow

Description

The separation of the pedestrian walk phase from the flashing yellow arrow (permissive) left-turn phase. When an intersection has pedestrian pushbutton activation and the pedestrian phase is activated, the flashing yellow arrow indication is not displayed for the duration of the pedestrian walk phase. The flashing yellow arrow is either delayed or suppressed.

Figure 5-4. No-pedestrian Phase with Flashing Yellow Arrow

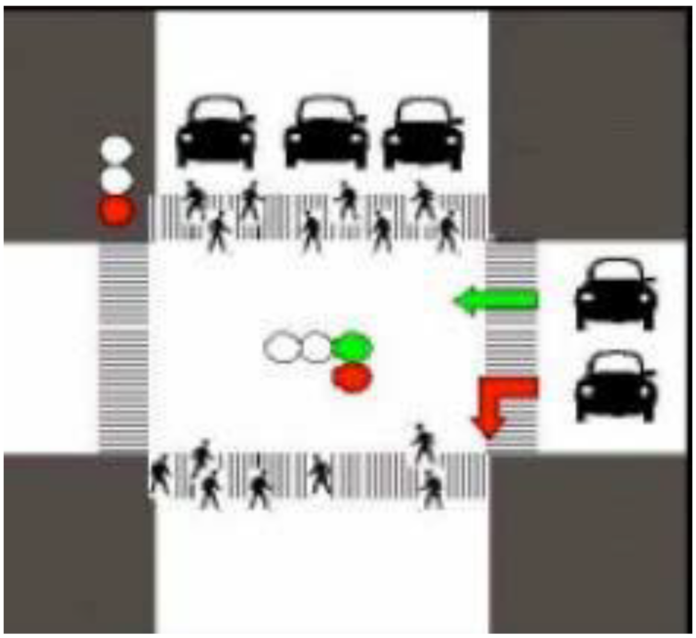


Image source: PedBikeSafe

Applications

Where the volume of pedestrians crossing the crosswalk, in conflict with the left-turning traffic, is high, or where there is a high frequency of left-turning vehicles failing to yield to pedestrians during the flashing yellow arrow indication.

Considerations

It is important to consider the potential delay to left-turning vehicles by implementing this countermeasure. In order to implement this countermeasure, verify that the existing signal software will be able to support it.

ODOT CRF Value

43%

Reduction in **pedestrian crashes** at **all severities** (including PDOs)

Range of Effectiveness

43%

Safety Effects

This separation allows the pedestrian to cross the approach entirely before the flashing yellow arrow indication is displayed, thereby reducing potential vehicle to pedestrian conflicts.

References

Safety Evaluation of Protected Left-turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety (FHWA-HRT-18-044)

Special Conditions

This countermeasure cannot be implemented without push button activation for pedestrians. If pedestrian push buttons do not already exist, installing them can be included as part of this countermeasure. Include protected left turns which, similar to a not-pedestrian right turn overlaps, completely remove the occurrence of permissive left-turn conflicts with the pedestrian phase. Only apply pedestrian crashes for turn phases in the cost benefit calculation for the permissive conflicts it is reducing.

5.5 BP5-Reduce Vehicle-pedestrian Conflicts with Permissive Right Turn

Description

A leading pedestrian interval before permissive right turn (flashing yellow arrow) to reduce Vehicle-pedestrian conflicts. Pedestrians using marked crosswalks at intersections are given an advanced walk signal, providing pedestrians with several seconds to start crossing before vehicles receive a flashing yellow arrow for permissive right-turn. The duration of the pedestrian walk phase is protected.

Figure 5-5. Signal Phase for Reducing Vehicle-pedestrian Conflicts in Permissive Right Turn

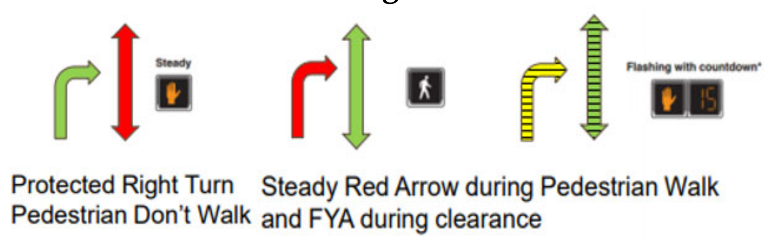


Image source:

Applications

Where there is a high frequency of right-turning vehicles failing to yield to pedestrians, or where conflicts between right-turning vehicles and pedestrians is high.

Considerations

It is important to consider the potential delay impacts by implementing this countermeasure. Verify that the existing signal software will be able to support it before implementing the countermeasure. May require additional programming and signal head additions.

ODOT CRF Value

20%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

20%

Safety Effects

Allows pedestrians to cross the approach entirely before the flashing yellow indication is displayed, thereby reducing potential conflicts between vehicles and pedestrians.

References

ODOT Engineering Judgement

Special Conditions

This countermeasure would only reduce right-turning pedestrian crashes for the movement it is being installed on and can only be implemented where right-turn lanes exist. Only apply pedestrian crashes for turn phases in the cost benefit calculation for the permissive conflicts it is reducing..

5.6 BP6-Install Green Bike Lanes at Conflict Points in Urban Area

Description

Green bike lanes are green-colored pavement placed on the roadway to enhance visibility of a bicycle lane.

Figure 5-6. Green Bike Lane

Image source: BTA Oregon

ODOT CRF Value

39%

Reduction in **bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

39%

Safety Effects

It helps bring awareness of the presence of potential bicyclists in locations where drivers may not be expecting them.

References

Crash Modification Factors Clearinghouse (CMF ID: 3258)

Applications

In locations that have a high frequency of bicycle-vehicle conflicts where enhanced awareness of the presence of a bicycle lane could decrease the potential number of conflicts.

Considerations

It is important to consider the added maintenance costs to install this kind of treatment, especially in locations where vehicles may be regularly passing over the markings.

Special Conditions

Refer to the MUTCD Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14) for additional guidance.

5.7 BP7-Install Bike Box at Conflict Points

Description
The bike box is a designated space for bicyclists at an intersection (often painted green) that allows bicyclists to position themselves ahead of vehicle traffic.

Figure 5-7. Bike Box at Intersection

Image source: Portland Mercury

Applications
Where there is a high frequency of right-turning vehicles failing to yield to through moving bicyclists at an intersection.

Considerations
It is important to consider the added maintenance costs to install this treatment, especially in locations where vehicles may be regularly passing over the markings.

Special Conditions
Refer to the MUTCD Interim Approval for Optional Use of an Intersection Bicycle Box (IA-18) for additional guidance.

ODOT CRF Value

35%

Reduction in **bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

35%

Safety Effects

Bike boxes make bicyclists more visible to motorists by placing them in their direct line of sight when stopped at an intersection. They alert vehicles to the presence of bicyclists at an intersection and can serve as a reminder to drivers to yield to bicyclists when they are turning right.

References

Signalized Intersections Informational Guide (FHWA-SA-13-027)

5.8 BP8-Install Pedestrian Refuge Island

Description
Concrete pedestrian refuge islands with crosswalk markings placed on a street at unsignalized intersections or midblock locations to separate crossing pedestrians from motor vehicles and provide pedestrians with the ability to cross one direction of traffic at a time.

Figure 5-8. Pedestrian Refuge Island

Image source: FHWA

Applications
Where there is a high frequency of pedestrian crashes or vehicles crashes caused by pedestrians that could be reduced by minimizing the crossing distance and maximizing the visibility of pedestrians.

Considerations
It is important to provide sufficient pavement width to accommodate the largest size of vehicles expected to travel on the road in question. It is also important to consider the potential impact to turning movements at any nearby accesses as a result of the median island.

ODOT CRF Value
32%
Reduction in **pedestrian crashes**
at **all Severities**
(including PDOs)

Range of Effectiveness
26%-32%

Safety Effects
Pedestrians are able to more safely make a two-stage crossing by looking for a gap in one direction of traffic at a time while being protected by a concrete curbed island.

References
Crash Modification Factors Clearinghouse (CMF ID: 8799)
Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP 841)

FHWA Proven Safety Countermeasure

Special Conditions

- Consider raised medians on sections of multilane roadways in urban and suburban areas, particularly in areas where there are mixtures of significant pedestrian and vehicle traffic (more than 12,000 AADT) and intermediate or high travel speeds (40 MPH or more);
- Place medians/refuge islands at least 4 feet wide (preferably 8 feet wide to accommodate pedestrian comfort and safety) and of adequate length to allow the anticipated number of pedestrians to stand and wait for gaps in traffic before crossing the second half of the street;
- On the state highway system, marked crosswalks at uncontrolled (unsignalized) locations require State Traffic Engineer approval;
- To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.9 BP9-Install Rectangular Rapid Flashing Beacon on 2-Lane Road

Description

Rectangular Rapid Flash Beacons (RRFB) are user-actuated amber LED that supplement warning signs at unsignalized intersections or midblock crosswalks. The signals rest in the dark phase until activated by a push button and then flash in a rapid stutter flash pattern.

Figure 5-9. Rectangular Rapid Flashing Beacon

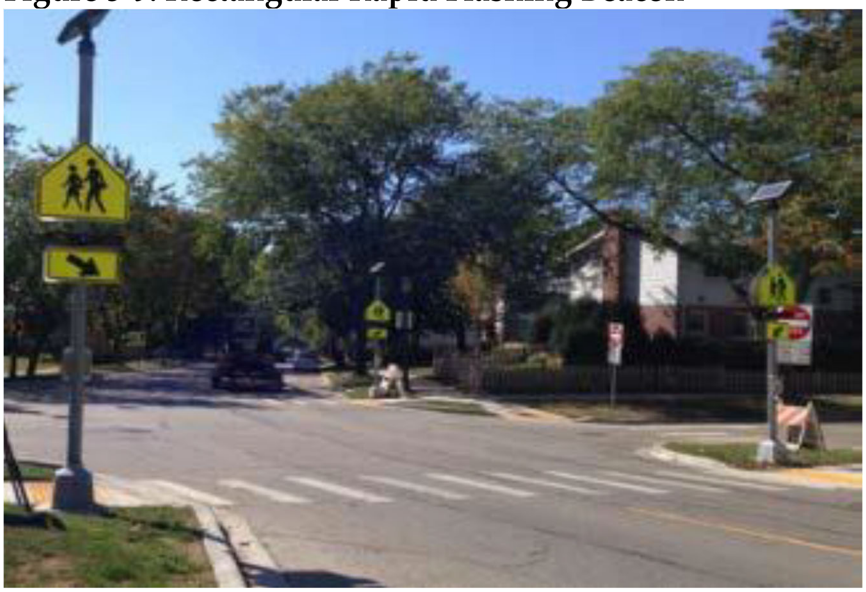


Image source: Frank Ockenfels

Applications

On 2-lane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations

It may be important to provide educational outreach to the community on safe use of RRFBs. There are instances where pedestrians have been shown to blindly trust that vehicles will immediately yield to them once they activate the RRFB. Their failure to check for oncoming traffic can result in a pedestrian crash regardless of the presence of an RRFB.

ODOT CRF Value

10%

Reduction in **pedestrian crashes** at **all severities** (including PDOs)

Range of Effectiveness

10%-56%

Safety Effects

RRFBs can enhance safety by reducing crashes between vehicles and pedestrians by increasing driver awareness of potential pedestrian conflicts.

References

Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)

ODOT Engineering Judgement

Special Conditions

- RRFBs are meant to supplement standard pedestrian crossing warning signs and crosswalk markings. Typically, pedestrian crossing warning signs are placed on the left and right sides of the road at the crossing. Placing advanced stop bars are optional;
- Refer to the MUTCD Interim Approval for Optional Use of Pedestrian-actuated Rectangular Rapid-Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21) for additional guidance;
- On the State Highway System, RRFBs and marked crosswalks at uncontrolled locations require State Traffic Engineer approval;
- To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.10 BP10-Install Rectangular Rapid Flashing Beacon on 3-lane or More Roadway without Median

Description

RRFB are user-actuated amber LED that supplement warning signs at unsignalized intersections or midblock crosswalks. The signals rest in the dark phase until activated by a push button and then flash in a rapid stutter flash pattern.

Figure 5-10. Rectangular Rapid Flashing Beacon

Image source: Google

Applications

On multilane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations

It may be important to provide educational outreach to the community on safe use of RRFB. There are instances where pedestrians have been shown to blindly trust that vehicles will immediately yield to them once they activate the RRFB. Their failure to check for oncoming traffic can result in a pedestrian crash regardless of the presence of an RRFB.

Special Conditions

- RRFBs are meant to supplement standard pedestrian crossing warning signs and crosswalk markings. Typically, pedestrian crossing warning signs are placed on the left and right sides of the road at the crossing. Placing advanced stop bars is highly recommended on multilane facilities;

ODOT CRF Value

10%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

10%

Safety Effects

RRFB's can enhance safety by reducing crashes between vehicles and pedestrians by increasing driver awareness of potential pedestrian conflicts.

References

[Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)]

ODOT Engineering Judgement

- Refer to the MUTCD Interim Approval for Optional Use of Pedestrian-actuated Rectangular Rapid-Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21) for additional guidance;
- On the state highway system, RRFBs and marked crosswalks at uncontrolled locations require State Traffic Engineer approval;
- To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.11 BP11-Install Rectangular Rapid Flashing Beacon on 3-lane or More Roadway with Median

Description

RRFB are user-actuated amber LED that supplement warning signs at unsignalized intersections or midblock crosswalks. The signals rest in the dark phase until activated by a push button and then flash in a rapid stutter flash pattern. This countermeasure includes installation of a pedestrian refuge island in addition to the RRFB.

Figure 5-11. Rectangular Rapid Flashing Beacon on Roadway with Median

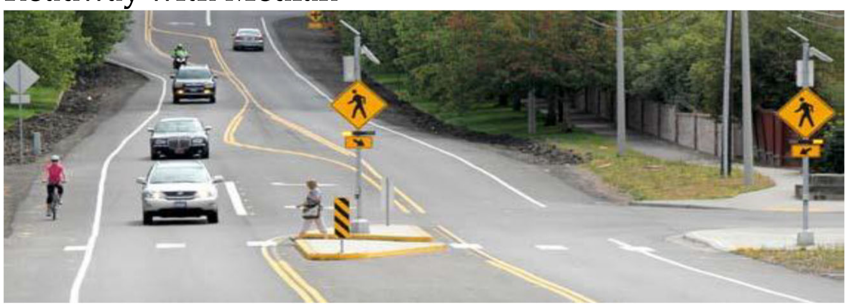


Image source: Washington County, Oregon

Applications

On multilane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations

If placed at an intersection with designated left-turn lanes, a pedestrian refuge island will impact left-turning movements. It may be important to provide educational outreach to the community on safe use of RRFBs. There are instances where pedestrians have been shown to blindly trust that vehicles will immediately yield to them once they activate the RRFB. Their failure to check for oncoming traffic can result in a pedestrian crash regardless of the presence of an RRFB. It is important to provide sufficient pavement width to accommodate the largest size of vehicles expected to travel on the road in question.

ODOT CRF Value

56%

Reduction in **pedestrian crashes** at **all severities** (including PDOs)

Range of Effectiveness

10%-56%

Safety Effects

RRFB with a pedestrian refuge island, allows pedestrians to more safely make a two-stage crossing by only looking for a gap in one direction of traffic at a time while being protected by a concrete curbed island.

References

Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)

ODOT Engineering Judgement

Special Conditions

- RRFBs are meant to supplement standard pedestrian crossing warning signs and crosswalk markings. Typically, pedestrian crossing warning signs are placed on the left and right sides of the road at the crossing. Placing an RRFB in the pedestrian refuge island and advanced stop bars are highly recommended on multilane facilities;
- Refer to the MUTCD Interim Approval for Optional Use of Pedestrian-actuated Rectangular Rapid-Flashing Beacons at Uncontrolled Marked Crosswalks (IA-21) for additional guidance;
- On the state highway system, RRFBs and marked crosswalks at uncontrolled locations require State Traffic Engineer approval;
- To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.12 BP12-Install Pedestrian Activated Beacon at Intersection

Description
A pedestrian activated warning device located at roadside pedestrian intersection crossings. Pedestrian activated beacons are similar to rectangular rapid flashing beacons.

Figure 5-12. Pedestrian Activated Beacon

Image source: NCHRP

Applications
On multilane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations
Educational outreach to the community on safe use of pedestrian activated beacons may be needed. Pedestrians' failure to check for oncoming traffic and blindly trusting that vehicles will yield to them once they activate the beacon can result in a pedestrian crash even in the presence of a pedestrian activated beacon.

ODOT CRF Value
10%
Reduction in **pedestrian crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%-56%

Safety Effects
Pedestrian activated beacons at intersections can enhance safety by reducing crashes between vehicles and pedestrians/bicyclists by increasing driver awareness of potential pedestrian conflicts.

References
Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)
ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

Special Conditions

To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.13 BP13-Install Pedestrian Activated Beacon at Midblock

Description
A pedestrian activated warning device located at roadside pedestrian crossings. A flashing beacon that is activated by a pedestrian at midblock locations.

Figure 5-13. Pedestrian Crossing at Midblock

Image source: FHWA

Applications
On multilane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations
Educational outreach to the community on safe use of pedestrian activated beacons may be needed. Pedestrians' failure to check for oncoming traffic and blindly trusting that vehicles will yield to them once they activate the beacon can result in a pedestrian crash even in the presence of a pedestrian activated beacon.

ODOT CRF Value
10%
Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
Pedestrian activated beacons at a midblock can enhance safety by reducing crashes between vehicles and pedestrians by increasing driver awareness of potential pedestrian conflicts.

References
Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)
ODOT Engineering Judgement

Special Conditions
- This type of treatment is most commonly used on unsignalized urban streets with heavy traffic, where the gaps available for pedestrians to cross the street are limited;
- To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as

mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.14 BP14-Install Pedestrian Activated Flashing Beacon in Conjunction with Median and Stop Bar

Description

A pedestrian activated warning device located at roadside pedestrian crossings. This countermeasure involves a flashing beacon that will flash when activated by the pedestrian, a median located at the crosswalk to provide a pedestrian refuge area, and stop bars provided as white lines on the pavement surface to indicate where a vehicle must stop when the pedestrian beacon is activated.

Figure 5-14. Pedestrian Activated Flashing Beacon with Median and Stop Bar

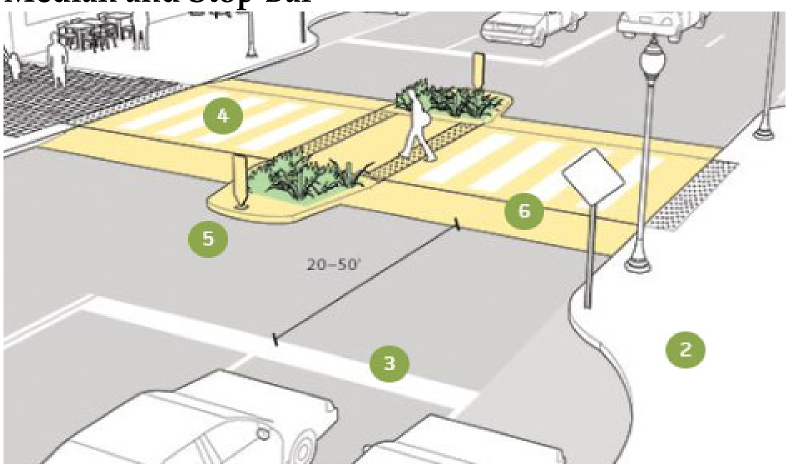


Image source: NACTO

Applications

On multilane roads where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian a crossing opportunity.

Considerations

Educational outreach to the community on safe use of pedestrian activated beacons may be needed. Pedestrians' failure to check for oncoming traffic and blindly trusting that vehicles will yield to them once they activate the beacon can result in a pedestrian crash even in the presence of a pedestrian activated beacon.

ODOT CRF Value

56%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

56%

Safety Effects

Pedestrian activated beacons in conjunction with a median and stop bar enhance safety by reducing crashes between vehicles and pedestrians by increasing driver awareness of potential pedestrian conflicts

References

Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP Report 841)

ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

Special Conditions

To accommodate large vehicles on state highways, the pedestrian median curb may need to have a mountable outside edge. When the outside edge is designed as mountable, additional delineation might be needed to make the median more visible. Refer to ODOT's Standard Drawings and Details for design guidance and the Traffic Line Manual for guidance on delineation.

5.15 BP15-Install Continental Crosswalk Markings and Advance Pedestrian Warning Signs at Uncontrolled Locations

ODOT CRF Value

15%

Reduction in **pedestrian crashes** at **all severities** (including PDOs)

Range of Effectiveness

15%

Safety Effects

Crosswalks help call attention to pedestrians crossing a road and provide a defined location in which to do so.

References

Low-cost Safety Enhancements for Stop-controlled and Signalized Intersections (FHWA-SA-09-020)

Description

A crosswalk is a location where the pedestrian leaves the sidewalk and enters the roadway and the pedestrian's path of travel crosses the motorist's path of travel. Marked crosswalks use pavement markings to indicate optimal or preferred locations for pedestrians to cross and help designate right of way for motorists to yield to pedestrians.

Figure 5-15. Crosswalk Markings and Pedestrian Warning Signs at Unsignalized Intersection

Image source: Google

Applications

Where there is a high frequency of pedestrian crashes or vehicles crashes caused by pedestrians.

Considerations

Too many and unnecessary marked crosswalks on a segment of road has a high potential to result in driver complacency and reduced yielding compliance.

Special Conditions

This countermeasure can be applied at intersections or midblock locations. It is important to remember that all intersections are legal pedestrian crossings in Oregon, regardless if they are marked or not. Advanced stop bars are REQUIRED in multi-lane sections. Consider marking a crosswalk at non-signalized locations where engineering judgment dictates that the number of motor vehicle lanes, pedestrian exposure, ADT, posted speed limit, and geometry of the location would make the use of specially designated crosswalks desirable for traffic/pedestrian safety and mobility. Do not use marked crosswalks alone (i.e., without traffic-calming treatments, traffic signals and pedestrian signals when warranted, or other substantial crossing improvement) under the following conditions:

- Where the speed limit exceeds 40 MPH;

- On a roadway with four or more lanes without a raised median or crossing island that has (or will soon have) an ADT of 12,000 or greater; or
- On a roadway with four or more lanes with a raised median or crossing island that has (or soon will have) an ADT of 15,000 or greater.

On the state highway system, marked crosswalks at uncontrolled locations require State Traffic Engineer approval. Refer to FHWA's Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations (FHWA-HRT-04-100) for additional guidance.

5.16 BP16-Install Curb Ramps and Extensions with a Marked Crosswalk and Pedestrian Warning Signs

Description
Curb extensions (also known as bulb-outs) extend the sidewalk or curb line out into the parking lane, which reduces the effective street width.

Figure 5-16. Curb Ramp and Extension

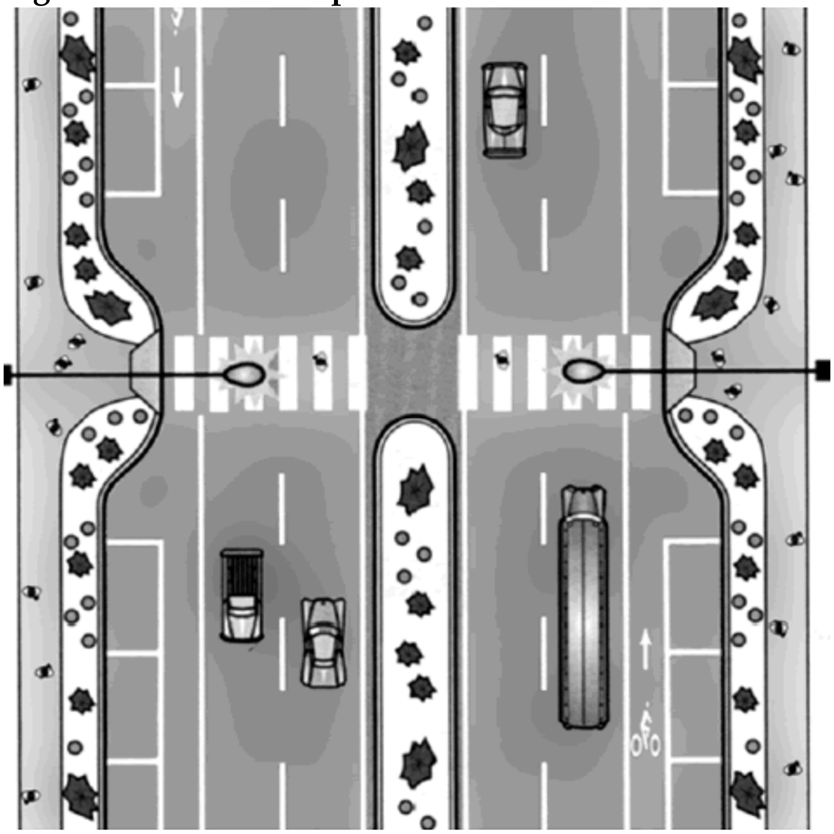


Image source: FHWA

ODOT CRF Value
37%
Reduction in **pedestrian crashes**
at **all severities**
(including PDOs)

Range of Effectiveness
37%

Safety Effects
Curb extensions significantly improve pedestrian crossings by reducing the pedestrian crossing distance, improving the ability of pedestrians and motorists to see each other, and reducing the time that pedestrians are in the street.

References
[Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)]

Applications
Where there is a high frequency of pedestrian crashes or vehicles crashes caused by pedestrians that could be reduced by minimizing the crossing distance and maximizing the visibility of pedestrians.

Considerations
It is important to provide sufficient pavement width to accommodate the largest size of vehicles expected to travel on the road in question..

Special Conditions

This countermeasure can be used at intersections or midblock locations. Use curb extensions where there is a parking lane and where transit and cyclists will be traveling outside the curb edge for the length of the street. On the state highway system, marked crosswalks at uncontrolled locations require State Traffic Engineer approval.

5.17 BP17-Install Advance Pedestrian or Bicycle Warning Signs

Description

Yellow warning symbol signs with appropriate supplemental plaques warning of pedestrian and/or bicycles (W11-1, W11-2, W11-15) potentially crossing the road.

Figure 5-17. Advance Pedestrian or Bicycle Warning Sign

Image source: Google

Applications

Where crash data indicates a need to provide additional notification to motorists of the presence of crossing pedestrians and/or bicyclists.

Considerations

Reserve this countermeasure for use in locations that have shown a need through crash data to avoid sign clutter and driver complacency.

Special Conditions

The combined Bicycle/Pedestrian (W11-15) sign may be used where both bicyclists and pedestrians might be crossing the roadway, such as at an intersection with a shared-use path. Refer to the 2009 MUTCD for additional guidance on placement of these signs and the appropriate supplemental plaques that should be included. This countermeasure cannot be used with any of the marked crosswalk countermeasures as signs are already included in those countermeasures.

ODOT CRF Value

5%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

5%-15%

Safety Effects

It warns motorists of locations where unexpected entries into the roadway by pedestrians and/or bicycles might occur.

References

[Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)]

5.18 BP18-Install Pedestrian Signal

Description

Traffic signals are a traffic control device positioned on roadways to efficiently control and manage competing flows of traffic (vehicles, pedestrians and/or bicycles). A Pedestrian signal controls the flow of traffic and provides sufficient time for safe and efficient pedestrian and/or bicycle crossings.

Figure 5-18. Pedestrian Signal

Image source: Google

ODOT CRF Value

55%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

15%-69%

Safety Effects

It warns motorists of locations where unexpected entries into the roadway by pedestrians and/or bicycles might occur.

References

Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

Applications

Where there is a high frequency of pedestrian/bicycle crashes or vehicle crashes caused by pedestrians/bicycles and other less aggressive countermeasures have been proven to be ineffective.

Considerations

Discuss which type of pedestrian activated traffic control device is the most appropriate countermeasure for a location. In some locations, placement of a pedestrian signal could result in an increase in vehicle crashes and a decrease in compliance from either vehicles or pedestrians.

Special Conditions

Pedestrian signals are appropriate where it is difficult to find a gap in traffic to make a crossing and there are a significant number of pedestrians wanting to cross at a particular location. A pedestrian signal is warranted by MUTCD Warrant #4. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

5.19 BP19-Install Pedestrian Hybrid Beacon

ODOT CRF Value
55%
Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness
55%-69%

Safety Effects
They provide positive guidance to pedestrians regarding the permitted signal interval to cross a street and prohibit pedestrian crossings when conflicting traffic may impact pedestrian safety.

References
[CMF Clearinghouse ID: 9020]
[NCHRP 926]
[Safety Effectiveness of the HAWK Pedestrian Crossing Treatment (FHWA-HRT-10-042)]

FHWA Proven Safety Countermeasure

Description

The pedestrian hybrid beacon (PHB), also known as the high intensity activated crosswalk, is a pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings. The beacon head consists of two red lenses above a single yellow lens. The beacon head is "dark" until the pedestrian desires to cross the street. When activated it displays a brief flashing and steady yellow intervals followed by a steady red indication to drivers and a "WALK" indication to pedestrians.

Figure 5-19. Pedestrian Hybrid Beacon

Image source: FHWA

Applications

Where there is a high frequency of pedestrian/bicycle crashes or vehicles crashes caused by pedestrians/bicycles and other less aggressive countermeasures have been proven to be ineffective. Can be installed to provide a controlled crossing point at a location where increased pedestrian visibility is needed.

Considerations

Discuss which type of pedestrian activated traffic control device is the most appropriate countermeasure for the location. In some locations, placement of a PHB could result in an increase in vehicle crashes and a decrease in compliance from either vehicles or pedestrians. Since the PHB is an unfamiliar traffic control device (for many people), Outreach to the public is encouraged before implementation so there is no confusion for drivers and pedestrians about how the beacon operates.

Special Conditions

In general, use PHB's if gaps in traffic are not adequate to permit pedestrians to cross, if vehicle speeds on the major street are too high to permit pedestrians to cross, or if pedestrian delay is too long. PHBs may be used at locations with lower volumes than what is required for a pedestrian signal. The MUTCD guidance for the placement of PHBs should be reviewed as installation of this treatment is considered. State Traffic Engineer approval is REQUIRED for all PHB installations on the state highway.

5.20 BP20-Convert 4-lane Roadway to 3-lane Roadway with Center Turn Lane (road diet)

Description
A road diet involves converting an undivided four-lane roadway into three lanes consisting of two through lanes and a center TWLTL. Reducing the number of through lanes and providing a TWLTL addresses crashes by:

- Separating left-turning traffic from through traffic;
- Reducing the number of oncoming lanes through which a left-turning driver must search for a gap; and
- Removing the multiple-threat situation because there is no longer an adjacent lane.

Figure 5-20. Segment before and after Road Diet

Image source: FHWA

Applications
Where there is a high frequency of the following crash types:

- Rear-end crashes from left turns or sideswipe overtaking;
- Left turning crashes; and
- Multiple-threat pedestrian crashes from a vehicle stopped for a pedestrian, blocking the view of the driver in the adjacent lane.

Typical candidate four-lane roadways have 20,000 ADT or less.

Considerations
Stakeholders represent a wide range of interests and needs within a community therefore it is important to involve them early in discussions to make sure a road diet is the right solution.

ODOT CRF Value
29%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
29%

Safety Effects
Road diets can also decrease other incidents by providing designated spaces (sidewalks and bicycle lanes) that reduce opportunities for conflicts between motor vehicles and other road users.

References
Accident Modification Factors for Traffic Engineering and ITS Improvements (NCHRP Report 617)
Highway Safety Manual

FHWA Proven Safety Countermeasure

Special Conditions

The reduction of lanes in a road diet allows for the roadway to be reallocated for other uses such as bike lanes, pedestrian crossing islands and/or parking. Road diets can be low cost if planned in conjunction with reconstruction or simple overlay projects since a road diet mostly consists of restriping.

5.21 BP21-Install Bike Signal

Description

A bicycle signal face provided at a signalized intersection exclusively for bicycle use. Steady and flashing red, yellow and green bicycle signal indications have the same meanings as described in the 2009 MUTCD for steady and flashing circular red, yellow and green signal indications for motor vehicles.

Figure 5-21. Typical Arrangements of Signal Sections in Bicycle Signal Faces

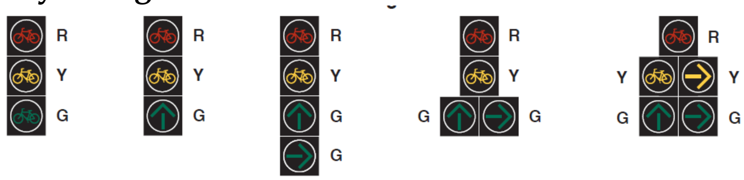


Image source: MUTCD

Applications

At a signalized intersection where there is a higher frequency of bicycle crashes that could be mitigated with an exclusive bicycle signal phase.

Considerations

Where passive detection is used, it is important to consider the type of bicycle detection that will be the most appropriate for the location in question. On older signals there may be conduit capacity issues and structural issues related to where to mount the signal head(s).

ODOT CRF Value

45%

Reduction in **bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

45%

Safety Effects

A bike signal provides a separate phase for bicycles and minimizes potential vehicle to bicycle right of way conflicts.

References

Interim Approval for Optional Use of a Bicycle Signal Face (IA-16)

Special Conditions

Bicycle signals are appropriate where conflicts between turning vehicles and bicycles occur enough to warrant exclusive bicycle phasing. Where the potential exists for a conflict between the bicycle phase and vehicles turning right on a red indication, it is required to prohibit right turn vehicle movements on red. For more guidance on installing bike signals, refer to the ODOT Traffic Signal Policy and Guidelines and the MUTCD Interim Approval for Optional Use of a Bicycle Signal Face (IA-16). The MUTCD interim approval for the placement of bicycle signals should be reviewed as installation of this treatment is considered. State Traffic Engineer approval and warrant analysis is REQUIRED for all potential signal installations on the state highway.

5.22 BP22-Install Bike Lanes

Description
Bike lanes are defined as a portion of the roadway that has been designated by signing and pavement marking for the preferential or exclusive use by bicyclists. Typically, there is one bike lane provided on each side of the roadway and travels in the same direction as the motorized vehicle lane.

Figure 5-22. Bike Lane

Image source: FHWA

Applications
Where there is a high frequency of bicycle crashes particularly where there is a high volume of bicycle traffic along a corridor, such as known or designated bicycle routes.

Considerations
This countermeasure can be costly depending on right of way needs and drainage impacts. It is important to provide adequate space between the bike lane and parked cars so that open doors do not create a potential for collision for bicyclists and to avoid termination of bike lanes where bicyclists are left in a vulnerable situation.

Special Conditions
For more guidance on bike lanes and their design standards, refer to the AASHTO Guide for the Development of Bicycle Facilities, the Oregon Bicycle and Pedestrian Design Guide and Section 9C.04 of the Oregon Supplement to the MUTCD.

ODOT CRF Value

36%

Reduction in **bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

0%-53%

Safety Effects

Bicycle lanes make the movements of both motorists and bicyclists more predictable and provide a consistent separation between bicyclists and passing motorists.

References

Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

5.23 BP23-Install Cycle Tracks

Description
A bike lane (one- or two-way) with a physical barrier between the bike and motor vehicle travel lanes, such as a curb or parking lanes.

Figure 5-23. Cycle Track on Roadway Segment

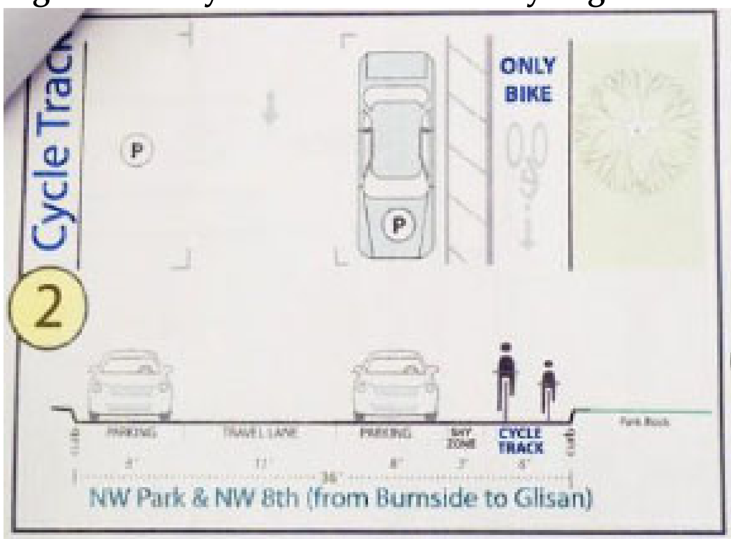


Image source: City of Portland

ODOT CRF Value
59%
Reduction in **bicycle crashes**
at **all injury severities**
(not including PDOs)

Range of Effectiveness
59%-74%

Safety Effects
Provides a dedicated and protected space for bicyclists from vehicles and reduces the probability of a parked car opening their door in the path of a bicyclist.

References
[Crash Modification Factors Clearinghouse (CMF ID: 4102)]

Applications
Where bicycle crash data indicates a need to provide additional separation between bicycles and vehicles (parked or moving).

Considerations
This countermeasure can be costly depending on right of way acquisition needs and drainage impacts. Potential for increase in crashes at intersections where turning vehicles cannot see bicyclists emerging from behind parked cars or standing pedestrians.

Special Conditions
For more guidance, refer to the Oregon Bicycle and Pedestrian Design Guide and the NACTO Urban Bikeway Design Guide.

5.24 BP24-Install Buffered Bike Lanes

Description
A conventional bike lane with an adjacent buffer space (painted median) separating the bicycle lane from the vehicle travel lane and/or adjacent parking lane.

Figure 5-24. Buffered Bike Lane

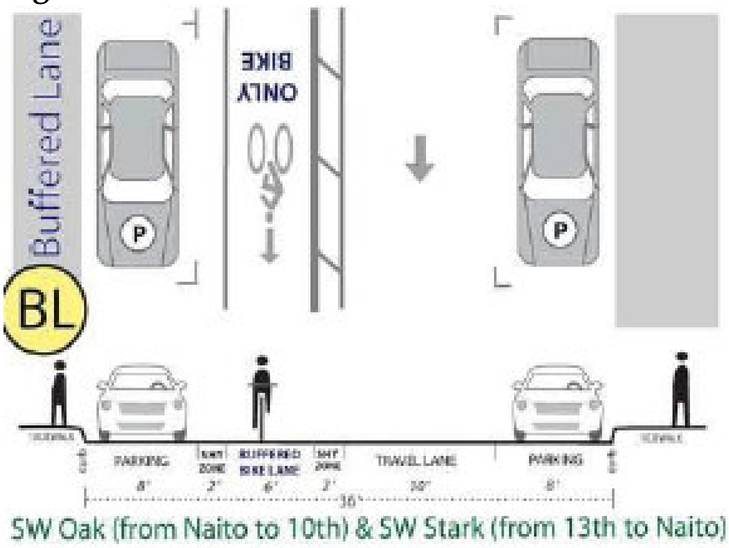


Image source: City of Portland

Applications
Where bicycle crash data indicates a need to provide additional separation between bicycles and vehicles (parked or moving).

Considerations
This countermeasure can be costly depending on right of way acquisition needs and drainage impacts.

ODOT CRF Value

47%

Reduction in **bicycle crashes**
at **all injury severities**
(not including PDOs)

Range of Effectiveness

N/A

Safety Effects

Provides a larger separation between bicyclists and motorists in the adjacent travel lane. It also provides more space for bicyclists to maneuver around a parked car with their door open.

References

ODOT Engineering Judgement

Special Conditions
For more guidance, refer to the Oregon Bicycle and Pedestrian Design Guide and the NACTO Urban Bikeway Design Guide.

5.25 BP25-Prohibit Right-turn-on-red

Description

A sign indicating that a vehicle is prohibited from making a right turn when the signal is red.

Figure 5-25. No Turn on Red Sign

Image source: Google

Applications

At signalized intersections with a high pedestrian or bicycle volumes and frequency of crashes resulting from vehicles turning right.

Considerations

Prohibiting right-turn-on-red may lead to higher right-turn-on-green conflicts when there are concurrent signals. Place signs so that they are visible to drivers. Consider structural analysis to assess wind loading created by the addition of the sign to the signal mast arm.

Special Conditions

At intersections experiencing high pedestrian volumes, prohibiting right-turn-on-red along with a leading pedestrian interval could provide additional safety benefits for pedestrians. Where a right-turn-on-red restriction is needed during certain times of the day, a part-time or variable message no-turn-on-red sign could be used.

ODOT CRF Value

41%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

26%-44%

Safety Effects

Prohibiting vehicles from turning right on red can improve safety at intersections with limited sight distances and could reduce conflicts between right turning vehicles and pedestrians.

References

Highway Safety Manual

5.26 BP26-Advanced Yield or Stop Markings and Signs

Description

Markings and signs placed in advance of marked crosswalks to indicate where vehicles should yield or stop for pedestrians.

Figure 5-26. Unsignalized Pedestrian Crosswalk Sign

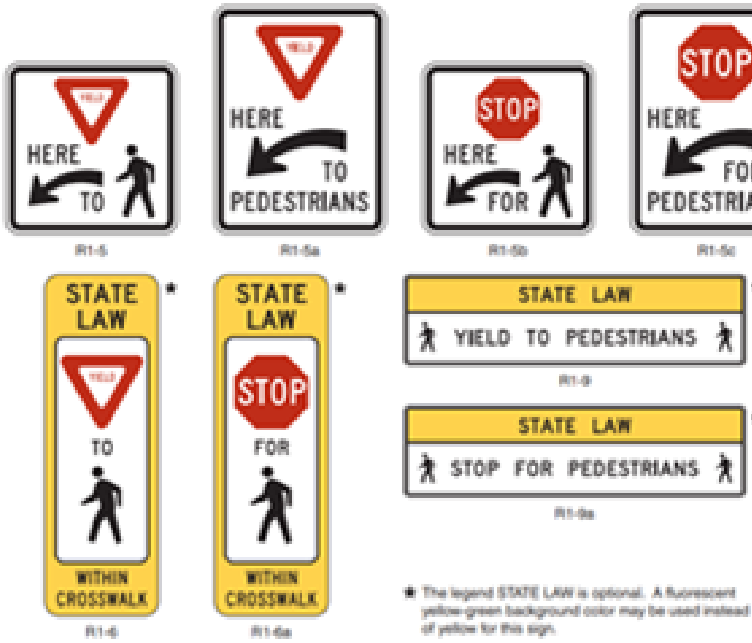


Image source: PedBikeSafe

Applications

Where there is a high frequency of vehicle-pedestrian crashes along roadways or at unsignalized intersections.

Considerations

Effectiveness of advanced yield or stop markings and signs depends on motorists' compliance with the markings and signs. Consider placement location of these marking and signs as motorists may ignore them if they are placed too far away from a pedestrian crosswalk.

Special Conditions

This countermeasure can greatly reduce crashes at unsignalized midblock crossings.

ODOT CRF Value

25%

Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

25%

Safety Effects

Advanced yield or stop markings & signs improve the visibility of pedestrians therefore reducing crashes between vehicles and pedestrians. The traffic signs and pavement markings will discourages drivers from stopping too close to crosswalks and blocking other drivers' view of pedestrians. Pedestrians can see if a vehicle is stopping or not to take appropriate action.

References

[Crash Modification Factors Clearinghouse (CMF ID: 9017)]

5.27 BP27-Install Bicycle Boulevard

Description

Bicycle boulevards are designated areas for use by bicyclists. Side streets that are signed and improved.

Figure 5-27. Bicycle Boulevard

Image source: City of Berkeley, California

Applications

Where there is a high frequency of vehicle-bicycle crashes along roadways.

Considerations

Consider additional paved surface to provide space for pedestrian sidewalks. Development of bicycle boulevards in rural areas may be difficult due to lack of alternate through roadways and amount of traffic on the roadway.

Special Conditions

Refer to the Oregon Bicycle and Pedestrian Design Guide and the NACTO Urban Bikeway Design Guide for additional guidance.

ODOT CRF Value

63%

Reduction in **bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness

63%

Safety Effects

Properly implemented bicycle boulevards provide bicyclists with a safer alternative to riding on arterial streets and reduce vehicle-bicycle collisions.

References

Cyclist Safety on Bicycle Boulevards and Parallel Arterial Routes in Berkeley, California

Crash Modification Factors Clearinghouse (CMF ID: 3092)

5.28 BP28-Install Raised Crosswalk

Description
Raised crosswalks are the same height as the sidewalk they connect with and span the width of the roadway.

Figure 5-28. Raised Crosswalk

Image source: FHWA

Applications
Where there is a high frequency of pedestrian and bicycle crashes due to vehicles traveling too fast which causes a decrease in motorists' reaction time.

Considerations
Typically installed on 2-lane or 3-lane roads with low speed limits (less than 30 MPH) and an average AADT below 9000. Not applicable on arterial streets, truck routes, or emergency routes. With larger vehicles, this countermeasure can cause noise and because of this, public buy-in may be needed. Consider drainage as this may also pose a challenge.

Special Conditions
Raised crosswalks are often placed at midblock crossing locations.

ODOT CRF Value
30%
Reduction in **pedestrian and bicycle crashes** at **all severities** (including PDOs)

Range of Effectiveness
30%

Safety Effects
Raised crosswalks provide improved visibility of pedestrians to drivers and reduces vehicle speeds therefore reducing collisions. Raised crosswalks create a safer pedestrian crossing environment.

References
Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (FHWA-SA-014)

5.29 BP29-Add Sidewalk

ODOT CRF Value
20%
Reduction in **pedestrian crash** (along roadway segment)
at **all severities** (including PDOs)

Range of Effectiveness
20%

Safety Effects
Sidewalks provide refuge for pedestrians and create a safer walking environment away from traffic. Sidewalks help improve roadway operations, safety, and mobility.

References
ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

Description
A sidewalk is a paved path, located along roadways, designated for use by pedestrians. Sidewalks are usually raised and can be separated from roads by curbs and/or planting strips or swales.

Figure 5-29. Sidewalk

Image source: Google

Applications
Where there is a high frequency of pedestrian crashes or vehicle crashes caused by pedestrians walking along a roadway.

Considerations
Consider sidewalks as a treatment for accommodating pedestrians along heavily traveled corridors where frequent pedestrian use is expected. Sidewalk furnishings can also be implemented to provide additional buffering between pedestrians and vehicles.

Special Conditions
This countermeasure is only applicable to crashes involving pedestrians walking along a roadway, not crossing. For further guidance and standards, refer to the ODOT Bicycle and Pedestrian Design Guide.

5.30 BP30-Install Speed Hump or Table for Non-state Highways

ODOT CRF Value

40%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

40%

Safety Effects

Speed humps are effective at reducing traffic speeds by forcing drivers to slow down and increase driver awareness.

References

Crash Modification Factors Clearinghouse (CMF ID: 132)

Description

A speed hump is a raised area (normally 3-4 inches in height) in the roadway pavement surface extending transversely across the roadway.

Figure 5-30. Speed Hump for Reducing Vehicle Speed

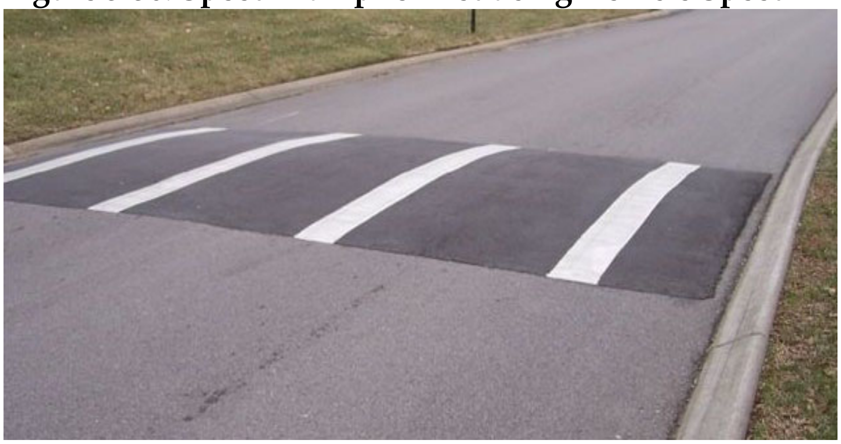


Image source: NACTO

Applications

In residential areas or on low-speed local streets where speeding increases the probability of crashes.

Considerations

Adequate signing and marking of each speed hump to warn roadway drivers that speed humps are present.

Special Conditions

This countermeasure CRF is specific to installing speed humps on low-speed urban roadways.

5.31 BP31-Add Street Trees to Support Blueprint for Urban Design

Description
The addition of street trees along a roadway commonly placed adjacent to sidewalks, curb edges, or within roadway medians. Street trees narrow a driver's visual field, providing distinct roadway edges, which help motorists guide their movements and assess their speed.

Figure 5-31. Street Trees for Safety Improvement

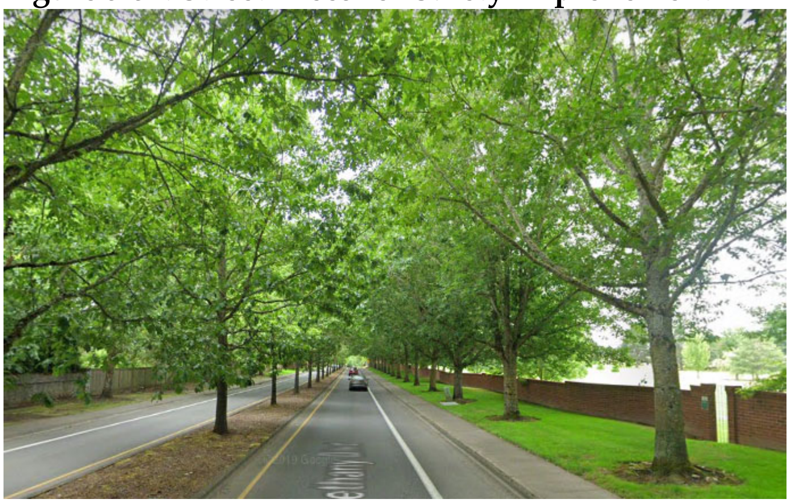


Image source: Google

Applications
Along roadways with a frequency of crashes related to vehicle speed, where speed is a contributor to pedestrian and bicycle crashes.

Considerations
Consider placement, and spacing of street trees. Pso that they provide a clear line of sight and do not block street lights or utilities. Maintain street tree's to increase driver and pedestrian visibility

ODOT CRF Value
10%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
Street trees can provide traffic calming and may have a positive influence on safety when properly placed and spaced. Placement of street trees can also provide separation between motorists and pedestrians, creating a safer walking environment.

References
ODOT Engineering Judgement

Special Conditions
This countermeasure supports ODOT's Blueprint for Urban Design. For further guidance on street tree placement and spacing, refer to the ODOT Highway Design Manual.

Chapter 6 Safety Improvement Countermeasures for Roadway Departure Crashes

Roadway departure crashes involve vehicles that leave the travel lane and encroach onto the shoulder and beyond and hit one or any number of natural or artificial objects, such as bridge walls, poles, embankments, guardrails, parked vehicles, and trees. A roadway departure crash, which typically consists of a vehicle encroaching onto the right shoulder and roadside, can also occur on the median side where the highway is separated (or on the opposite side when the vehicle crosses the opposing lanes of a non-divided highway). Roadway departure crashes usually involve only a single vehicle.

The common solution to roadway departure crashes is to keep the vehicle in the proper lane. While this may not eliminate crashes with other vehicles, pedestrians, bicyclists, or trains, it would eliminate many fatalities that result when a vehicle strays from the lane onto the roadside or into oncoming traffic. Reducing the likelihood that a vehicle will leave the roadway through roadway design prevents deaths and injuries resulting from roadway departure crashes. When an errant vehicle does encroach on the roadside, fatalities and injuries can be reduced if an agency either can minimize the likelihood of the vehicle crashing into an object, or overturning, or can reduce the severity of the crash.

A collection of countermeasures have been developed by many federal, state and local agencies to effectively reduce fatalities and serious injuries from roadway departure crashes. Practitioners now have many resources and tools available to help them identify potential safety improvements and decide which ones to implement. For example, the CMF Clearinghouse is a comprehensive and searchable database of published CMFs and offers transportation professionals a central, web-based repository of crash modification factors for various safety countermeasures on roadway departure crashes. The *NCHRP Report 500 Volume 6: A Guide for Addressing Run-off-road Collisions* listed 15 strategies for reducing roadway departure crashes. Specifically, FHWA developed the following proven safety countermeasures for reducing the roadway departure crashes:

- Wider edge lines
- Enhanced delineation for horizontal curves
- Longitudinal rumble strips and stripes
- Safety Edge
- Roadside design improvements at curves
- Median barriers

Meanwhile, ODOT has also developed its own programs for roadway departure crashes. ODOT updated the *Oregon Roadway Departure Implementation Plan* in 2017 and included both systemic and comprehensive approaches for reducing roadway departure crashes. The 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. The comprehensive approach introduces human behavior considerations into the plan. The focus areas within the comprehensive approach are alcohol and drug education and enforcement, and speed education and enforcement.

To provide technical guidance for state and local agencies on how to select safety improvement countermeasures for the ARTS program, ODOT developed the safety improvement countermeasures based on results from CMF Clearinghouse, technical reports on roadway departure crashes, and references from other sources. A total of 28 engineering countermeasures are discussed in details in this chapter, including a description of the safety countermeasure, typical scenario for applying the safety countermeasure, additional factors for consideration when using the countermeasure, and special conditions for the countermeasure. The treatments and programs selected for inclusion in this document are those that have been in place for an extended period of time and/or have proven effective. To reflect the most recent research results on roadway departure crashes, the list will be evaluated periodically to add or remove some safety improvement countermeasures. Listed below are countermeasures for roadway departure crashes:

- RD1-Increase distance to rural roadside obstacles from 3 feet to 16 feet
- RD2-Increase distance to rural roadside obstacles from 16 feet to 30 feet
- RD3-Flatten rural side slopes
- RD4-Increase pavement friction by installing high friction surface treatment – intersection or segment application
- RD5-Provide safety edge for rural pavement edge drop off
- RD6-Install recommended chevron signs on rural horizontal curves
- RD7-Install chevron signs on rural horizontal curves (ballbanking and revised speed riders included)
- RD8-Install oversized doubled up and/or fluorescent yellow sheeting for advance curve warning signs
- RD9-Provide static combination horizontal alignment/advisory curve warning signs
- RD10-Install advance curve warning flashers (curve warning signs exist)
- RD11-Install dynamic speed feedback sign for curves
- RD12-Speed feedback signs
- RD13-Install raised or recessed pavement markers
- RD14-Install post-mounted delineators (curve application)
- RD15-install rural edge line striping (tangent or curve application)
- RD16-Install centerline rumble strips
- RD17-Install centerline rumble strips
- RD18-Install shoulder rumble strips
- RD19-Install profiled line pavement markings

- RD20-Widen paved shoulder by 1 foot
- RD21-Widen paved shoulder by 2 feet
- RD22-widen paved shoulder by 3 feet
- RD23-Upgrade existing markings to wet/reflective pavement markings
- RD24-Install wider edgelines (4 inches to 6 inches)
- RD25-Install any type of median barrier
- RD26-Install new guardrail (not median barrier application)
- TD27-Install seasonal wildlife warning signs)
- RD28-Install wildlife detection system

6.1 RD1-Increase Distance to Rural Roadside Obstacle from 3 Feet to 16 Feet

Description

Increasing the clear zone of a roadway by removing fixed objects within 16 feet of the roadway. A clear zone is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway.

Figure 6-1. Roadside Obstacles on Rural Roadway

Image source: Google

Applications

Where there is a high frequency of roadway departure crashes attributed to striking fixed objects, ditches, or other roadside fixed objects.

Considerations

Removing objects can be costly and the appropriate easements may be needed to remove objects outside of the agency's right of way.

Special Conditions

This countermeasure only applies to rural areas.

ODOT CRF Value

22%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

22%-44%

Safety Effects

By increasing the clear zone area, the likelihood that a roadway departure results in a safe recovery rather than a crash will be increased.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 35)

FHWA Proven Safety Countermeasure

6.2 RD2-Increase Distance to Rural Roadside Obstacle from 16 Feet to 30 Feet

Description

Increasing the clear zone of a roadway by removing fixed objects within 30 feet of the roadway. A clear zone is an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of a vehicle that has left the roadway.

Figure 6-2. Clear Zone for Rural Highways

Image source: FHWA

Applications

Where there is a high frequency of roadway departure crashes attributed to striking fixed objects, ditches, or other fixed objects.

Considerations

Removing objects can be costly and the appropriate easements may be needed to remove objects outside of the agency's right of way.

Special Conditions

This countermeasure only applies to rural areas.

ODOT CRF Value

44%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

22%-44%

Safety Effects

By increasing the clear zone area, the likelihood that a roadway departure results in a safe recovery rather than a crash will be increased.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 36)

FHWA Proven Safety Countermeasure

6.3 RD3-Flatten Rural Side Slopes

Description
Side slopes are flat areas adjacent to the travel way that are sloped to provide drainage. They can provide a safe recovery area for vehicles departing their lane.

Figure 6-3. Side Slope on Rural Roadway

Image source: FHWA

Applications
Where there is a high frequency of overturn crashes that could be mitigated with flattening the side slope (e.g. on the outside of curves with small radii, or where the side slope has a slope of greater than 3:1).

Considerations
The provision of flattened side slopes may support erosion mitigation and may have property impacts, requiring extensive right of way acquisition.

ODOT CRF Value
See Table 6-1
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
3%-15%

Safety Effects
Improves ability for vehicles to recover after leaving the travel way. The flatter the slope, the more traversable the side slope becomes.

References
Highway Safety Manual

FHWA Proven Safety Countermeasure

Special Conditions
This countermeasure could be applied systemically and could be installed in conjunction with a paving project. This countermeasure could potentially be very costly depending on the type of roadside mitigation needed and the right of way impacts.

Table 6-1. Potential Crash Effects on Total Crashes of Flattening Sideslopes

Treatment	Road Type	Traffic Volume	Crash Type/ Severity	CMF				
Flatten sideslopes	Rural 2-lane road	Unspecified	All types /unspecified	Sideslope in Before Condition	Sideslope in After Condition			
					1V:4H	1V:5H	1V:6H	1V:7H
				1V:2H	6%	9%	12%	15%
				1V:3H	5%	8%	11%	15%
				1V:4H		3%	7%	11%
				1V:5H			3%	8%
				1V:6H				5%

Note: Base condition is existing sideslope in before condition. Standard error of the CMF is unknown.

6.4 RD4-Increase Pavement Friction by Installing High Friction Surface Treatment on Segment

Description

Pavement surfacing systems with exceptional skid-resistant properties not typically provided by conventional materials.

Figure 6-4. High Friction Surface Treatment for Roadway Segment

Images source: FHWA

Applications

In locations where you have frequent crashes where insufficient friction is a contributing factor (i.e. wet weather). These are generally locations where drivers are braking frequently; for example, when going around curves or ramps, down hills or steep grades, or when approaching an intersection. The road surface can become prematurely polished, reducing the pavement friction and allowing vehicles to skid or hydroplane.

Considerations

It is costly to install and could be costly to maintain so it's important to reserve this treatment for the most needed locations. It is important to closely follow the manufacturer's installation instructions in order to reduce any chances of product failure. For more information on High Friction Surface Treatment, please refer to the FHWA website. They have provided many informational materials on the subject.

ODOT CRF Value

52%

Reduction in **wet road crashes** at **all severities** (including PDOs)

Range of Effectiveness

20%-68%

Safety Effects

It uses aggregates that are both polish- and wear-resistant and develop channels to prevent water buildup on wet surfaces creating an exceptionally durable surface capable of withstanding extreme roadway friction demands.

References

Crash Modification Factors Clearinghouse (CMF ID: 195)

FHWA Proven Safety Countermeasure

Special Conditions

Consider the pavement quality, location, posted speed, user type and crash history when selecting locations for high friction surface treatments.

6.5 RD5-Provide Safety Edge for Rural Pavement Edge Drop-off

ODOT CRF Value

6%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

5%-15%

Safety Effects

It minimizes the edge change in pavement elevation by providing a more manageable recovery area for vehicles departing their travel lane.

References

[Crash Modification Factors Clearinghouse (CMF ID: 4312)]

FHWA Proven Safety Countermeasure

Description

Safety edge is a pavement edge sloped at an angle (30-35 degrees) to make it easier for a driver to safely reenter the roadway after inadvertently driving onto the shoulder.

Figure 6-5. Safety Edge for Rural Roadway

Image source: FHWA

Applications

Install at locations where there is a high frequency of paved edge elevation changes, particularly on rural roads with unpaved shoulders.

Considerations

Installing the safety edge during the paving process is critical to achieving a durable pavement edge. Vegetation near the roadbed will need to be cleared for the machine needed to install safety edge.

Special Conditions

This countermeasure can only be applied in combination with a paving project. Apply systemically, for example on all paving projects.

6.6 RD6-Install RECOMMENDED Chevron Signs on Rural Horizontal Curves

Description
The chevron alignment sign (W1-8) defines a change in horizontal alignment of a roadway. The signs show the shape and degree of curvature and help guide drivers through the curve or turn. This countermeasure applies to installing chevrons where the MUTCD only RECOMMENDS their installation.

Figure 6-6. W1-8 and W1-6 Signs for Curve Segment

Images source: MUTCD

Applications
Install chevrons per the MUTCD guidelines. Where chevrons are not required, t install on a curve or turn with a history of roadway departure crashes. They can be installed at locations where no chevrons currently exist, or to supplement chevrons that are already in place.

Considerations
There may not be enough spacing to place a sufficient amount of chevrons around a curve or turn. Where engineering judgment determines the need, large turn arrow(s) can be used in place of chevrons. This is consistent with MUTCD guidance.

Special Conditions
The historic standard of practice for installing a large arrow is limited to locations with sharper curves or turns. One primary benefit of installing chevrons over one large arrow is that if one chevron in a set is displaced in a crash or other event, the other chevrons would still provide guidance around a curve until the chevron could be replaced. The displacement of one large arrow does not provide this benefit.

ODOT CRF Value
16%
Reduction in **run-off-road crashes**
at **all injury severities**
(not including PDOs)

Range of Effectiveness
4%-25%

Safety Effects
Chevrons help delineate an upcoming curve, helping drivers to be aware of the presence of an approaching curve and help navigate their path.

References
[Crash Modification Factors Clearinghouse (CMF ID: 2438)]

FHWA Proven Safety Countermeasure

6.7 RD7-Install REQUIRED Chevron Signs on Rural Horizontal Curves (ballbanking and revised speed riders included)

Description
The chevron alignment sign (W1-8) defines a change in horizontal alignment of a roadway. The signs show the shape and degree of curvature and help guide drivers through the curve or turn. This countermeasure applies to install chevrons where the MUTCD REQUIRES their installation. This countermeasure includes ballbanking to the 2009 MUTCD standard and replacing speed riders where appropriate.

Figure 6-7. W1-8 and W1-6 Signs for Curve Segment

Image source: MUTCD

Applications
Install chevrons per the MUTCD guidelines. They should be installed at any curve or turn with a history of roadway departure crashes. They can be installed at locations where no chevrons currently exist, or to supplement chevrons that are already in place.

Considerations
There may not be enough spacing to place a sufficient amount of chevrons around a curve or turn. Where engineering judgment determines the need, large turn arrow(s) can be used in place of chevrons. This is consistent with MUTCD guidance.

ODOT CRF Value
16%
Reduction in **run-off-road crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness
16%

Safety Effects
Chevrons help delineate an upcoming curve, helping drivers be aware of the presence of an approaching curve and help navigate their path.

References
ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

Special Conditions
The historic standard of practice for installing a large arrow is limited to locations with sharper curves or turns. One primary benefit of installing chevrons over one large arrow is that if one chevron in a set is displaced in a crash or other event, the other chevrons would still provide guidance around a curve until the chevron could be replaced. The displacement of one large arrow does not provide this benefit.

6.8 RD8-Install Oversized, Doubled-up and/or Fluorescent Yellow Sheeting for Advance Curve Warning Signs

Description

- "Doubled-up" refers to installing a second, identical sign on the left side of the roadway;
- Installing oversized signing refers to installing a larger sign than typical;
- Fluorescent yellow sheeting is a high-intensity retroreflective sheeting that makes the sign more visible to motorists who can recognize and respond to it earlier.

Figure 6-8. Advance Curve Warning Sign

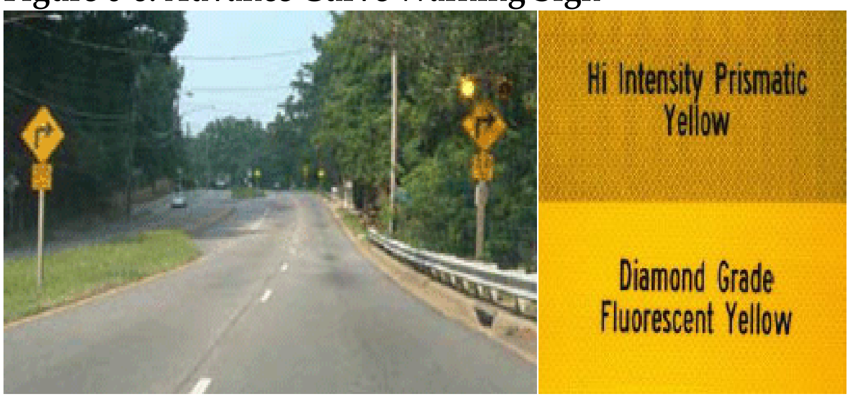


Image source: FHWA

Applications

Where there is a high number of curve crashes.

Considerations

It is encouraged that this countermeasure be used to enhance curves that have a crash history to help highlight the curves that need more driver attention.

Special Conditions

This countermeasure is encouraged to be applied systemically, on the curves with crash histories within a segment of roadway. More than one signing enhancement listed can be installed. The ODOT Roadway Departure Safety Implementation Plan can provide guidance on recommended crash thresholds for implementing these countermeasures.

ODOT CRF Value

20%

Reduction in **run-off-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

20%

Safety Effects

All of these signing enhancements can improve the effectiveness of curve warning and delineation signs by increasing the conspicuity, or prominent visibility, of the sign, especially during dark conditions.

References

ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

6.9 RD9-Provide Static Combination Horizontal Alignment and Advisory Speed Sign for Curve Segment

Description

A combined turn (W1-1) sign or the curve (W1-2) sign with the advisory speed (W13-1) plaque to form a combination warning sign that is placed at the beginning of a turn or curve.

Figure 6-9. Combination Horizontal Alignment and Advisory Speed Sign

Image source: MUTCD

Applications

Use it as a supplement to (not a replacement for) the advance horizontal alignment sign and advisory speed plaque where crash history depicts a need for enhanced curve warning.

Considerations

It is important, for curves with crash histories, to consider all curve warning enhancement options to determine which countermeasure is the most appropriate for the identified crash pattern(s).

ODOT CRF Value

13%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

13%-29%

Safety Effects

The sign is intended to remind motorists of the need to slow down as they begin to negotiate the alignment change.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 73)

FHWA Proven Safety Countermeasure

Special Conditions

This sign is often used on sequential curves that have different advisory speeds and are spaced too closely to be signed separately with advance horizontal alignment signs. The slower curve often needs additional warning. Refer to the 2009 MUTCD for additional guidance.

6.10 RD10-Install Advance Curve Warning Flashers with Existing Curve Warning Signs

Description
A flashing beacon placed on the advance horizontal alignment signs for a horizontal curve.

Figure 6-10. Advance Curve Warning Flashing Beacon and Curve Warning Sign

Image source: FHWA

ODOT CRF Value
10%
Reduction in **curve crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
Using flashing beacons with a warning sign is another way to gain motorists' attention.

References
ODOT Engineering Judgement

FHWA Proven Safety Countermeasure

Applications
Where there is a curve with a high frequency of roadway departure crashes and other more traditional, low-cost treatments have not shown an improvement in safety.

Considerations
In rural areas it may be difficult to find a power source.

Special Conditions
If there are doubled-up advance curve warning signs, flashing beacons can be placed on both signs flashing either alternately or simultaneously.

6.11 RD11-Install Dynamic Speed Feedback Sign for Curves

Description
Supplemental beacons and/or messages that activate when a motorist approaches the curve at a high speed.

Figure 6-11. Dynamic Speed Feedback Sign for Curve

Image source: FHWA

Applications
Where there is a curve with a high frequency of roadway departure or speed related crashes and other more traditional, low-cost treatments have not shown an improvement in safety.

Considerations
In rural areas it may be difficult to find a power source.

ODOT CRF Value

5%

Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness

5%

Safety Effects

It measures the speeds of approaching vehicles and provides messages to speeding drivers to slow down to an advisory speed. The advantage of this treatment is that the device has a much greater effect on high-speed vehicles than a static curve warning sign.

References

[Crash Modification Factors Clearinghouse (CMF ID: 6855)]

FHWA Proven Safety Countermeasure

Special Conditions
There are many types of dynamic curve warning signs. It is important to do more research on the type of sign that would be most appropriate for the location in question. Meanwhile, FHWA requires, for all federally funded projects, an Engineering Systems Document for ITS devices such as dynamic curve speed warning systems.

6.12 RD12-Speed Feedback Signs

Description
Speed feedback signs provide drivers with real-time information about their speed as they pass the sign.

Figure 6-12. Speed Feedback Sign

Image source: FHWA

ODOT CRF Value
10%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
10%

Safety Effects
When paired with enforcement, it helps manage driving speeds and reduces the probability of speed related crashes.

References
ODOT Engineering Judgement

Applications
In locations with a high frequency of speed-related crashes (potentially related to careless or reckless driving, or speed differential).

Considerations
Consider setting a maximum speed that's being reported back to the driver to discourage the potential "how fast can you go" driving competition. In addition, signs have been shown to be more effective where law enforcement is present.

Special Conditions
Use along with speed limit signs so that drivers know how their speed compares to the legal limit. Speed feedback signs may be either permanent installations or temporary for targeted enforcement efforts.

6.13 RD13-Install Raised or Recessed Pavement Markers

Description
Delineators placed on the roadway adjacent to the longitudinal pavement markings of a road. They are used to supplement the delineation provided by existing pavement markings.

Figure 6-13. Raised Pavement Markers

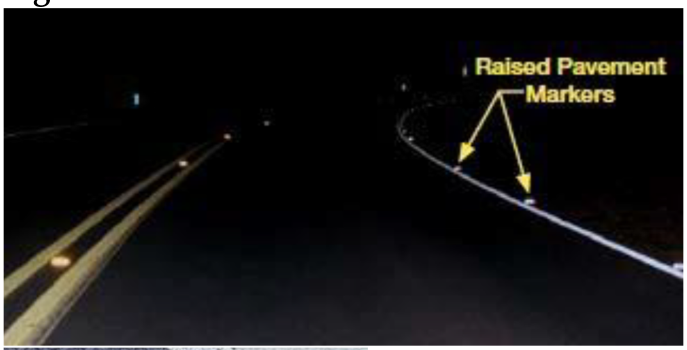


Image source: FHWA

ODOT CRF Value
15%
Reduction in **nighttime crashes**
at **all severities**
(including PDOs)

Range of Effectiveness
15%

Safety Effects
By installing raised or recessed pavement markers, the pavement markings are more prominent in adverse weather conditions, helping a driver to safely navigate the path of the roadway.

References
[Roadway Departure Implementation Plan]

Applications
Where there is a high frequency of roadway departure crashes, particularly during wet and/or nighttime conditions.

Considerations
Raised pavement markers usually don't withstand regular snow plowing.

Special Conditions
Install on roads with sufficient pavement quality to hold the devices in place. The decision to place raised or recessed pavement markers is dependent on traffic volume and weather conditions typical of the road in question. The color of the pavement markers shall match the color of the adjacent pavement markings.

6.14 RD14-Install Post-mounted Delineators on Curves

Description
A flexible fiber or aluminum post retroreflective device mounted above the roadway surface and along the side of the roadway in a series to show roadway alignment.

Figure 6-14. Post-mounted Curce Delineator

Image source: FHWA

Applications
Place delineators on curves with a history of crashes, particularly at nighttime. For best results, post-mounted delineators are to be installed on each chevron support post and coupled with edge line and center line pavement markings.

Considerations
Depending on the crash history of a curve, they may need to be replaced often.

Special Conditions
The MUTCD requires the color of the delineators to match the color of the adjacent edge line. Adjust spacing of delineators on approaches to and throughout the horizontal curves so that several delineators are always visible to the motorist.

ODOT CRF Value

30%

Reduction in **nighttime curve crashes** at **all severities** (including PDOs)

Range of Effectiveness

0%-30%

Safety Effects

Retroreflective material, such as post-mounted delineators, can be a highly effective treatment for delineating curves, especially at nighttime. They improve driver lane position both at the entry to the curve and at its midpoint.

References

Desktop Reference for Crash Reduction Factors (FHWA-SA-08-011)

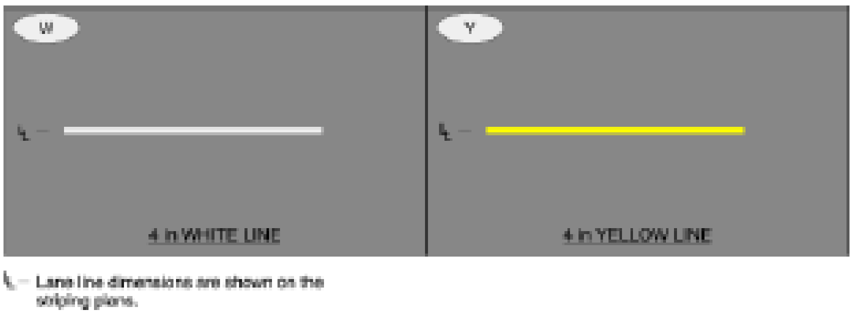
FHWA Proven Safety Countermeasure

6.15 RD15-Install Rural Edge line Striping on Tangent or Curve Segment

Description

Edge line markings separate the travel lane from the shoulder. A standard edge line marking is 4 inches wide.

Figure 6-15. Edge Line for Rural Roadways



Applications

On rural roadways with a traveled way of 20 feet or more in width where there is a high frequency of roadway departure crashes and edgeline striping is not already in place.

Considerations

Adding in edge line striping where none has previously existed will increase maintenance costs.

ODOT CRF Value

11%

Reduction in **run-off-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

11%-13%

Safety Effects

Edge lines communicate the intended roadway alignment and travel path to the driver. This can be especially beneficial during nighttime or adverse weather conditions.

References

Crash Modification Factors Clearinghouse (CMF ID: 1943)

FHWA Proven Safety Countermeasure

Special Conditions

Refer to the ODOT Traffic Line Manual for more guidance on where to place edge line striping.

6.16 RD16-Install Centerline Rumble Strips

Description

Rumble strips are ground/milled in patterns on the roadway that provide both an audible warning (rumbling sound) and a physical vibration to drivers.

Figure 6-16. Centerline Rumble Strip

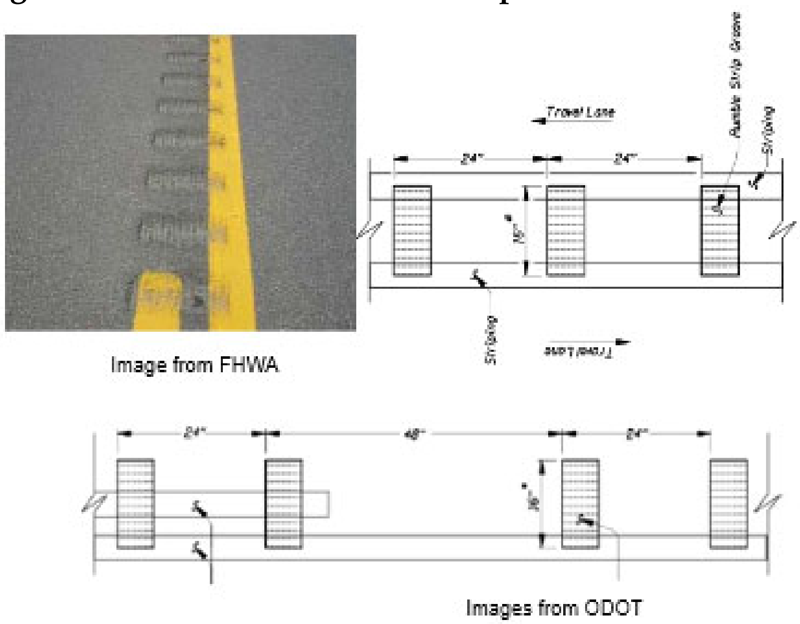


Image source: FHWA and Oregon DOT

Applications

Where there is a high frequency of roadway departure crashes, particularly head-on or sideswipe meeting crashes. This countermeasure may be applied to any roadways with rural characteristics.

Considerations

It is important to consider that there is adequate pavement or lane width to minimize the amount of external noise generated by rumble strips. It is also important to consider the potential noise impacts to nearby residential areas. Finally, pavement quality needs to be considered before placing rumble strips to avoid reducing the design life of the pavement.

Special Conditions

Apply this countermeasure systemically.

ODOT CRF Value

23%

Reduction in **run-off-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

9%-45%

Safety Effects

Rumble strip alerts drivers that they are leaving their travel lane, allowing them time to make a safe recovery back into their lane.

References

[Crash Modification Factors Clearinghouse (CMF ID: 2423)]

FHWA Proven Safety Countermeasure

6.17 RD17-Install Centerline Rumble Strips

ODOT CRF Value

45%

Reduction in **head-on** and **sideswipe crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

9%-45%

Safety Effects

Rumble strip alerts drivers that they are leaving their travel lane, allowing them time to make a safe recovery back into their lane.

References

[Crash Modification Factors Clearinghouse (CMF ID: 3360)]

FHWA Proven Safety Countermeasure

Description

Rumble strips are ground/milled in patterns on the roadway that provide both an audible warning (rumbling sound) and a physical vibration to drivers.

Figure 6-17. Centerline Rumble Strips

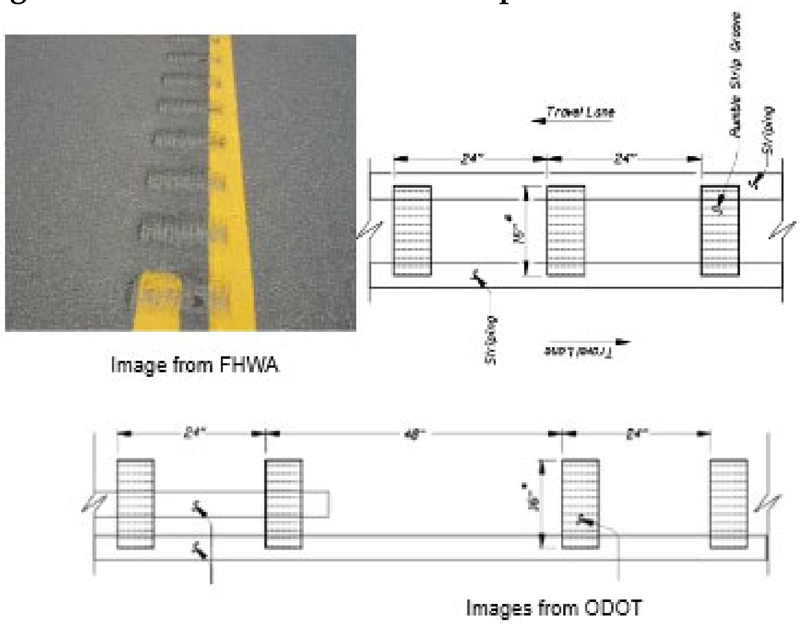


Image source: FHWA and Oregon DOT

Applications

Where there is a high frequency of roadway departure crashes, particularly head-on or sideswipe meeting crashes. This countermeasure may be applied to any roadways with rural characteristics.

Considerations

It is important to consider that there is adequate pavement or lane width to minimize the amount of external noise generated by rumble strips. It is also important to consider the potential noise impacts to nearby residential areas. Finally, pavement quality needs to be considered before placing rumble strips to avoid reducing the design life of the pavement.

Special Conditions

Apply this countermeasure systemically

6.18 RD18-Install Shoulder Rumble Strips

Description
Rumble strips are ground/milled in patterns on the roadway that provide both an audible warning (rumbling sound) and a physical vibration to drivers.

Figure 6-18. Shoulder Rumble Strip

Images source: FHWA

Applications
Where there is a high frequency of roadway departure crashes, particularly fixed object and non-collision crashes.

Considerations
It is important to consider that there is adequate pavement or lane width to minimize the amount of external noise generated by rumble strips and provide bicycles with adequate shoulder width to ride on. It is also important to consider the potential noise impacts to nearby residential areas. Finally, pavement quality needs to be considered before placing rumble strips to avoid reducing the design life of the pavement.

Special Conditions
Apply this countermeasure systemically. Shoulder rumble strips can be placed on or adjacent to the edge line pavement markings.

ODOT CRF Value

22%

Reduction in **run-off-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

16%-42%

Safety Effects

The audible warning and physical vibration inside the car alerts drivers that they are leaving their travel lane, allowing them time to make a safe recovery back into their lane.

References

Crash Modification Factors Clearinghouse (CMF ID: 2423)

FHWA Proven Safety Countermeasure

6.19 RD19-Install Profiled Line Pavement Markings

Description
A type of pavement marking consisting of a base stripe with raised shapes located at regular and predetermined intervals.

Figure 6-19. Profiled Line Pavement Marking

Image source: Contrafed Publishing Co.

Applications
Where there is a high frequency of roadway departure crashes and are unable to place ground/milled in rumble strips.

Considerations
Profiled line pavement markings do not withstand regular snow plowing. The effectiveness and design life of profiled line is considerably less than ground/milled in rumble strips as the markings are gradually worn down as vehicles travel over them.

Special Conditions
Profiled line pavement markings can be used for centerline or edge line markings.

ODOT CRF Value

9%

Reduction in **night** and **wet-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

0%-9%

Safety Effects

Profiled line pavement markings produces a rumble effect and enhances the visibility of the pavement markings. In addition, they rove visibility during wet or rainy conditions.

References

Crash Modification Factors Clearinghouse (CMF ID: 9803)

Safety Evaluation of Profiled Thermoplastic Pavement Markings (FHWA-HRT-17-075)

6.20 RD20-Widen Paved Shoulder by One Foot

Description
Increasing the width of the paved surface adjacent to or outside of the travel lanes by one (1) foot.

Figure 6-20. Paved Shoulder

Image source: FHWA

Applications
Where there is a high frequency of roadway departure crashes. The primary roadway departure safety benefit of widening the paved shoulder on a roadway is that it provides a larger stable recovery area for errant drivers leaving their travel lane. Additional benefits to shoulder widening are listed below:

- A place to maneuver to avoid crashes;
- Improves stopping sight distance at horizontal curves by providing an offset to objects such as barrier and bridge piers;
- Improves bicycle accommodations; and
- Provides space for emergency storage of disabled vehicles.

ODOT CRF Value
6%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
3%-6%

Safety Effects
Provides a larger stable recovery area for errant drivers leaving their travel lane

References
Crash Modification Factors Clearinghouse (CMF ID: 5277)

FHWA Proven Safety Countermeasure

Considerations
This countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts and environmental mitigation.

Special Conditions

Per FHWA guidance, for narrow pavement widths, it is beneficial to provide narrower lanes with wider shoulders at low AADTs (less than 1,000 vpd), while the configuration with 12-foot lanes and no shoulders appears to be most beneficial for large AADTs (greater than 1,000 vpd).

6.21 RD21-Widen Paved Shoulder by Two Feet

Description
Increasing the width of the paved surface adjacent to or outside of the travel lanes by two (2) feet.

Figure 6-21. Paved Shoulder

Image source: FHWA

ODOT CRF Value
13%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
5%-13%

Safety Effects
Provides a larger stable recovery area for errant drivers leaving their travel lane

References
Crash Modification Factors Clearinghouse (CMF ID: 5279)
Impact of Shoulder Width and Median Width on Safety (NCHRP Report 633)

FHWA Proven Safety Countermeasure

Applications
On rural undivided highways where there is a high frequency of roadway departure crashes. The primary roadway departure safety benefit of widening the paved shoulder on a roadway is that it provides a larger stable recovery area for errant drivers leaving their travel lane. Additional benefits to shoulder widening are listed below:

- A place to maneuver to avoid crashes;
- Improves stopping sight distance at horizontal curves by providing an offset to objects such as barrier and bridge piers;
- Improves bicycle accommodations; and
- Provides space for emergency storage of disabled vehicles.

Considerations
This countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts and environmental mitigation.

Special Conditions

Per FHWA guidance, for narrow pavement widths, it is beneficial to provide narrower lanes with wider shoulders at low AADTs (less than 1,000 vpd), while the configuration with 12-foot lanes and no shoulders appears to be most beneficial for large AADTs (greater than 1,000 vpd).

6.22 RD22-Widen Paved Shoulder by Three Feet

ODOT CRF Value
18%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
6%-18%

Safety Effects
Provides a larger stable recovery area for errant drivers leaving their travel lane

References
Crash Modification Factors Clearinghouse (CMF ID: 5281)
Impact of Shoulder Width and Median Width on Safety (NCHRP Report 633)

FHWA Proven Safety Countermeasure

Description

Increasing the width of the paved surface adjacent to or outside of the travel lanes by three (3) feet.

Figure 6-22. Paved Shoulder

Image source: FHWA

Applications

Where there is a high frequency of roadway departure crashes.

Considerations

This countermeasure could have significant costs associated with adding more impervious surface. Typical examples are right of way acquisition, drainage impacts and environmental mitigation. The primary roadway departure safety benefit of widening the paved shoulder on a roadway is that it provides a larger stable recovery area for errant drivers leaving their travel lane. Additional benefits to shoulder widening are listed below:

- A place to maneuver to avoid crashes;
- Improves stopping sight distance at horizontal curves by providing an offset to objects such as barrier and bridge piers;
- Improves bicycle accommodations; and
- Provides space for emergency storage of disabled vehicles.

Special Conditions

Per FHWA guidance, for narrow pavement widths, it is beneficial to provide narrower lanes with wider shoulders at low AADTs (less than 1,000 vpd), while the configuration with 12-foot lanes and no shoulders appears to be most beneficial for large AADTs (greater than 1,000 vpd).

6.23 RD23-Upgrade Existing Markings to Wet or Reflective Pavement Markings

Description

Applied on existing roadway surface edge lines as a paint, tape, or a thermoplastic material. Wet-reflective elements allow a pavement marking to retain its retroreflectivity when covered by water.

Figure 6-23. Wet Reflective Pavement Marking

Image source: FHWA and 3M

Applications

Where there is a high frequency of roadway crashes in wet weather conditions when non-wet reflective pavement markings tend to disappear, leading to reduced driver visibility.

Considerations

Costs associated with installation and maintenance of wet-reflective pavement markings.

ODOT CRF Value

28%

Reduction in **wet-road crashes** at **all severities** (including PDOs)

Range of Effectiveness

28%

Safety Effects

Wet-reflective pavement markings increase the retroreflectivity of the edge line markings on roads, which improves visibility and helps guide motorists safely along the roadway path.

References

[Crash Modification Factors Clearinghouse (CMF ID: 8137)]

Special Conditions

This countermeasure is helpful in reducing crashes in nighttime wet road conditions, and in work zones where drivers encounter unfamiliar traffic patterns.

6.24 RD24-Install Wider Edgelines (4 inches to 6 inches)

Description
Widen edgelines from 4 inches to 6 inches.

Figure 6-24. Wide Edgeline for Roadway Segment

Image source: Minnesota DOT

Applications
Where there is a high frequency of roadway departure crashes.

Considerations
Cost of widening edgelines varies depending on material used.

Special Conditions
Wider edgeline pavement markings have been shown to have a positive effect on the safety of rural two-lane roadways.

ODOT CRF Value
18%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
18%

Safety Effects
Increasing the width of roadways increases visibility for drivers. Improves safety by keeping drivers in their designated travel lane and allows more time for drivers to focus on critical driving tasks.

References
Crash Modification Factors Clearinghouse (CMF ID: 4736)

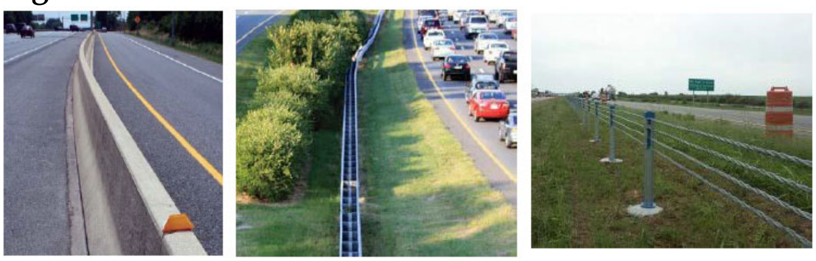
FHWA Proven Safety Countermeasure

6.25 RD25-Install Any Type of Median Barrier

Description

Median barriers are longitudinal barriers most commonly used to separate opposing directions of traffic on a divided highway.

Figure 6-25. Median Barrier



Images source: FHWA

Applications

On divided highways with high speeds and high volumes, or on divided highways with a high frequency of fatal or serious injury median crossover crashes.

Considerations

Ease and costs of maintenance and repair for these barrier systems is an important consideration.

Special Conditions

There are three basic categories of median barriers that each have their own set of pros and cons. Consideration of vehicle types, roadway geometry and potential severity of median crossover crashes must be considered when choosing a median barrier type. The three types are rigid barrier systems (i.e. concrete barrier), semi-rigid barrier systems (i.e. guardrail) and flexible barrier systems (i.e. cable barrier). Rigid barriers have a high installation cost but a low life-cycle cost. They are associated with more severe injury crashes relative to other barrier types but are proven highly effective in locations with heavy truck traffic and insufficient median widths for the other barrier types. Semi-Rigid barriers are most suitable for use in traversable medians having no or little change in grade and cross slope. Initial cost is lower than rigid barriers but it generally has a higher life cycle cost due to repair needs. Typical installation of semi-rigid median barrier is on divided roadways with

ODOT CRF Value

30%

Reduction in **all crashes** at **all injury severities** (not including PDOs)

Range of Effectiveness

30%

Safety Effects

While these systems may not reduce the frequency of crashes due to roadway departure, they do help prevent a median crash from becoming a median crossover head-on collision which has a high chance of resulting in a fatality or severe injury.

References

Highway Safety Manual

Crash Modification Factors Clearinghouse (CMF ID: 43)

FHWA Proven Safety Countermeasure

20,000 ADT or more and medians less than 50 feet wide. Flexible barriers are the most forgiving barrier systems available for reducing the severity of median crossover crashes. They generally have a lower installation cost than rigid and semi-rigid barriers but typically have a higher life cycle cost due to repair needs. Typical installations of flexible median barriers are in medians less than 50 feet wide.

6.26 RD26-Install New Guardrail (not median barrier application)

Description
A semi-rigid barrier typically consisting of connected segments of metal railing supported by posts and blocks.

Figure 6-26. Guardrail

Images source: FHWA

Applications
Install Guardrails where there is evidence (i.e. crash history) of the need to shield motorists from a roadside fixed object that has a higher probability for fatal or serious injury crashes than the guardrail itself. Potential roadside fixed objects could be point (such as a bridge pier or utility pole), medium-sized (such as roadside culverts), and long (such as steep roadside slopes).

Considerations
Guardrails themselves are a fixed objects that a motorist can potentially strike (subsequently creating a lot of potential maintenance costs as well) so it is important to minimize guardrail installation to locations where there is a need to protect a motorist from roadside fixed objects that have a higher probability for fatal or serious injury crashes.

Special Conditions
For more guidance on installation of guardrails see NCHRP Report 638.

ODOT CRF Value

47%

Reduction in r**un-off-road crashes**
at **all injury severities**
(not including PDOs)

Range of Effectiveness

47%

Safety Effects

Because guardrail systems are designed to absorb energy during a crash, and the entire assembly is designed to move or deflect during an impact, guardrail systems usually minimize potential injuries in run-off-road or roadway departure crashes.

References

Crash Modification Factors Clearinghouse (CMF ID: 38)

FHWA Proven Safety Countermeasure

6.27 RD27-Install Seasonal Wildlife Warning Signs

Description
Seasonal wildlife warning signs that are only present during certain times of the year when wildlife cross roadway systems most frequently.

Figure 6-27. Seasonal Wildlife Warning System

Image source: FHWA

Applications
Where there is a high frequency of roadway crashes related to crossing wildlife.

Considerations
It may be important to provide educational outreach to the public on the use of seasonal wildlife warning signs as well as give drivers advice on the best actions to take to avoid collisions with wildlife.

Special Conditions
Seasonal wildlife signs are used most frequently in rural areas where wildlife are attracted to roadside vegetation.

ODOT CRF Value
26%
Reduction in **all crashes** at **all severities** (including PDOs)

Range of Effectiveness
26%

Safety Effects
Seasonal wildlife warning signs improves the safety of roadways by alerting drivers to areas where wildlife could be present to help reduce crashes with vehicles.

References
[Wildlife Warning Signs and Animal Detection Systems]

6.28 RD28-Install Wildlife Detection System

Description

Wildlife detection systems that utilize sensors to detect large animals.

Figure 6-28. Wildlife Detection System

Image source: FHWA

Applications

Where there is a high frequency of roadway crashes related to crossing wildlife.

ODOT CRF Value

87%

Reduction in **wildlife only crashes** at **all severities** (including PDOs)

Range of Effectiveness

87%

Safety Effects

Wildlife detection systems, when placed in appropriate locations, can reduce collisions between wildlife and vehicles by informing drivers when wildlife is present.

References

[Advances in Wildlife Crossing Technologies (FHWA-HRT-09-006)]

Considerations

When installing detection systems, the sensors need to be set at the appropriate height for specific species. Sensors that are installed too low to the ground may detect other small species, leading to false wildlife detections. Establish a management plan that includes regular checks of the system's basic functions. Other considerations include: system readability, robustness (performance over time and maintenance), length of road the sensors will need to cover, and sign/system placement.

Special Conditions

This countermeasure is specific to wildlife only crashes in rural areas.

6.29 RD29-Install Glare Reduction

Description

Headlight glare can cause disruption to vision, debilitating a driver and making the driving task less safe, potentially leading to crashes. Glare reductions are used to alleviate glare caused by the headlights of traffic in opposing lanes and may be mounted on guardrails or concrete median barriers.

Figure 6-29. Glare Reduction installed on Concrete Median Barrier

Image source: FHWA

ODOT CRF Value

15%

Reduction in **nighttime crashes only crashes** at **all severities** (including PDOs)

Range of Effectiveness

15%

Safety Effects

Glare reductions will alleviate glare caused by the headlights of traffic in opposing lanes

References

ODOT Engineering Judgement

Application

Typical locations of glare reductions are on divided highways where headlight glare has been a contributing factor in a significant number of crashes, such as urban freeways with narrow medians and high traffic volumes, interchanges where ramps of opposing traffic flows are immediately adjacent to one another, curved highway segments in which the inside roadway is elevated slightly above the outside roadway, or locations where the public has made it known that glare issues exist.

Consideration

Glare reductions are not recommended when overhead lighting is provided on urban freeways. In segments with horizontal curvature, check if the glare reductions affect stop sight distance before installation. Paddle-style glare reductions are the best choice because of their effectiveness. Disadvantages for paddle-style glare reductions are that they have known maintenance issues. Vegetation is also allowed as a form of glare reduction in areas such as the highway medians depending on the alignment and type of vegetation used. The planting must not hinder sight distance or reduce other safety features or elements.