Contributing Factors for Focus Crash and Facility Types: Quick Reference Guide

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FOREWORD

The research documented in this guide was conducted as part of the Federal Highway Administration's (FHWA's) Evaluation of Low-Cost Safety Improvements Pooled Fund Study (ELCSI-PFS). FHWA established this PFS in 2005 to conduct research on the effectiveness of the safety improvements identified by the National Cooperative Highway Research Program Report 500 Series as part of the implementation of the American Association of State Highway and Transportation Officials' Strategic Highway Safety Plan.(1) The ELCSI-PFS studies provide a crash modification factor and benefit–cost economic analysis for each of the targeted safety strategies identified as priorities by the pooled fund member States.

The goal of this study was to identify common target crash types, their associated facility types, and contributing factors to inform applications of systemic safety improvements. This document serves as a quick reference guide for transportation professionals in State and local agencies that are interested in applying a systemic approach to road-safety management. This guide provides brief overviews based on an analysis of national and State data of the systemic approach and common focus crash types and facility types with their contributing factors. This guide supplements the technical report *Contributing Factors for Focus Crash and Facility Types* (FHWA-HRT-20-052) developed under the Focus Crash Types and Contributing Factors study.(2) This guide will benefit safety engineers and safety planners by providing greater insight into highway safety.

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16. Abstract

This document serves as a quick reference guide for transportation professionals in State and local agencies that are interested in applying a systemic approach to road-safety management. This guide provides brief overviews of the systemic approach, common target crash types and their associated facility types, and contributing factors. It also provides a six-step process to identify countermeasures as well as lists and descriptions of specific countermeasures for common target crash types and facility types. The common target crash types, facility types, and contributing factors are based on an analysis of national and State data and serve as a quick reference for agencies interested in applying systemic safety approaches to these most common crash and facility types. Agencies can reference the contributing factors in this guide to help identify countermeasures and prioritize sites for systemic safety improvements. Agencies with sufficient data and analysis capabilities can also refer to the FHWA's *Systemic Safety Project Selection Tool* for discussions on how to analyze their own data to identify crash types, facility types, and contributing factors.[3]

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF ABBREVIATIONS

B/C	benefit–cost
CMF	crash modification factor
FCFT	focus crash and facility type
FHWA	Federal Highway Administration
MUTCD	*Manual on Uniform Traffic Control Devices*
NCHRP	National Cooperative Highway Research Program
SHSP	strategic highway safety plan

CHAPTER 1. INTRODUCTION

OVERVIEW OF SYSTEMIC APPROACH

At the most fundamental level, the process of road-safety management consists of three steps: planning, implementation, and evaluation. The intent of this process is to identify and improve sites expected to benefit the most from targeted, cost-effective crash countermeasures. This intent aligns with the purpose of the Highway Safety Improvement Program, to significantly reduce fatalities and serious injuries on all public roads.[(4)] To achieve these goals, the process of road-safety management should seek to maximize opportunities to improve safety, otherwise agencies might allocate resources inefficiently to sites with less potential for cost-effective safety improvement while locations with a higher potential for improvement remain untreated.

There are two general approaches to road-safety management: (1) selecting and treating sites based on the frequency and severity of crashes observed at specific sites (sometimes called the hot-spot approach) and (2) selecting and treating sites based on site-specific geometric, operational, and other attributes known to increase crash potential (the systemic approach). These two approaches are complementary and support a comprehensive approach to road-safety management. The primary difference between the two is the way in which analysts identify issues and develop projects in the planning stage.

In the systemic approach, analysts identify potential sites for safety improvement based on site-specific geometric, operational, and other attributes (e.g., possibly including observed crash history) rather than on observed crash history alone. The first three steps that make up the planning component of the systemic approach to road-safety management are (1) identify focus crash and facility types (FCFTs) and contributing factors, (2) screen and prioritize candidate locations, and (3) select countermeasures. The following list provides an overview of these steps:

1. **Identify FCFTs and contributing factors:** The first step of the systemic approach is to select FCFTs and contributing factors. Focus crash types typically reflect prevalent severe crash types for a given jurisdiction. Focus facility types typically include the facility and site types where the focus crash types are most prevalent (e.g., rural two-lane undivided segments or urban four-leg signalized intersections). Contributing factors are site-specific attributes associated with an increased potential of focus crash types occurring. Contributing factors may include site-specific crash history (if available), geometric and operational characteristics, and surrounding sociodemographic and environmental attributes. Refer to the Federal Highway Administration's (FHWA's) *Systemic Safety Project Selection Tool* for further information on identifying FCFTs and contributing factors.[(3)]

2. **Screen and prioritize candidate locations:** The second step of the systemic approach is to develop a prioritized list of potential locations at which to install systemic improvements that will address a focus crash type. Using contributing factors for that crash type as a guide, analysts identify sites of the focus facility types as candidate locations. To prioritize candidate locations, analysts assign a level of crash potential to each site based on the site-specific geometric and operational characteristics, crash

history, and other attributes that indicate higher chances of crashes occurring. Analysts also apply thresholds or weights to each contributing factor to further prioritize the list of sites based on available resources and program objectives. Refer to FHWA's *Systemic Safety Project Selection Tool* for further information related to screening and prioritizing candidate locations.(3)

3. **Select countermeasures:** The third step of the systemic approach is to select countermeasures. Given the list of contributing factors for the FCFTs, agencies select targeted countermeasures to address or mitigate the influence of the contributing factors at the prioritized locations across the network. Refer to the *Systemic Safety Project Selection Tool* for further information related to selecting countermeasures.(3)

Consider a scenario where an agency identified head-on crashes as a focus crash type based on the number of fatal and severe injury crashes of that type. The agency noted these crashes are most prevalent on rural four-lane road segments, so it selected them as the focus facility type for head-on crashes. The agency reviewed data for all head-on crashes that occurred on rural four-lane road segments and determined that potential contributing factors include narrow roadway cross sections (i.e., lanes and shoulders), narrow or no medians, and no median barriers (for segments with medians). The agency noted that alternative countermeasures to address these underlying contributing factors include installing centerline or median shoulder/edgeline rumble strips, widening roadway cross sections, widening medians, or installing median barriers (for segments with medians). The agency deemed the latter three options cost-prohibitive for the wide-scale deployment that is part of the systemic approach to road-safety management. As such, the agency selected rumble strips as an appropriate countermeasure to address the contributing factors (i.e., centerline rumble strips on undivided facilities, median shoulder, or edgeline rumble strips on divided facilities). At this point, the agency considered installing rumble strips on all rural four-lane roads. Considering budgetary constraints, the agency realized it did not have available funds to install rumble strips on all rural four-lane, roads. Instead, the agency began to prioritize candidate locations and established thresholds for countermeasure implementation (e.g., rural four-lane roads that have lane widths less than 11 ft).

The following list includes potential uses for the systemic approach to road-safety management:

- Agencies can use the systemic approach to target emphasis areas from their strategic highway safety plans (SHSPs). By targeting issues that are common among sites, agencies can implement similar countermeasures that address priority crash types and contributing factors across the sites.

- Agencies typically aim to make modest site-specific safety improvements with proven countermeasures at sites with relatively high crash potential identified by the presence of contributing factors rather than by site-specific crash history alone.

- Agencies can apply the systemic approach without site-level crash and exposure data or when the observed crash frequency at individual sites is relatively low (i.e., highly dispersed crashes scattered across the road system at low densities).

- When agencies implement similar improvements (e.g., enhancing signing or striping, installing rumble strips, or upgrading signal heads) across many sites (i.e., the systemic approach), the improvements are generally low cost. Nevertheless, agencies should still consider high-cost improvements, but the improvements should be highly effective to justify the increased costs.

- While agencies should begin their systemic approach to road-safety management by identifying FCFTs, they can also begin with the intent to implement a proven, low-cost countermeasure and identify appropriate locations for implementation based on contributing factors. In general, the use of proven, low-cost countermeasures will result in a positive return on investment; however, a benefit–cost (B/C) analysis is useful to determine the most effective (i.e., greatest reduction in crashes and resulting injuries) and most efficient (i.e., greatest return on investment) alternatives.

The systemic approach is an opportunity to achieve safety benefits across a large portion of the system. This opportunity arises from the focus on priority crash types that may be highly dispersed across the road system and their contributing factors rather than focusing on site-specific crash history alone. For example, consider a $3 million safety program and the opportunity to implement one of two options. The first option is to install roundabouts at three sites at an average cost of $1 million per site. The sites identified have an average crash history of 20 crashes per year, and it is assumed that the treatment will result, on average, in a 40-percent reduction in crashes. The system benefit for the first option is an expected reduction of 24 crashes per year. The second option is to install intersection-improvement packages at 500 sites at an average cost of $6,000 per site. The sites identified have an average crash history of three crashes per year, and it is assumed that the treatment will result, on average, in a 5-percent reduction in crashes. The system benefit for the second option is an expected reduction of 75 crashes per year. Even with a modest crash reduction per site, targeted systemic improvements can have a large impact on the system as a whole.

The systemic approach addresses contributing factors rather than crash history. Specifically, it applies countermeasures to locations with features that increase crash potential, but the sites are not required to have a history of crashes to receive countermeasure treatments. This distinction is important because the types of crashes occurring on a system remain relatively consistent from year to year, while the locations of crashes tend to fluctuate, particularly on low-volume and rural roads. In many States, these roads exhibit a high proportion of severe crashes sparsely distributed across many segments and intersections. It is difficult to address these sites with the hot-spot approach due to the low density of crashes. The systemic approach helps to overcome these limitations by focusing on the underlying contributing factors across the network as opposed to only considering the crash history at individual locations.

A primary challenge related to the systemic approach is justifying the cost of improving sites, specifically those with no recent crash history. In some cases, there is also limited information on the safety effectiveness of countermeasures well suited to systemic implementation. While there are more than 5,000 crash modification factors (CMFs) available in the CMF Clearinghouse, many of these CMFs reflect the average safety effect of projects implemented based on the hot-spot approach or countermeasures that require substantial engineering work prior to implementation at each site.[(5)] It is generally unknown if systemic applications will result in the same average level of benefit as the crash-based application for the same countermeasure. As such, it can be difficult to analyze the expected benefit and cost-effectiveness of some systemic implementations. Project and maintenance costs can also range from negligible to relatively high depending on the type of countermeasure and level of implementation. Although the unit cost per site is often relatively low, the service life for low-cost countermeasures is typically less than the service life for high-cost countermeasures. As such, it is important to consider the lifecycle costs prior to implementation.

OVERVIEW OF QUICK REFERENCE GUIDE

This quick reference guide (herein referred to as "the guide") serves as a concise reference on focus crash types, focus facility types, contributing factors, and countermeasures for applying the systemic approach to road safety management.

The guide is organized into five chapters. Chapter 1 provides an overview of the systemic approach, the guide, the target audience, and additional resources. Chapter 2 discusses identifying FCFTs, including common FCFTs based on an analysis of national and State data documented in the technical report *Contributing Factors for Focus Crash and Facility Types* for the Development of Crash Modification Factors program.[2] Chapter 3 discusses identifying contributing factors, including common contributing factors for FCFTs, based on the same analysis of national and State data. Chapter 4 describes the process of matching appropriate countermeasures to contributing factors. It also provides a list of potential countermeasures to consider for systemic implementation, including a description of the countermeasure, typical reasons for implementation, target facility types, considerations, and related resources. Chapter 5 provides a summary of the guide and conclusions.

TARGET AUDIENCE

The guide's target audience includes transportation professionals in State and local agencies, such as traffic and safety engineers and planners, who are interested in the systemic approach to road-safety management.

Resources

The following are key resources relevant to the systemic approach to road-safety management:

- ***Systemic Safety Project Selection Tool***—presents a step-by-step process for incorporating systemic safety planning into road-safety management.[3]
- **National Cooperative Highway Research Program (NCHRP) Report 500 Series**—presents 22 emphasis areas that affect overall highway safety, strategies for reducing crashes that correspond to these emphasis areas, and an outline of what is needed to implement each strategy.[1]
- ***Reliability of Safety Management Methods: Systemic Safety Program***—describes the state of the practice and latest tools that support systemic safety analyses.[6]

CHAPTER 2. IDENTIFYING FCFTS

Readers with sufficient data and analysis capabilities may refer to FHWA's *Systemic Safety Project Selection Tool* for discussion on how to analyze jurisdiction-specific data to identify FCFTs.(3) Those with limited data and analysis capabilities may refer to State, regional, or local SHSPs to identify focus crash types based on emphasis areas. Further analysis of the emphasis areas can help identify focus facility types (i.e., in which facility types are the focus crash types more prevalent). Readers with limited data and analysis capabilities may also refer to the following lists of intersection and nonintersection FCFTs, which represent common priorities based on an analysis of national and State data documented in *Contributing Factors for Focus Crash and Facility Types*.(2)

Potential intersection FCFTs include the following:

- Angle crashes on rural two-lane roads at four-leg minor-road stop-controlled intersections (daytime and nighttime).
- Angle crashes on urban two-lane roads at four-leg minor-road stop-controlled intersections (daytime).
- Angle crashes on rural two-lane roads at three-leg minor-road stop-controlled intersections (daytime).
- Angle crashes on urban multilane divided roads at four-leg signalized intersections (daytime).
- Angle crashes on urban multilane undivided roads at four-leg signalized intersections (daytime).
- Angle crashes on rural multilane divided roads at four-leg minor-road stop-controlled intersections (daytime).

Potential nonintersection FCFTs include the following:

- Run-off-road crashes on rural two-lane roads on horizontal curves (daytime and nighttime).
- Run-off-road crashes on rural two-lane roads on tangent segments (daytime and nighttime).
- Lane-departure crashes on rural two-lane roads on horizontal curves (daytime and nighttime).
- Lane-departure crashes on rural two-lane roads on tangent segments (daytime and nighttime).
- Head-on crashes on rural two-lane roads on horizontal curves (daytime and nighttime).
- Head-on crashes on rural two-lane roads on tangent segments (daytime and nighttime).
- Angle crashes on rural two-lane roads on tangent segments (daytime).
- Rollover/overturn crashes on rural two-lane roads on horizontal curves (daytime and nighttime).
- Rollover/overturn crashes on rural two-lane roads on tangent segments (daytime and nighttime).

CHAPTER 3. IDENTIFYING CONTRIBUTING FACTORS

Analysts can identify contributing factors for FCFTs and relative crash potential by analyzing crash data from their jurisdictions or reviewing previous research studies. It is important to use reliable, data-driven methods to identify contributing factors and inform decisions. The *Highway Safety Manual* presents predictive methods to relate crash frequency to roadway design and operational characteristics using safety performance functions and CMFs.[7] A predictive approach based on a combination of historical crash, exposure, and roadway data is more reliable than an approach based only on cross-tabulations or ad hoc analyses to identify geometric and operational attributes that may increase crash potential.

Agencies can use the systemic approach in the absence of high-quality, historical, site-level crash data. Rather than analyzing observed crash frequencies at specific locations, analysts investigate prevalent severe crash types across identified focus facility types to correlate the presence of potential contributing factors (e.g., selected geometric and operational roadway characteristics) with the crash types of interest. Agencies then use those roadway characteristics with higher crash potential as a basis for implementing countermeasures to address the focus crash types. Beyond the presence of contributing factors, analysts may identify thresholds at which a characteristic increases crash potential. For example, rather than simply identifying sites with horizontal curves, an analyst may specify the degree of curve over or radius under which crash potential increases. An analyst may also apply weights to these contributing factors to prioritize sites for countermeasure implementation. For example, contributing factors for roadway-departure crashes may include lane width, shoulder width, and horizontal curvature; however, sharper horizontal curves may increase crash potential more than narrower lanes. If this is the case, an analyst may place more weight on the curve-related contributing factor and less weight on the lane width–related contributing factor.

Readers with sufficient data and analysis capabilities may refer to the *Systemic Safety Project Selection Tool* for discussion on how to analyze data to identify contributing factors given a specific FCFT.[3] However, readers with limited data and analysis capabilities may refer to *Contributing Factors for Focus Crash and Facility Types*, which identifies contributing factors based on an analysis of crash, traffic, roadway, weather, and sociodemographic data from multiple States using a random-forest approach.[2] Table 1 and table 2 present the common contributing factors from this analysis for intersection and nonintersection FCFTs.[1] The conclusions and recommendations in this report touch on several limitations in the data and analysis, such as a lack of information on the presence and type of safety countermeasures at the analyzed sites and a lack of detail on some roadway features. The researchers' work in this report is the first-known application of random forests in this context, and they offered recommendations for future refinements when using the approach. However, the roadway factors uncovered by the analysis as influencing the frequencies of the different crash types were generally consistent with expectations based on previous research and existing practice.

Table 1. Contributing factors for intersection FCFTs.

Contributing Factor	Angle R2L 4ST	Angle U2L 4ST	Angle R2L 3ST	Angle UML Div. 4SIG	Angle UML Undiv. 4SIG	Angle RML Div. 4ST
Larger mainline AADT	●	○	●	●	○	○
Larger cross street AADT	●	○	○	○	○	●
Smaller curve radius	—	—	○	—	—	—
Wider lane width	●	—	○	○	—	—
Wider median width	—	—	—	○	—	○
Absence of mainline left-turn channelization	○	—	—	—	—	—
Absence of cross-street right-turn channelization	—	—	—	—	○	—
Design speed/higher speed limit	●	●	○	●	○	—

●Contributing factor in multiple States.
○Contributing factor in select States.
—Not a contributing factor in any State.
AADT = average annual daily traffic; N/A = not applicable; Angle R2L 4ST = angle crashes on rural two-lane roads at four-leg minor-road stop-controlled intersections; Angle U2L 4ST = angle crashes on urban two-lane roads at four-leg minor-road stop-controlled intersections; Angle R2L 3ST = angle crashes on rural two-lane roads at three-leg minor-road stop-controlled intersections; Angle UML Div. 4SIG = angle crashes on urban multilane divided roads at four-leg signalized intersections; Angle UML Undiv. 4SIG = angle crashes on urban multilane undivided roads at four-leg signalized intersections; Angle RML Div. 4ST = angle crashes on rural multilane divided roads at four-leg minor-road stop-controlled intersections.

Table 2. Contributing factors for nonintersection FCFTs.

Contributing Factor	ROR R2L Curve	ROR R2L Tangent	LD R2L Curve	LD R2L Tangent	HO R2L Curve	HO R2L Tangent	Angle R2L Tangent	RO/OT R2L Curve	RO/OT R2L Tangent
Larger AADT	●	●	●	●	●	●	●	●	●
Smaller percentage of trucks on the roadway	○	○	○	○	○	○	—	○	○
Larger percent grade	○	○	●	●	○	○	—	●	●
Smaller curve radius	●	N/A	●	N/A	●	N/A	N/A	●	N/A
Narrower surface width	○	○	○	○	○	○	—	○	○
Narrower shoulder width	●	●	○	○	○	—	○	○	○
Unpaved shoulder	—	○	—	○	—	○	—	—	—
Higher speed limit	○	○	○	○	○	○	—	○	○
Narrower lane width	—	—	—	○	—	—	—	—	—
Mountainous terrain	—	—	—	—	—	—	—	—	○

●Contributing factor in multiple States.
○Contributing factor in one State.
—Not a contributing factor in any State.
AADT = average annual daily traffic; N/A = not applicable; ROR R2L Curve = run-off-road crashes on rural two-lane roads on horizontal curves; ROR R2L Tangent = run-off-road crashes on rural two-lane roads on tangent segments; LD, R2L, Curve = lane-departure crashes on rural two-lane roads on horizontal curves; LD R2L Tangent = lane-departure crashes on rural two-lane roads on tangent segments; HO R2L Curve = head-on crashes on rural two-lane roads on horizontal curves; HO R2L Tangent = head-on crashes on rural two-lane roads on tangent segments; Angle R2L Tangent = angle crashes on rural two-lane roads on tangent segments; RO/OT R2L Curve = rollover/overturn crashes on rural two-lane roads on horizontal curves; RO/OT R2L Tangent = rollover/overturn crashes on rural two-lane roads on tangent segments.

CHAPTER 4. IDENTIFYING TARGETED COUNTERMEASURES

This chapter provides an overview of countermeasures and describes the process of identifying potential countermeasures that address the FCFTs and contributing factors in the previous two chapters. This chapter includes several potential countermeasures for intersection and nonintersection FCFTs, respectively, that State and local transportation agencies can consider as part of a systemic approach to road-safety management.

COUNTERMEASURE SELECTION

The countermeasure selection process provided in this guide consists of six steps, which are described in the following subsections.

Step 1. Identify a Focus Crash Type

The first step is to identify a focus crash type, which should be based on an analysis of available data and the priorities of the transportation agency as outlined in the State or regional SHSP. A focus crash type will be defined by the type of maneuver (e.g., run off road), time of day (i.e., daytime or nighttime), and type of segment (i.e., curve versus tangent) or type of intersection (e.g., four-leg signalized). Readers should refer to chapter 2 of this guide for lists of common focus crash types.

Step 2. Identify Contributing Factors for the Focus Crash Type

The second step is to identify the contributing factors for the focus crash type. Some factors may be expected to contribute to the increase of the crash type, such as the presence of an unpaved shoulder, whereas others may decrease certain crash types, such as increasing (i.e., flattening) the radius of a horizontal curve. Readers should refer to chapter 3 of this guide for more discussion on identifying contributing factors.

Step 3. Assemble a List of Potential Countermeasures That Address the Focus Crash Type

The third step is to assemble a list of potential countermeasures that address the contributing factors of the focus crash type. A wide range of resources, including the following, could be used to assemble a list of potential countermeasures:

- NCHRP Report 500 Series.[1]
- *Highway Safety Manual*.[7]
- CMF Clearinghouse.[5]
- FHWA Proven Safety Countermeasures.[8]
- *Countermeasures that Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*.[9]
- PEDSAFE.[10]
- BIKESAFE.[11]
- State-generated list of common countermeasures within a State (i.e., a toolbox).

This list should contain a wide pool of potential countermeasures, including those that address any part of the focus crash type. Readers should refer to the sections Systemic Countermeasures for Intersection FCFTs and Systemic Countermeasures for Nonintersection FCFTs in this chapter for potential countermeasures.

Step 4. Identify Countermeasures That Explicitly Address Contributing Factors Associated with the Focus Crash Type

The fourth step is to identify countermeasures that explicitly address the contributing factors associated with the focus crash type. Compare the information known about each countermeasure on the list from step 3 to the contributing factors identified in step 2 to identify countermeasures that specifically address one or more of the contributing factors. During this process, logical links can be drawn between many countermeasures and contributing factors. For the purpose of this process, only a clear, explicit relation to contributing factors should be indicated.

Step 5. Identify Countermeasures with CMFs

The fifth step is to use CMF resources to identify which countermeasures on the list from step 3 have CMFs that quantify the safety effect. A countermeasure with a known effect can be compared to other countermeasures in a prioritized selection and can be used to generate a B/C analysis of proposed alternatives. Countermeasures for which a robust set of CMFs are available may have CMFs that address the focus crash type specifically. If this is the case, extra consideration should be given to these countermeasures during the final selection.

The most comprehensive and accessible resource of CMF information is the CMF Clearinghouse.(5) Other sources for CMF information may include State-specific CMF lists.(12)

Step 6. Select a Countermeasure

The sixth and final step is to select a countermeasure from the pool of eligible countermeasures generated in step 3. The selection should consider how well each countermeasure addresses the specific contributing factors for the focus crash type as determined in step 4 and the extent to which CMFs are available for each countermeasure as determined in step 5.

SYSTEMIC COUNTERMEASURES FOR INTERSECTION FCFTS

Table 1 summarizes contributing factors associated with intersection FCFTs based on an analysis of data from multiple States described in *Contributing Factors for Focus Crash and Facility Types*.(2) The roadway-related contributing factors include the intersection being located on a horizontal curve with a smaller curve radius, wider lane widths, wider median widths, absence of mainline left-turn channelization, absence of cross-street right-turn channelization, and higher speed limit or design speed.

Table 3 summarizes countermeasures related to the contributing factors for the intersection FCFTs. These countermeasures include left- and right-turn lanes, yellow change intervals, backplates with retroreflective borders, application of multiple low-cost countermeasures, and advance signs. More detailed information on what each countermeasure is and why and where they are used as well as other considerations and related resources are provided in the following sections. The first four countermeasures in table 3 and most of the detail provided for each are from FHWA's Office of Safety Proven Safety Countermeasures initiative.(8) The last two countermeasures and supplemental information for the other four proven countermeasures are from the Institute of Transportation Engineers' Unsignalized Intersection Improvement Guide website, FHWA's Intersection Safety website, and a FHWA brochure, *Intersection Safety Strategies*.(25–27)

Table 3. Systemic countermeasures for intersection contributing factors.

Countermeasure	Smaller Curve Radius (Intersection on Curve)	Wider Mainline Lane Width	Wider Mainline Median Width	Absence of Mainline Left-Turn Channelization	Absence of Minor Street Right-Turn Channelization (Signalized Intersections)	Design Speed/Higher Speed Limit
Left- and right-turn lanes	—	—	—	●	●	●
Yellow change intervals	—	—	—	—	—	●
Backplates with retroreflective borders	—	●	●	—	—	●
Application of multiple low-cost countermeasures	●	●	●	●	●	●
Advance signs	●	●	●	—	—	●

●Contributing factor in multiple States.
—Not a contributing factor in any State.

Left- and Right-Turn Lanes

What: Auxiliary lanes for left- or right-turning vehicles provide physical separation between slowing or stopped turning traffic and adjacent through traffic at intersection approaches. These lanes are also for deceleration prior to a turn and storage of waiting vehicles.

Why: Crashes occurring at intersections are often related to turning maneuvers. The focus crash types include collisions of vehicles turning left across opposing through traffic and rear-end collisions of vehicles turning left or right with other vehicles following closely behind. Turn lanes help reduce the potential for these types of crashes.

Where: Turn lanes should be considered for major road approaches at both three- and four-leg intersections with two-way stop control on the minor road where significant turning volumes exist and there is a history of turn-related crashes.

Considerations: Pedestrian and bicyclist safety and convenience should also be considered when adding turn lanes at an intersection.

Resources: The following resources provide further information about left- and right-turn lanes:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website for additional information on the implementation of this countermeasure.(8)
- Refer to the report *Safety Effectiveness of Intersection Left- and Right-Turn Lanes* for more information on the implementation of this countermeasure.(28)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure.(5)

Yellow Change Intervals

What: The yellow change interval is the length of time that a yellow signal indication is displayed following a green signal indication. The yellow signal provides a warning to drivers of impending change in right-of-way. Well-timed yellow change intervals can help improve signalized intersection safety and reduce red-light running.

Why: Red-light running is a leading cause of severe crashes at signalized intersections. If the yellow change interval is too short, drivers may be unable to stop safely, causing rear-end crashes or leading to unintentional red-light running. If the yellow change interval is too long, drivers may treat the yellow as an extension of the green phase, inviting intentional red-light running.

Where: Yellow change intervals should be considered at all signalized intersections.

Considerations: Agencies should consider instituting regular evaluation and adjustment protocols for existing traffic signal timing.

Resources: The following resources provide further information about yellow change intervals:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website for additional information on the implementation of this countermeasure.(8)
- Refer to NCHRP Report 731, *Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections*, for more information on this countermeasure.(29)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure.(5)

Backplates with Retroreflective Borders

What: Backplates with retroreflective borders are added to traffic signal heads to improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background.

Why: Signal heads that have backplates equipped with retroreflective borders are more conspicuous in both daytime and nighttime conditions. This treatment enhances traffic signal visibility for both older and color vision–deficient drivers. This countermeasure is also advantageous during periods of power outages when the signals would otherwise be dark, providing a visible cue for drivers at night.

Where: This countermeasure could be implemented at all signalized intersections.

Considerations: Agencies should consider adopting this countermeasure as a standard treatment for signalized intersections across a jurisdiction.

Resources: The following resources provide further information about backplates with retroreflective borders:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website for additional information on the implementation of this countermeasure.(8)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure (CMF ID 1410).(5)

Application of Multiple Low-Cost Countermeasures

What: The systemic approach to intersection safety involves deploying a group of multiple low-cost countermeasures, such as enhanced signing and pavement markings at many stop-controlled intersections within a jurisdiction.

The countermeasures include any combination of the following improvements on through or stop approaches:

- Through approach improvements are as follows:
  - Doubled-up (i.e., positioned on the left and right), oversized advance-intersection warning signs with street name sign plaques.
  - Enhanced pavement markings that delineate through lane edgelines.
- Stop approach improvements are as follows:
  - Doubled-up (i.e., positioned on the left and right), oversized advance "Stop Ahead" intersection warning signs.
  - Doubled-up (i.e., positioned on the left and right), oversized stop signs.
  - Retroreflective sheeting on sign posts.
  - Properly placed stop bars.
  - Removal of any vegetation, parking, or obstruction that limits sight distance.
  - Double-arrow warning sign at stem of T-intersections.

Why: These multiple low-cost countermeasures are designed to increase driver awareness and recognition of the intersections, traffic control, and potential conflicts.

Where: These countermeasures could be deployed at all stop-controlled intersections.

Considerations: Agencies should consider adopting these countermeasures as a common treatment for stop-controlled intersections across a jurisdiction.

Resources: The following resources provide further information about multiple low-cost countermeasures:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website for additional information on the implementation of these countermeasures.(8)
- Refer to the TechBrief *Safety Evaluation of Multiple Strategies at Stop-Controlled Intersections* for more information on these countermeasures.(30)

Advance Signs

What: Advance signs include the following:

- Advance warning signs (e.g., intersection ahead, signal ahead, and stop ahead).
- Advance informational signs (e.g., advance street name).

Why: Advance signs provide drivers with advance information and warnings that call attention to unexpected conditions on or adjacent to a roadway that might require a reduction of speed or an action in the interest of safety and efficient traffic operations.

Where: Refer to the *MUTCD* for information on the use of specific advance signs at unsignalized and signalized intersections.(15) In general, the use of advance signs may depend on warrants or may be based on an engineering study or judgment.

Considerations: Use of advance signs should be kept to a minimum as overuse could jeopardize the effectiveness of the countermeasure. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist. Agencies should apply signing devices uniformly based on the characteristics of the roadway.

Resources: The following resources provide further information about advance signs:

- Refer to the brochure *Intersection Safety Strategies* for additional information on the implementation of this countermeasure.(27)
- Refer to chapter 2C of the *MUTCD* for more information on this countermeasure.(15)
- Refer to the CMF Clearinghouse for the safety effectiveness of various advance signs.(5)

SYSTEMIC COUNTERMEASURES FOR NONINTERSECTION FCFTS

FCFTs based on an analysis of data from multiple States are described in *Contributing Factors for Focus Crash and Facility Types* and summarized in table 2.(2) The roadway-related contributing factors include larger percent grade, smaller curve radius, narrower surface width, narrower shoulder width, presence of unpaved shoulders, higher speed limit, narrower lane width, and mountainous terrain. Table 4 summarizes countermeasures related to these contributing factors for the nonintersection FCFTs. These countermeasures include SafetyEdgeSM, rumble strips and stripes, enhanced friction for horizontal curves, enhanced delineation for horizontal curves, roadside design improvements at curves, advance markings for curves, and advance signs. More detailed information on what each countermeasure is and why and where they are used, as well as other considerations and related resources, are provided in the following sections. The first five countermeasures in table 4, and much of the detail provided for each in the following sections, are drawn from FHWA's Office of Safety Proven Safety Countermeasures initiative.(8) FHWA promotes widespread implementation of these countermeasures through transportation agencies to reduce serious injuries and fatalities based on proven effectiveness and benefits.(8) The last two countermeasures in table 4 and supplemental information for the other five proven countermeasures are from the FHWA report *Low-Cost Treatments for Horizontal Curve Safety*.(13) FHWA's Roadway Departure Safety website provides additional discussion on and tools for strategic approaches to roadway-departure safety that fall into three categories:[(14)]

- Keep vehicles on the roadway.
- Provide for safe recovery.
- Reduce crash severity.

Table 4. Systemic countermeasures for nonintersection contributing factors.

Countermeasure	Larger Percent Grade	Narrower Lane Width	Narrower Paved Surface Width	Narrower Shoulder Width	Unpaved Shoulder	Higher Speed Limit	Mountainous Terrain	Smaller Curve Radius
SafetyEdge	●	●	●	●	●	●	—	●
Rumble strips and stripes	—	●	●	●	●	●	●	●
Enhanced friction for horizontal curves	●	—	●	—	—	●	—	●
Enhanced delineation for horizontal curves	—	—	●	—	—	●	—	●
Roadside design improvements at curves	—	—	—	—	—	●	—	●
Advance markings for curves	—	●	●	●	●	●	—	●
Advance signs	—	●	●	●	—	●[a]	●	●

[a]Refer to the *Manual on Uniform Traffic Control Devices* for advance-warning-sign requirements based on speed differentials.[(15)]
●Contributing factor in multiple States.
—Not a contributing factor in any State.

SafetyEdge

What: The edge of the pavement is shaped at approximately 30 degrees from the pavement cross slope to eliminate the vertical drop-off. It is installed during the paving process and has a minimal effect on pavement project cost.

Why: SafetyEdge gives drivers the opportunity to maintain control of their vehicles and allows drifting vehicles to return to the pavement safely.

Where: SafetyEdge may be used in paving and resurfacing projects on both asphalt and concrete.

Considerations: This countermeasure is not necessary where curbs are present. The adjacent shoulder or slope should be flush with the top of pavement.

Resources: The following resources provide further information about SafetyEdge:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website and SafetyEdge website for additional information on the implementation of this countermeasure.[8,16]
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure.[5]

Rumble Strips and Stripes

What: Longitudinal rumble strips are milled or raised elements on pavement intended to alert a driver through vibration and sound that their vehicle has left the travel lane. The strips can be installed on the shoulder, along the edgeline of the travel lane, or at or near the centerline of an undivided roadway. Rumble stripes are edgeline or centerline rumble strips where the pavement marking is placed over the rumble strip, which result in increased visibility of the pavement marking during wet nighttime conditions.

Why: Rumble strips and stripes are designed to address roadway-departure crashes caused by distracted, drowsy, or otherwise inattentive drivers who drift from their lane. These crashes account for more than half of the fatal roadway crashes annually in the United States.(14)

Where: Driver error may occur on any road, so a systemic application is recommended.

Considerations: Transportation agencies should consider installing milled rumble strips with bicycle gaps.

Resources: The following resources provide further information about rumble strips and stripes:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website and Rumble Strips and Rumble Stripes website for additional information on the implementation of this countermeasure.(8,17)
- Refer to the report *State of the Practice for Shoulder and Center Line Rumble Strip Implementation on Non-Freeway Facilities* for more information on this countermeasure.(18)
- Refer to NCHRP Report 641, *Guidance for the Design and Application of Shoulder and Centerline Rumble Strips*, for more information on this countermeasure.(19)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure.(5)

Enhanced Friction for Horizontal Curves

What: Enhanced friction treatments include the following:

- **High-friction surface treatment:** This treatment involves the application of high-quality aggregate to a pavement using a polymer binder to restore and/or maintain pavement friction at existing or potentially high-crash areas.
- **Pavement grooving:** This treatment involves applying longitudinal or transverse cuts onto a pavement surface to increase or restore pavement friction.

Why: Enhanced friction treatments compensate for the high-friction demand at curves where current pavement friction is not adequate to support operating speeds.

Where: Enhanced friction treatments should be used at the following locations:

- Sharp curves.
- Inadequate cross-slope design.
- Wet conditions.
- Polished roadway surfaces.

Considerations: High-friction surface treatments are not an answer for corridor paving but for spot applications. Pavement grooving is only appropriate for concrete pavements.

Resources: The following resources provide further information about high-friction surface treatments:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website, Horizontal Curve Safety website, High Friction Surface Treatments website, and report *Evaluation of Pavement Safety Performance* for additional information on the implementation of this countermeasure.(8,20–22)
- Refer to the report *Low-Cost Treatments for Horizontal Curve Safety* for additional information on this countermeasure.(13)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure (CMF IDs 7900, 7901, 7229, 7234, and 7271).(5)

Enhanced Delineation for Horizontal Curves

What: Enhanced delineation may include one or more of the following:

- Pavement markings.
- Post-mounted delineation.
- Larger signs and signs with enhanced retroreflectivity (in advance of and/or within the curve).
- Dynamic advance-curve warning signs and sequential curve signs.

Why: Enhanced delineation can alert drivers to the presence of a curve in advance, which can increase driver awareness and improve driver behavior (e.g., selecting the appropriate speed) through the curve.

Where: Horizontal curves may be effective on any facility type.

Considerations: Enhanced delineation countermeasures can be applied in combination, and applications may vary by the severity of the curvature and vehicle operating speed.

Resources: The following resources provide further information about horizontal curves:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website and Horizontal Curve Safety website for additional information on the implementation of this countermeasure.(8,20)
- Refer to the report *Low-Cost Treatments for Horizontal Curve Safety* for additional information on this countermeasure.(13)
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure (CMF IDs 2438 and 2439).(5)

Roadside Design Improvements at Curves

What: The following improvements are designed to increase the chances of safely recovering errant vehicles:

- Providing an unobstructed, traversable area beyond the edge of the through traveled way.
- Flattening side slopes.
- Adding or widening shoulders.

The following improvements are designed to reduce crash severity at locations where departing the roadway could result in higher chances of severe injury than striking a roadside barrier:

- **Cable barrier:** A flexible barrier made from wire rope supported between frangible posts.
- **Guardrail:** A semirigid barrier, usually either a steel box beam or W-beam.
- **Concrete barrier:** A rigid barrier that does not deflect.

Why: Clear zone, side slope, and shoulder improvements provide favorable conditions for errant vehicles to recover and regain control in the event of a roadway departure. Roadside barriers help reduce the severity of the crash event at locations where departing the roadway could result in higher chances of severe injury than striking a roadside barrier.

Where: Roadside design improvements can be implemented alone or in combination at horizontal curves and locations with a higher percentage of roadway-departure fatalities.

Considerations: Concrete barriers are typically reserved for use on divided roadways. Guardrails deflect less than flexible barriers, so they can be located closer to objects where space is limited.

Resources: The following resources provide further information about roadside improvements at curves:

- Refer to FHWA's Office of Safety Proven Safety Countermeasures website and Clear Zones website for additional information on the implementation of this countermeasure.[8,23]
- Refer to the CMF Clearinghouse for the safety effectiveness of this countermeasure.[5]

Advance Markings for Curves

What: Advance markings for curves include the following:

- **Speed advisory marking in lane:** This treatment includes the use of word, symbol, or arrow markings to supplement advance-curve warning signs and advisory speed plaques. The markings supplement the curve warning sign with an advisory speed plaque by providing the same information in the driver's direct line of sight and emphasizing the message to the driver.

- **Optical speed bars (speed-reduction markings):** These bars are transverse stripes spaced at gradually decreasing distances in the direction of travel. The intent of this treatment is to increase the driver's awareness of their speed, causing them to slow down.

Why: Pavement markings in advance of horizontal curves provide conspicuous, supplementary warning information about the presence of horizontal curves in the driver's direct line of sight.

Where: Speed advisory markings may be more appropriate for high-speed roads where the curve advisory speed is significantly lower than the posted speed, curves where crash reports indicate speed-related issues, and corridors where speed studies indicate excessive speeding. Optical speed bars should be reserved for unexpected curves. Overuse of optical speed bars could jeopardize the visual effect of the countermeasure, and this countermeasure has been shown to be most effective at locations that have higher volumes of unfamiliar drivers.

Considerations: Advance markings for curves should supplement, not substitute, for appropriate warning signs and may be appropriate at locations where signs alone have proved ineffective. The advance distance at which such markings are applied depends on both the approach speed and design speed of the curve. Durable marking materials are preferred because of the exposure to traffic volume over time.

Resources: The following resources provide further information about advance markings for curves:

- Refer to FHWA's Horizontal Curve Safety website for additional information on the implementation of this countermeasure.(20)
- Refer to the report *Low-Cost Treatments for Horizontal Curve Safety* for additional information on this countermeasure.(13)
- Refer to the *Manual on Uniform Traffic Control Devices* (MUTCD) for design and application criteria of this countermeasure.(15)
- Refer to NCHRP Report 600, *Human Factors Guidelines for Road Systems*, for information on which markings are more or less effective at reducing speeds on horizontal curves.(24)

Advance Signs

What: Advance signs include the following:

- Advance warning signs (e.g., curves, narrow roads, and advisory speeds).
- Advance informational signs (e.g., percent grade signs).

Why: Advance signs provide drivers with advance information and warnings that call attention to unexpected conditions on or adjacent to a roadway. These signs alert drivers to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

Where: Refer to the *MUTCD* for information on the use of specific advance signs.(15) In general, the use of advance signs may depend on warrants or be based on an engineering study or judgment.

Considerations: Overuse of advance signs could jeopardize the effectiveness of the countermeasure. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist. Agencies should apply signing devices uniformly based on the characteristics of the roadway.

Resources: The following resources provide further information about advance signs:

- Refer to FHWA's Horizontal Curve Safety website for additional information on the implementation of this countermeasure.(20)
- Refer to the report *Low-Cost Treatments for Horizontal Curve Safety* for additional information on this countermeasure.(13)
- Refer to chapter 2C of the *MUTCD* for additional information on this countermeasure.(15)
- Refer to the CMF Clearinghouse for the safety effectiveness of various types of advance signs.(5)

CHAPTER 5. SUMMARY AND CONCLUSIONS

This quick reference guide is for transportation professionals in State and local agencies interested in applying a systemic approach to road-safety management. It provided brief overviews of a systemic approach, common target crash types and their associated facility types, and contributing factors. It also described a step-by-step process to select countermeasures and included lists of potential countermeasures for intersections and nonintersections that could mitigate the presence of specific contributing factors.

A systemic approach to road-safety management relies on identifying and addressing contributing factors rather than crash history. The relatively low costs associated with this approach allow for the opportunity to achieve safety benefits across the system or a large portion of the system. Even with a modest crash reduction per site, a well-implemented systemic approach can have a significant impact on safety.

Identifying FCFTs is key to selecting appropriate countermeasures. This guide included a brief discussion of the tools and resources that agencies can use for their jurisdiction. The guide also detailed a six-step process to identify countermeasures as well as descriptions of potential countermeasures for common FCFTs. The vast majority of these countermeasures are from FHWA's Office of Safety Proven Safety Countermeasures website.[(8)] Readers with limited data or analysis capabilities can also find lists of potential FCFTs for intersections and nonintersections, which were developed based on an analysis of national and State datasets, in *Contributing Factors for Focus Crash and Facility Types*.[(2)] Finally, the guide also detailed contributing factors associated with those FCFTs based on the same analysis of national and State datasets.

This guide is not meant to provide complete lists of contributing factors or countermeasures but to be a quick reference for agencies interested in applying systemic safety approaches to the most common FCFTs. This guide may be particularly useful for agencies without sufficient data and analysis capabilities; they can reference the factors developed in this research to help identify countermeasures and prioritize sites for systemic safety improvements. Agencies with sufficient data and analysis capabilities can refer to FHWA's *Systemic Safety Project Selection Tool* for discussions on how to analyze data to identify FCFTs and contributing factors for specific crash types.[(3)]

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