A Systemic Approach to Highway Safety: An Introduction

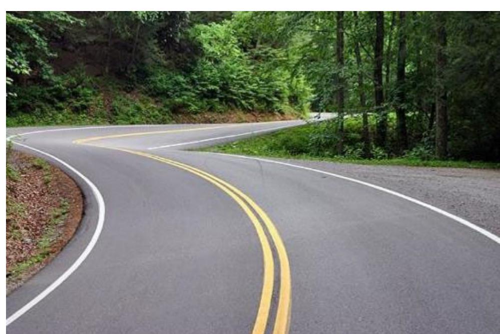
National Summit on Rural Road Safety
December 5, 2018

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives
http://safety.fhwa.dot.gov

Agenda

- Overview
- Systemic Safety Analysis
  - 4-Step Process
- Case Studies
- Conclusion



https://www.mkd.mk/makedonija/poradi

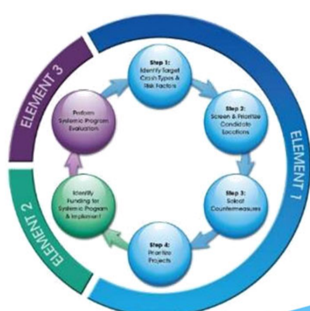
Course Objectives

- Gain high-level understanding of systemic approach.
- Understand and apply 4-step systemic planning process.
- Understand related resources.
- Develop **desire and determination to start or enhance** systemic safety approach within your agency.

http://goldenchamber.org/uncategorized/what-are-the-key-elements-i-must-put-in-place-to-reach-my-goals/attachment/goals/

Overview of

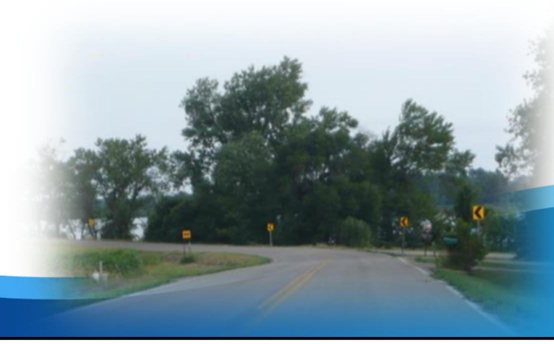
Systemic Approach to Safety



Systemic Safety: Definition

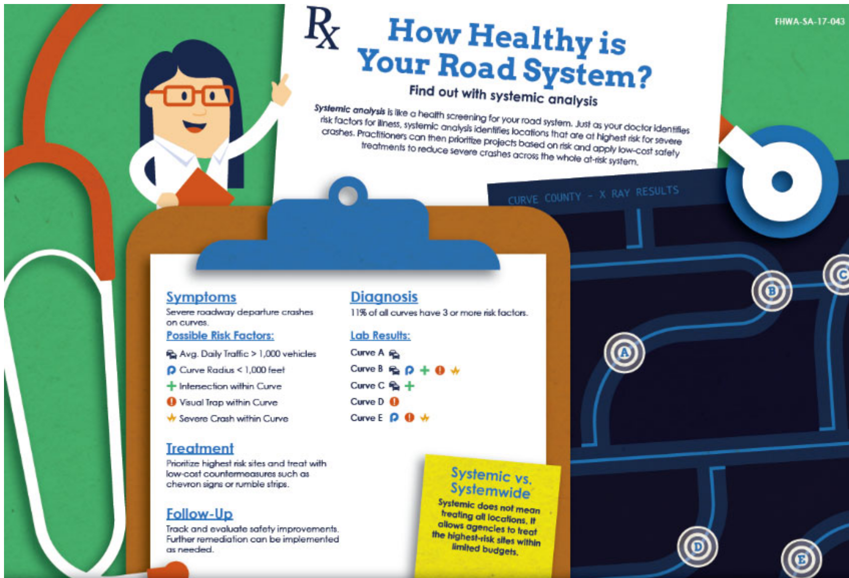
The term "systemic safety improvement" means an improvement that is **widely implemented** based on **high-risk roadway features** that are correlated with **particular crash types, rather than crash frequency.**

-- 23 USC 148 (a)(12) Systemic safety improvement



Systemic Safety: Definition

"A proactive safety approach that focuses on evaluating an entire roadway network using a defined set of criteria." *--CALTRANS*



https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/ddsa_resources/ddsa_systemic_analysis.pdf

Reasons for Systemic Approach

Minnesota

- Rural paved secondary
  - 22,000 miles
  - 13,000 intersections
  - 19,000 curves
  - 0 locations > 1.0 severe crash/year

Note: 60% of Minnesota's severe crashes (fatal + serious injury) occurred on local system (with half on county owned roads)

Cleveland, Minnesota
https://commons.wikimedia.org/wiki/File:2009-0805-MN-DoddRoad.jpg

Reasons for Systemic Approach

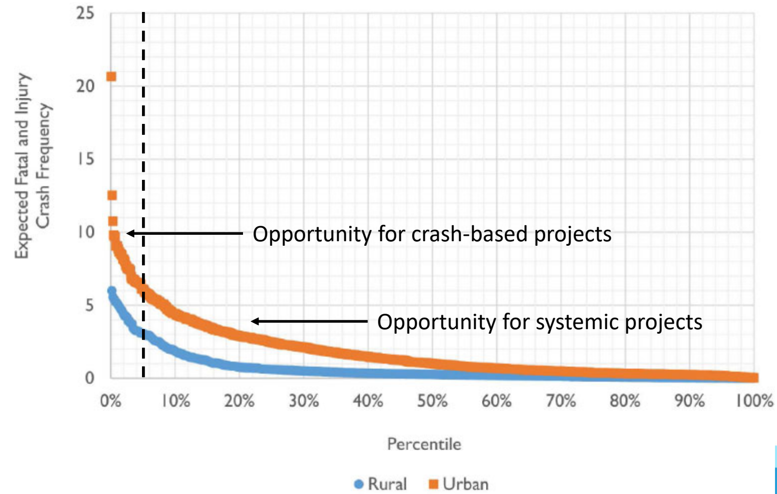
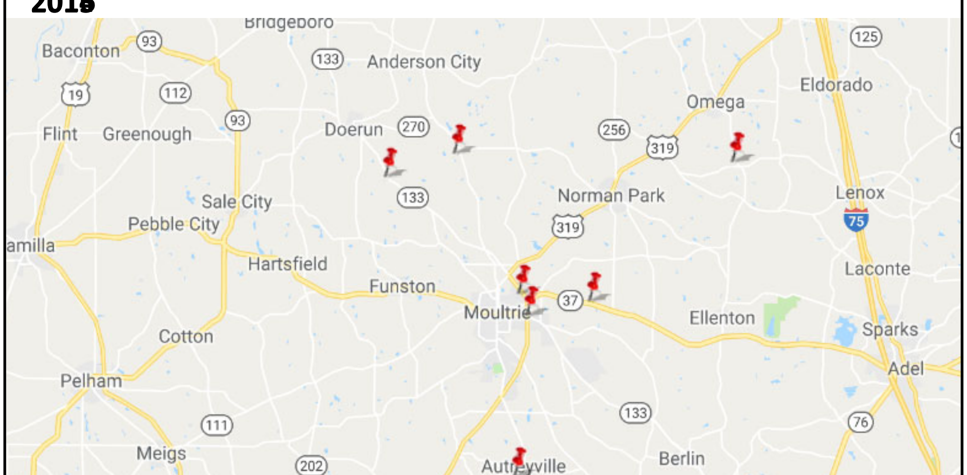


Figure 3. Graph. Statewide distribution of intersection safety performance.

Example: Fatal Crash Locations

2016



Source: NHTSA (https://cdan.nhtsa/gov/stsi.htm#)

Example: Major Fatal Crash Types in Washington by FHWA Focus Area

Crash Type	2012		2013		2014		2015	
	#	%	#	%	#	%	#	%
Roadway Departure	243	60%	247	62%	252	59%	290	56%
Pedestrian/Bicycle	87	22%	60	15%	84	20%	100	19%
Intersection	98	24%	110	27%	131	31%	160	31%
TOTAL	403		401		429		516	

Source: FHWA - https://rspcb.safety.fhwa.dot.gov/Dashboard/Default.aspx

Systemic Approach

- Complementary approach to site-specific
  - Proactively identify safety improvements
  - Does not replace reactionary approach
- Primary approach for rural and local roads
  - Can be applicable to urban roads

Source: FHWA - https://safety.fhwa.dot.gov/roadway_dept/countermeasures/horicurves/fhwasa15084/

Source: FHWA - https://safety.fhwa.dot.gov/intersection/other_topics/corridor/cam_tech/sa15005.pdf

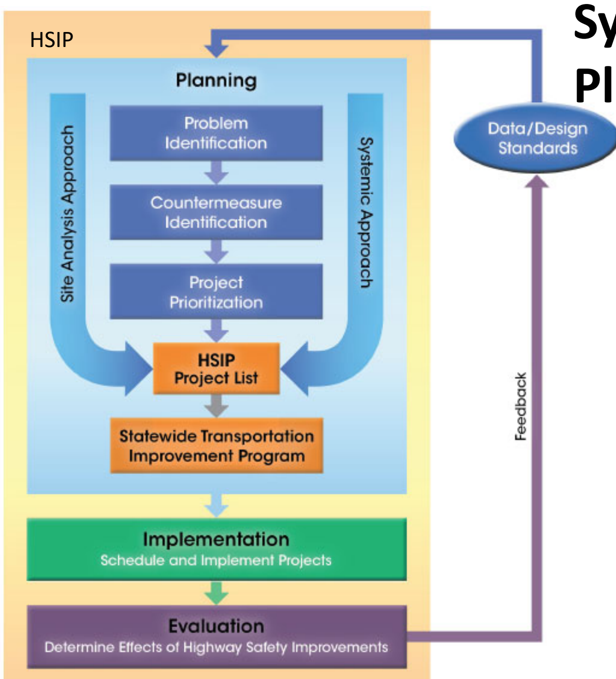
Systemic Approach

- Crashes alone do not establish prioritization
- Sometimes prioritization is obvious from data (*inferred prioritization*)

Curve ID	Road Name	Scoring	5-year Crash Rate	Fatal or Serious Crash
182	Hawks Prairie Road NE	6.5	1.2	Yes
194	Boston Harbor Road NE	6.0	1.1	No
143	Delphi Road NW	6.0	0.9	No
203	Johnson Point Road NE	5.5	0.4	No
202	South Bay Road NE	5.5	0.2	No
136	Waddell Creek Road SW	5.5	10.3	Yes

https://safety.fhwa.dot.gov/systemic/fhwasa13019/sspst.pdf

Systemic Safety Planning



https://safety.fhwa.dot.gov/systemic/fhwasa13019/sspst.pdf

Benefits of Systemic Safety Planning

- Proactive program to address severe crashes
  - – Seemingly occur at “random” locations
- Greater knowledge of severe crashes
  - – Contributing factors and location characteristics
  - – Improve planning, design, and maintenance practices
  - – Risk management for tort liability
- Magnitude of crash reductions
  - – Case by case (more later)

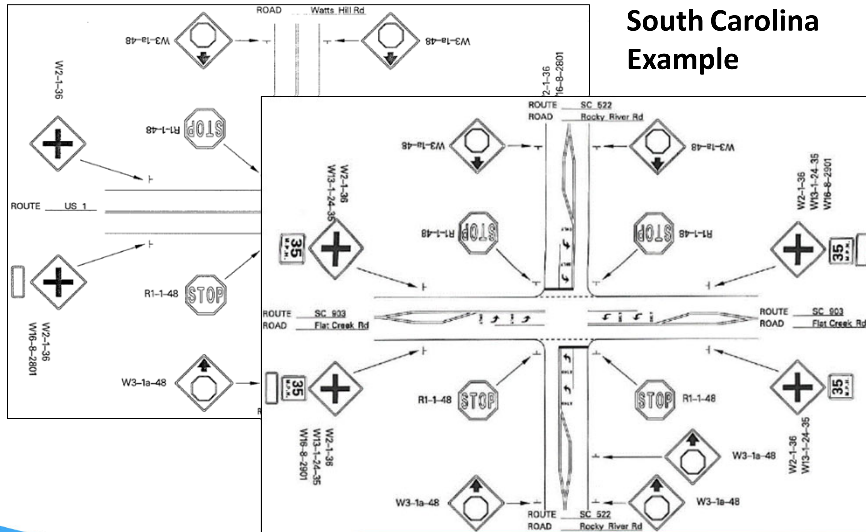
Benefits of Systemic Safety Planning

South Carolina Example

- Systemic intersection improvement program
  - – Signing
  - – Pavement Marking
  - – Signal Enhancements
- Signalized
  - – Benefit Cost Ratio – 4.1
- Stop-Controlled
  - – Benefit-Cost Ratio – 12.4

http://www.jbcharleston.jb.mil/News/Article/235728/stop-signs-know-who-has-the-right-of-way/

Benefits of Systemic Safety Planning



South Carolina Example

Site-Specific vs. Systemic (Total crashes)

Budget = $3M

- Site-specific
  - 3 roundabouts @
  - 40% reduction/ir
  - 10-20 crashes/ye
  - Benefit = reduce
- Systemic
  - 500 intersections
  - 5% reduction/int
  - 3 crashes/year be
  - Benefit = reduce

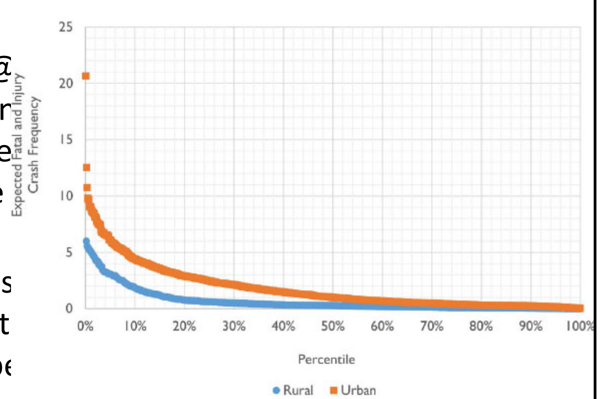


Figure 3. Graph. Statewide distribution of intersection safety performance.

Benefits of Systemic Projects: Site-Specific Improvements

Countermeasure	Coverage[1]	Project Costs	Net Safety Benefits	Benefit Cost Ratio
Add Left Turn Lanes	14 intersections	$9,884,000	$62,386,011	6.3
High Friction Surface Treatment	100 sites	$10,000,000	$498,263,771	49.8
Reconfigure Intersection	12 intersections	$9,864,000	$134,293,525	13.6
Reduce Intersection Skew and Add Left Turn Lanes	9 intersections	$9,954,000	$83,931,637	8.4
Road Diet Without Resurfacing	100 miles	$10,000,000	$631,888,312	63.2
Road Diet Including Resurfacing and Reconstruction Costs	10 miles	$10,000,000	$63,188,831	6.3
Roundabout	13 intersections	$9,607,000	$111,682,769	11.6
Average	37 sites	$9,901,286	$226,519,265	23.0

1. Assumes one mile, one curve, and one intersection are equivalent to a single site.

Benefits of Systemic Projects: Systemic Improvements

Countermeasure	Coverage[1]	Project Costs	Net Safety Benefits	Benefit Cost Ratio
Cable Median Barrier	51 miles	$9,996,000	$58,006,096	5.8
Centerline and Shoulder Rumble Strips	2,000 miles	$10,000,000	$126,771,305	12.7
Ramp Curve Signage	1,000 curves	$10,000,000	$2,928,925,502	292.9
Curve Warning Signage (Chevrons)	6,250 curves	$10,000,000	$640,014,079	64.0
Low Cost Intersection Improvements - Signal	1,428 intersections	$9,996,000	$279,526,340	28.0
Low Cost Intersection Improvements - Stop	1,666 intersections	$9,996,000	$168,073,055	16.8
Average	2,066 sites	$9,998,000	$700,219,396	70.0

1. Assumes one mile, one curve, and one intersection are equivalent to a single site.

Benefits of Systemic Projects: Comparison

Economic Measure	Site-Specific	Systemic
Total Cost	$9,901,286	$9,998,000
Total Benefit	$226,519,265	$700,219,396
Overall Benefit-Cost Ratio	**23.0**	**70.0**

Systemic Safety Project Selection

1. Systemic Process
2. Balance Funds
3. Evaluate Effectiveness

FHWA's Systemic Safety Tool

https://safety.fhwa.dot.gov/systemic/fhwasa13019/sspst.pdf

A systemic illustration…

- You could select cable median barrier locations on fatal crash data alone...

but considering other roadway characteristics would likely lead to a better risk-based solution.

Photo Source: Iowa DOT

Illinois cable median barrier

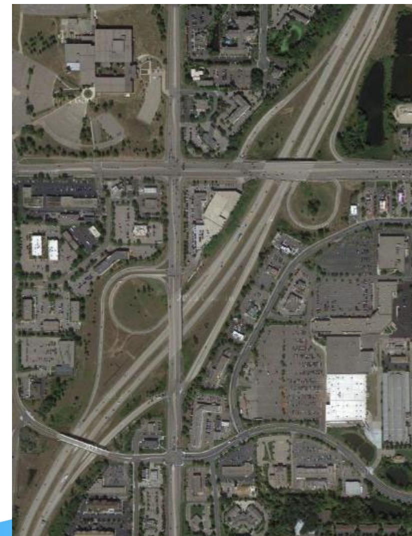
median width

traffic volume

Other possible risk factors

horizontal alignment

weather/climate



interchange location/spacing

A systemic illustration…

- You could select High-Friction Surface Treatment locations on fatal crash data alone…

but considering other roadway characteristics would likely lead to a better risk-based solution.

Photo Source: CH2M HILL

- Curve Radius
- Traffic Volume
- Wet-Weather Crashes
- Friction Data

Element 1
Systemic Safety Planning Process

Systemic Safety Planning Process

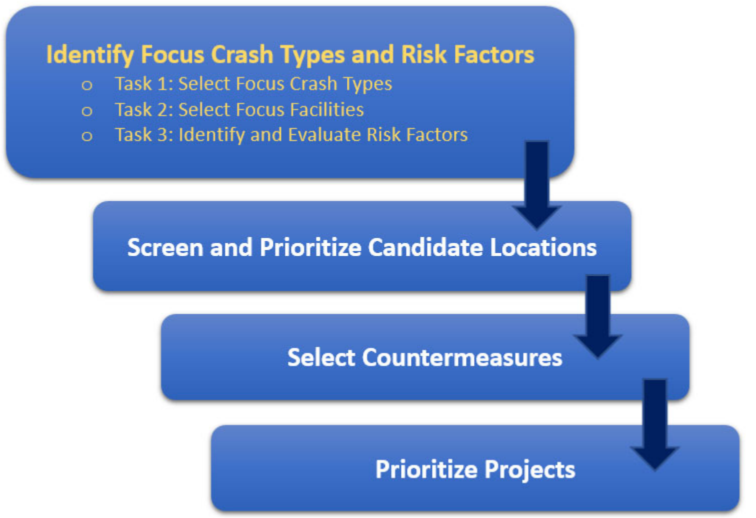
Step 1 — Identify Focus Crash Types and Risk Factors

Step 2 — Screen and Prioritize Candidate Locations

Step 3 — Select Countermeasures

Step 4 — Prioritize Projects

Step 1: Identify Focus Crash Types, Facility Types, and Risk Factors



What we mean by "focus crash type"

The crash type that represents the **greatest number of severe crashes** across the roadway system being analyzed and provides the **greatest potential to reduce fatalities and severe injuries**.

- Roadway Departure
- Intersection
- Pedestrian
- Speeding

Task 1: Select Focus Crash Types

- Systemwide analysis
- Strategic Safety Plans
  - Strategic Highway Safety Plans
    - Emphasis areas
  - Safety Implementation Plans
    - Examples: IL, KY, LA, MN, MO, NE, OH, NY, Thurston County, WA.
- Regional and jurisdictional analyses
  - May differ from statewide needs

https://www.maxpixel.net/Accident-Broken-Auto-Damage-Vehicle-Total-Damage-1409006

Task 1: Select Focus Crash Types

Fatal and Severe Injury Crashes (2007-2011)
Percent by Jurisdiction

Emphasis Area	Statewide 114,592 mi	
Total Fatal/Serious Injury	100%	63,443
Pedestrian	19%	11,786
Bicycle	5%	3,390
Heavy Vehicle	5%	3,123
Road Departure	26%	16,668
Intersection	41%	25,791
Head-on and Sideswipe	5%	3,071

Helpful Hints

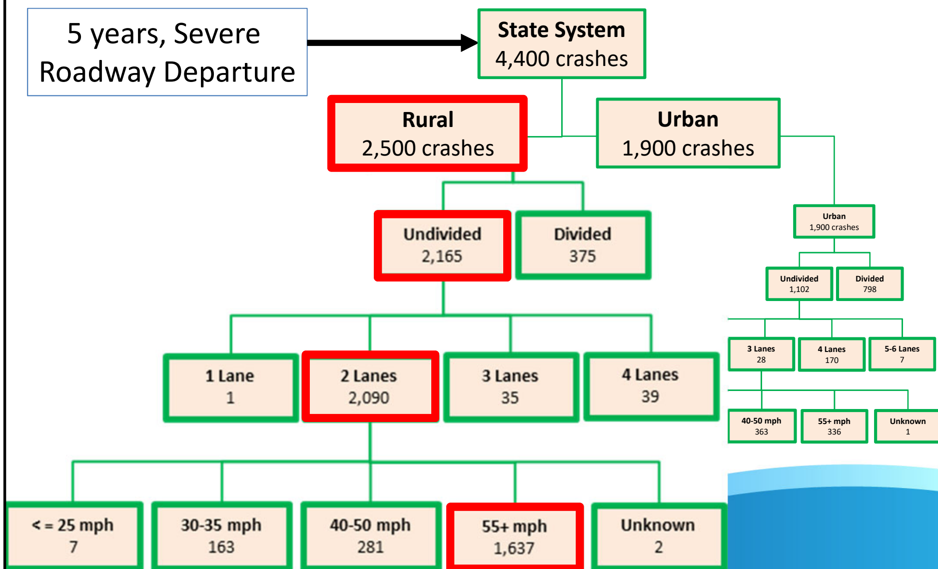
- Local focus crash types can differ from statewide focus crash types
- Focus crash types can include causal factors from the 4 E's

What we mean by "focus facility"

The facility type on which the **focus crash type most frequently occurs**.

- Rural, Two-Lane Highways
- Urban, Signalized Intersections
- Horizontal Curves
- Rural, Thru-STOP Intersections

Task 2: Select Focus Facilities



OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

35

Crash Tree Combinations

Primary

- State / local
- Rural / urban
- Segment / intersection
- Segment type
  - Freeway, multilane, two-lane, one-way
- Intersection control
  - Signalized
  - Unsignalized
  - Uncontrolled

Secondary

- Tangent / curve
- High-speed / low-speed
- Street lighting
- District or regions
- Traffic volume
- Lane width
- Shoulder type/width
- Alignment
- Land use

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

36

Helpful Hints

- Crash trees can include all severe crashes or just severe crashes for one focus crash type
  - Narrow crash types to target countermeasures
  - Narrow facility types to identify candidate sites
- Examine total and severe crash categories
  - May reveal different patterns
- Experience suggests 100+ crashes for identifying patterns
  - Increase sample size by:
    - Increasing number of years
    - Increasing geographic area (region instead of county)
    - Include minor injuries
  - Note: For smaller or rural jurisdictions, less crash data can be utilized for analysis.

What we mean by "risk factor"

A representation of risk in terms of the observed **characteristics associated with** the locations where the **targeted crash types** occurred.

- Volume
- Alignment
- Intersection Control
- Presence of Shoulders

Task 3: Identify and Evaluate Risk Factors

- Identify potential risk factors
  - Roadway and intersection features
  - Traffic volume
  - Transit stops, land use, etc.
- Evaluate risk factors
- Select final risk factors

http://www.creative-commons-images.com/highway-signs/r/risk.html

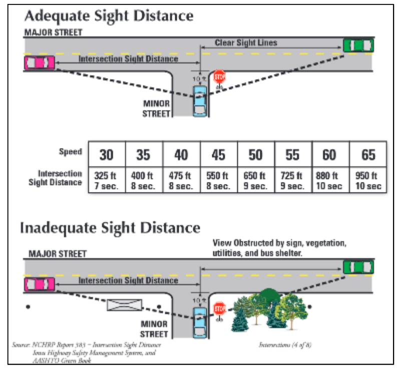
Potential Risk Factors

Roadway features:
- Number of lanes
- Lane width
- Shoulder width / type
- Median width / type
- Horizontal curvature
  - Superelevation
  - Delineation
  - Advance warning
  - Speed differential
  - Visual trap
- Pavement condition / friction
- Roadside features
  - Sideslope design
  - Clear zone
- Driveway density
- Other features
  - Rumble strips
  - Lighting
  - On-street parking

Potential Risk Factors

Intersection features:

- Traffic control device
- Left-turn or right-turn lanes
- Skew angle
- Advance warning signs
- Located in or near horizontal curve
- Type of development (e.g., commercial)
- Signals
  - Left-turn phasing
  - Number of signal heads vs. number of lanes
  - Backplates
  - Right-turn-on-red
  - Overhead versus pedestal mounted



Potential Risk Factors

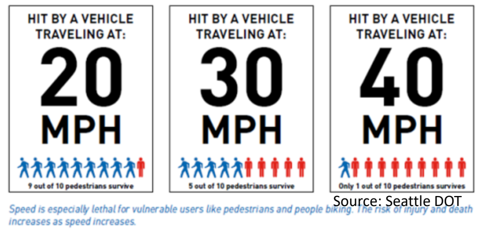
Pedestrian-related features:

- Type of intersection control
- Crosswalk presence
- Crossing distance
- Pedestrian signal / type
- Sidewalk presence
- Adjacent land uses
- Lighting

Potential Risk Factors

Other general features:

- Traffic volume
- Speed
  - Posted, operating
- Railroad crossing
- Automated enforcement
- Adjacent land use type
  - Schools, commercial, or alcohol-sales establishments)
- Bus stops (presence and location)

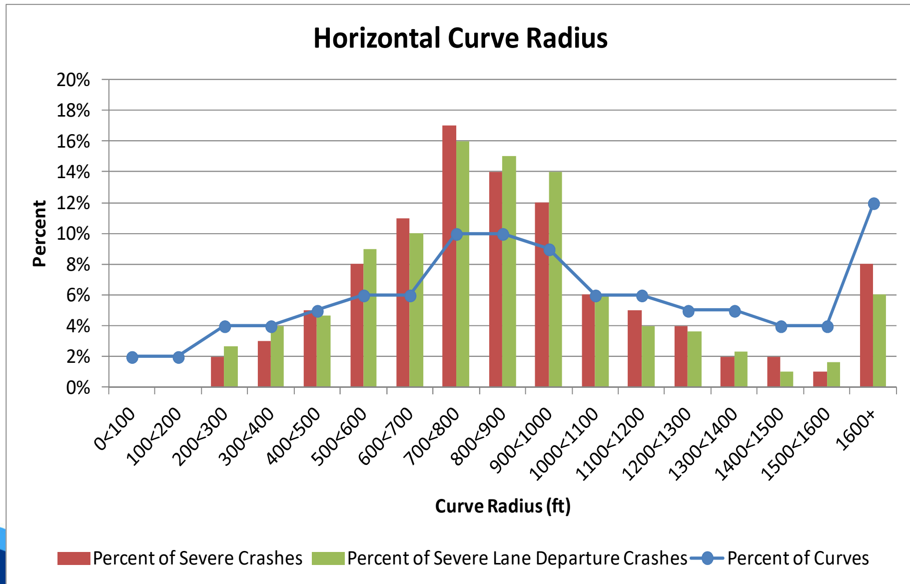


Source: Seattle DOT

Evaluate Potential Risk Factors

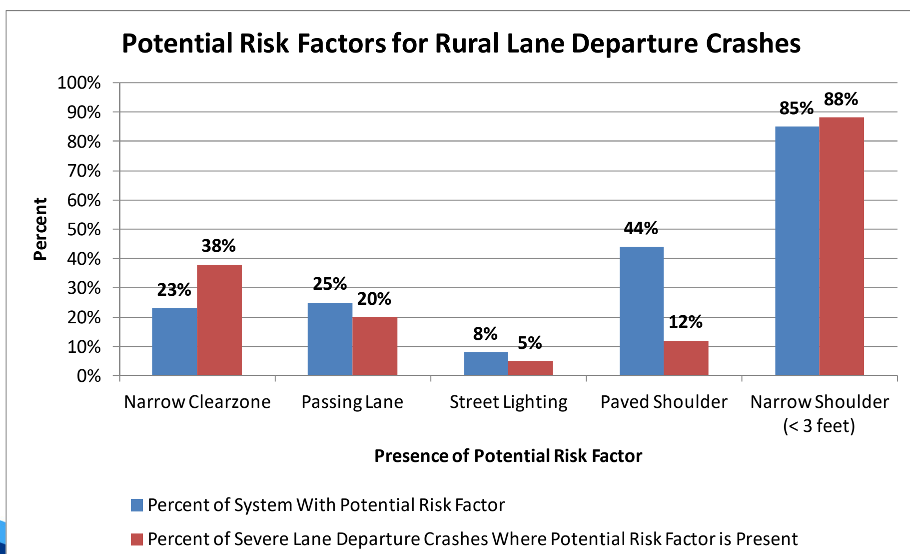
- What is future crash potential
  - Descriptive statistics
  - Published research

Descriptive Statistics Analysis



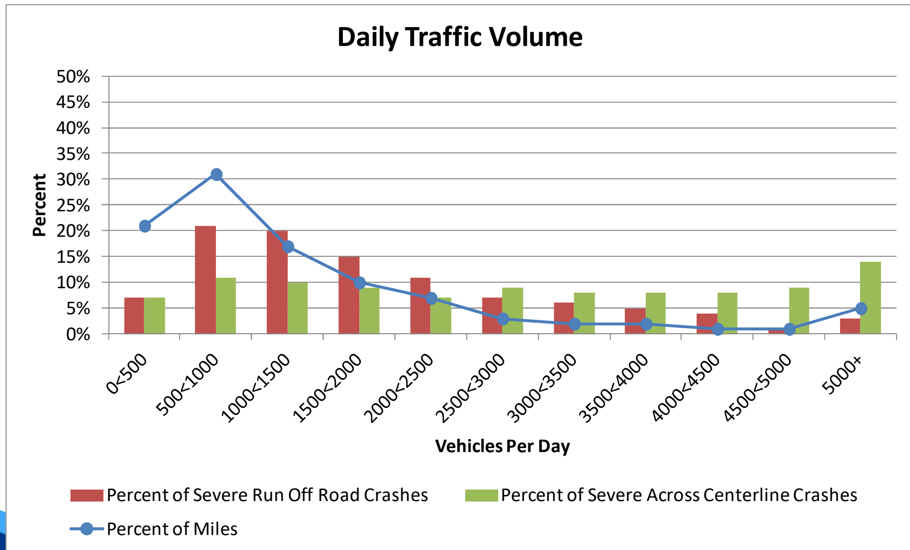
45

Descriptive Statistics Analysis

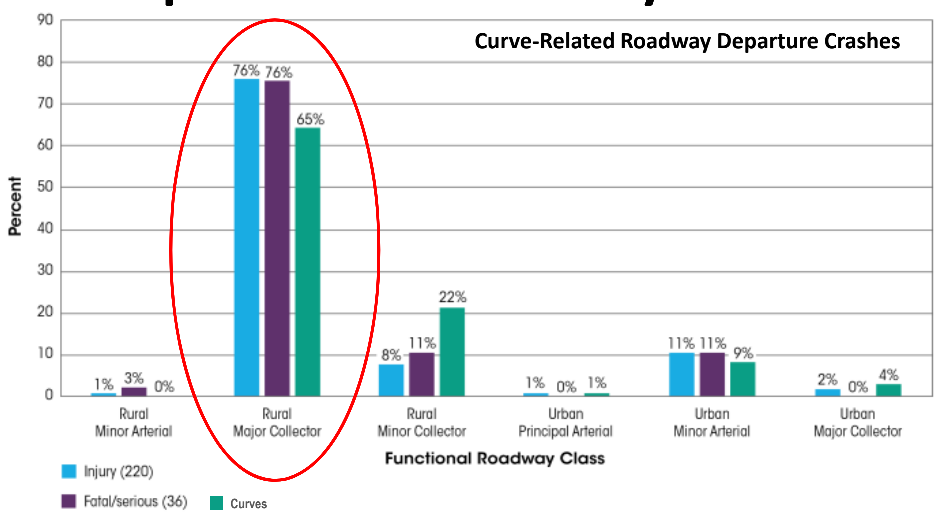


46

Descriptive Statistics Analysis



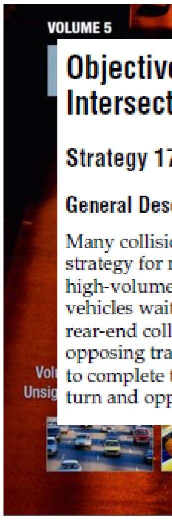
Descriptive Statistics Analysis



https://safety.fhwa.dot.gov/systemic/fhwasa13019/sspst.pdf

Published Research

CMF
CRASH MODIFICATION FACTORS CLEARINGHOUSE



Objective 17.1 B—Reduce the Frequency and Severity of Intersection Conflicts through Geometric Design Improvements

Strategy 17.1 B1—Provide Left-Turn Lanes at Intersections (P)

General Description

Many collisions at unsignalized intersections are related to left-turn maneuvers. A key strategy for minimizing such collisions is to provide exclusive left-turn lanes, particularly on high-volume and high-speed major-road approaches (Exhibit V-4). Left-turn lanes remove vehicles waiting to turn left from the through-traffic stream, thus reducing the potential for rear-end collisions. Because they provide a sheltered location for drivers to wait for a gap in opposing traffic, left-turn lanes may encourage drivers to be more selective in choosing a gap to complete the left-turn maneuver. This may reduce the potential for collisions between left-turn and opposing through vehicles.

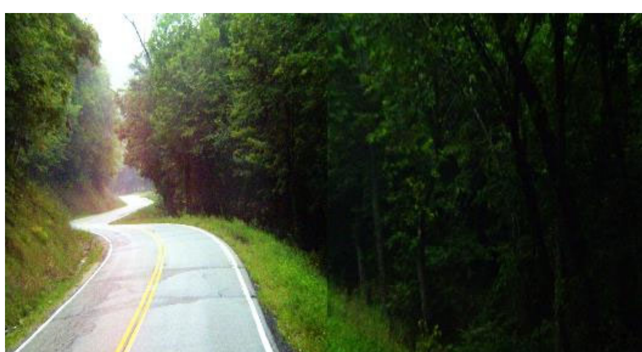
- **Reduce the frequency and severity of intersection conflicts through geometric design improvements**—Reducing the frequency and severity of vehicle-vehicle conflicts at intersections can reduce the frequency and severity of intersection crashes. This can be accomplished by separating through and turning movements at the intersection, restricting or eliminating turning maneuvers, providing acceleration lanes, and closing or relocating intersections.

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

49

Select Risk Factors

- Relationship to future crash potential
- Relationship to focus crash and facility types



OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

50

Helpful Hints

- Minimum of 2 to 3 risk factors is suggested to differentiate between sites
- Many counties use more
  - For example, counties in Washington State used on average 6-7 risk factors
- Combining risk factors may be appropriate
  - Can indicate if a particular crash type is overrepresented
  - Look to literature

Data to Identify Focus Crash/Facility Types

- Crash type
- Crash severity
- Crash location
- Crashes by system
  - State
  - Local

- Crashes by facility type
  - Rural, 2-lane roads (all, segments, curves)
  - Urban, 2-way stop-controlled intersection

Data to Identify Risk Factors

- AADT
- Corridor Geometrics
- Crash Types
- Speed

Data Sources

- Crash data
  - Law enforcement
  - State or local database
  - FARS
- Roadway data
  - State or local database
  - Video logs
  - Online aerial imagery
  - Windshield surveys
- Exposure data (AADT)
  - State or local database
  - Traffic counts

Where do these data come from in your jurisdiction?

Example: Select Focus Crash Type, Focus Facility Type, and Potential Risk Factors

You work for a **State DOT** and are leading the development of a new systemic program for the **state highway system**. There is a **summary table of severe crashes** by emphasis area by jurisdiction. There is also a **crash tree for severe crashes** on the state system.

Topics of Discussion:

- **Identify focus crash type and facility type** for new state program
  - How would selection change if you were instead focused on county roads?
- **Identify potential risk factors**
  - What factors would you evaluate if you had robust roadway data linked with crash records?
  - What potential risk factors would ideally still be in the database if you had limited variables, and why?

Example: Select Focus Crash Type

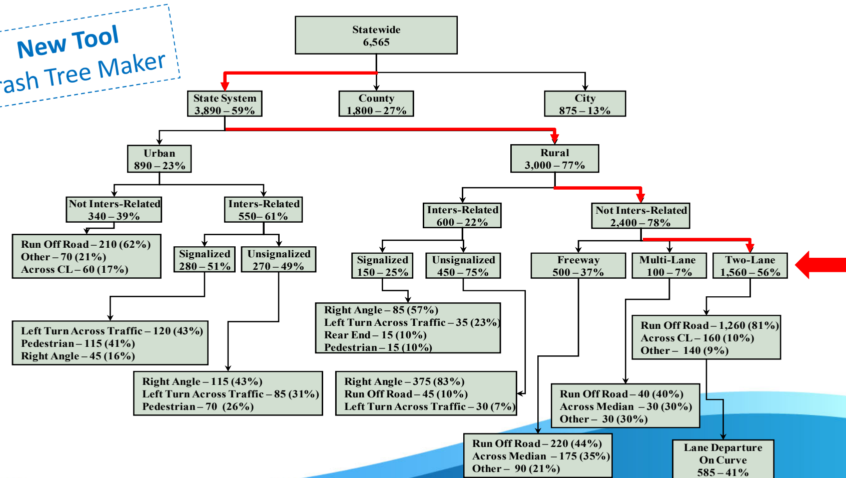
What focus crash type should be selected for the state roads?
How would the crash type change if focusing on county roads?

Emphasis Area		State (All Roads)		State Highways	
		Percent	No.	Percent	No.
Drivers	Young drivers (under 21)	17%	1,105	15%	580
	Older drivers (over 64)	12%	765	14%	535
	Aggressive driving and speeding-related	16%	1,040	13%	515
	Drug- and alcohol-related	35%	2,[illegible] (3)	37%	1,4[illegible] (3)
	Distracted Drivers	3%	195	4%	150
	Unbelted vehicle occupants	40%	2,[illegible] (2)	30%	1[illegible] (1)
Special Users	Pedestrian crashes	5%	360	5%	200
	Bicycle crashes	1%	55	1%	20
Vehicles	Motorcycles crashes	7%	440	6%	220
	Heavy vehicle crashes	11%	690	15%	565
Highways	Run Off Road Crashes	50%	[illegible] (1)	46%	1,7[illegible] (2)
	Across Centerline or Across Median Crashes	11%	720	11%	425
	Intersection crashes	26%	1,730	30%	1,150
	Work zone crashes	2%	120	2%	95
Total Severe (Fatal and Life-Changing Injury) Crashes		6,565		3,890	

Example: Select Focus Facility Type

What focus facility type should be selected?

New Tool
Crash Tree Maker



Example: ID Potential Risk Factors

Based on your selection, brainstorm to **identify potential risk factors** you would evaluate if the state maintained a robust data system that is linked with crash records.

Shoulder width/type, lane width, roadside rating

If the statewide database contains a limited number of variables, **what potential risk factors would ideally still be in the database**, and why?

How would you evaluate risk factors and why?

Activity 1

Select Focus Crash Type

Select Focus Facility Type

Identify Potential Risk Factors

- Identify Focus Crash Types and Risk Factors
- Screen and Prioritize Candidate Locations
- Select Countermeasures
- Prioritize Projects

Step 2: Screen and Prioritize Candidate Locations

- Identify Focus Crash Types and Risk Factors
- **Screen and Prioritize Candidate Locations**
  - Task 1: Identify Network Elements to Analyze
  - Task 2: Conduct Risk Assessment
  - Task 3: Prioritize Focus Facility Elements
- Select Countermeasures
- Prioritize Projects

Task 1: Identify Network Elements

- Spot-based (curves, intersections)
- Segments
- Verify selected risk factors

https://www.washingtontimes.com/news/2015/mar/3/long-and-winding-road-driving-mauis-famed-highway-/

Example: Identify Network Element

Corridor	Route Type	Route Number	Start	End	Length (miles)	Average Daily Traffic
144.01	CNTY	89	CSAH-30	CSAH-30	1.4	480
40.04	CSAH	40	New London Corp Limit	CSAH-2	5.9	450
131.01	CNTY	89	CSAH-30	MNTH-23	0.7	145
9.02	CSAH	9	CR-90, Willmar Corp Limit	CSAH-10	5.6	940
5.06	CSAH	5	150th Ave NW, CSAH-29	CSAH-1	10.1	628
31.02	CSAH	31	New London Corp Limit	MNTH-23	1.6	920
8.01	CSAH	8	Renville County Line	Lake Lillian Corp Limit	3.6	750
4.01	CSAH	4	CSAH-8	CSAH-20	6.7	320
2.05	CSAH	2	CSAH-10	MNTH-23	9.8	385
4.04	CSAH	4	CR-98	CSAH-40	2.4	290
38.01	CSAH	38	CSAH-40	CSAH-48	2.1	130
132.01	CNTY	89	CSAH-8	CSAH-8	2.2	190
42.01	CSAH	42	CSAH-7	County Line	0.5	120
9.03	CSAH	9	CSAH-10	CSAH-40, Redwood Street	4.9	1,800
25.01	CSAH	25	CSAH-5	USTH-71	3.2	1,315

Task 2: Conduct Risk Assessment

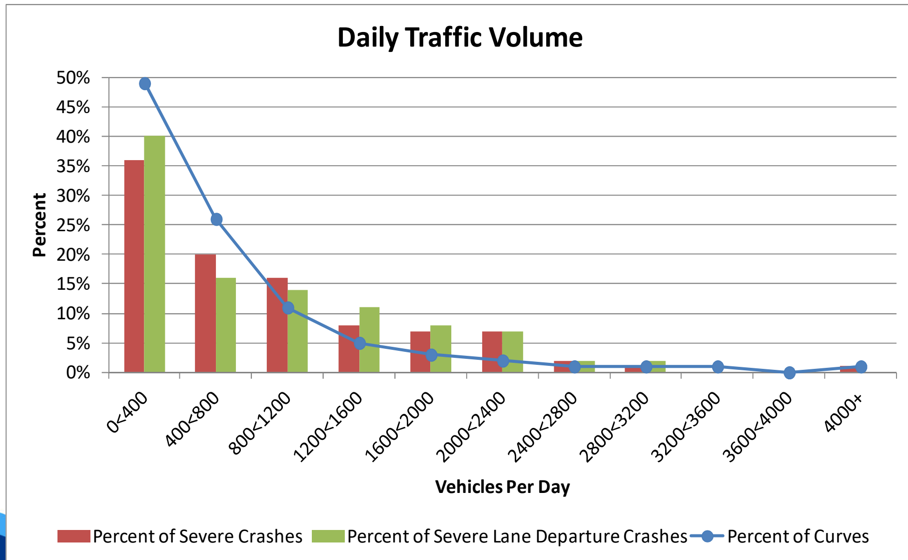
- Document crash history and patterns
- Document physical and traffic characteristics
- Conduct evaluation of network elements

Rank	Corridor	ADT Range	Road Departure Density	Access Density	Curve Critical Radius Density	Edge Risk	Totals
1	144.01	★	★	★	★	★	★★★★★
2	40.04	★	★	★	★	★	★★★★★
3	131.01		★	★	★	★	★★★★
4	9.02	★	★	★	★		★★★★
5	5.06	★	★	★	★		★★★★
6	31.02	★	★	★	★		★★★★
7	8.01	★	★			★	★★★
8	4.01		★	★		★	★★★
9	2.05			★	★	★	★★★

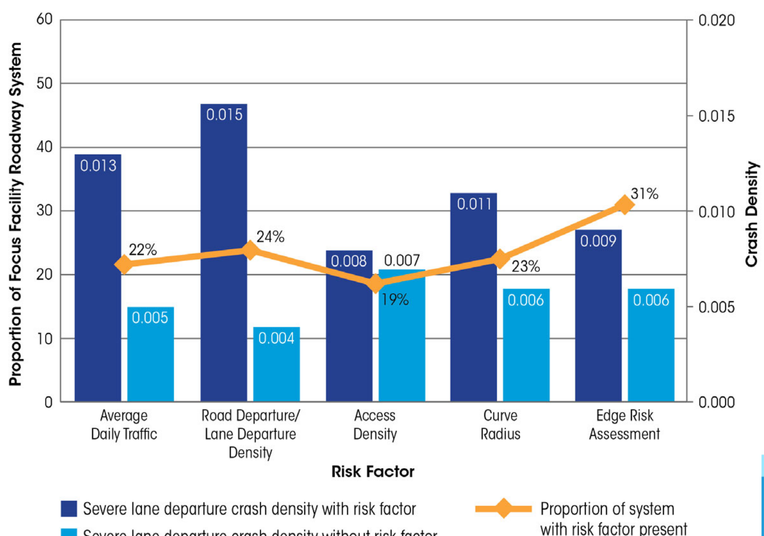
Data Driven: Quantitative vs. Qualitative

- **Use qualitative ratings when needed:**
  - Good, Fair, Not-So-Good (curve radius, roadside, etc.)
  - Number per segment, mile, roadway (curves, driveways, intersections, etc.)
  - High, Medium, Low (traffic volumes, pedestrian volumes, crash frequency, etc.)
- **It is important to include the risk factors that are key to your roadway network**

Risk Factor Assessment



Risk Factor Assessment



OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

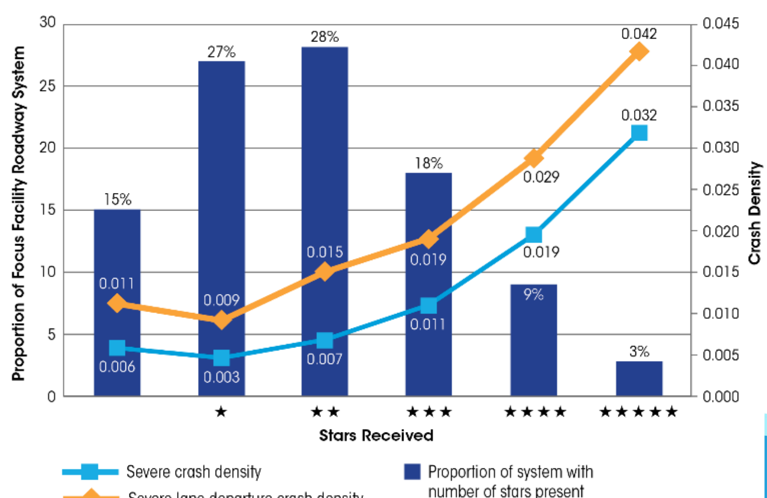
Task 3: Prioritize Focus Facility Elements

- Total the number of risk factors present
  - Assign equal or relative weights
  - Set threshold for high-priority candidates

Example Criteria for Relative Weight of Risk Factors

Category	Higher Confidence	Lower Confidence
Factor overrepresented by **X** percentage points	> 10%	≤ 10%
Factor present in **X%** of severe crashes	≥ 30%	< 30%
Weight	1 point	½ point
* Served as a guide, not a standard		

Use of Risk Assessment Results to Set Thresholds for Candidate Selection



Helpful Hints

CMF
CRASH MODIFICATION FACTORS CLEARINGHOUSE

- Assess risk factors
  - Do selected characteristics represent increased risk?
  - Data-driven (descriptive statistics and CMFs)
- Prioritize locations for further consideration
  - What level of risk deserves treatment?
- Collect additional data as needed
  - Is there sufficient data to conduct risk assessment?
  - Document characteristics of crash locations

Step 3: Select Countermeasures

Identify Focus Crash Types and Risk Factors

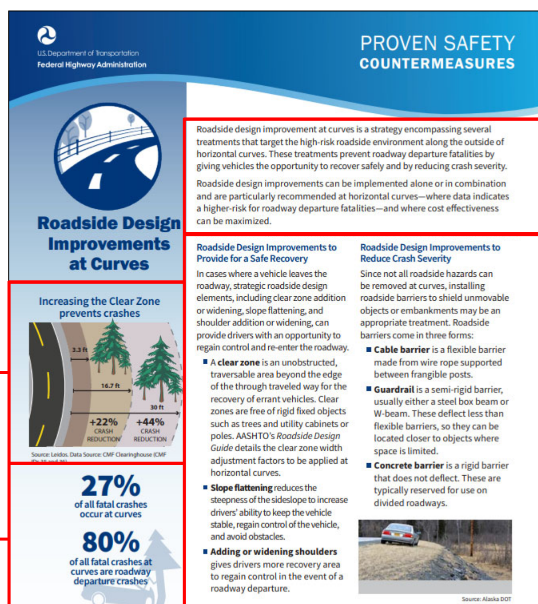
Screen and Prioritize Candidate Locations

Select Countermeasures
- Task 1: Assemble Comprehensive List of Countermeasures
- Task 2: Evaluate/Screen Countermeasures
- Task 3: Select Countermeasures for Deployment

Prioritize Projects

Task 1: Assemble Comprehensive List of Countermeasures

http://safety.fhwa.dot.gov/provencountermeasures


U.S. Department of Transportation
Federal Highway Administration

PROVEN SAFETY COUNTERMEASURES

Roadside Design Improvements at Curves

Roadside design improvement at curves is a strategy encompassing several treatments that target the high-risk roadside environment along the outside of horizontal curves. These treatments prevent roadway departure fatalities by giving vehicles the opportunity to recover safely and by reducing crash severity.

Roadside design improvements can be implemented alone or in combination and are particularly recommended at horizontal curves—where data indicates a higher-risk for roadway departure fatalities—and where cost effectiveness can be maximized.

Increasing the Clear Zone prevents crashes

+22% CRASH REDUCTION
+44% CRASH REDUCTION

27% of all fatal crashes occur at curves

80% of all fatal crashes at curves are roadway departure crashes

Roadside Design Improvements to Provide for a Safe Recovery

In cases where a vehicle leaves the roadway, strategic roadside design elements, including clear zone addition or widening, slope flattening, and shoulder addition or widening, can provide drivers with an opportunity to regain control and re-enter the roadway.

- A **clear zone** is an unobstructed, traversable area beyond the edge of the through traveled way for the recovery of errant vehicles. Clear zones are free of rigid fixed objects such as trees and utility cabinets or poles. AASHTO's *Roadside Design Guide* details the clear zone width adjustment factors to be applied at horizontal curves.
- **Slope flattening** reduces the steepness of the sideslope to increase drivers' ability to keep the vehicle stable, regain control of the vehicle, and avoid obstacles.
- **Adding or widening shoulders** gives drivers more recovery area to regain control in the event of a roadway departure.

Roadside Design Improvements to Reduce Crash Severity

Since not all roadside hazards can be removed at curves, installing roadside barriers to shield unmovable objects or embankments may be an appropriate treatment. Roadside barriers come in three forms:

- **Cable barrier** is a flexible barrier made from wire rope supported between frangible posts.
- **Guardrail** is a semi-rigid barrier, usually either a steel box beam or W-beam. These deflect less than flexible barriers, so they can be located closer to objects where space is limited.
- **Concrete barrier** is a rigid barrier that does not deflect. These are typically reserved for use on divided roadways.

Source: Alaska DOT

Description

Graphic

Body

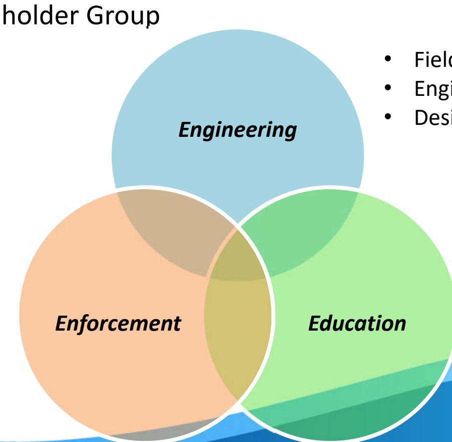
Statistics

http://safety.fhwa.dot.gov/provencountermeasures

Potential Countermeasures

Approaches to Assemble Countermeasures:

- Review Literature
- Convene Stakeholder Group



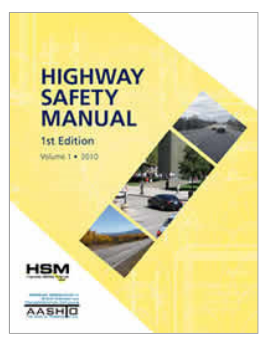
- Field Visit
- Engineering Standards
- Design/Operations

- Public Awareness
- Forums/Classes
- Countermeasure Education

- Traffic regulations and laws
- Law enforcement visibility

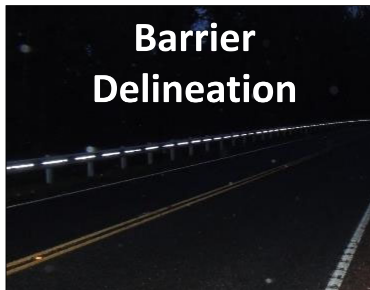
References for Countermeasures

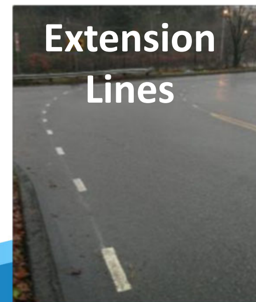
- **FHWA's Proven Safety Countermeasures**
- CMF Clearinghouse
- Highway Safety Manual
- **NHTSA's Countermeasures That Work**
- Strategic Highway Safety Plan
- Intersection Safety Plans
- Roadway Departure Safety Plans
- Human Factors Guidelines
- FHWA Desktop Reference for CRF's
- **National Cooperative Highway Research Program (NCHRP) Report 500**



Remember to Consider:
- Agency experience
- **Engineering judgment!**

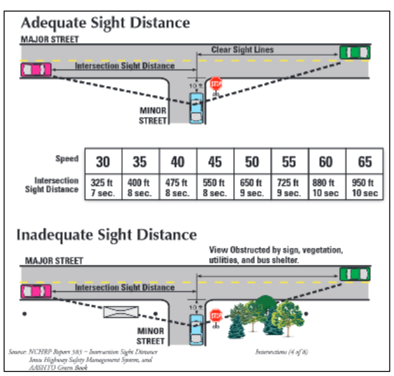
Roadway Departure Countermeasures



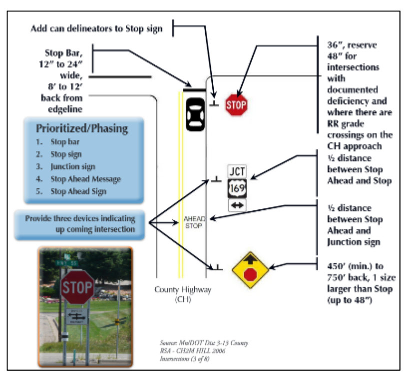


Source: Scott Davis, Thurston County, WA

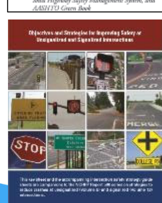
Intersection Countermeasures



Improve Sight Distance



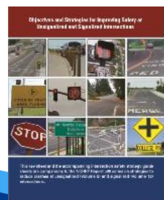
Enhance Signing and Delineation



https://safety.fhwa.dot.gov/intersection/other_topics/fhwasa08008/inter_guide_key.pdf

Pedestrian Countermeasures

Countdown Timers and Leading Pedestrian Intervals



https://safety.fhwa.dot.gov/intersection/other_topics/fhwasa08008/inter_guide_key.pdf

Publicized Sobriety Checkpoints

Effectiveness: ★★★★★	Cost: $$$	Use: Medium	Time: Short

- Authorized in 38 States + DC
- Documented Crash Reduction
  - All Crashes: 10-15%
  - Alcohol-related crashes: 17%
  - Alcohol-related fatal crashes: 9%

Page 1-21, https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/812202-countermeasuresthatwork8th.pdf

Short-Term High-Visibility Belt Checks

Effectiveness: ★★★★★	Cost: $$$	Use: Medium†	Time: Medium

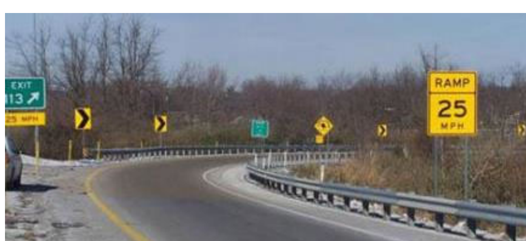
† Used in many jurisdictions but often only once or twice each year

- Documented Belt Use Increase
  - 16% increase
- Increased use in conjunction with public education/outreach and paid/donated media

Page 2-17, https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812202-countermeasuresthatwork8th.pdf

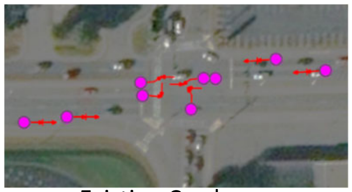
Task 2: Evaluate and Screen Countermeasures

- Documented **effectiveness**
- Implementation and maintenance **costs**
- Consistency with agency polices, practices, and experiences

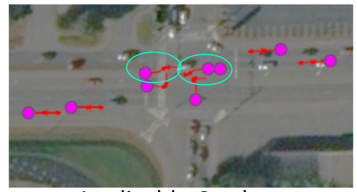


Source: Kentucky Transportation Cabinet

CMF Clearinghouse & CMF Evaluation



Existing Crashes



Applicable Crashes

Convert permissive to permissive/protected	
CMF	0.86
Crash Type	Left Turn
Crash Severity	All
Area Type	Urban
Geometry	4-leg
Star Quality Rating	★★★★☆

Proposed CMF

Crashes ***WITH*** Treatment =
CMF * Crashes ***WITHOUT*** Treatment

Crash Reduction

http://www.cmfclearinghouse.org/

Task 3: Select Countermeasures

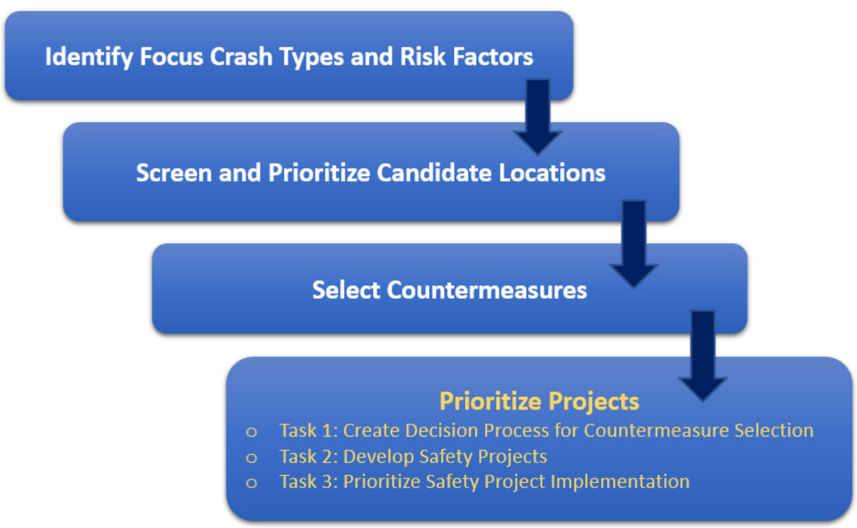
- Represent highest priorities
  - Most **cost-effective** countermeasures addressing **targeted** crash types
- Provide a range of options for **flexibility**
- Consistent with agency practices and policies

https://commons.wikimedia.org/wiki/File:Rumble_strip1.jpg

Helpful Hints

- Seek input from stakeholders during screening process
- Remove initial countermeasures that are not feasible
- There is no optimum number of countermeasures
  - Provide at least one alternative
- Determine appropriate number of locations for initial list
  - Goals and funding amounts
  - Identify locations for on-the-shelf projects
  - Implement with typical construction and maintenance projects
- Consider bundling low cost improvements.

Step 4: Prioritize Projects

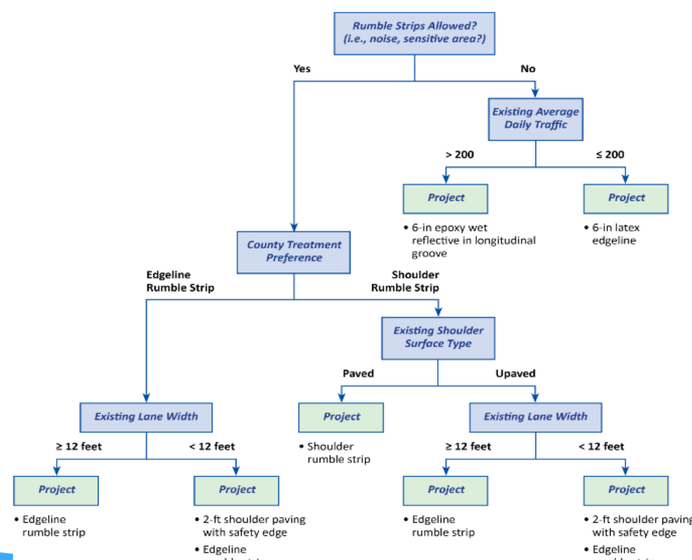


Task 1: Create Decision Process

- **Decision process**: set of criteria to identify appropriate countermeasure.
  - Provides consistency in project development
  - Considers multiple locations for which countermeasures are appropriate and affordable
  - E.g., traffic volume, environment, adjacent land use, or cross-section

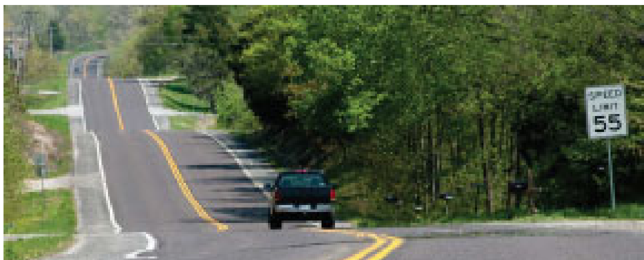
https://commons.wikimedia.org/wiki/File:Centerline_Rumble_Strip.jpg

Example Decision Process



Task 2: Develop Safety Projects

- Apply decision process
- Identify specific countermeasures for each candidate site
- Document decision process and results



https://safety.fhwa.dot.gov/provencountermeasures/uslimits2/

Example Documentation for Safety Project

Short List of Strategies Considered

Description	Type	Cost per mi	Mileage	Cost	Notes - Noise sensitive area adjacent to Big Lake.
2' Shoulder Pave+RS+Safety Edge	Proactive	$40,000	0.0	$0	
Rumble Strip	Proactive	$3,000	0.0	$0	
Rumble StripE	Proactive	$3,500	6.0	$21,000	
6" Edge Lines	Proactive	$650	0.0	$0	
Ground In Wet-Reflective Markings	Proactive	$8,500	2.0	$17,000	

Implementation Cost

Federal Funds	$34,200
Local Match (10% of Total project cost)	$3,800
Total Project Cost	**$38,000**

Rank:	1
Segment ID:	26.01
Date:	2/12/2011

Benefit-Cost Analysis

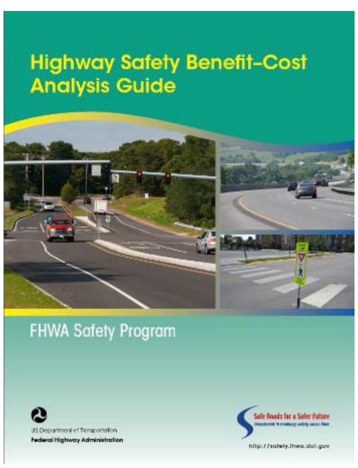
1. Determine if project is sound investment
2. Compare with alternative projects

Typical Measures:

- Crashes
- Fuel Use
- Travel Time
- Operating Costs

	Project 1	Project 2	Project 3
Benefits	$200,000	$150,000	$400,000
Costs	$50,000	$100,000	$200,000
B/C Ratio (Benefits/Costs)	4.0	1.5	2.0
Net Benefit (Benefits – Costs)	$150,000	$50,000	$200,000

FHWA Highway Safety Benefit-Cost Analysis Guide and Tool



https://safety.fhwa.dot.gov/hsip/docs/fhwasa18001.pdf

Systemic Benefit-Cost Example

- Curve treatments at multiple locations
  - Focus crash type = fatal and serious injury
  - Focus facility type = rural two-lane curves
  - Small curve radius is primary risk indicator
- BCA can support project prioritization

Summary of Potential Curves

Curve	AADT (vehicles per day)	Length of Curve (miles)	Radius of Curve (feet)
1	6,500	0.070	350
2	7,500	0.100	500
3	5,000	0.060	450
4	7,000	0.110	500
5	5,500	0.060	250
6	7,500	0.190	450
7	10,000	0.230	500
8	6,000	0.070	250
9	8,500	0.170	400
10	9,500	0.210	500

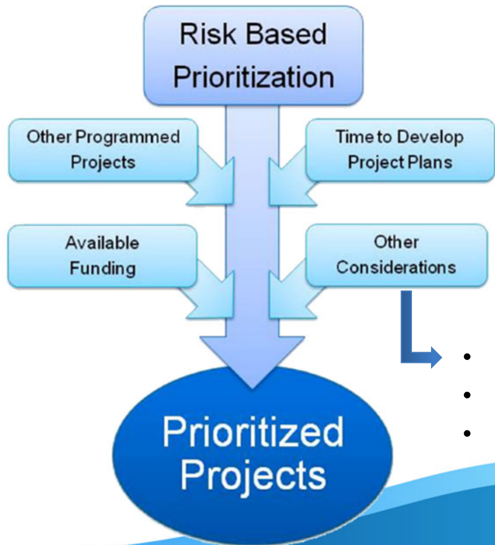
Summary of Safety Performance

Curve	AADT	Length	Radius	HSM Base SPF (Total Crashes)	CMF	With Curve (Total Crashes)
1	6,500	0.070	350	0.1216	3.11	0.3784
2	7,500	0.100	500	0.2004	2.03	0.4078
3	5,000	0.060	450	0.0802	2.92	0.2339
4	7,000	0.110	500	0.2057	1.94	0.3992
5	5,500	0.060	250	0.0882	4.45	0.3924
6	7,500	0.190	450	0.3807	1.61	0.6111
7	10,000	0.230	500	0.6145	1.45	0.8910
8	6,000	0.070	250	0.1122	3.96	0.4439
9	8,500	0.170	400	0.3861	1.76	0.6799
10	9,500	0.210	500	0.5330	1.49	0.7957

Systemic Curve Program: BCA Results

Curve	Safety	Travel Time	Fuel Use	Emissions	Total Present Value Benefit	Benefit-Cost Ratio
1	$53,692	$132	$9	$4	$53,836	53.84
2	$60,689	$143	$9	$4	$60,845	60.85
3	$34,502	$82	$5	$2	$34,591	34.59
4	$60, 075	$140	$9	$4	$60,227	60.23
5	$59,850	$138	$9	$4	$60,001	60.00
6	$88,177	$213	$14	$6	$88,410	88.41
7	$130,835	$311	$20	$9	$131,176	131.18
8	$67,912	$156	$10	$4	$68,082	68.08
9	$97,414	$237	$16	$7	$97,673	97.67
10	$114,698	$277	$18	$8	$115,002	115.00

Task 3: Prioritize Safety Projects



- Education
- Enforcement
- Maintenance

EXERCISE: Select Risk Factors, Countermeasure, and the High Priority System

You're developing a systemic safety program:

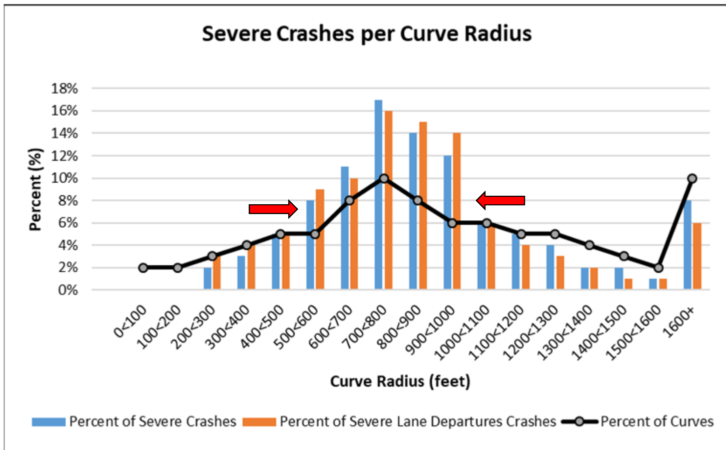
- Focus crash type: **severe lane departure crashes**
- Focus facility type: **rural paved horizontal curves**
- 7 potential risk factors

Topics of Discussion:

- Review potential risk factors
  - **Which are actual risk factors for further risk assessment?**
- Discuss potential systemic countermeasures
  - **What are 2-3 targeted systemic countermeasures?**
- Discuss potential decision process (i.e., triggers)
  - **Where/when to deploy each countermeasure?**
- Discuss 4th chart (summary of risk assessment)
  - **What portion of the system you will deploy your countermeasures?**

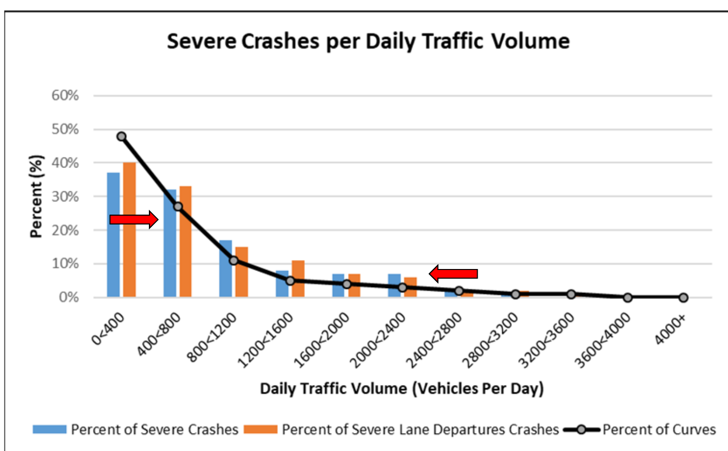
EXAMPLE: Select Risk Factors

Risk Factor 1



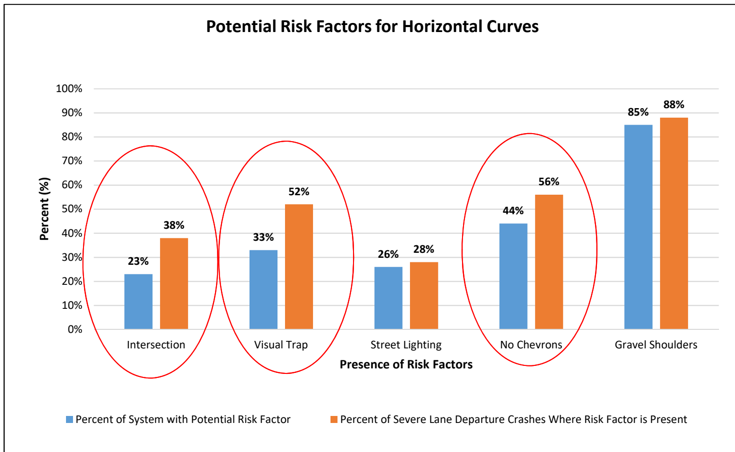
EXAMPLE: Select Risk Factors

Risk Factor 2



EXAMPLE: Select Risk Factors

Risk Factor 3-7



OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

99

EXAMPLE: Select Countermeasures

Topics of Discussion:

- Select up to 3 targeted countermeasures for systemic implementation.
- Discuss the decision process (i.e., triggers) for where to deploy each countermeasure.

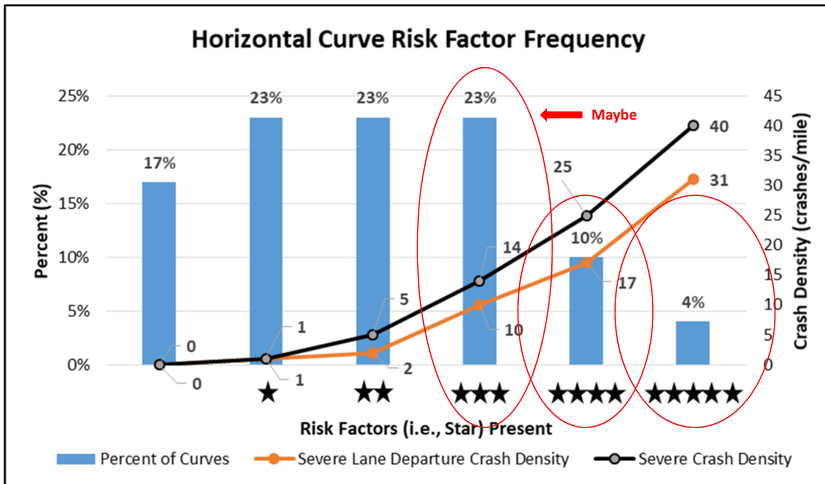
Appropriate countermeasures may include:

- Installing chevrons
- Installing edge line extensions through intersections
- Paving shoulders
- Installing centerline or edge rumble strips

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

100

Example: Select Portion of System to Apply Countermeasures

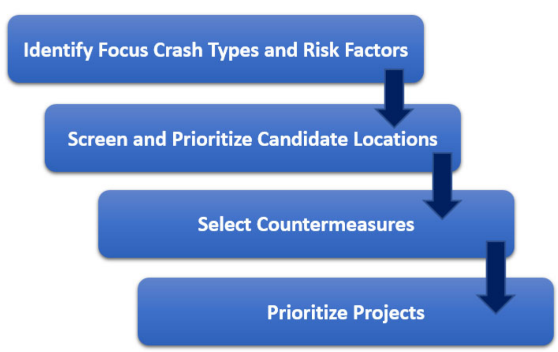


Activity 2

Select Risk Factors

Identify Potential Countermeasures

Create Decision Tree



Systemic Variations in Practice

Table 1. Summary of variations to the systemic approach.

Method	Approach	Benefits
Benefit-Cost Threshold	Begins with crash-based or systemic approach, but adds site-based crash threshold to achieve minimum desired benefit-cost ratio.	Helps to maintain a minimum benefit-cost ratio. Potential for a higher return on investment.
Hybrid Systemic and Crash-Based	Combines the crash-based and systemic approach to identify candidate locations based on safety performance.	Identifies sites with potential for improvement based on observed or expected safety performance.

https://safety.fhwa.dot.gov/rsdp/downloads/fhwasa16041.pdf

Benefit-Cost Threshold Example

- Roadway
  - Rural
  - 2 Lane Undivided
- Prioritized Sites
  - > 5,000 vehicles per day
  - > 0.01 head-on crashes/mile
- Funding
  - B/C Ratio 2.0
  - $2,500 per mile
  - CMF 0.70
  - $400,000 per crash
- Results
  - Final B/C Ratio 4.0

https://www.flickr.com/photos/zaheerm/5256064985

https://safety.fhwa.dot.gov/rsdp/downloads/fhwasa16041.pdf

Hybrid Systemic/Crash-Based Example

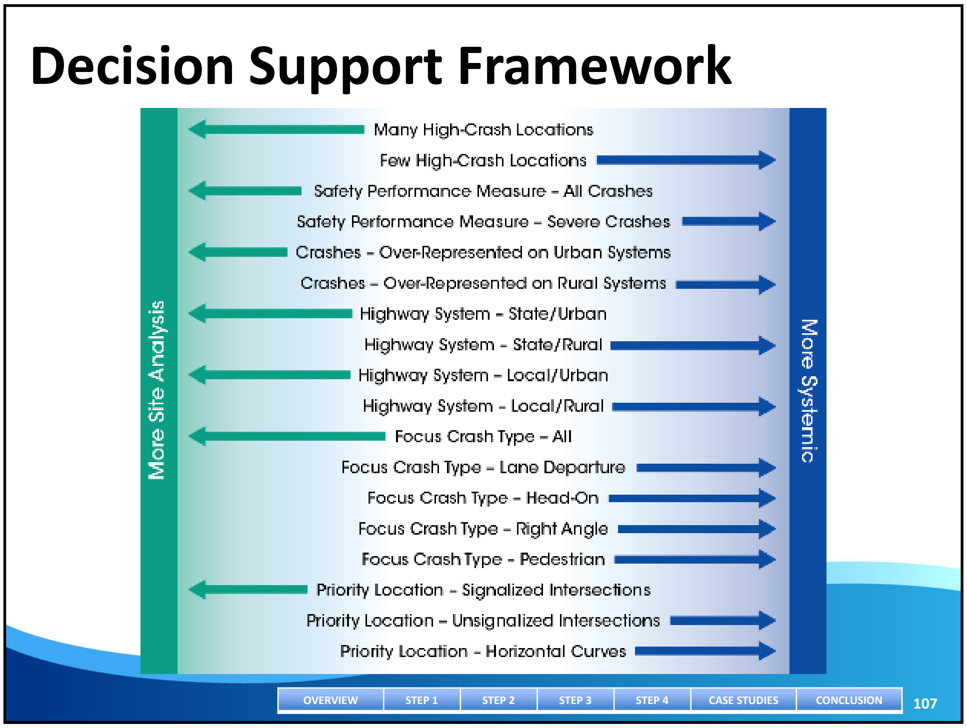
https://commons.wikimedia.org/wiki/File:MUTCD_W1-2L.svg

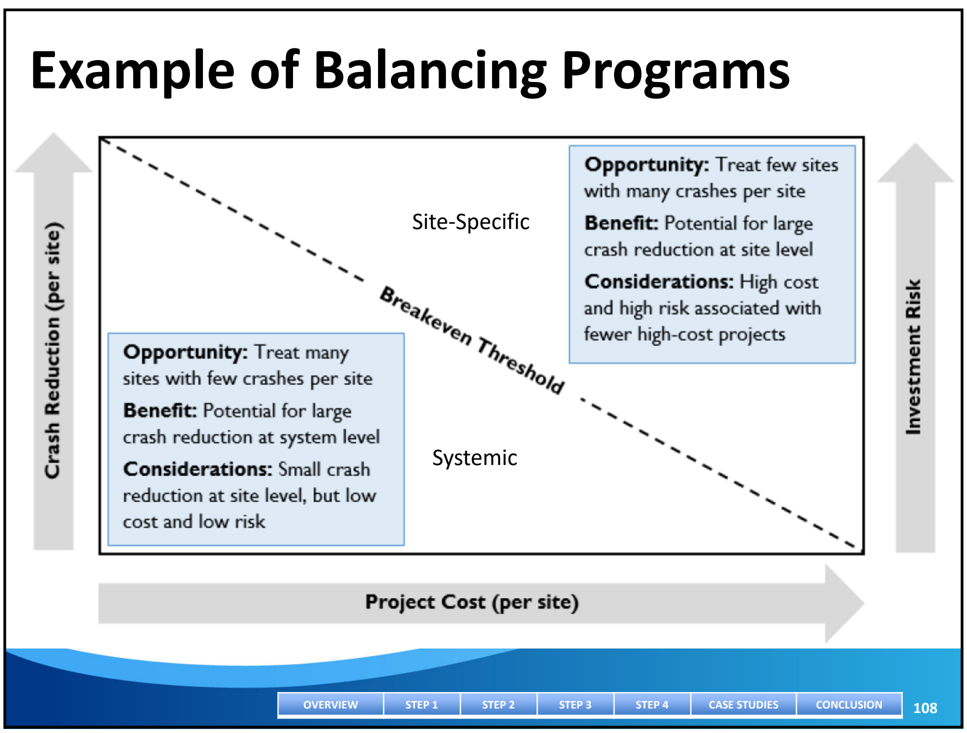
- Focus Crash Type
  - Roadway Departure
- Performance Measure
  - Excess expected RwD crashes
- Common Characteristics
  - Horizontal curvature
  - Lack of advance warning
  - Lack of in-curve warning
- Countermeasure Package
  - Advance warning
  - In-curve warning

https://safety.fhwa.dot.gov/rsdp/downloads/fhwasa16041.pdf

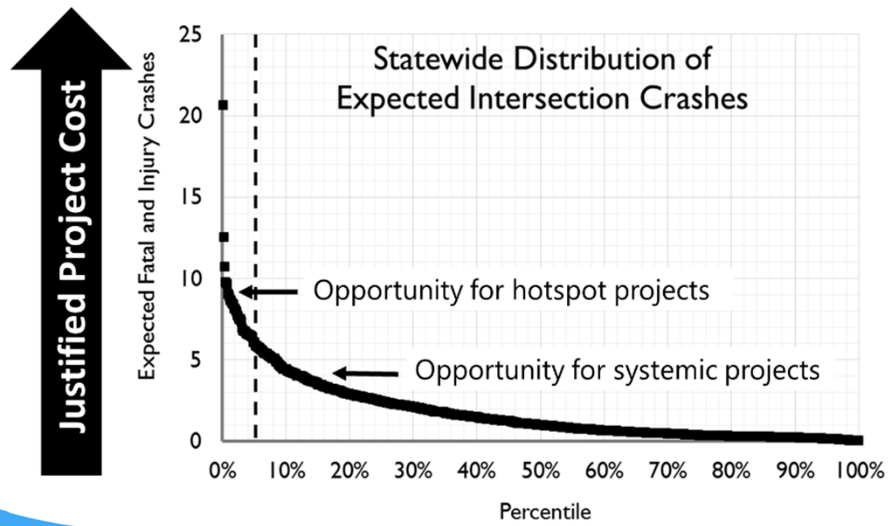
Additional Considerations

- Element 2
- Element 3


Decision Support Framework
More Site Analysis
More Systemic
Many High-Crash Locations
Few High-Crash Locations
Safety Performance Measure – All Crashes
Safety Performance Measure – Severe Crashes
Crashes – Over-Represented on Urban Systems
Crashes – Over-Represented on Rural Systems
Highway System – State/Urban
Highway System – State/Rural
Highway System – Local/Urban
Highway System – Local/Rural
Focus Crash Type – All
Focus Crash Type – Lane Departure
Focus Crash Type – Head-On
Focus Crash Type – Right Angle
Focus Crash Type – Pedestrian
Priority Location – Signalized Intersections
Priority Location – Unsignalized Intersections
Priority Location – Horizontal Curves
OVERVIEW
STEP 1
STEP 2
STEP 3
STEP 4
CASE STUDIES
CONCLUSION
107


Example of Balancing Programs
Crash Reduction (per site)
Investment Risk
Project Cost (per site)
Site-Specific
Breakeven Threshold
Systemic
Opportunity: Treat few sites with many crashes per site
Benefit: Potential for large crash reduction at site level
Considerations: High cost and high risk associated with fewer high-cost projects
Opportunity: Treat many sites with few crashes per site
Benefit: Potential for large crash reduction at system level
Considerations: Small crash reduction at site level, but low cost and low risk
OVERVIEW
STEP 1
STEP 2
STEP 3
STEP 4
CASE STUDIES
CONCLUSION
108

Example of Balancing Programs



Three-Level Systemic Program Evaluation

1. Output / activity level
   – Are projects implemented?
2. Observed trends in crash frequency and severity for focus crash type
   – Are trends decreasing?
3. Countermeasure performance
   – What is actual effectiveness?

https://www.flickr.com/photos/71195909@N03/28955874330

Case Studies

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

111

Minnesota: Ped Bike Safety Case Study

Using Systemic Safety to Address Pedestrian and Bicycle Crashes

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

112

Minnesota: Ped Bike Safety Case Study

Severe Pedestrian Crashes (2008 – 2012)

- ❖649 severe crashes
- ❖9% of all severe crashes
- ❖16% of all pedestrian crashes were severe
- ❖78% occurred in urban areas
- ❖74% occurred on local roads
- ❖51% occurred at intersections

Severe Bicyclist Crashes (2008 – 2012)

- ❖286 severe crashes
- ❖4% of all severe crashes
- ❖85% occurred in urban areas
- ❖85% occurred on local roads
- ❖67% occurred at intersections

Minnesota: Ped Bike Safety Case Study

Identify Focus Crash Types

Why?

- ➢ Determine the categories of severe crashes with the greatest opportunity for reduction

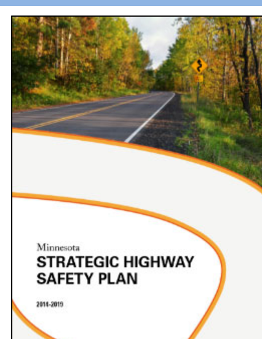
How?

- ➢ MnDOT used results of a statewide crash data analysis performed for Minnesota's 2014 SHSP update to identify focus crash types

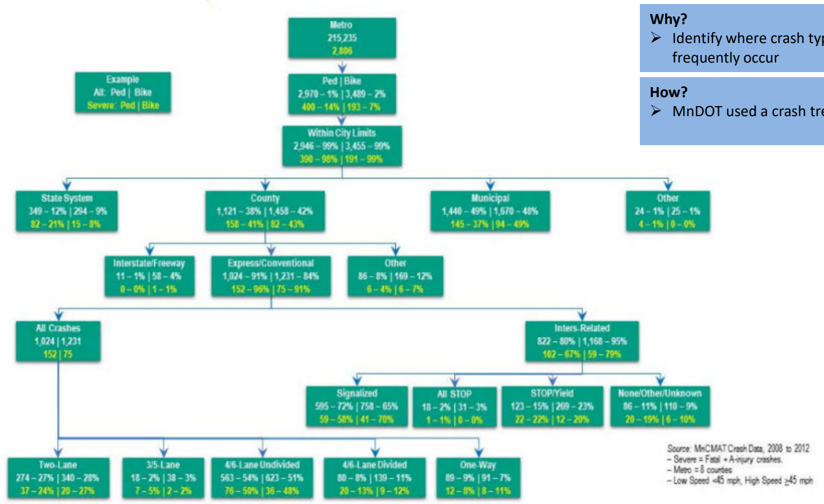
Focus Area	Crashes	Percent
Lane departure	3,199	45.5%
Intersection	2,945	41.9%
Unbelted occupants	2,463	35.0%
Impaired roadway users	1,850	26.3%
Younger drivers	1,367	19.4%
Inattentive drivers	1,319	18.7%
Speed	1,309	18.6%
Motorcyclists	1,244	17.7%
Older drivers	1,028	14.6%
Commercial vehicles	714	10.1%
Unlicensed drivers	702	10.0%
Pedestrians	**649**	**9.2%**
Bicyclists	**286**	**4.1%**
Work zones	103	1.5%
Trains	21	0.3%

Minnesota's Focus Crash Types

Source: http://www.dot.state.mn.us/trafficeng/safety/shsp/



Minnesota: Ped Bike Safety Case Study



Select Focus Facility Types

Why?
- Identify where crash types most frequently occur

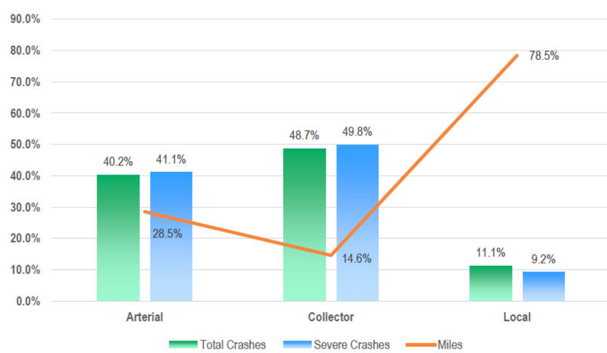
How?
- MnDOT used a crash tree analysis

Source: Adapted from CH2M, 2014.

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

115

Minnesota: Ped Bike Safety Case Study



Source: Adapted from CH2M, 2016.

Select Focus Facility Types

Why?
- Identify where crash types most frequently occur

How?
- MnDOT compared the proportion of roadway mileage to the proportion of crashes

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

116

Minnesota: Ped Bike Safety Case Study

Identify Risk Factors

Why?

- Identify roadway characteristics and network elements to use as an initial set of potential risk factors to be further evaluated for use in systemic network screening

How?

- MnDOT analyzed data to identify an initial list of recurring roadway and traffic characteristics at crash locations

Characteristic	Minnesota County Roadway Safety Plans	Minnesota District Safety Plans
Traffic Signal	●	●
Speed Limit	●	●
Four Legs	●	
Undivided	●	
Bus Stop	●	
Ped Generator	●	●
Volume	●	●
Skew		●
Curve		●

Source: CH2M, 2016.

Minnesota: Ped Bike Safety Case Study

Evaluate Risk Factors

Why?

- Establish recurring roadway characteristics at crash locations

How?

- MnDOT used the identified risk factors during a systemic analysis to identify recurring roadway characteristics at crash locations

4 Common Intersection Characteristics

- **Traffic Signal Control.** >60% of severe pedestrian and bicycle crashes occurred at intersections; nearly 60% of these intersections had traffic signal control
- **Speed Limit.** Nearly 60% of severe pedestrian and bicycle crash locations had a 30 MPH speed limit
- **Surrounding Land Use.** ~75% of severe pedestrian and bicycle crashes occurred at intersections where a pedestrian generator (retail or institutional land use) was present
- **Volume.** Nearly 60% of severe pedestrian and bicycle crashes occurred at intersections where the major road entering volume was greater than 17,500 vehicles per day

Minnesota: Ped Bike Safety Case Study

Prioritize Focus Facility Elements

Why?

- Evaluate the risk factors of the systems and locations selected for analysis using roadway and traffic characteristics in order to rank/prioritize at-risk locations

How?

- Used aerial photography and video-logs to screen the focus facilities to document risk factors present at 1,979 signalized intersections
- Prioritized intersections as candidates for safety investments based on the number of risk factors present
- When the number of risk factors present was equal across a number of intersections, the ranking was then based on the designated crash cost

#	Intersection ID	Route System	Route No.	Description	Speed Limit	Cross Product[b]	Traffic Control	Major Corridor Speed	Skew	On/Near Curve	Primary Land Use	Severe Ped/Bike Crash Density	Total Stars	Crash Cost
34	3.210.025	MN	210	4TH ST NWCSAH20 MSAS103/BRNRD	35	★	★	★		★	★		★★★★★	$1,050,200
35	3.024.009	MN	24	CSAH 75/CLEARWATER	40	★	★	★	★		★		★★★★★	$747,600
36	3.023.028	MN	23	19 1/2 AV/ST CLD	35	★		★	★	★	★		★★★★★	$574,800
37	3.023.050	MN	23	TH 25/FOLEY	45	★	★	★	★		★		★★★★★	$558,000
38	3.027.015	MN	27	4TH ST MSAS 106/LITTLE FALLS	30	★	★		★	★	★		★★★★★	$366,400

Source: CH2M, 2016.

Minnesota: Ped Bike Safety Case Study

Select Countermeasures

Why?

- Identify feasible countermeasures that are proven to reduce pedestrian and bicycle crashes

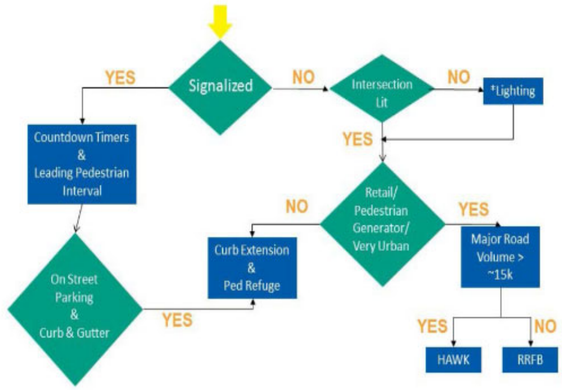
How?

- Assembled comprehensive list of countermeasures
- Evaluated and screened initial list to identify feasible countermeasures
- Identified short list based on evaluation and agency priorities, practices, and policies

Countermeasure	Crash Reduction Factor	Implementation Cost
Countdown Timers	25%	$12,000 per intersection
Leading Pedestrian Interval	Up to 60%	$600 per intersection
Lighting	33%-44%	$10,000-$25,000 per intersection
Curb Extensions	30%-46%	$36,000 per corner
Median Refuge Island	39%-46%	$24,000 per approach
High-intensity Activated crossWalK (HAWK) Signals	69%	$50,000-$120,000
Rapid Flash Beacons	Increase Yield to Pedestrians	$15,000

Source: CH2M, 2016.

Minnesota: Ped Bike Safety Case Study



Project Development

Why?

- Identify and prioritize at-risk candidate intersections for safety projects

How?

- MnDOT developed a project development decision tree

#	Intersection ID	Route System	Route No.	Description	Reference Point	Risk Rating	Countdown Timers	Leading Ped Interval	HAWK	RRFB	Curb Extension	Median Refuge	Lighting	Project Cost
34	3.210.025	MN	210	4TH ST NWCSAH20 MSAS103/BRNRD	121+00.917	★★★★★	1					4		$ 108,000
35	3.024.009	MN	24	CSAH 75/CLEARWATER	044+00.401	★★★★★	1							$ 12,000

Source: CH2M, 2016.

Minnesota: Ped Bike Safety Case Study

- Summary
  - Systemic process assisted in the identification of focus crash and facility types
  - Adoption of a set of risk factors
  - Screening and prioritizing of the systems
  - Development of a short-list of safety countermeasures
  - Identification of more than $13 million worth of pedestrian and bicycle focused safety projects at designated high risk candidate locations

Thurston County, Washington

Applying Systemic Safety on Local Roads

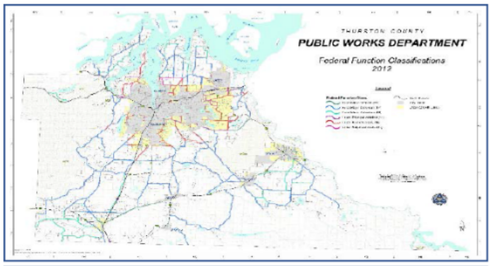
OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

Thurston County, Washington

2006-2010 Collision Data	Fatal/Serious Injury Crashes Only		
	All Roads	All Counties	Thurston County
Angle (left-Turn)	16% (2175)	13% (468)	9% (16)
Intersection-Related	33% (4557)	22% (812)	19% (34)
Horizontal Curve	26% (3674)	39% (1419)	45% (80)

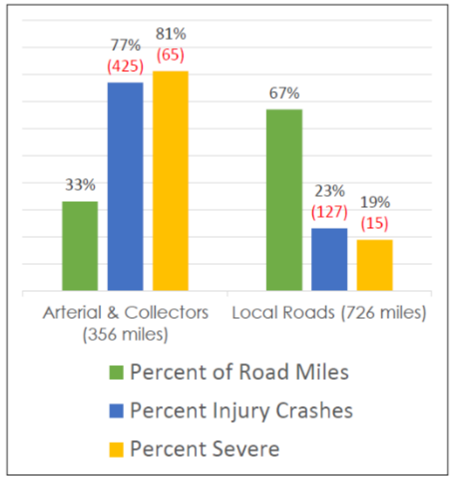
OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

Thurston County, Washington



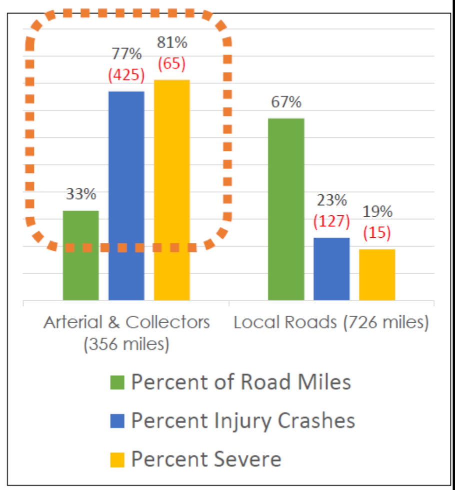
Next we were left with:

- Over 1000 centerline miles
- Over 1500 crashes



Thurston County, Washington

Focus area reduced to about 350 centerline miles



Thurston County, Washington

Focus Crash Type

Roadway Departures in Horizontal Curves

Focus Facility Type

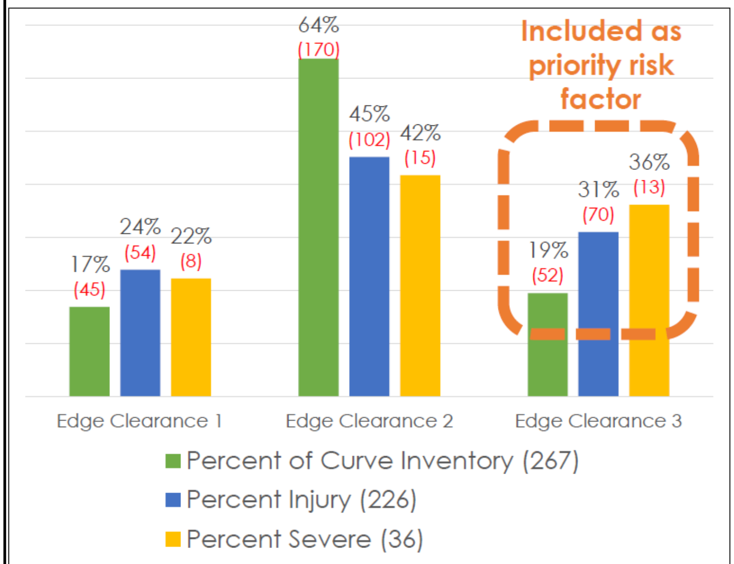
Arterial and Collector Roadways

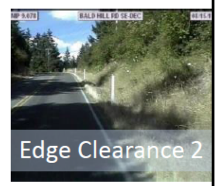
Thurston County, Washington

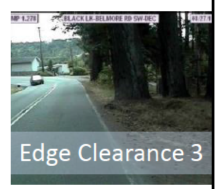
9 Risk Factors

- Roadway Class of Major Rural Collector
- Presence of Intersection
- Traffic Volume
- Edge Clearance Rating
- Width of Paved Shoulder
- Presence of Vertical Curve
- Consecutive Horizontal Curves
- Speed Differential
- Visual Trap

Thurston County, Washington

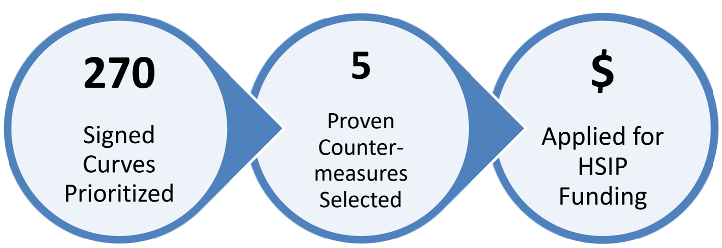






Source: Thurston County Public Works

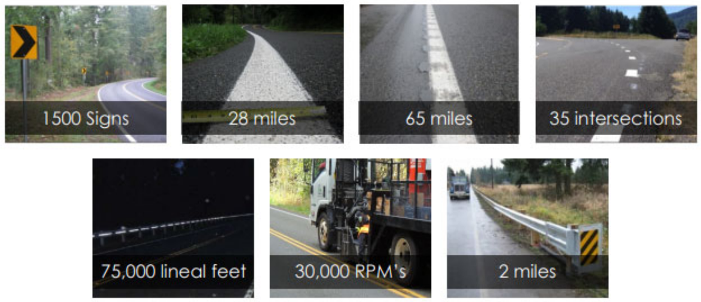
Thurston County, Washington

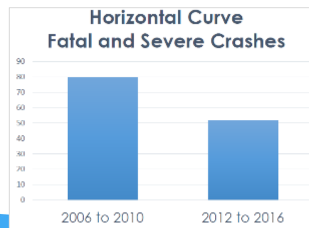


- Chevron and large arrow signs
- Larger signs
- Rumble strips
- Barrier delineation
- Extension lines

Note: In addition to the 5 proven countermeasures provided, Thurston County use low-cost and corridor consistency countermeasures.

Thurston County, Washington





35% Reduction in Target Crashes

Source: http://www.countyengineers.org/assets/docs/LRSP%20Pilot_Webinar%203.pdf

Ohio: Intersection and Curve Case Study

Applying Systemic Safety at Intersections and Curves

Ohio: Intersection and Curve Case Study

Ohio DOT

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Ohio LTAP

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Systemic Signage Intersection and Curve Upgrade Program for Targeted Ohio Townships

Ohio: Intersection and Curve Case Study

Source: Ohio DOT/LTAP

BEFORE

AFTER

Conclusion

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

135

Workshop Goals

http://goldenchamber.org/uncategorized/what-are-the-key-elements-i-must-put-in-place-to-reach-my-goals/attachment/goals/

- Familiarity with systemic safety planning concept
- High-level understanding of the systemic approach
- Knowledge of the resources required to apply the systemic approach
- Desire and determination to start or continue systemic safety planning

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION

136

Learning Objectives

- Understand and apply the 4-step systemic safety planning process
- Access and apply available resources for applying the systemic approach

Key Takeaways

- Develop a Systemic Safety Planning Approach
  - Identify data needs and potential risk factors
  - Implement systemic projects
- Promote Systemic Approach
  - Share success stories
- Other Possible Action Items?

Factors Influencing Approach

- Data availability
- Resources
- Established priorities
- State/local agency relationship

Systemic Safety Resources

- State
  - Strategic Highway Safety Plans
  - Safety Implementation Plans
- FHWA
  - Systemic Safety Project Selection Tool
  - Crash Tree Maker and User Guide
  - CMF Clearinghouse
  - Reliability of Safety Management Series
  - Highway Safety Benefit-Cost Analysis Guide and Tool
- AASHTO
  - Highway Safety Manual (HSM)
  - NCHRP Report 500 Series
  - AASHTOWare Safety Analyst
- Roadway Safety Foundation
  - US Road Assessment Program (usRAP)

Roadway Safety Data Program (RSDP) Toolbox

https://safety.fhwa.dot.gov/rsdp/

Systemic Approach to Safety

Using Risk to Drive Action

Source: https://safety.fhwa.dot.gov/systemic/

OVERVIEW | STEP 1 | STEP 2 | STEP 3 | STEP 4 | CASE STUDIES | CONCLUSION