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Reducing Crashes through Systemic Safety Analysis

August 4, 2021

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REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

Learning Objective

Use systemic safety management approaches in program safety improvement projects

#TRBwebinar

Reducing Crashes through Systemic Safety Analysis

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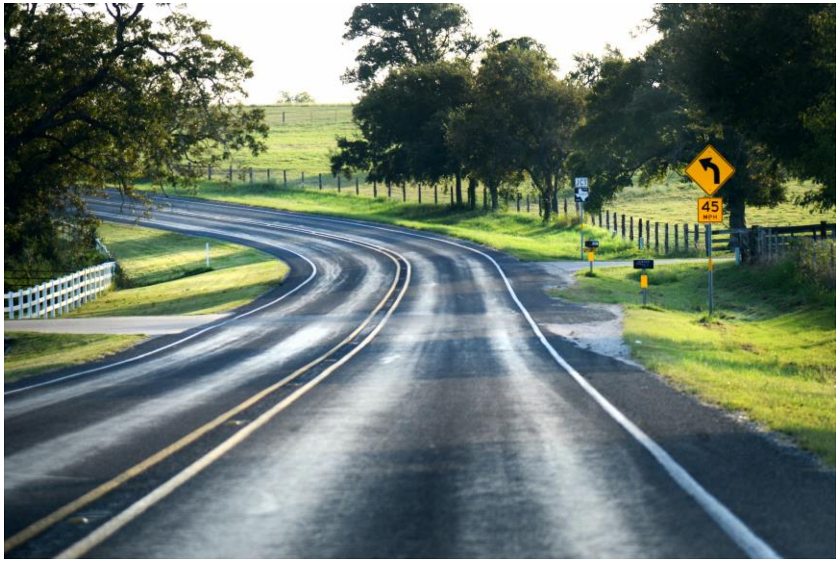
Outline

- Introduction
- Safety Management Approaches
- Systemic Safety Management in Depth
- Selecting Appropriate Systemic Approach and Software Tool
- Systemic Safety in Use (Best Practices)
- Summary of Systemic Safety Management Approach
- Primary Products of Research
- Future Research Needs



Introduction

Background

- Focusing safety treatments on “hot spot” locations has limitations:
  - Short-term crash counts can fluctuate
    - Not good predictor of future crashes
    - Regression to the mean
  - Severe crashes tend to be spread out across system
  - Most money is spent at only a few locations
  - Hot-spot analysis is reactive

Background

- Agencies seek complement to crash-history-based safety management approach (i.e., hot-spot analysis)….

Systemic Safety Management:

– More proactive

– Solutions that address more locations

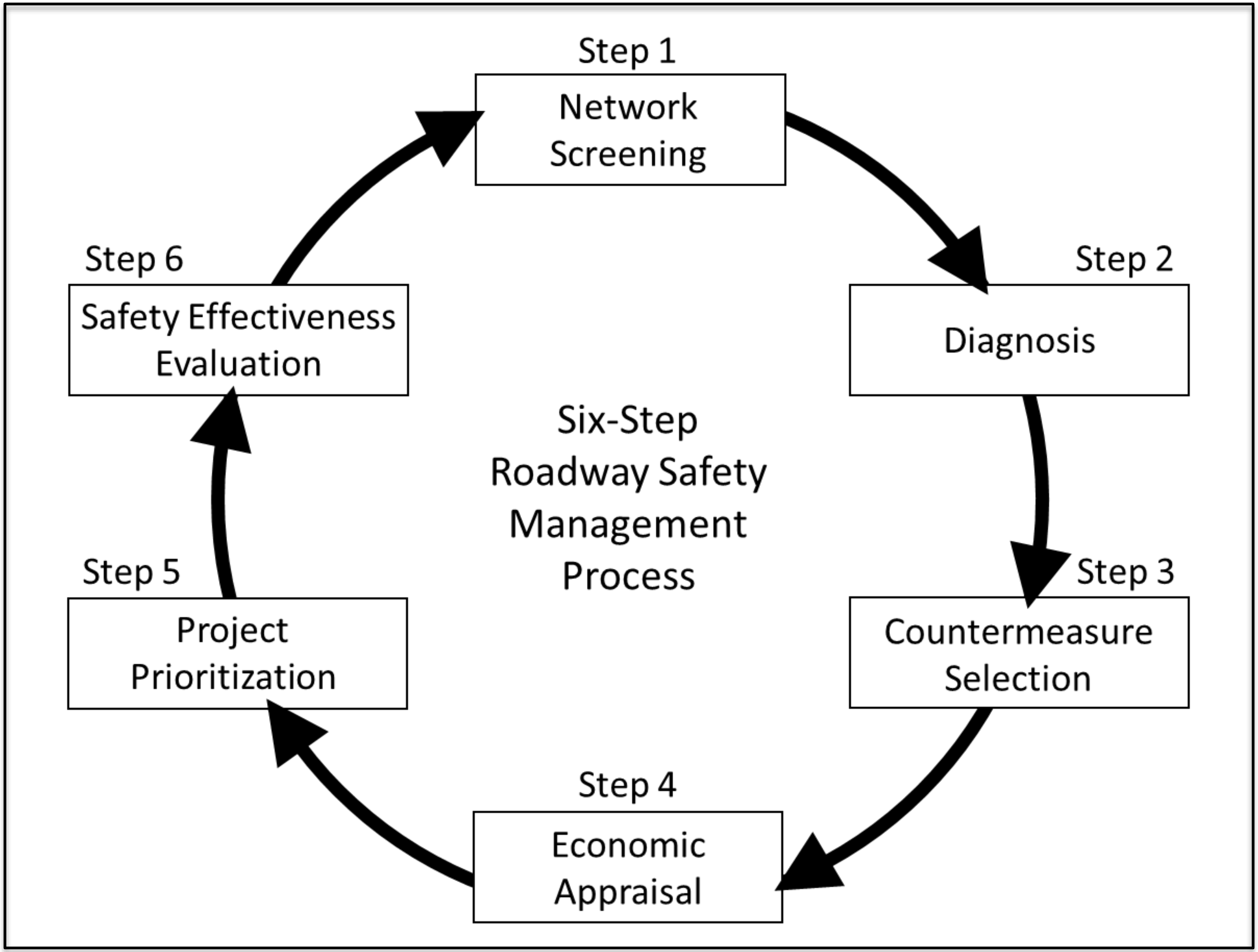
– Strategies address crash types spread across system

Objectives and Scope

- Objective—*Develop guide and training materials to assist state DOTs, MPOs, local agencies, and other safety practitioners to better understand, use, and implement quantitative approaches to systemic safety analysis*
- Scope—
  - Define quantitative approaches to systemic safety and distinguish from other safety management approaches
  - Communicate benefits of systemic safety analysis
  - Review existing tools and resources
    - Data needs
    - Capabilities
    - Appropriate applications
  - Recommend methods for evaluating results
  - Identify best practices

Safety Management Approaches

Six-Step Safety Management Process (HSM)



Crash-History-Based Safety Management Approach

Purpose: Identify locations on system where high frequency or rate of crashes has occurred and to improve those sites to remedy the situation

- Identifies locations with high crash experience
- Requires reliable crash data with location information
- Performance measures:
  - Observed crash frequencies and/or rates
  - Expected and/or excess crash frequencies
  - Level of service of safety (LOSS)

- Goal is to reduce crash patterns of interest that occur with high frequency at individual locations

Crash-History-Based Approach Benefits and Limitations

- Benefits:
  - Focuses resources at sites with crash history
  - Treatments tailored to crashes at individual sites
  - Addresses wide range of safety conditions and tradeoffs using quantitative and logical process

- Limitations:
  - Sites need crash history before improvements are made
  - May be addressing crashes that would not occur again (i.e., regression to the mean)
  - Higher cost treatments limit number of improved sites
  - Difficult to address crash types dispersed across system

Systemic Safety Management Approach

Purpose: Be more proactive in programming safety improvements and address crash types not well suited for remedy using crash-history-based safety management approach by widely implementing low-cost countermeasures

- Works well for highly-dispersed crash types:
  - Lane departure
  - Rollover
  - Fixed object
  - Speed-related
  - Impaired driving
  - Young/elderly driver involved
  - Pedestrians
  - Bicyclists
  - Nighttime

- Performance measures are expected future crashes based on presence/absence of site characteristics associated with certain crash types or crash prediction models

Systemic Safety Approach Benefits and Limitations

- Benefits:
  - Can be applied in absence of high-quality crash data
  - Proactive
  - Program projects further into future based on site characteristics that do not change year to year
  - Easier to more equally distribute funds regionally
  - Adaptable based on available data

- Limitations:
  - Software tools can be expensive, data intensive, or require substantial training or resources
  - Process for evaluating benefits not well understood
  - Staff may be reluctant to spend resources at sites with no crashes

Policy-Based Safety Management Approach

Purpose: Bring design or operational features of sites up to specified standard or policy

- Applies proven countermeasure to all sites on system where treatment is relevant
  - Does not require detailed crash data for all sites
  - Primarily low-cost treatments
  - Implementation can be done by incorporating into other scheduled projects (reducing costs)

- Economic analyses are often not performed

Policy-Based Approach Benefits and Limitations

- Benefits:
  - Focuses on low-cost, proven treatments
  - Can be used where crash data are not available
  - Proactive
  - Easily understood
  - Implementation costs may be less when incorporated into programmed projects

- Limitations:
  - May take years to fully implement
  - May be viewed as increasing construction/maintenance costs
  - Resources may not be allocated efficiently to address sites with greatest potential for crash reduction first

Distinguishing Systemic Safety Management from Other Safety Management Approaches

- Sometimes safety management steps are re-ordered where analysis starts with crash type of interest or even countermeasure of interest and then sites are prioritized for addressing that crash type/using specified countermeasure

- Network screening generally uses one of two approaches:
  - Safety performance functions (or crash prediction models) address specific crash types
  - Rating system used to prioritize locations based on presence/absence of features associated with crashes

- Diagnosis and countermeasure selection cursory in nature

Systemic Safety Management

Systemic Safety Management Approaches

- Application of FHWA *Systemic Safety Project Selection Tool*
- Application of SPFs for systemic safety
- Application of usRAP methodology and ViDA software

Application of FHWA *Systemic Safety Project Selection Tool*

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

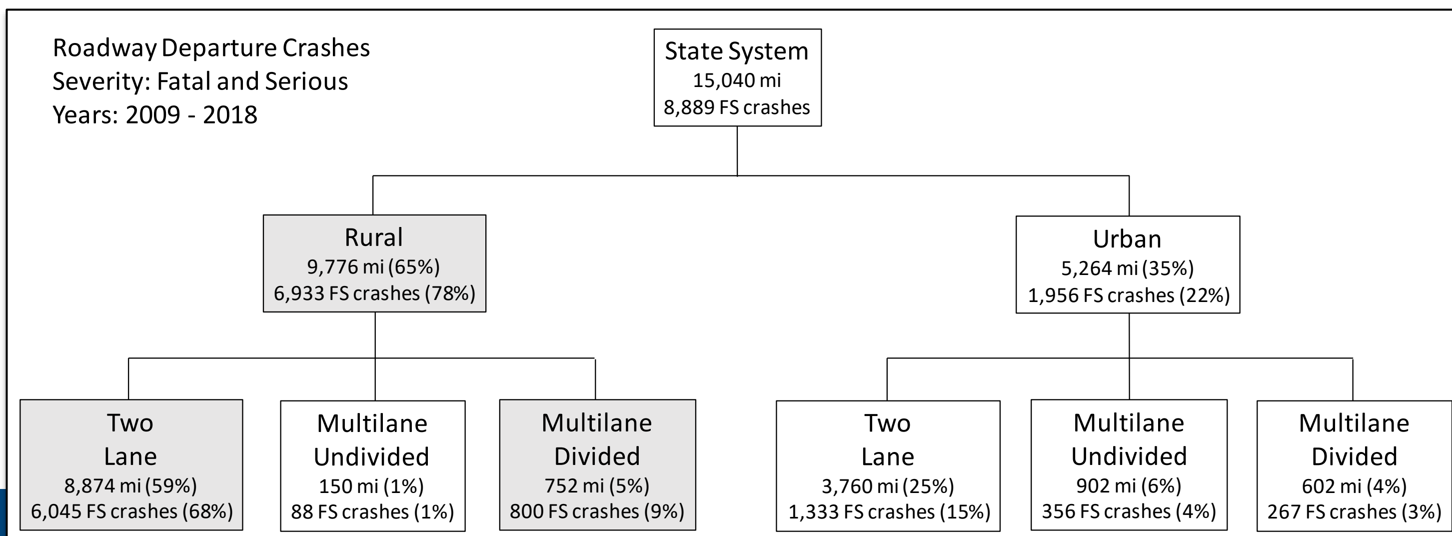
- Target crash types and contributing factors
  - Options for identifying target crash types:
    - Conduct systemwide analysis of crash and/or roadway inventory data
    - Refer to state or regional safety plan
  - Common crash data elements used to identify target crash types:
    - Crash Severity
    - Manner of Collision/Collision Impact
    - First Harmful Event
    - Speeding Related
    - Alcohol Involvement
    - Drug Involvement
    - Light Condition
    - Sequence of Events

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Target crash types and contributing factors
  - Common target crash types:
    - Lane departure
    - Rollover
    - Fixed object
    - Head on
    - Angle
    - Speed-related
    - Impaired driving
    - Young/elderly driver involved
    - Pedestrians/bicyclists
    - Nighttime
  - Where are target crash types occurring?
    - Common approach is using crash tree diagrams

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Target crash types and contributing factors
  - Common crash data elements used to identify facility types of interest:
    - Crash severity
    - Relation to junction
    - Type of intersection
    - Trafficway description
    - Total lanes in roadway
    - Roadway alignment and grade
    - Roadway functional class
    - Annual average daily traffic
    - Motor vehicle posted/statutory speed limit
    - Width of lane(s) and shoulder(s)
    - Access control



Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Target crash types and contributing factors
  - Common target crash types and facility types

Facility Type	Crash Type				
	Run-off-road	Lane-departure	Head-on	Angle	Rollover
Roadway Segments					
Rural, two-lane roads on horizontal curve sections	X	X	X		X
Rural, two-lane roads on tangent sections	X	X	X	X	X
Intersections					
4-leg minor-road stop controlled intersections on rural two-lane roads				X	
4-leg minor-road stop controlled intersections on urban, two-lane roads				X	
3-leg minor-road stop controlled intersections on rural, two-lane roads				X	
4-leg signalized intersections on urban, multilane divided roads				X	
4-leg signalized intersections on urban, multilane undivided roads				X	
4-leg minor-road stop controlled intersections on rural, multilane divided roads				X	

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Target crash types and contributing factors
  - Common target crash types and potential contributing factors

Target Crash Types	Potential Contributing Factors
Roadway departure	Lane width
	Shoulder width/type
	Median width/type
	Horizontal curvature, delineation, or advance warning devices
	Superelevation
	Horizontal curve density
	Horizontal curve and tangent speed differential
	Presence of a visual trap at a curve or combination of vertical grade and horizontal curvature
	Roadway gradient
	Roadside or edge hazard rating (potentially including sideslope design and frequency of fixed objects)
	Driveway presence, design, and density
	Sight distance from access location
	Presence of shoulder rumble strips
	Presence of centerline rumble strips
	Posted speed limit or operating speed
	Presence of lighting
	Quality of roadway surface (or pavement condition and friction)
	Average daily traffic volumes
Rollover	Roadside or edge hazard rating (potentially including sideslope design and frequency of fixed objects)
	Quality of roadway surface (or pavement condition and friction)
	Shoulder width/type
	Median width/type
	Posted speed limit or operating speed

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Target crash types and contributing factors
  - Potential contributing factors and associated MIRE and MMUCC data elements

Contributing Factor	MIRE Data Element	MMUCC Data Element
Roadway Segments		
Number of lanes	Number of Through Lanes (FDE)	Total Lanes in Roadway
Lane width	Outside Through Lane Width Inside Through Lane Width	Width of Lane(s) and Shoulder(s)
Shoulder surface width/type	Right Shoulder Type Right Shoulder Total Width Right Paved Shoulder Width	Width of Lane(s) and Shoulder(s)
Median width/type	Median Type (FDE) Median Width	Median Width
Horizontal curvature, delineation, or advance warning devices	Horizontal Curve Degree or Radius	Roadway Curvature Roadway Alignment and Grade
Superelevation	Curve Superelevation	No relevant variable available
Horizontal curve density	No relevant variable available	No relevant variable available
Horizontal curve and tangent speed differential	No relevant variable available	No relevant variable available
Presence of a visual trap at a curve or combination of vertical grade and horizontal curvature	No relevant variable available	No relevant variable available
Roadway gradient	Vertical Alignment Feature Type Percent of Gradient	Grade Roadway Alignment and Grade
Roadside or edge hazard rating (potentially including sideslope design and frequency of fixed objects)	Roadside Clearzone Width Right Sideslope Right Sideslope Width Left Sideslope Left Sideslope Width Roadside Rating	No relevant variable available

Application of FHWA *Systemic Safety Project Selection Tool* (cont'd)

- Screen and Prioritize Candidate Locations
  - Screening methodology based on presence/absence of contributing factors
  - Methodology can weigh contributing factors equally or assign weights to contributing factors
- Countermeasure Selection
  - Countermeasures should be:
    - Appropriate for target crash and facility types
    - Evidence-based
    - Low cost
    - Provide significant crash reduction

- Project Prioritization
  - Decision-making framework should be established based on potential countermeasures, contributing factors, and characteristics of candidate locations

Application of Safety Performance Functions (SPFs) for Systemic Safety Management

- Application of SPFs for network screening
  - SPF: equation that predicts number of crashes on a roadway or at an intersection based on site characteristics
- Network screening SPFs do not require same amount of data as SPFs for project level analysis (i.e., HSM Part C)

Potential Inventory Data Elements for Network Screening SPFs

Description	MIRE Data Element
Roadway Segments	
Segment length	Segment Length (FDE)
Area type	Rural/Urban Designation (FDE)
Number of through lanes (by direction)	Number of Through Lanes (FDE)
Median type (divided / undivided)	Median Type (FDE)
Two-Way vs. One-Way Operation	One/Two-Way Operations (FDE)
Access control (freeway/nonfreeway)	Access Control (FDE)
Within interchange area (freeways only)	No relevant variable available
Intersections	
Area type	No relevant variable available
Number of intersection legs	Intersection/Junction Number of Legs Intersection/Junction Geometry (FDE)
Type of traffic control	Intersection/Junctional Traffic Control (FDE)

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- SPFs can be used to calculate multiple performance measures such as predicted, expected, or excess crash frequencies of target crashes

- Agencies may develop SPFs or calibrate existing SPFs for their entire network or portions of network

- Agencies may develop in-house tools or use existing software
  - AASHTOWare Safety Analyst

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont’d)

- Capabilities of Safety Analyst
  - Module 1—Network Screening Tool
  - Module 2—Diagnosis Tool and the Countermeasure Selection Tool
  - Module 3—Economic Appraisal Tool and the Priority Ranking Tool
  - Module 4—Countermeasure Evaluation Tool
  - Module 5—Systemic Site Selection Tool

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont’d)

- Input data needs for Safety Analyst
  - Required data elements:
    - Inventory data for roadway segments, intersections, and ramps
    - Traffic volume data
    - Crash data
  - Most “required” data elements are Fundamental Data Elements (FDEs)
    - States are required to have access to complete collection of MIRE FDEs on all public roads by September 30, 2026

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Input data needs for Safety Analyst

Table 6. Required Safety Analyst Data Elements

Data Element	Description
Roadway Segment Data	
Segment ID **(MIRE FDE)**	This item is a unique, agency-specific, identifier for the roadway segment.
Route Type **(MIRE FDE)**	The value of this item is the category of the route where the site is located. This item should be included whether it is part of the location identifier or not, as searches may be conducted separately on this item. Default values include: • Interstate - Route category interstate • US route - Route category US route • State route - Route category state route • Business route - Route category business route • Business loop - Route category business loop • Spur route - Route category spur route • County road - Route category county road • Township road - Route category township road • Local road - Route category local road • Other - Route category other • Unknown - Route category unknown
Route Name **(MIRE FDE)**	The value of this item is the number or name of the route where the site is located. Where routes overlap, the more important route type and the corresponding lower route number normally take precedence. For routes without numbers, the road or street name should be used.
Segment ID **(MIRE FDE)**	This item is a unique, agency-specific, identifier for the roadway segment.

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Sample Safety Analyst systemic site selection: network screening results

ID	Site Type	Site Subtype	County	Route	Site Start Location	Site End Location	Average Observed Crashes for Entire Site[1]	Location with Highest Potential for Safety Improvement														Rank	Additional Windows of Interest
								Average Observed Crashes[1]	Predicted Crash Frequency[1]	Expected Crash Frequency				Excess Crash Frequency				Modified LOSS		Start Location	End Location		
										Expected Frequency[1]	Variance[2]	No. of Fatalities	No. of Injuries	Excess Frequency[1]	Variance[2]	No. of Fatalities	No. of Injuries	Δ	Cat				
4148	Seg	Seg/Rur; 2-lane	18	1425710	19.485	24.148	0.23	3.00	0.22	0.61	0.01	0.02	0.68	0.40	0.03	0.01	0.44	0.81	III	19.985	20.085	1	'20.285_20.385; 20.385_20.485; 21.285_21.385; 21.685_21.785; 22.385_22.485; 23.885_23.985'
6204	Seg	Seg/Rur; 2-lane	18	1427301	2.516	6.204	0.29	3.09	0.20	0.57	0.01	0.02	0.64	0.37	0.03	0.01	0.41	0.80	III	5.016	5.116	2	'2.616_2.716; 3.716_3.816; 4.716_4.816; 5.816_5.916; 6.016_6.116'
2516	Seg	Seg/Rur; 2-lane	18	1427301	0.000	2.516	0.48	2.84	0.20	0.56	0.01	0.02	0.62	0.37	0.03	0.01	0.41	0.80	III	2.000	2.100	3	'0.500_0.600; 0.700_0.800; 1.000_1.100; 1.600_1.700; 1.800_1.900; 2.100_2.200'
8177	Seg	Seg/Rur; 2-lane	17	551706	4.826	8.177	0.18	2.79	0.19	0.55	0.01	0.02	0.61	0.36	0.03	0.01	0.40	0.79	III	6.926	7.026	4	''
6628	Seg	Seg/Rur; 2-lane	17	551310	13.576	16.628	0.17	2.43	0.18	0.51	0.01	0.02	0.56	0.33	0.02	0.01	0.37	0.75	III	13.976	14.076	5	''
0306	Seg	Seg/Rur; 2-lane	14	502809	8.991	10.306	0.71	4.65	0.12	0.51	0.01	0.02	0.56	0.38	0.01	0.01	0.42	1.06	III	9.691	9.791	6	''
6275	Seg	Seg/Rur; 2-lane	16	933209	5.027	6.275	0.26	1.54	0.27	0.49	0.01	0.02	0.54	0.22	0.04	0.01	0.24	0.40	III	5.127	5.227	7	'5.727_5.827'
1166	Seg	Seg/Rur; 2-lane	17	551706	8.177	11.166	0.34	1.46	0.19	0.47	0.02	0.02	0.52	0.29	0.03	0.01	0.32	0.64	III	9.277	9.477	8	''
7932	Seg	Seg/Rur; 2-lane	15	899407	4.302	7.932	0.32	2.69	0.16	0.46	0.01	0.02	0.51	0.30	0.02	0.01	0.34	0.74	III	5.702	5.802	9	'7.402_7.502'
3065	Seg	Seg/Rur; 2-lane	15	899004	0.000	3.065	0.20	1.42	0.25	0.46	0.01	0.02	0.51	0.20	0.04	0.01	0.23	0.38	III	2.000	2.100	10	'2.200_2.300; 2.500_2.600; 2.800_2.900'
0265	Seg	Seg/Rur; 2-lane	16	933209	6.275	10.265	0.12	1.53	0.25	0.45	0.01	0.02	0.50	0.20	0.04	0.01	0.22	0.38	III	6.875	6.975	11	'8.175_8.275; 9.575_9.675'
9443	Seg	Seg/Rur; 2-lane	14	503510	6.128	9.443	0.17	2.58	0.15	0.45	0.01	0.02	0.49	0.29	0.02	0.01	0.32	0.73	III	9.328	9.428	12	'9.343_9.443'
2453	Seg	Seg/Rur; 2-lane	12	565810	1.207	2.453	0.41	2.58	0.15	0.44	0.01	0.02	0.48	0.29	0.02	0.01	0.32	0.72	III	2.107	2.207	13	''
5832	Seg	Seg/Rur; 2-lane	16	932308	0.859	5.832	0.06	2.90	0.15	0.43	0.01	0.02	0.48	0.29	0.02	0.01	0.32	0.73	III	1.859	1.959	14	''
6556	Seg	Seg/Rur; 2-lane	18	1425710	9.381	16.556	0.25	2.78	0.15	0.43	0.01	0.02	0.48	0.29	0.02	0.01	0.32	0.73	III	12.281	12.381	15	'15.181_15.281'
3524	Seg	Seg/Rur; 2-lane	18	1431908	0.000	3.524	0.18	1.49	0.22	0.41	0.01	0.01	0.45	0.19	0.03	0.01	0.21	0.38	III	1.000	1.100	16	'1.200_1.300; 2.300_2.400; 2.400_2.500'
7164	Seg	Seg/Rur; 2-lane	17	551310	0.000	7.164	0.12	1.37	0.14	0.38	0.01	0.01	0.42	0.24	0.02	0.01	0.26	0.62	III	1.900	2.100	17	'2.000_2.200'
5172	Seg	Seg/Rur; 2-lane	15	899310	13.009	15.172	0.17	2.20	0.13	0.37	0.00	0.01	0.41	0.25	0.01	0.01	0.27	0.67	III	13.909	14.009	18	''
7445	Seg	Seg/Rur; 2-lane	12	566510	1.497	7.445	0.20	1.48	0.14	0.37	0.01	0.01	0.41	0.23	0.02	0.01	0.26	0.62	III	3.997	4.197	19	''
1778	Seg	Seg/Rur; 2-lane	12	565703	0.303	1.778	0.21	2.84	0.12	0.36	0.00	0.01	0.40	0.24	0.01	0.01	0.27	0.68	III	1.503	1.603	20	''

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Sample Safety Analyst systemic site selection: optimization results (ranked by total crashes reduced per site)

Proposed Site-CM	Site ID	Site Type	County	Route	Beginning Location	Ending Location	Countermeasure	CM Start Location	CM End Location	Construction Cost for Single Implementation	Safety Benefit	Present Value of Construction Cost for Analysis Period	Net Benefits per Site	Net Benefits per Mile	Total Crashes Reduced per Site*	Total Crashes Reduced per Mile*
19	7445	Seg/Rur; 2-lane	12	566510	1.497	7.445	Install continuous milled-in shoulder rumble strips	1.497	7.445	$8,922	$3,157,561	$14,949	$3,142,611	$528,348	36.21	6.09
16	3524	Seg/Rur; 2-lane	18	1431908	0.000	3.524	Install continuous milled-in shoulder rumble strips	0.000	3.524	$5,286	$2,803,583	$8,857	$2,794,726	$793,055	17.85	5.07
15	6556	Seg/Rur; 2-lane	18	1425710	9.381	16.556	Install continuous milled-in shoulder rumble strips	9.381	16.556	$10,763	$2,254,955	$18,033	$2,236,921	$311,766	14.22	1.98
17	7164	Seg/Rur; 2-lane	17	551310	0.000	7.164	Install continuous milled-in shoulder rumble strips	0.000	7.164	$10,746	$1,680,840	$18,006	$1,662,834	$232,110	13.71	1.91
14	5832	Seg/Rur; 2-lane	16	932308	0.859	5.832	Install continuous milled-in shoulder rumble strips	0.859	5.832	$7,460	$728,645	$12,499	$716,146	$144,007	9.33	1.88
2	6204	Seg/Rur; 2-lane	18	1427301	2.516	6.204	Install continuous milled-in shoulder rumble strips	2.516	6.204	$5,532	$1,305,400	$9,269	$1,296,131	$351,445	7.92	2.15
4	8177	Seg/Rur; 2-lane	17	551706	4.826	8.177	Install continuous milled-in shoulder rumble strips	4.826	8.177	$5,026	$564,834	$8,422	$556,412	$166,043	6.15	1.84
1	4148	Seg/Rur; 2-lane	18	1425710	19.485	24.148	Install continuous milled-in shoulder rumble strips	19.485	24.148	$6,994	$869,347	$11,720	$857,627	$183,922	5.90	1.27
10	3065	Seg/Rur; 2-lane	15	899004	0.000	3.065	Install continuous milled-in shoulder rumble strips	0.000	3.065	$4,598	$890,929	$7,703	$883,226	$288,165	5.56	1.82
3	2516	Seg/Rur; 2-lane	18	1427301	0.000	2.516	Install continuous milled-in shoulder rumble strips	0.000	2.516	$3,774	$906,394	$6,324	$900,071	$357,739	5.35	2.13
6	0306	Seg/Rur; 2-lane	14	502809	8.991	10.306	Install continuous milled-in shoulder rumble strips	8.991	10.306	$1,972	$482,598	$3,305	$479,293	$364,481	4.40	3.35
7	6275	Seg/Rur; 2-lane	16	933209	5.027	6.275	Install continuous milled-in shoulder rumble strips	5.027	6.275	$1,872	$540,478	$3,137	$537,341	$430,562	4.07	3.26
9	7932	Seg/Rur; 2-lane	15	899407	4.302	7.932	Install continuous milled-in shoulder rumble strips	4.302	7.932	$5,445	$492,633	$9,123	$483,510	$133,198	3.68	1.01
8	1166	Seg/Rur; 2-lane	17	551706	8.177	11.166	Install continuous milled-in shoulder rumble strips	8.177	11.166	$4,484	$302,767	$7,512	$295,254	$98,780	3.60	1.20
11	0265	Seg/Rur; 2-lane	16	933209	6.275	10.265	Install continuous milled-in shoulder rumble strips	6.275	10.265	$5,985	$404,996	$10,028	$394,968	$98,990	3.13	0.79
12	9443	Seg/Rur; 2-lane	14	503510	6.128	9.443	Install continuous milled-in shoulder rumble strips	6.128	9.443	$4,972	$104,990	$8,332	$96,658	$29,158	1.62	0.49
20	1778	Seg/Rur; 2-lane	12	565703	0.303	1.778	Install continuous milled-in shoulder rumble strips	0.303	1.778	$2,212	$205,119	$3,707	$201,412	$136,551	1.56	1.06
13	2453	Seg/Rur; 2-lane	12	565810	1.207	2.453	Install continuous milled-in shoulder rumble strips	1.207	2.453	$1,869	$231,050	$3,132	$227,918	$182,920	1.53	1.23
5	6628	Seg/Rur; 2-lane	17	551310	13.576	16.628	Install continuous milled-in shoulder rumble strips	13.576	16.628	$4,578	$89,658	$7,671	$81,987	$26,863	0.56	0.18
18	5172	Seg/Rur; 2-lane	15	899310	13.009	15.172	Install continuous milled-in shoulder rumble strips	13.009	15.172	$3,245	$15,862	$5,436	$10,426	$4,820	0.11	0.05
									Totals:	$105,735	$18,032,639	$177,166	$17,855,473	$4,862,923	146.48	38.73

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Key strengths and advantages of Safety Analyst
  - Software improves effectiveness of decision making by automating state-of-the-art statistical approaches to improve identification and programming of site-specific safety improvements
  - Software improves efficiency of decision support by integrating all parts of safety management process into single software package
  - Software includes default SPFs which are automatically calibrated. Software also provides capability to enter alternative SPF functional forms and parameter values.
  - Software provides capability to easily adjust input values and rerun analyses efficiently

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Key strengths and advantages of Safety Analyst (cont'd)
  - Most "required" data elements are FDEs. Software can also make use of existing roadway inventory, traffic volume, and crash databases, when available.
  - Decisions on where to systemically place selected countermeasures are based on quantitative economic analyses
  - Full crash history is reviewed for each site
  - Statistical procedures account for traffic volume
  - Analyses can explicitly consider pedestrian, bicycle, and motorcycle crashes, in addition to motor-vehicle crashes
  - All default countermeasures included in software, with safety effectiveness information provided, are considered reliable. If safety effectiveness information in not provided, user has capability to input as part of analysis.

Application of Safety Performance Functions (SPFs) for Systemic Safety Management (cont'd)

- Key weaknesses and limitations of Safety Analyst
  - Software requires mapping and importing of data elements which can be quite burdensome
  - Systemic site selection procedures only consider one countermeasure at a time
  - Limited information on reliable countermeasures is incorporated into software due to current state of knowledge
  - Software requires purchasing annual license

Only a few states have limited experience using systemic site selection module since this functionality was only recently added to software

Application of usRAP methodology and ViDA software

- Capabilities of usRAP and ViDA software
  - Software can perform two types of analyses:
    - Develop star ratings
    - Develop safer roads investment plans
  - Star ratings and safer roads investment plans are developed for 328-ft (100-m) sections of roadway and then combined to provide recommended improvements for specific road sections, entire routes, and entire road networks

Application of usRAP methodology and ViDA software (cont'd)

- Capabilities of usRAP and ViDA software (cont'd)
  - Star ratings indicate extent to which geometric design and traffic control features known to have positive effects on safety are present on each 328-ft (100-m) segment of road network
  - Star ratings range from one star to five stars
  - Star ratings are assigned using scoring system based on available research on safety effects of road design features from around the world
  - Scoring system includes factors for both crash likelihood and crash severity for specific crash types

Application of usRAP methodology and ViDA software (cont'd)

- Capabilities of usRAP and ViDA software (cont'd)
  - Safer roads investment plans are infrastructure improvement programs consisting of cost-effective infrastructure improvements for specific locations across an entire road network
  - In developing a safer roads investment program, ViDA software considers over 70 specific countermeasures

Application of usRAP methodology and ViDA software (cont’d)

- Input data needs for ViDA software
  - Primary input data for ViDA is a spreadsheet file of more than 50 roadway characteristics for each 328-ft (100-m) roadway segment on road network
  - Input data can be coded from review of aerial photos and street-level photos of sites using highway agency photologs or web-based tools
  - Technicians or students can be trained as data coders
    - On average, it takes about 30 minutes of labor per mile for trained coder to prepare input data for a roadway
  - Coding tools available to prepare input data

Application of usRAP methodology and ViDA software (cont’d)

- Sample input data for ViDA software

Sample Input Variables Needed to Create Star Ratings and Safer Roads Investment Plans in ViDA
• Roadway type (divided/undivided) • Upgrade cost (extent of roadside development that would influence the cost of installing countermeasures) • Land use (separately for each side of the road) • Area type (rural/urban) • Speed limit • Truck speed limit (may be the same or differ from the general speed limit • Traffic volume (average annual daily traffic [AADT]) • Median type • Centerline rumble strips • Shoulder rumble strips • Roadside severity (object type and distance to object, separately for each side of the road) • Paved shoulder width • Intersection type • Intersection channelization • Intersecting road volume (grouped into broad categories) • Others….

Application of usRAP methodology and ViDA software (cont'd)

- Sample usRAP ViDA star rating summary table

Star Rating	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
	Length (mi)	Percent	Length (mi)	Percent	Length (mi)	Percent	Length (mi)	Percent
5 Stars	259.6	5%	146.2	3%	126.2	2%	83.2	2%
4 Stars	681.1	13%	267.9	5%	174.6	3%	54.6	1%
3 Stars	2,253.4	42%	2,168.3	40%	248.5	5%	328.3	6%
2 Stars	1,252.5	23%	1,595.5	30%	202.1	4%	916.4	17%
1 Star	937.5	17%	1,206.2	22%	725.0	13%	773.3	14%
Not Applicable	2.0	0%	2.0	0%	3,909.8	73%	3,230.2	60%
Totals	5,386.1	100%	5,3861.1	100%	5,3861.1	100%	5,3861.1	100%

Application of usRAP methodology and ViDA software (cont'd)

- Sample usRAP ViDA star rating summary table

Safer Roads Investment Plan

Currency: $ USD - Analysis Period: Multiple

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
29	14,721,078	7,362,507	256,422	2

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Roadside barriers – right side	14.80 km	10	4,951,398	2,944,500	304,896	2
Roadside barriers – left side	15.10 km	10	5,038,855	3,043,950	309,724	2
Clear roadside hazards – left side	11.00 km	3	1,297,757	111,540	44,066	12
Clear roadside hazards – right side	10.70 km	2	1,206,609	102,180	43,418	12
Improve delineation	9.60 km	1	691,293	342,886	254,306	2
Shoulder paving right side (> 3 ft)	5.80 km	1	532,012	351,050	338,311	2
Shoulder paving left (> 3 ft)	3.10 km	1	327,244	191,750	300,423	2
Bicycle lane (on-road)	3.50 km	0	71,094	43,680	315,004	2
Improve curve delineation	0.60 km	0	188,562	10,715	29,135	18
Lane widening (up to 1.5 ft)	0.70 km	0	181,437	120,373	340,149	2
Delineation and signing (intersection)	1 sites	0	20,542	17,859	445,737	1
Sideslope improvement – right side	0.50 km	0	86,434	29,250	173,504	3
Sideslope improvement – left side	0.50 km	0	89,299	29,250	167,938	3
Shoulder rumble strips	0.30 km	0	38,542	23,525	312,941	2

Application of usRAP methodology and ViDA software (cont'd)

- Key strengths and advantages of ViDA
  - Software is web-based and readily accessible
  - Software is free
  - Access to software is password protected
  - Software is easy to use
  - Input data consists mostly of familiar design and traffic control parameters that can be coded from aerial and street-level photographic images by trained technicians or students
  - Input data can be managed with commercially available software

Application of usRAP methodology and ViDA software (cont'd)

- Key strengths and advantages of ViDA (cont'd)
  - User can customize analysis parameters to match agency's experience and practices
  - Software can be calibrated if crash data are available
  - Software processes data rapidly to develop safer roads investment plans
  - All 70+ countermeasures built into software are considered for each 328-ft (100-m) road segment, reducing possibility that any desirable countermeasure will be missed
  - Results provide program of cost-effective potential infrastructure improvements to reduce fatal and serious-injury crashes
  - Software includes large amount of support information and transparency of process

Application of usRAP methodology and ViDA software (cont'd)

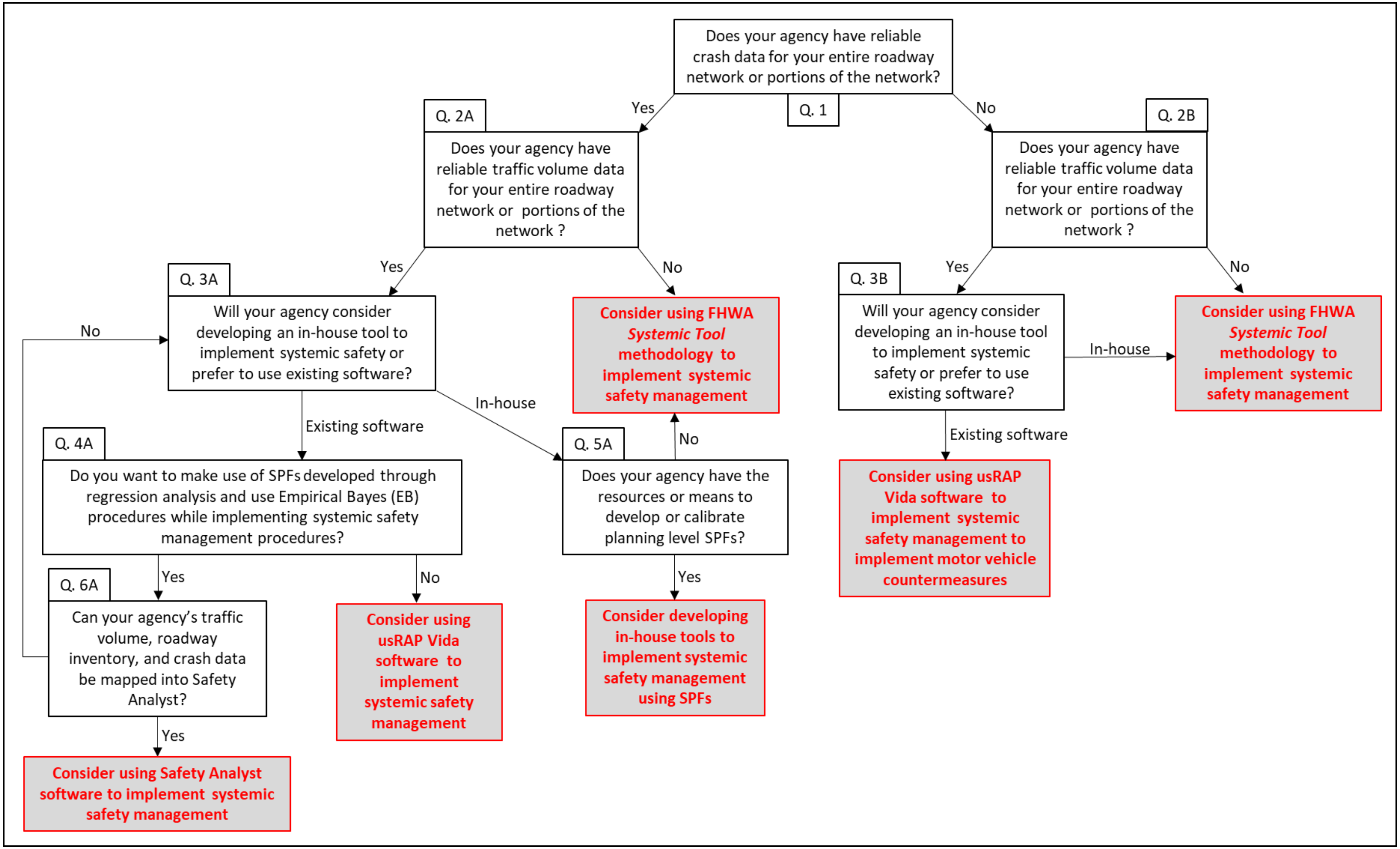
- Key weaknesses and limitations of ViDA
  - Software uses crash prediction models based on best worldwide safety research, much of which are from countries other than the U.S.
  - For many agencies, most of their network will rate as poor-to-fair simply because they are two-lane facilities
    - However, many low-volume and/or well-maintained roads may be perfectly adequate for their expected traffic
  - Software currently displays results in metric units

Selecting the Appropriate Systemic Safety Management Approach and Software Tool

Selecting the Appropriate Systemic Safety Management Approach and Software Tool

- Deciding which systemic safety management approach and/or software tool to use depends on several factors:
  - Which step in the process the agency is focused on
  - Availability and reliability of crash and roadway inventory data
  - Ability to develop and apply planning-level SPFs
  - Extent and type of roadway system to be evaluated
  - Amount of time and resources available to develop systemic safety project plans
  - Role of systemic safety in agency’s overall safety management program

Selecting the Appropriate Systemic Approach and Software Tool (cont'd)



Systemic Safety in Use
(Best Practices)

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches

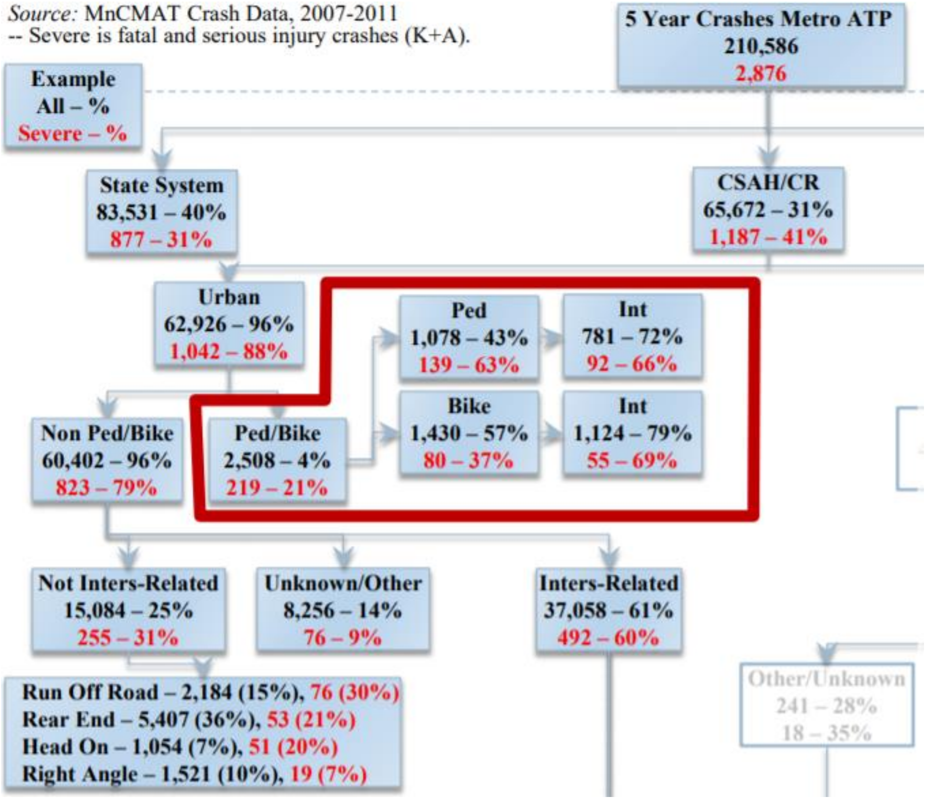
- FHWA *Systemic Safety Project Selection Tool*
  - Several states and local agencies have implemented this approach

  - Focus Crash Types, Facility Types, and Contributing Factors
    - Maine focused on lane departure crashes on two-lane rural roads

    - TxDOT and Thurston County focused on roadway departure crashes

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Focus Crash Types, Facility Types, and Contributing Factors
    - MnDOT used a crash tree diagram to identify crash types and facility types of interest



Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Focus Crash Types, Facility Types, and Contributing Factors
    - MaineDOT compared risk ratio scores on two-lane roads to identify which contributing factors should receive most focus

Contributing Factor (Run-Off-Road Crashes)	Comparison	Risk Ratio (Score)
Horizontal curvature	$> 4°$ vs $< 4°$	8.5
Horizontal curvature	$> 2°$ vs $< 2°$	3.5
Vertical curvature	Vertical curve vs tangent	2.5
Light conditions	Dusk-dark-dawn vs daylight	2.5
Grade	$> 3\%$ vs $< 3\%$	2.0

$$\text{Risk Ratio} = \frac{\text{Percent of Crashes (fatal and severe)}}{\text{Percent of Exposure (VMT))}}$$

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont’d)

- FHWA *Systemic Safety Project Selection Tool* (cont’d)
  - Screen and Prioritize Candidate Locations
    - MnDOT developed a methodology to prioritize potential improvements on curves

Crash Contributing Factors	Value	Threshold	Star Assignment
Speed limit (mph)	55	45 ≤ xx ≤ 55	
Radius (ft)	719	500 ≤ xx ≤ 1400	★
Traffic volume (vpd)	1650	600 ≤ xx ≤ 1300	
Lane width (ft)	11	11	★
Shoulder type	Gravel	None, curb, composite	
Total cross section width (ft)	30	28 ≤ xx ≤ 34	★
Adjacent intersection	None	Intersection, railroad	
Visual trap	None	Present	
Lighting	None	None	★
Outside edge risk	2S	2S or 3	★
Total Stars			★★★★★

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Screen and Prioritize Candidate Locations
    - TxDOT developed a method to prioritize locations for pedestrian safety improvements

Category	Weight (points)										
	0	1	2	3	4	5	6	7	8	9	10
Crash Total	≥ 0% and < 10%	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80% and < 80%	≥ 90% and < 100%	100%
Crash Over-Representation	0%	> 0% and < 2%	≥ 2% and < 3%	≥ 3% and < 4%	≥ 4% and < 5%	≥ 5% and < 6%	≥ 6% and < 7%	≥ 7% and < 8%	≥ 8% and < 9%	≥ 9% and < 10%	≥ 10% and ≤ 100%
Crash Under-Representation	0%	> 0% and < 2%	≥ 2% and < 3%	≥ 3% and < 4%	≥ 4% and < 5%	≥ 5% and < 6%	≥ 6% and < 7%	≥ 7% and < 8%	≥ 8% and < 9%	≥ 9% and < 10%	≥ 10% and ≤ 100%

$$\text{Total Weight} = 10 + CT + CO - CU$$

Where:

CT = weight based on crash total

CO = weight based on crash over-representation

CU = weight based on crash under-representation

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Screen and Prioritize Candidate Locations
    - Summary of calculated contributing factor weightings used by TxDOT to prioritize pedestrian improvements

Contributing Factor		Weight (points)	
		Rural	Urban
Median Type	No Median	7	8
	Unprotected	21	12
	Curbed	10	13
	Barrier	17	19
Number of Lanes	1 or 2	6	5
	3 or 4	23	22
	5 or more	11	21
Pavement Width (ft)	≤ 16	9	10
	17-24	2	4
	25-50	23	21
	> 50	23	23
Vehicle Volume Level	Low	2	2
	Moderate	9	5
	High	27	26
Truck Percentage (%)	≤ 10	≤ 5	4
	10-20	5-10	22
	20-30	10-20	19
	> 30	> 20	21

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

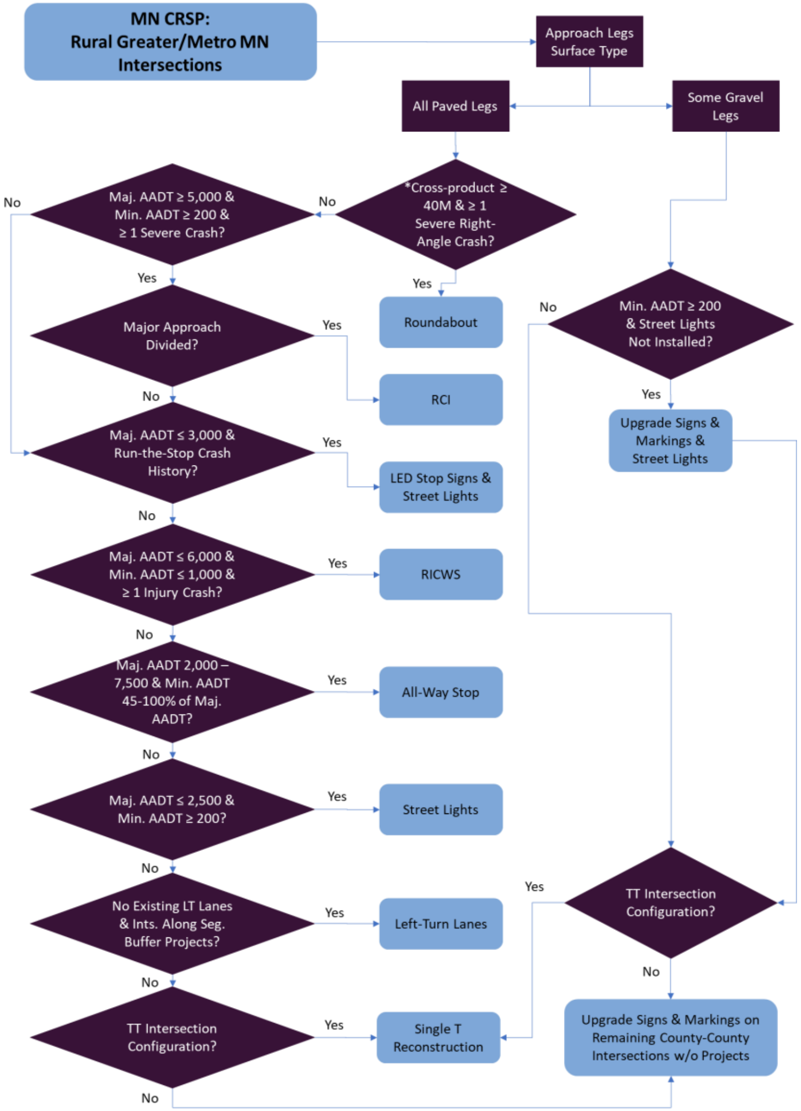
- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Countermeasure Selection
    - WSDOT and MaineDOT have deployed centerline and shoulder rumble strips

Several Countermeasures Implemented as Part of Systemic Safety Management

Context	Common Countermeasures
Roadway segments	• Rumble strips (both shoulder and centerline) • Cable median barrier • SafetyEdge^{SM} • High friction surface treatments • Enhanced pavement markings • Curve warning signs • Chevrons/delineators • Lane/shoulder widening • Speed feedback signs • Tree/clear zone removal
Intersections	• Signal backplates • Crosswalk enhancements – striping, signing, rectangular rapid flashing beacons • Countdown pedestrian signals • Pedestrian refuge islands • Curb extensions • Reflective strips on sign posts • Mini-roundabout • Lighting

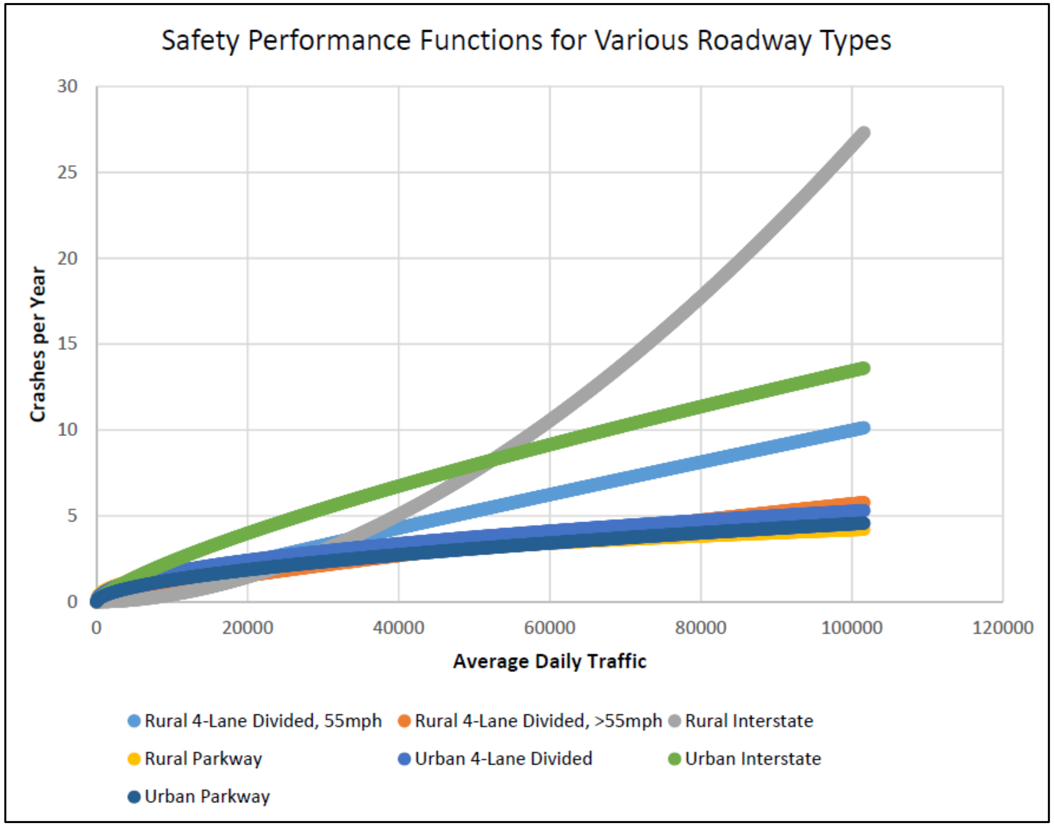
Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- FHWA *Systemic Safety Project Selection Tool* (cont'd)
  - Project Prioritization



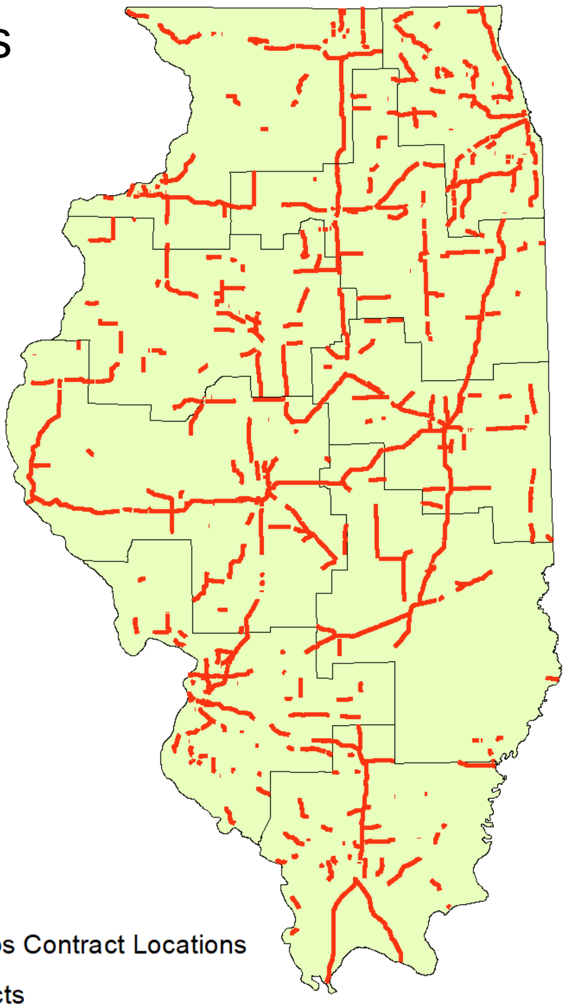
Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- Implementing Systemic Safety using SPFs
  - Identifying focus facility types using SPFs
    - KYTC developed SPFs to prioritize locations of cable median barrier to address roadway departure crashes



Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont’d)

- Implementing Systemic Safety using SPFs (cont’d)
  - Prioritizing installation of select countermeasures
    - Illinois DOT used SPFs to compute potential for safety improvement on rural two-lane roads with speed limits of 50 mph or greater
    - Ranked locations based on expected frequencies of head-on and sideswipe opposing-direction crashes for centerline rumble strips and overturned and fixed-object crashes for shoulder rumble strips



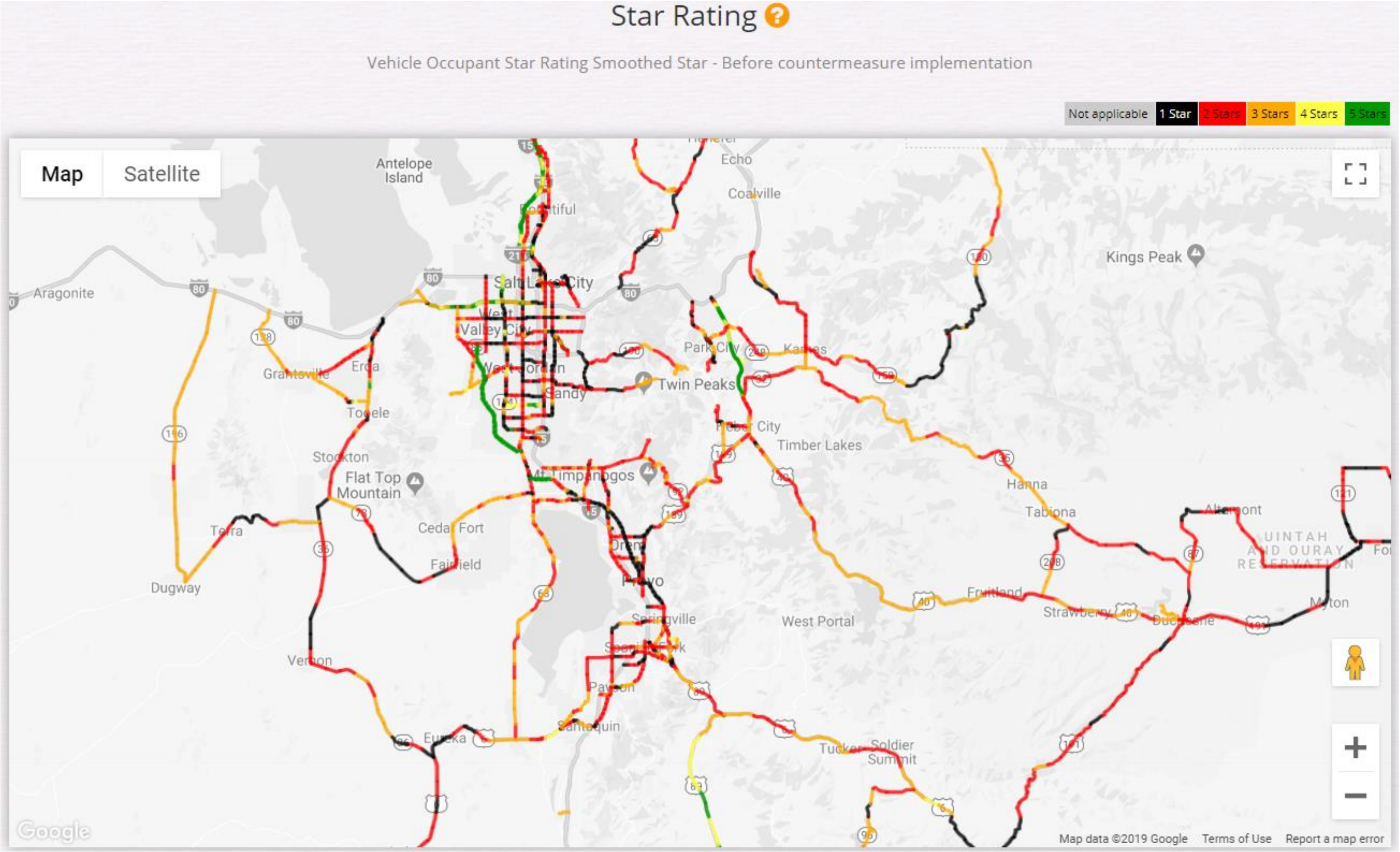
Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- Implementing systemic safety using usRAP
  - In 2013, Utah DOT chose to implement usRAP because it was a less resource-intense alternative to Safety Analyst
  - Used lidar-equipped van to drive all state highways and collected data for input into ViDA
    - Data collected by van provide approximately 80 percent of required data
    - Hired university to collect remaining data
  - usRAP provided star ratings for all state highways as well as recommendations for safety countermeasures along each 328-ft (100-m) segment

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- Implementing systemic safety using usRAP

Sample of Star Ratings for State Maintained Roads (Non-Interstates) in Utah



Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

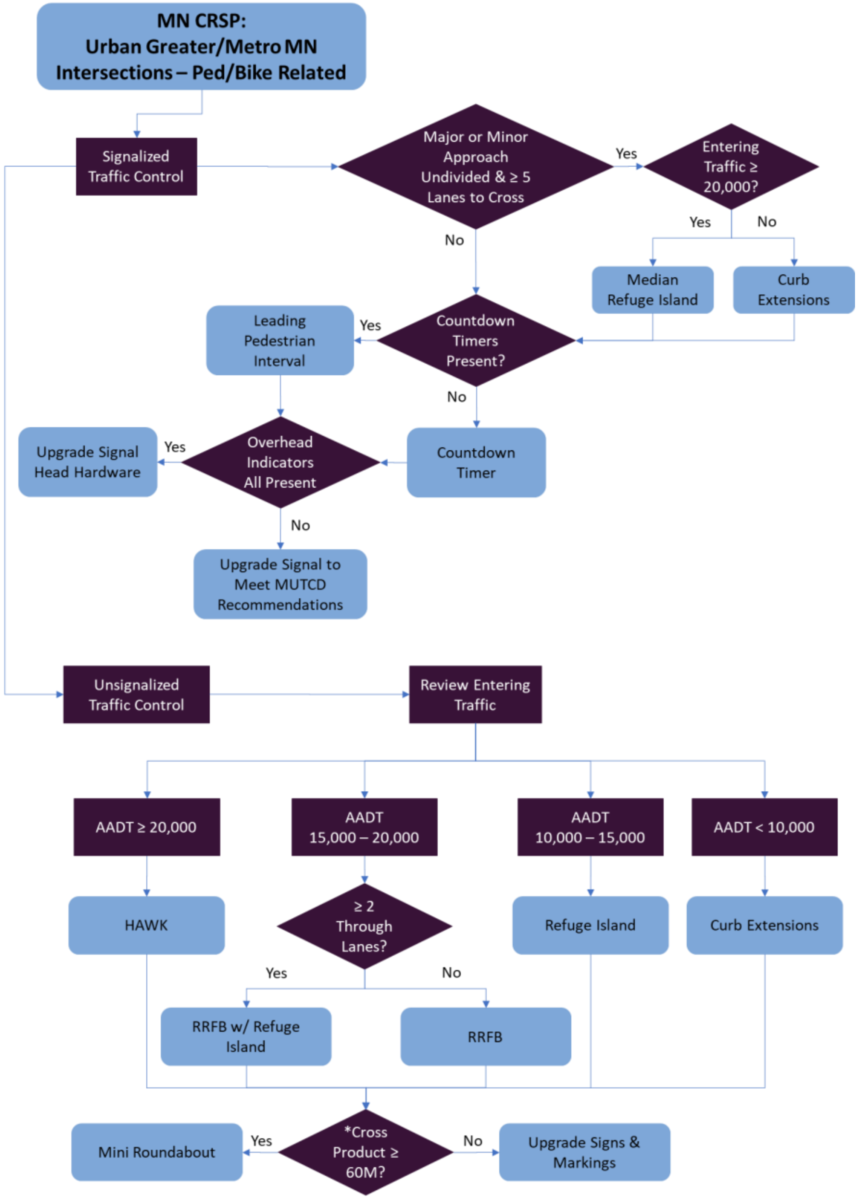
- Implementing systemic safety using usRAP (cont'd)
  - In Utah, DOT central office aids regional offices in selecting and prioritizing safety projects. Generally, regions identify projects they would like to complete and send their recommendations to central office, where staff evaluate those projects to determine the benefit-cost (B-C) ratio using three methodologies:
    - Calculate expected crash reduction using HSM predictive method
    - Apply CMF to average number of crashes from past three years
    - Use expected crash reduction calculated by usRAP
  - When regions need help identifying potential safety projects, central office provides assistance by suggesting projects recommended by usRAP

Case Studies: Applications of the Three Primary Systemic Safety Program Implementation Approaches (cont'd)

- Considerations for Success
  - Agencies appreciated flexibility and adaptability of approach described in FHWA *Systemic Tool* with small investment in training and data collection
  - Agencies that get their data into Safety Analyst and usRAP ViDA appreciate functionality and capabilities of these tools
  - Systemic safety management approach is adaptable based on available data, but can still be data-intensive
  - Strong leadership support and an effective communication plan are essential for establishing the systemic approach and for expanding the program

Case Studies: Local Applications of Systemic Safety

- Systemic safety management beneficial to local agencies with incomplete data
  - For their County Roadway Safety Plan, MnDOT developed a decision tree for intersections which takes into consideration contributing factors and assigns one or more safety treatments to reduce pedestrian and/or bicycle crashes



Case Studies: Local Applications of Systemic Safety (cont’d)

- Thurston County selected the following contributing factors and thresholds to screen their roadway network to address roadway departure crashes:
  - Roadway class of major rural collector
  - Presence of an intersection
  - Traffic volume of 3,000 to 7,500 AADT
  - Edge clearance rating of 3
  - Paved shoulders equal to or greater than 4 ft in width
  - Presence of a vertical curve
  - Consecutive horizontal curves
  - Speed differential between posted speed and curve advisory speed of 0, 5, and 10 mph
  - Presence of a visual trap (i.e., a minor road on the tangent extended)

Case Studies: Local Applications of Systemic Safety (cont'd)

- Considerations for Success
  - States have reached out to local jurisdictions to assist in developing local road safety plans
  - Limited information is available for local roads to implement a crash-history-based safety management approach so states have been working with local agencies to implement systemic safety management
  - FHWA *Systemic Tool* method is well suited for local agencies
    - Less reliant on crash data
    - Easy to employ without extensive training or experience
  - Application of usRAP methodology also well suited for use by local agencies
    - However, use is not particularly widespread among local agencies

Case Studies: Evaluation of Systemic Safety Management Programs

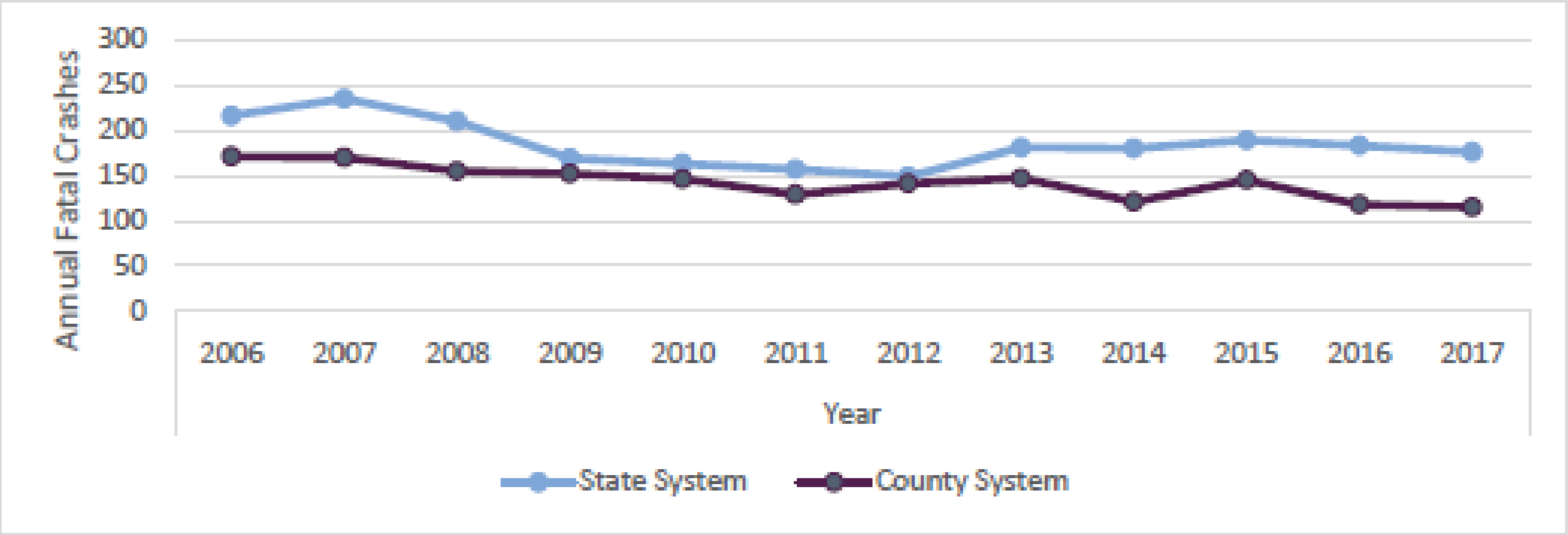
- Evaluation of systemic safety management programs can be conducted in a number of ways, depending on type and amount of data available, goals of evaluation, and available resources in terms of time and expertise

- Quantitative impacts of systemic safety management programs are most commonly analyzed using:
  - Trend analysis
  - Simple before-after study method
  - Shift of proportions method
  - Empirical-Bayes before-after study method

- Current state of practice and knowledge only provides limited information concerning overall effectiveness of systemic treatments

Case Studies: Evaluation of Systemic Safety Management Programs (cont'd)

- Trend analysis



Minnesota State and Local Fatality Trends

Case Studies: Evaluation of Systemic Safety Management Programs (cont'd)

- Simple before-after method

Safety Performance Evaluation of Maine Corridors with Centerline Rumble Strips Installed between 2006 and 2014

	Crashes		Fatalities		Incapacitating Injuries	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Overall Lane Departure						
Number	727	199	31	1	71	21
*Rate(/100 miles)	143.56	111.20	6.12	0.56	14.02	11.74
Percent Improvement (RATE)		22.5%		90.9%		16.3%
Head On						
Number	145	32	28	1	42	16
*Rate(/100 miles)	28.63	17.88	5.53	0.56	8.29	8.94
Percent Improvement (RATE)		37.5%		89.9%		-7.8%
Went Off Road						
Number	582	167	3	0	29	5
*Rate(/100 miles)	114.92	93.32	0.59	0.00	5.73	2.79
Percent Improvement (RATE)		18.8%		100.0%		51.2%

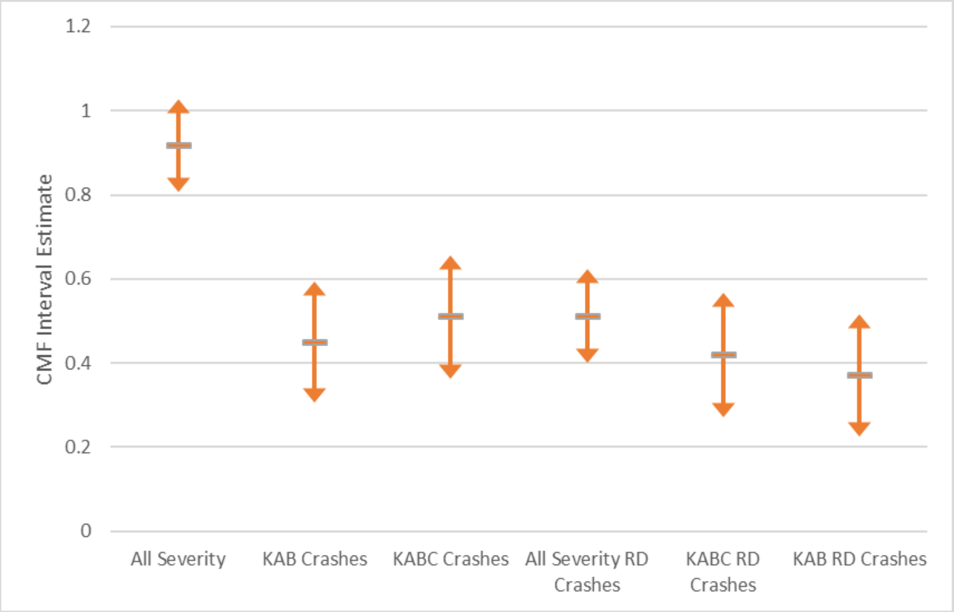
All corridors pro-rated on Miles and Before/After years of exposure (10 corridors, 55.56 miles).
Rates based on Crashes/Road miles per Year exposure in each corridor's available Before and After review period. Example: If a 10 mile rumble strip corridor had 8 years of Before history and 4 years of After, crash rate would be based on 80 miles (8 yrs × 10 miles) Before, and 40 miles (4 yrs × 10 miles) After. Exposure bases in annual miles of corridors reviewed: Before = 506.42 miles; After = 178.95 miles.

Case Studies: Evaluation of Systemic Safety Management Programs (cont'd)

- Shift of proportions
  - Common method when traffic is expected to be an influencing factor but traffic data are not available
  - Method computes ratio of total target crashes to total crashes of all types for before and after periods for population of project locations
    - Two ratios are compared to determine whether proportion of target crashes changed between before and after periods, indicating treatment may have influenced rate of target crashes
  - KYTC used method to evaluate impact of systemic treatments such as cable median barrier, high-friction surface treatments, and rumble strips
    - Found significant reduction in target crashes for all treatments

Case Studies: Evaluation of Systemic Safety Management Programs (cont'd)

- Empirical Bayes Before-After Method
  - Evaluates effectiveness of treatment by comparing number of observed crashes at treated sites to expected number of crashes that would have occurred had there been no treatment
  - Requires use of SPFs



IDOT Crash Modification Factor 95% Confidence Intervals
for Addition of Paved Shoulders with Rumble Strips and Pavement Markings

Case Studies: Evaluation of Systemic Safety Management Programs (cont'd)

- Considerations for Success
  - Because evaluation methods require several years of crash data, evaluations tend to lag behind program deployment
  - Because format of crash data may change over the evaluation period, it may be difficult to achieve consistency between before and after period datasets
    - Crash patterns may also change over time due to circumstances outside of the scope of an evaluation
  - Another challenge for evaluating systemic safety management programs and treatments is dataset size and reliability
  - Because needs of roadway system change over time, important that regular program evaluation is performed
    - Keeps systemic programming balanced and helps to optimize effectiveness

Summary of Systemic Safety Management Approach

Summary of Systemic Safety Management Approach

- Primary advantages of implementing systemic safety:
  - Can be implemented in absence of high-quality crash data
  - Countermeasures can be programmed for implementation at locations without crash history
  - Crash types that occur with high frequency but are dispersed across network can be remedied
  - Data-driven approach adaptable based on available data
- Common target crash types:
  - Lane departure
  - Rollover
  - Fixed object
  - Head on
  - Angle
  - Speed-related
  - Impaired driving
  - Young/elderly driver involved
  - Pedestrians/bicyclists
  - Nighttime

Summary of Systemic Safety Management Approach (cont'd)

- Common focus facility types:
  - Rural freeways
  - Rural multilane highways
  - Rural two-lane roads
  - Rural roads with pavement width less than 24 ft
  - Horizontal curves on rural, two-lane roads
  - Rural local roads
  - Low-volume local roads
  - Unpaved roads
  - Signalized and stop-controlled intersections

Summary of Systemic Safety Management Approach (cont'd)

- Common countermeasures implemented as part of systemic safety

Context	Common Countermeasures
Roadway segments	• Rumble strips (both shoulder and centerline) • Cable median barrier • SafetyEdge^{SM} • High friction surface treatments • Enhanced pavement markings • Curve warning signs • Chevrons/delineators • Lane/shoulder widening • Speed feedback signs • Tree/clear zone removal
Intersections	• Signal backplates • Crosswalk enhancements – striping, signing, rectangular rapid flashing beacons • Countdown pedestrian signals • Pedestrian refuge islands • Curb extensions • Reflective strips on sign posts • Mini-roundabouts • Lighting

Summary of Systemic Safety Management Approach (cont'd)

- Application of FHWA *Systemic Safety Project Selection Tool*
  - Least complex
  - Most adaptable

- Application of SPFs for systemic safety
  - Requires high-quality datasets
  - Most direct and comprehensive existing software is Safety Analyst

- Application of usRAP methodology and ViDA software
  - Unique in that it is most defined methodological approach yet is still adaptable for use
  - Tools available to develop required datasets

Summary of Systemic Safety Management Approach (cont'd)

- Systemic safety management programs are most commonly analyzed using:
  - Trend analysis
  - Simple before-after study method
  - Shift of proportions method
  - Empirical-Bayes before-after study method

- Evaluation results should be tailored to meet needs of target audience

Primary Products of Research

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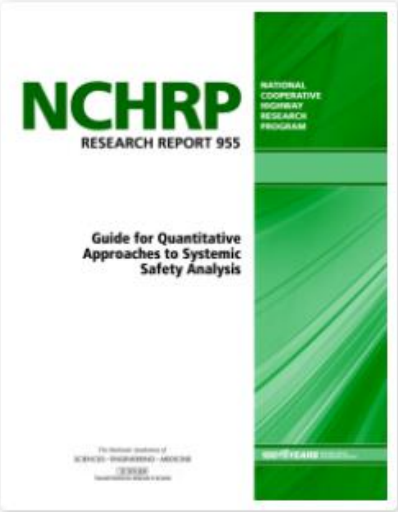
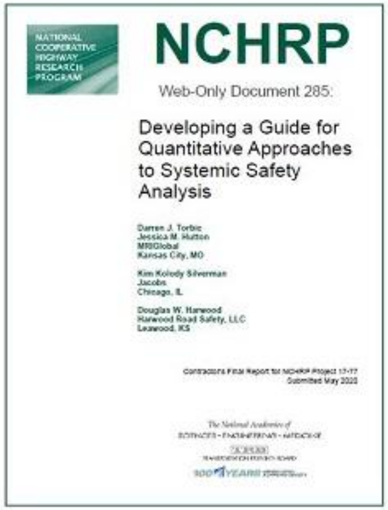
- NCHRP Report 955
- NCHRP Web-Only Document 285
- Two-page flyer to serve as marketing material to promote implementation of quantitative approaches to systemic safety analysis
- Two-page document to highlight benefits of systemic safety analysis to decision makers





Future Research Needs

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- New statistical methods to estimate effectiveness of treatments in absence of observed crashes prior to treatment implementation

- Selection and application of crash contributing factors for range of crash types and facility types

- Software to implement procedures in FHWA *Systemic Safety Project Selection Tool*

Questions???

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Today's Panelists

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