Quantifying Risk in The Systemic Approach to Safety

A key component of the Safe System Approach

Presented by
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December 8, 2023

The Safe System Approach

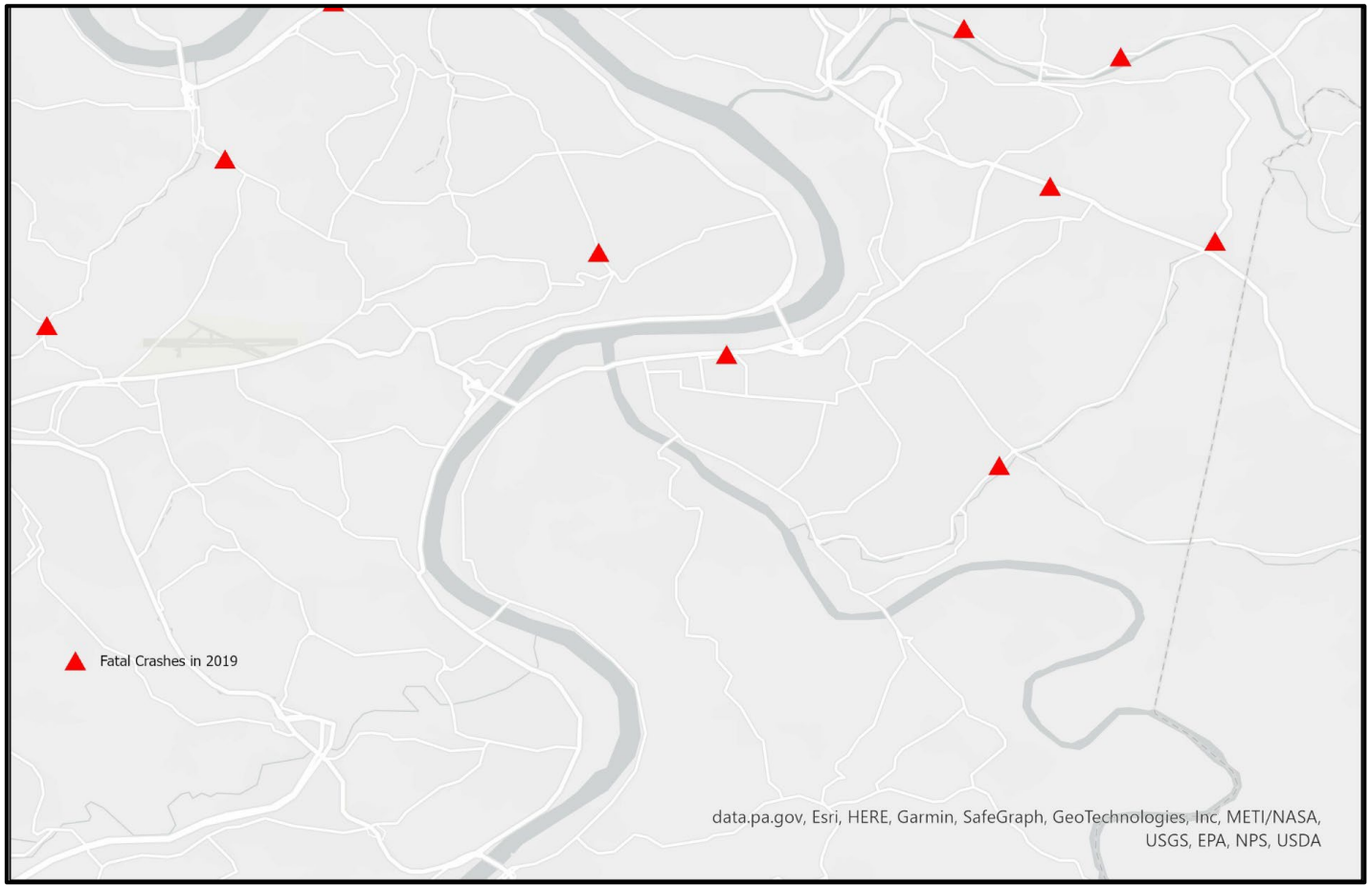
5 Core Elements

6 Principles

Source: FHWA

Fatal Crash Locations are Random

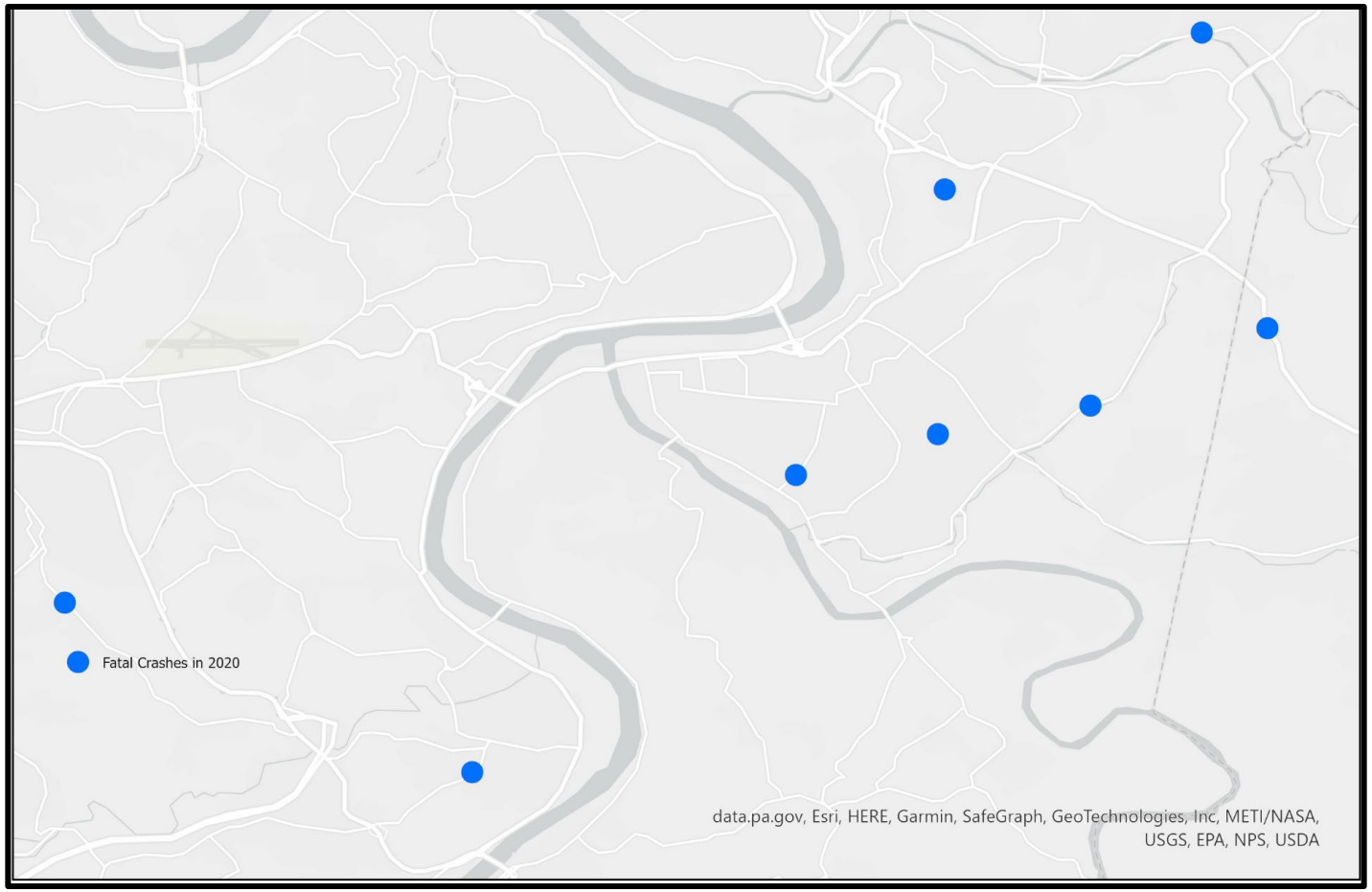
2019



Source: NHTSA (https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars)

Fatal Crash Locations are Random

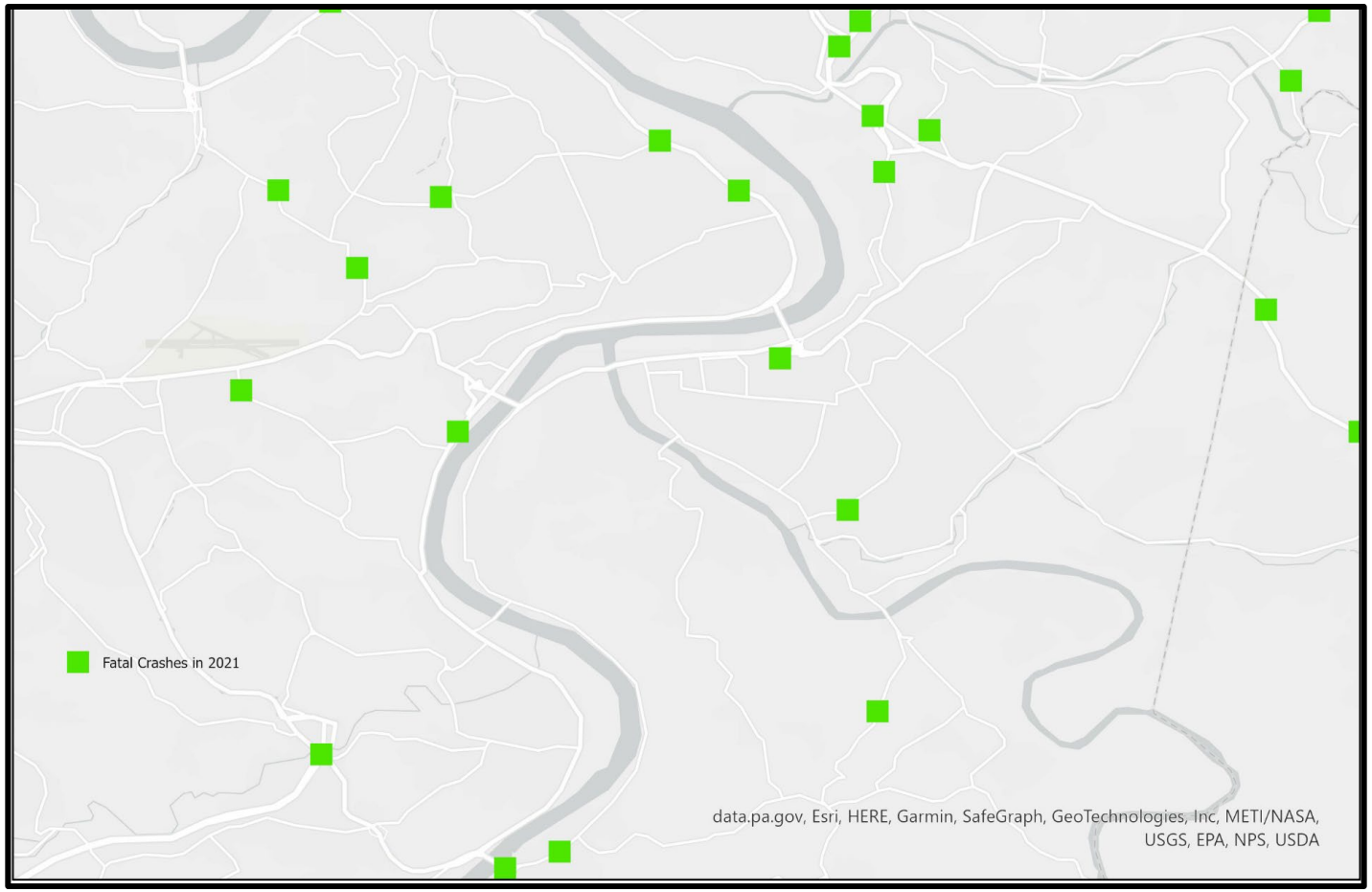
2020



Source: NHTSA (https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars)

Fatal Crash Locations are Random

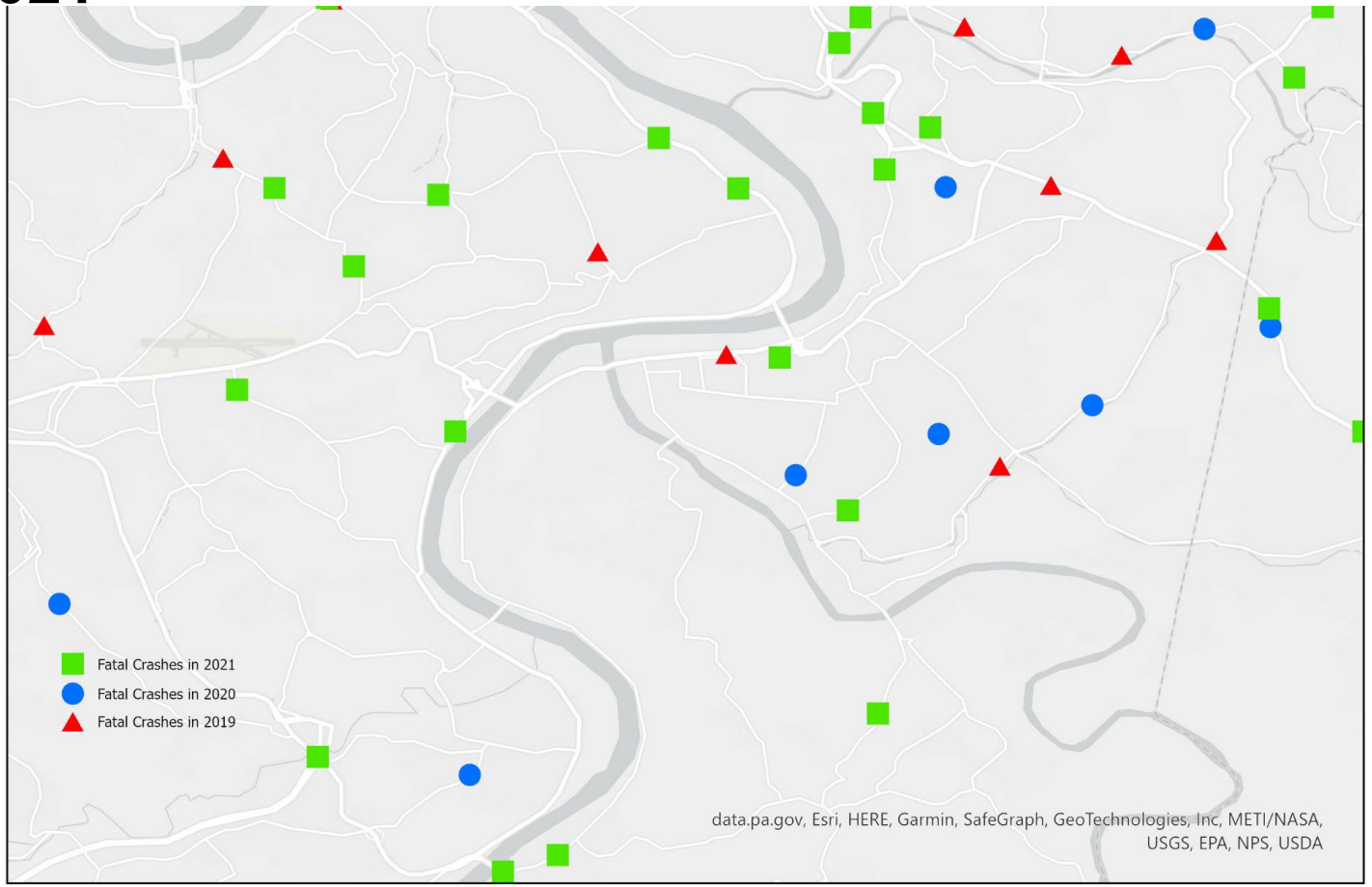
2021



Source: NHTSA (https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars)

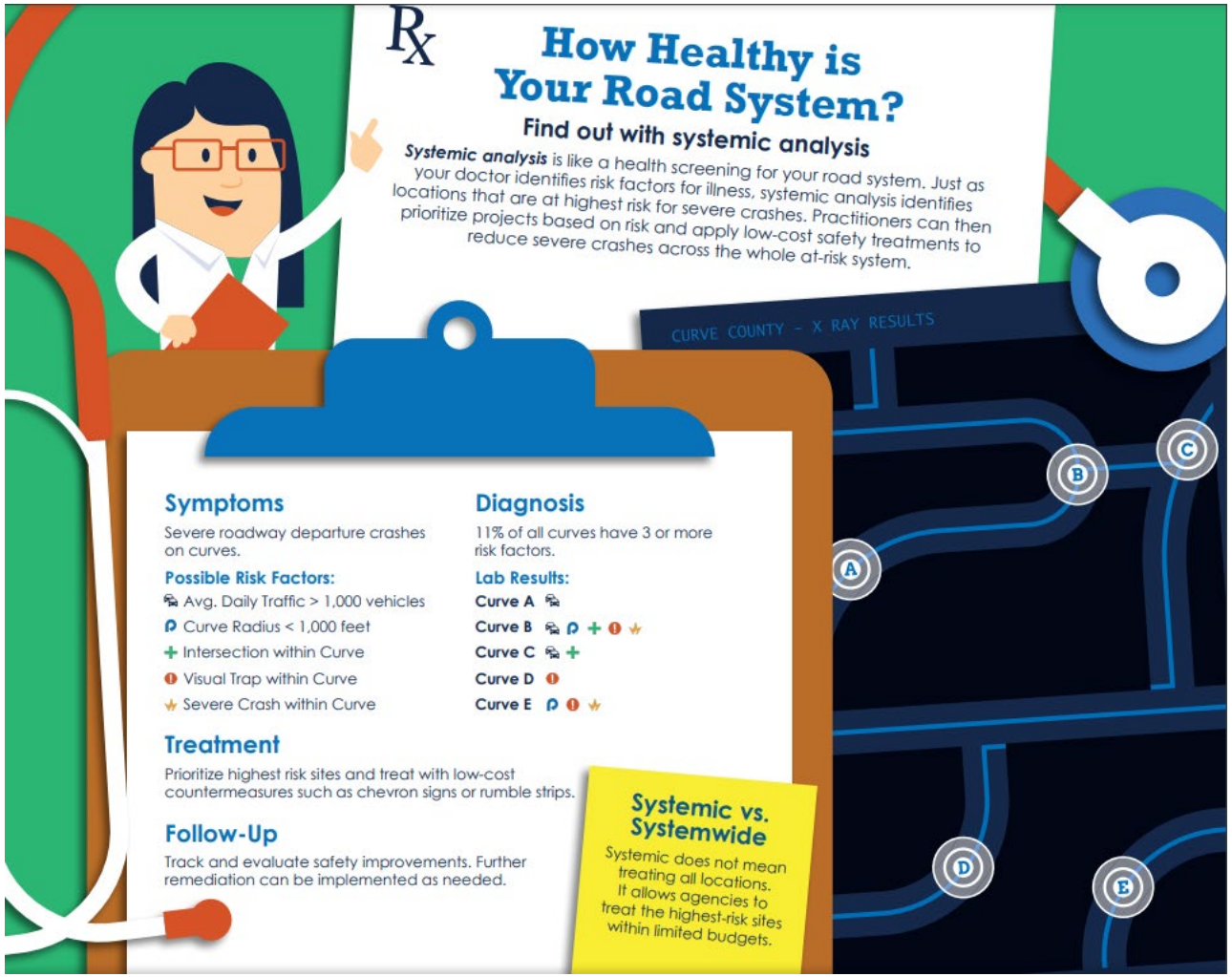
Fatal Crash Locations are Random

2019-2021



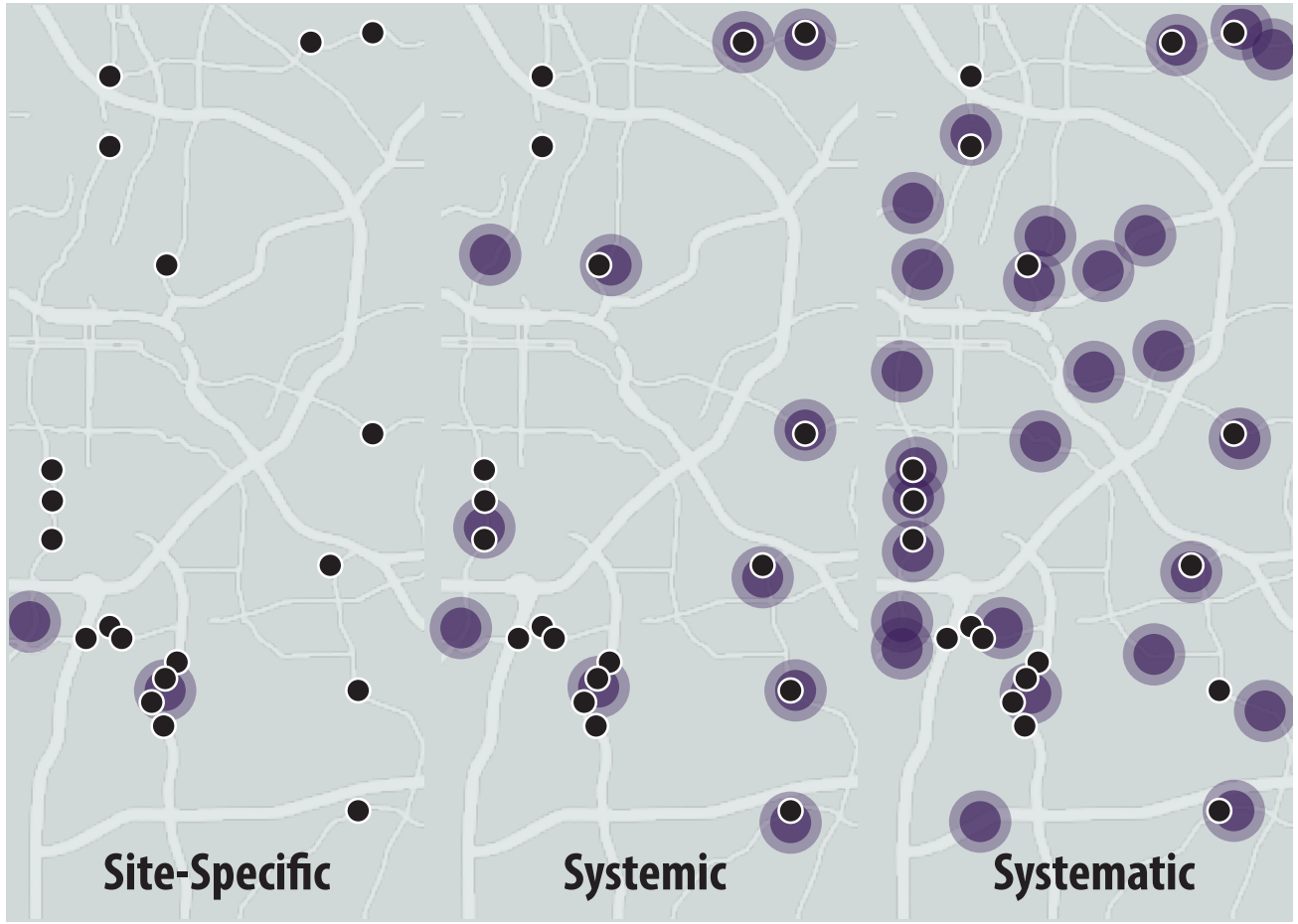
Source: NHTSA (https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars)

How healthy is your Road System?



Source: FHWA

Hot Spot (Site-Specific), Systemic, and Systematic Safety



Source: FHWA

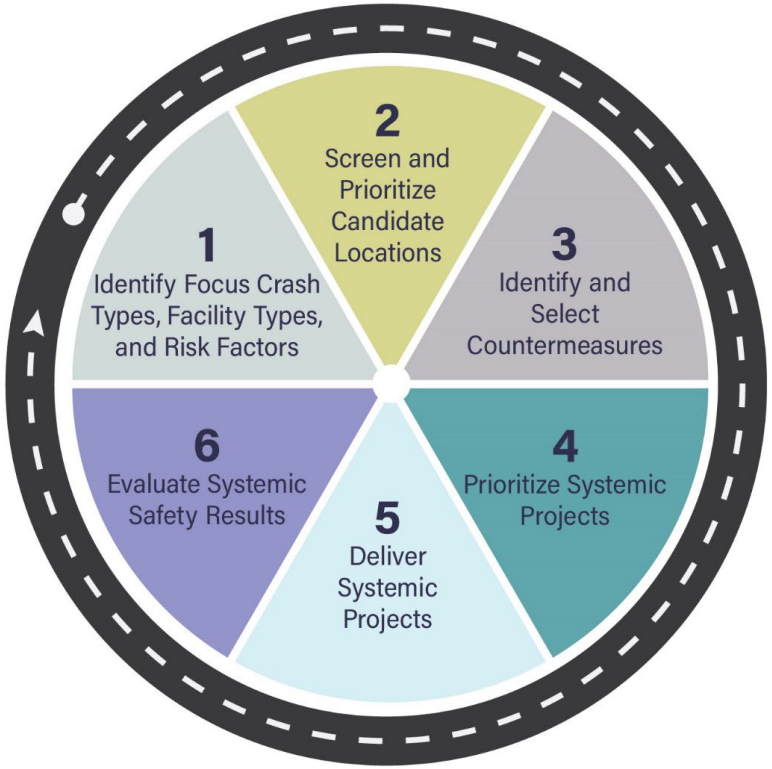
Implementing The Systemic Approach to Safety

Public agencies at all levels:

- ✓ **Federal**
- ✓ **State**
- ✓ **Tribal**
- ✓ **Local**
- ✓ **Regional**

Agency personnel includes:

- ✓ **Analysts**
- ✓ **Engineers**
- ✓ **Public Works Personnel**
- ✓ **Planners**
- ✓ **Program Managers**



Source: FHWA

Supporting Resources

- FHWA's Systemic Approach to Safety Webpage, *Systemic Safety Project Selection Tool*, and draft updated guide
- *NCHRP Report 893 – Systemic Pedestrian Safety Analysis*
- *NCHRP Report 955 – Guide for Quantitative Approaches to Systemic Safety Analysis*

Source: FHWA

Four Approaches (and Examples) of the Systemic Approach to Safety – Risk Identification

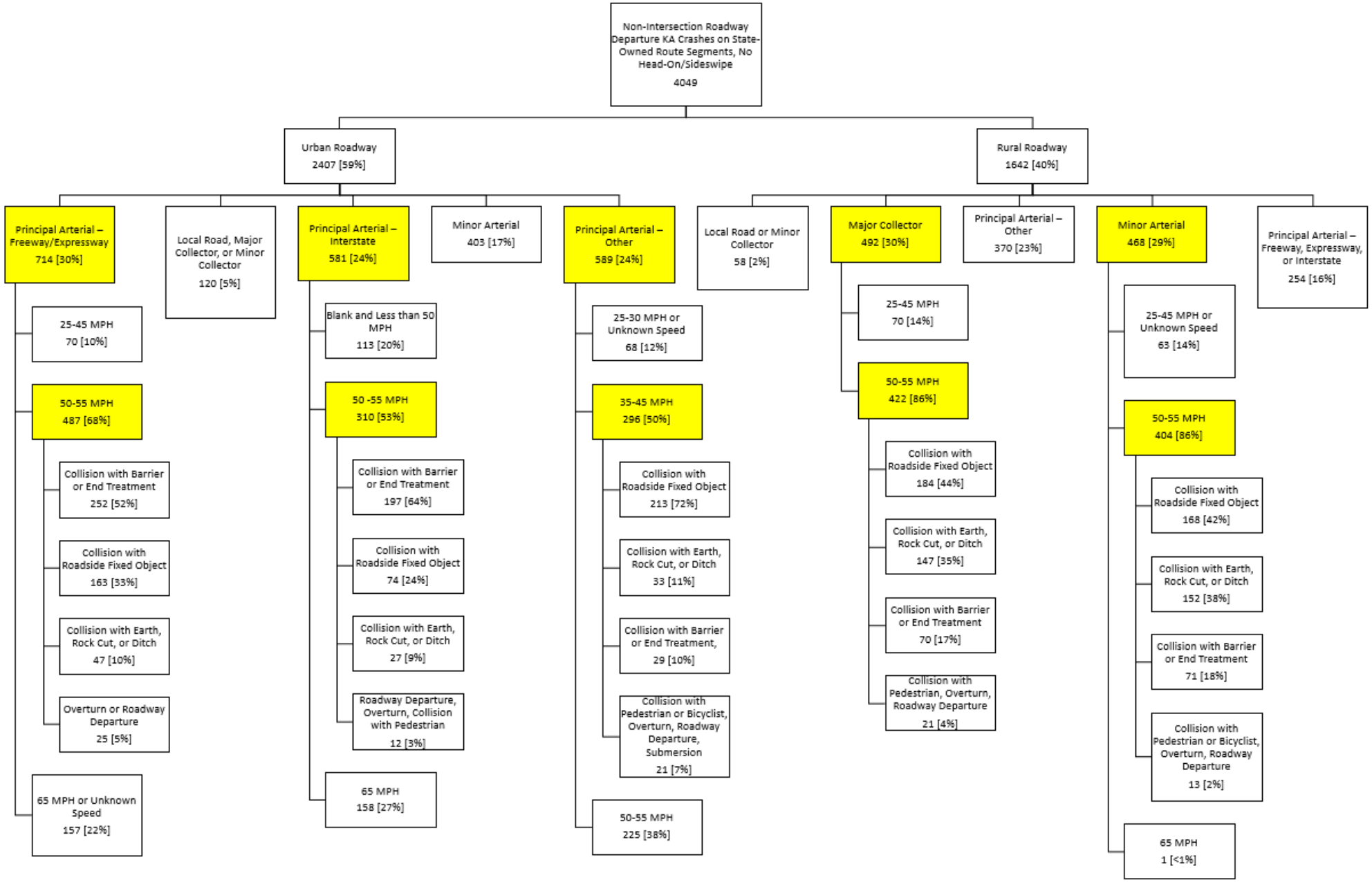
- New York Roadway Departure Safety Action Plan - Overrepresentation
- Massachusetts Older Driver Safety – Statistical Modeling
- San Juan National Forest Roadway Departure Safety – Established Findings
- Kentucky Local Road Safety Plans – Local Knowledge

Sophistication Level	High Analysis Sophistication	Low Analysis Sophistication
High Data Sophistication	**Statistical Modeling**	**Overrepresentation, Established Findings**
Low Data Sophistication	**Established Findings**	**Established Findings or Local Knowledge**

Example 1 - Roadway Departures in New York

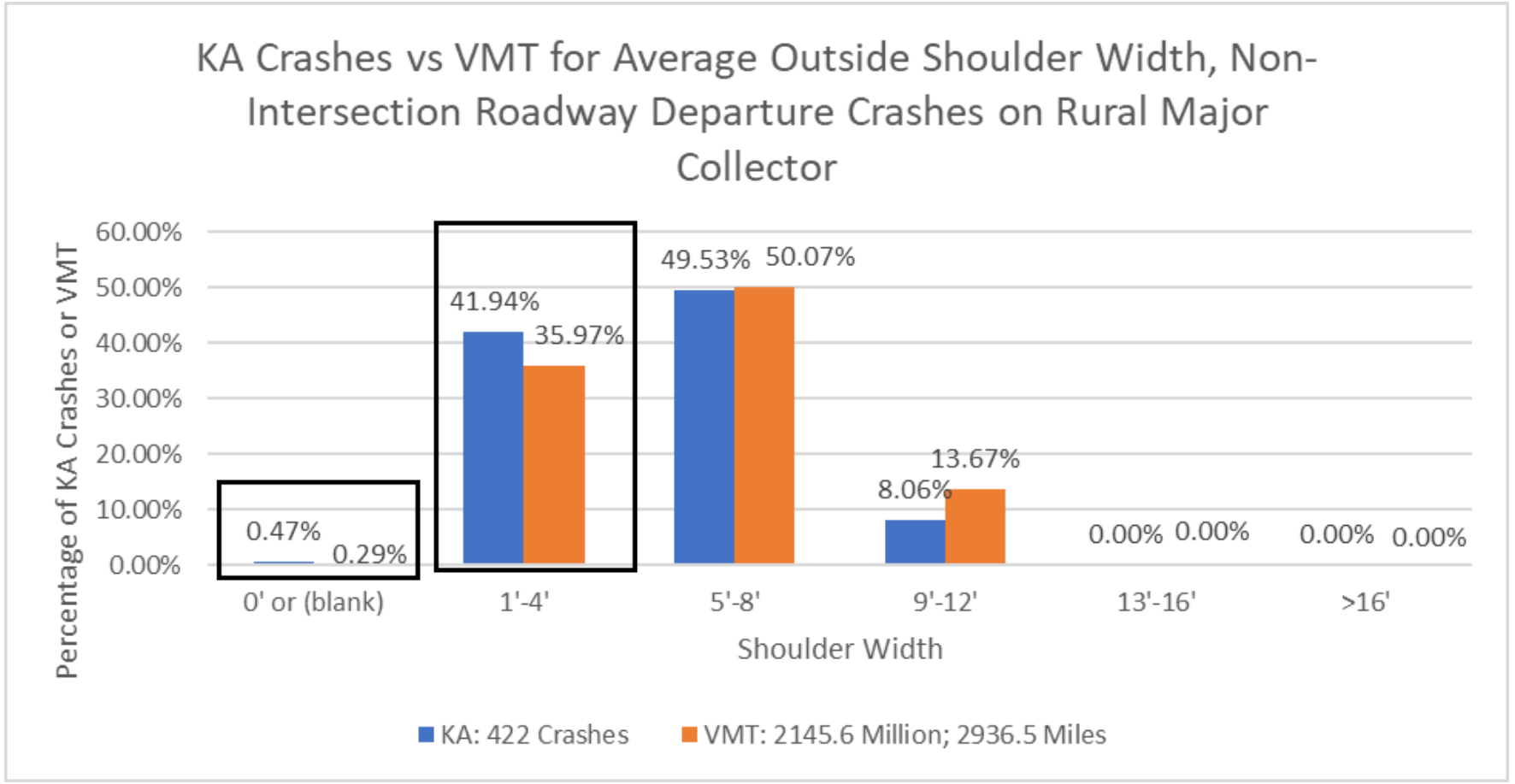
- Selected four focus crash types:
  - Non-intersection single-vehicle roadway departure crashes
  - Non-intersection head-on and sideswipe-opposite direction crashes
  - Non-intersection single-vehicle roadway departure crashes on horizontal curves
  - Non-intersection head-on and sideswipe-opposite direction crashes on horizontal curves

Source: FHWA



Source: NYSDOT, FHWA

Using Overrepresentation to Find Risk Factors



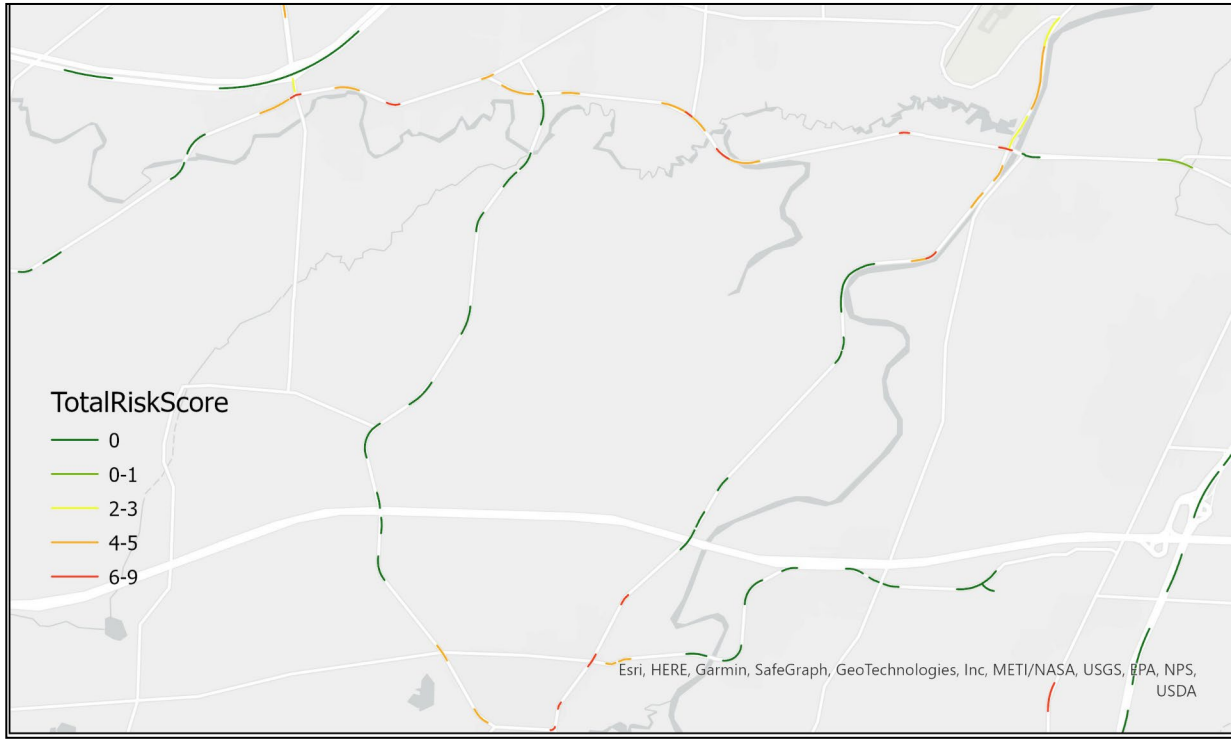
Source: NYSDOT, FHWA

Rural Horizontal Curves in New York

Facility Types	Rural Minor Arterial and Major Collector 50-55 MPH				Rural Principal Arterial - Other 50-55 MPH			
Risk Factors	Risk Factors	394 KA Crashes	1,934.5 Million VMT	2240 Miles	Risk Factors	151 KA Crashes	1,168.0 Million VMT	701 Miles
AADT	< 2,000	36%	26%	51%	< 4,000	50%	29%	54%
Median Type	N/A	N/A	N/A	N/A	No median	97%	90%	94%
Horizontal Curve Radius	< 875’	49%	31%	35%	< 1,125’	53%	33%	37%
Side Friction Demand	> 0.22	13%	5%	6%	> 0.1	25%	11%	13%
Shoulder Width	1’-4’	44%	34%	39%	1’-4’	36%	19%	21%
Shoulder Type	Stabilized with mowing	65%	61%	59%	Stabilized with mowing	N/A	N/A	N/A
Counties	Broome Columbia Dutchess Erie Essex Tompkins Wyoming	25%	15%	13%	Chautauqua Essex Niagara Orleans Ulster	26%	13%	14%
KA Crashes per Mile	> 0.35 KA RwD Crashes per Mile per Year	99%	5%	4%	> 0.38 KA RwD Crashes per Mile per Year	99%	8%	6%

What is New York doing now?

- Finalizing their implementation plan
  - Primarily delineation countermeasures for tangents
  - Tiered horizontal curve packages based on the level of risk
  - Countermeasures based on three engineering directives
    - Keep Vehicles on the Road
    - Reduce the Potential for Crashes when the Vehicle Leaves the Lane
    - Minimize the Severity of a crash



Source: NYSDOT, FHWA

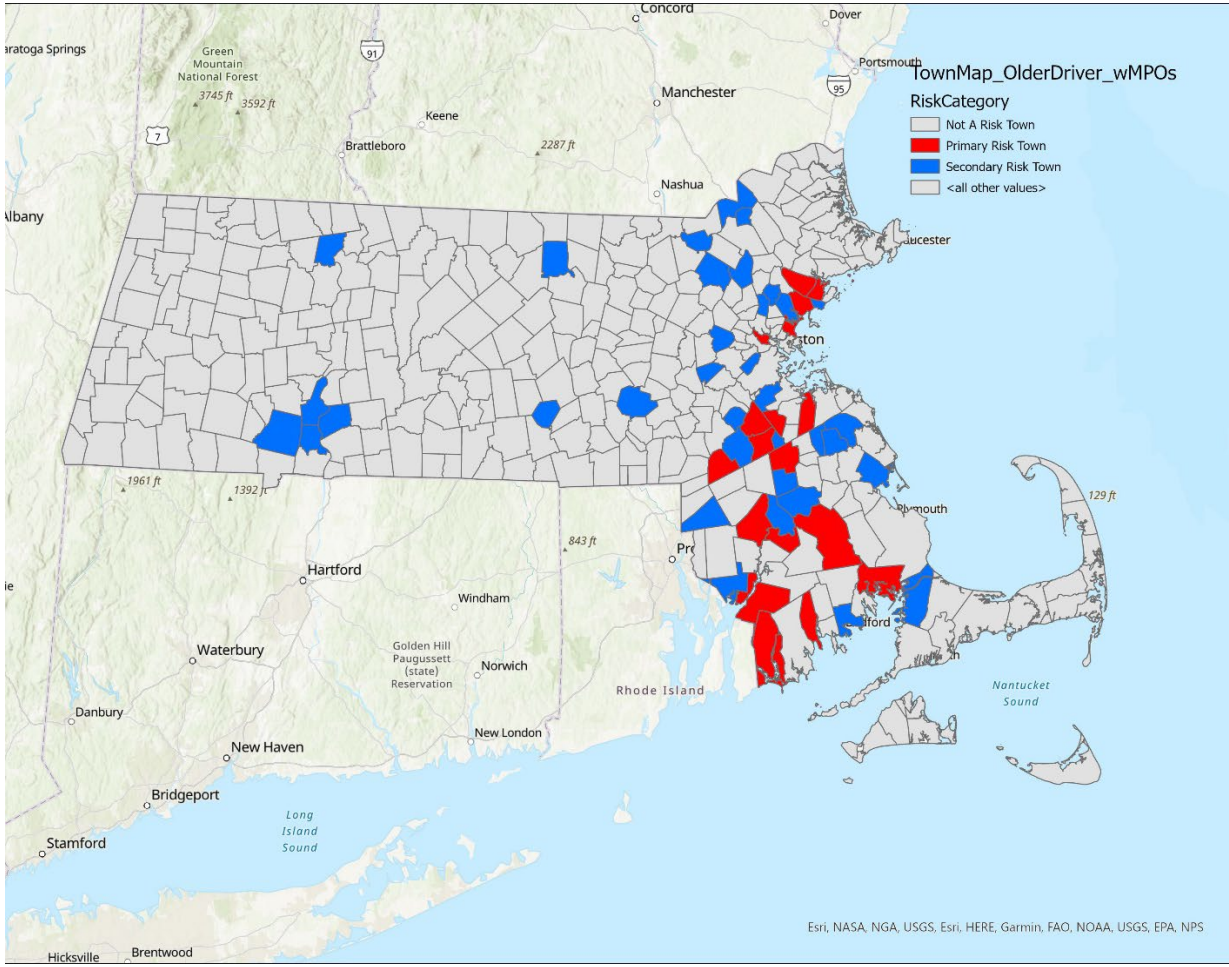
Example 2 – Older Drivers in Massachusetts

- Massachusetts included older drivers as an emphasis area in their 2018 SHSP.
- Traditional systemic approach is at the site level – segments, curves, intersections
- Does that make sense for something like older driver crashes.

Source: MassDOT

A Geographic Approach

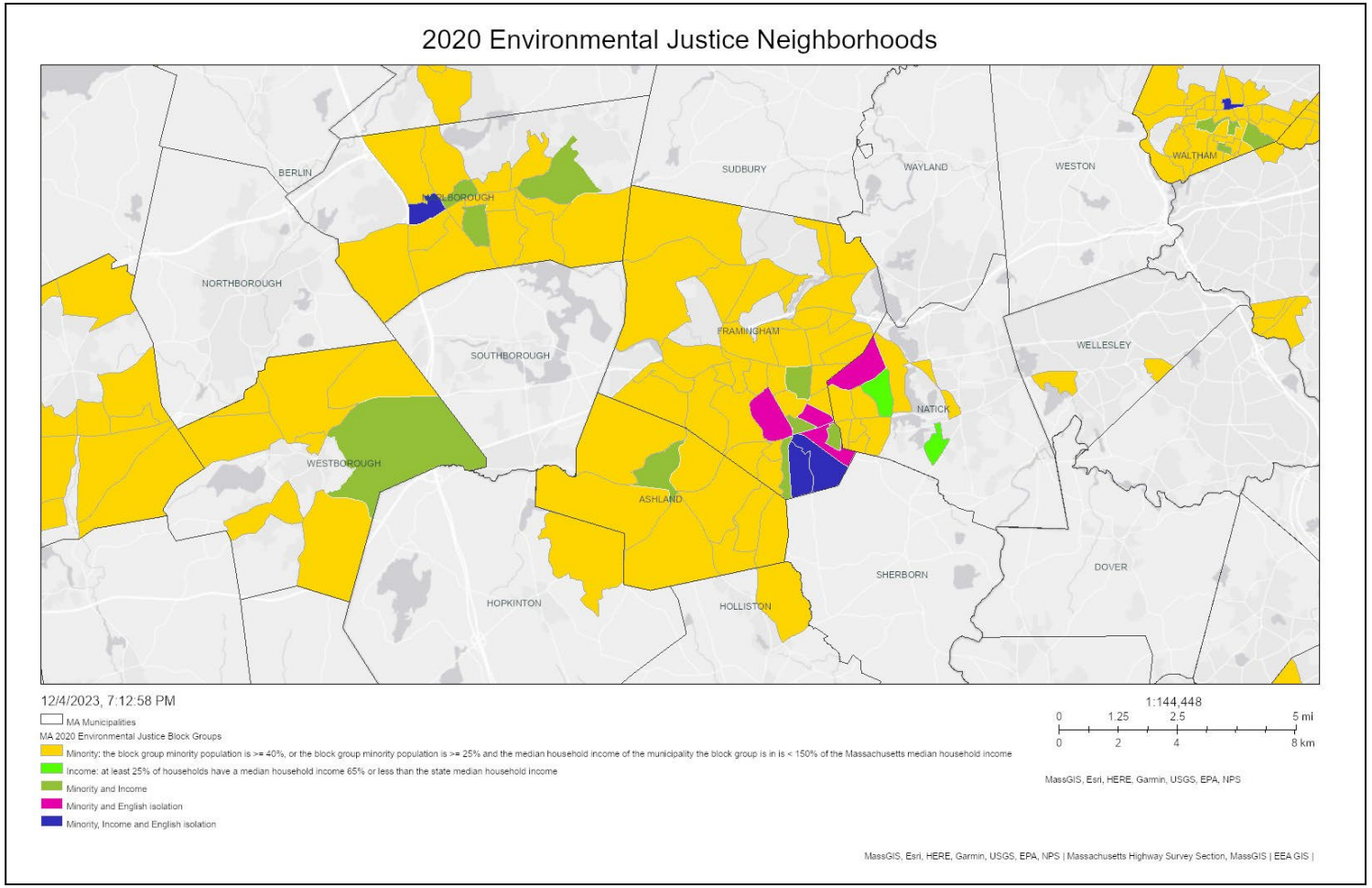
- Consider stakeholder needs
- Adapt the systemic approach
- Consider the data sources



Source: MassDOT

Statistical Models

- Crash Data
- Roadway Data
- Driver License Data
- School Location Data
- College and University Data
- Citation Data
- Healthy Aging Data
- Environmental Justice Data
- Other Data sets



Source: MassDOT

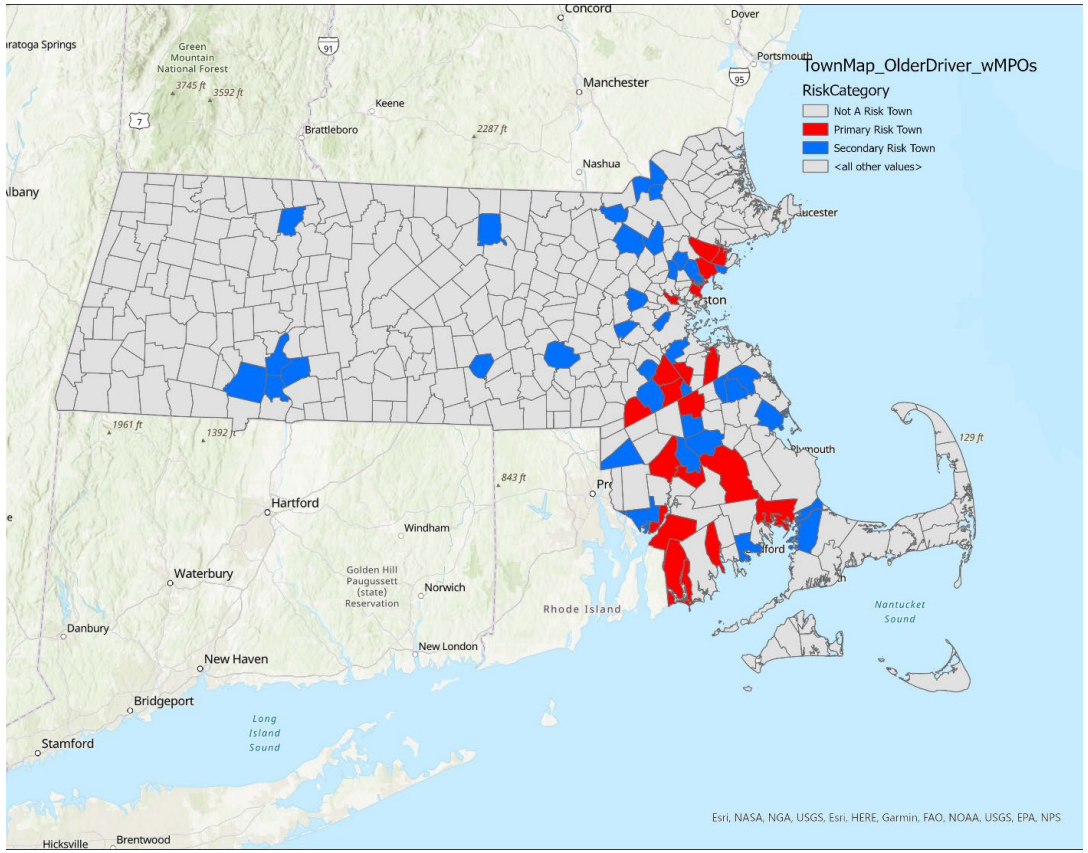
Resulting Statistical Model

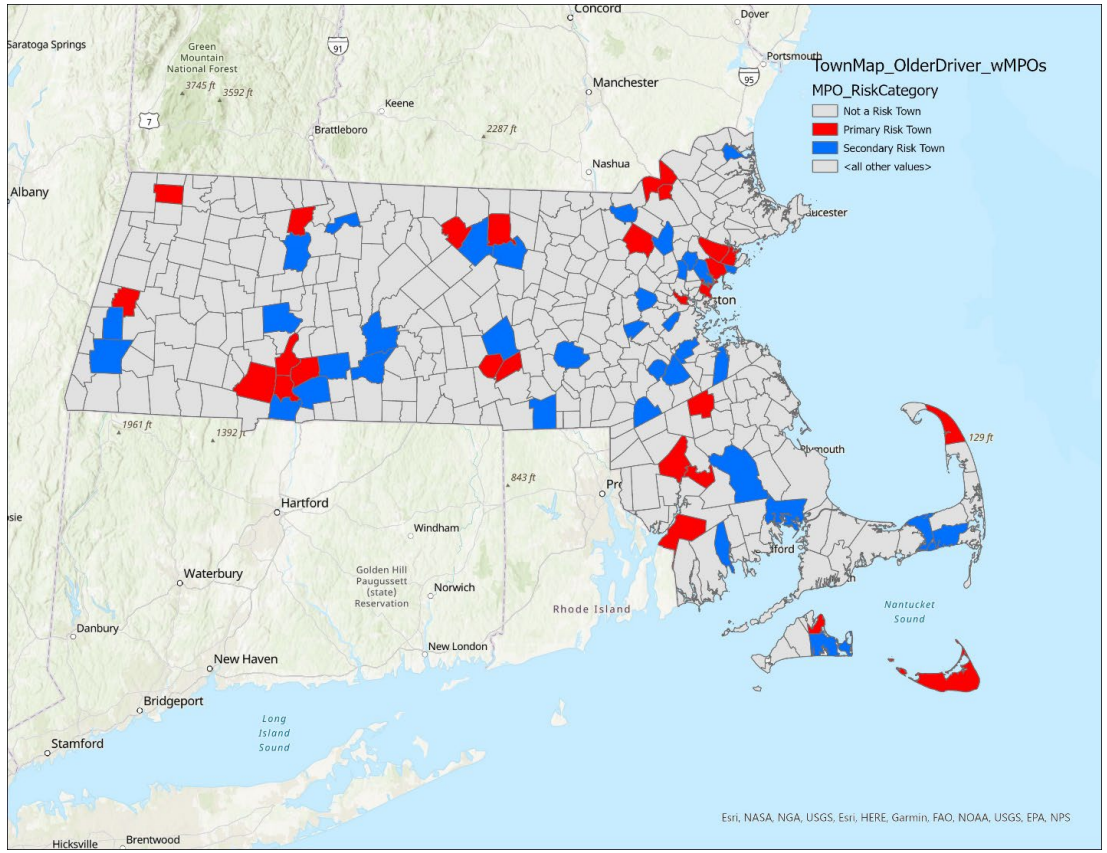
Variable (Number)	Coefficient	Standard Error	z-value	P>|z|	95% Confidence Interval	
Proportion of mileage that is interstate, freeway, or expressway	3.139	1.113	2.82	0.005	0.957	5.321
The number of senior care providers in the town is more than 0.	0.288	0.095	3.02	0.003	0.101	0.475
Annual impaired driving citations per centerline mile in the town is greater than 0.5.	0.230	0.102	2.25	0.025	0.030	0.430
Annual speeding citations per mile in the town is greater than 3.	0.193	0.081	2.38	0.017	0.034	0.353
Natural log of persons aged 65 or older in the town.	0.348	0.049	7.03	<0.001	0.251	0.444
2 or fewer assisted living facilities in the town	0.170	0.113	1.51	0.131	-0.051	0.391
The percentage of persons aged 65 or older with self-reported cognitive issues	2.430	1.128	2.16	0.031	0.220	4.640
Proportion of licensed drivers aged 65 or older	0.569	0.552	1.03	0.303	-0.513	1.651
MPO is SRPEDD or OCPC	0.508	0.101	5.02	<0.001	0.310	0.706
MPO is MVC	0.734	0.422	1.76	0.078	-0.083	1.570
MPO is CCC or BRMPO	0.295	0.086	3.43	0.001	0.127	0.463
Constant	-8.506	0.418	-20.32	<0.001	-9.326	-7.686
Natural log of the product of centerline mile length and 5 years of crash data in the town. (Offset)	1	N/A	N/A	N/A	-2.045	-1.433
alpha	0.176	0.156	N/A	N/A	0.129	0.238
Note: Number of observations = 350; Log likelihood = -803.56534; Pseudo R2 = 0.1277; LR chi2(11) = 235.31; Prob > chi2 = <0.0001.						

Assessing Risk

Risk Factors for Older Driver KA Crashes	Suggested Scoring
Proportion of mileage that is interstate, freeway, or expressway	Continuous from 0 to 1 for the range of values.
The number of senior care providers in the town is more than 0.	1 if true; 0 otherwise
Annual impaired driving citations per centerline mile in the town is greater than 0.5.	1 if true; 0 otherwise
Annual speeding citations per mile in the town is greater than 3.	1 if true; 0 otherwise
Natural log of persons aged 65 or older in the town.	Continuous from 0 to 2 for the range of values.
2 or fewer assisted living facilities in the town	1 if true; 0 otherwise
The percentage of persons aged 65 or older with self-reported cognitive issues	Continuous from 0 to 0.5 for the range of values.
Proportion of licensed drivers aged 65 or older	Continuous from 0 to 0.5 for the range of values.
MPO is SRPEDD or OCPC	0.75 if true; else
MPO is MVC	1 if true; else
MPO is CCC or BRMPO	0.25 if true; 0 otherwise
Maximum potential score for a town:	9.0

Next Steps for Massachusetts

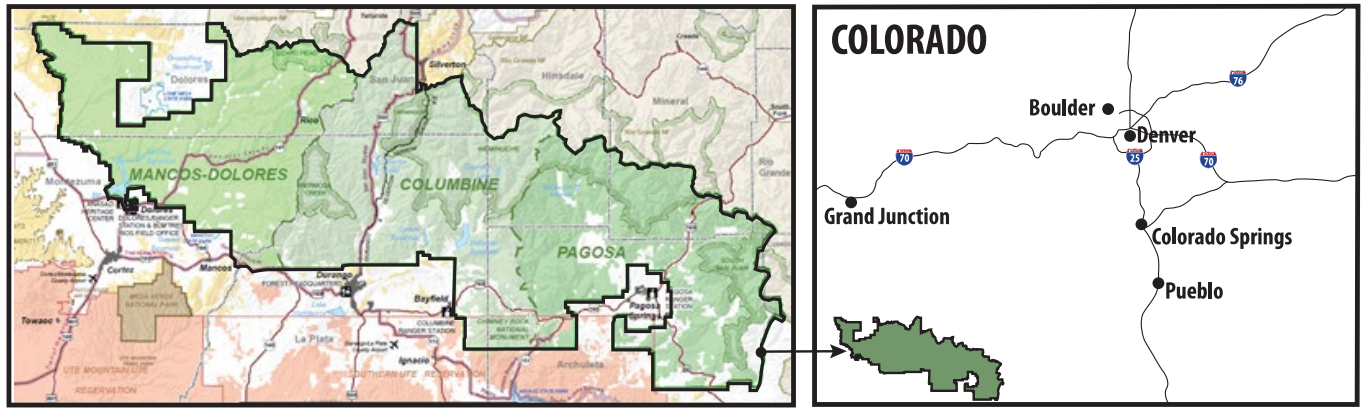




Source: MassDOT

Established Findings – Roadway Departures in San Juan National Forest

- San Juan National Forest (SJNF) falls under the jurisdiction of the United States Forest Service (USFS).
- The Forest covers 1.8 million-acres in southwest Colorado.
- USFS is responsible for Forest roads, maintaining roughly 2,500 miles of roadway in the Forest classified by maintenance level.
- Federal Lands Highway (FLH), in partnership with the Federal Highway Administration (FHWA) Office of Safety, developed this Forest Road Safety Plan (FRSP) to:
  - Assess policies.
  - Identify relevant risk factors.
  - Recommend key countermeasures.



Source: FHWA

Established Findings for Low-Volume Roads

- Al-Kaisy and Huda published a framework for screening low volume roads in Montana.
  - Framework does not necessarily require crash data.
- Segment-level risk factors include:
  - Road width.
  - Horizontal curve radius.
  - Vertical grade.
  - Concurrent with parallel research project through FLH Innovation and Research Council (IRC).

Risk Factor	Tangents	Curves
Average lane width	★	★
Shoulder width	★	★
Grade	★	★
Radius		★
Sideslope	★	★
Horizontal sight distance	★	★
Distance to fixed roadside objects	★	★
Driveway/access point density	★	
Intersection or driveway present		★

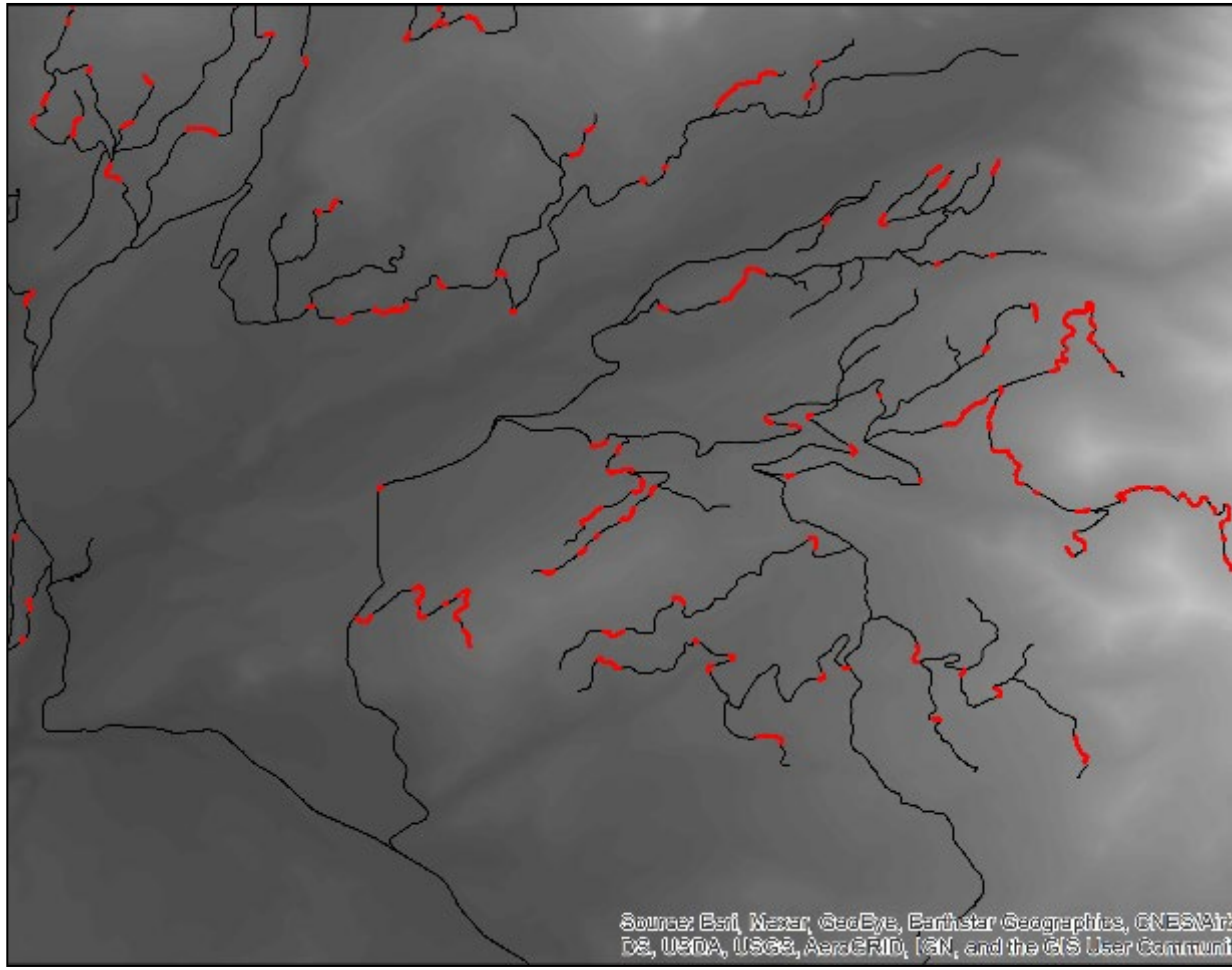
Assessing Available Data

- Focus on Forest roads, although CDOT road analysis summarized in plan.
  - Only 28 locatable crashes between 2010-2018.
  - Limited reliability with respect to exact location.
  - No meaningful spatial hotspots.
- Applied systemic safety principles to identify correlations with crash risk.
  - When and how are crashes occurring?
  - Where are crashes occurring relative to centerline mileage?

Operational Maintenance Level	Open Mileage (GIS) %	Total Crashes %
1 - BASIC CUSTODIAL CARE (CLOSED)	--	0%
2 - HIGH CLEARANCE VEHICLES	57%	7%
3 - SUITABLE FOR PASSENGER CARS	36%	75%
4 - MODERATE DEGREE OF USER COMFORT	5%	18%
5 - HIGH DEGREE OF USER COMFORT	1%	0%

Assessing Available Data

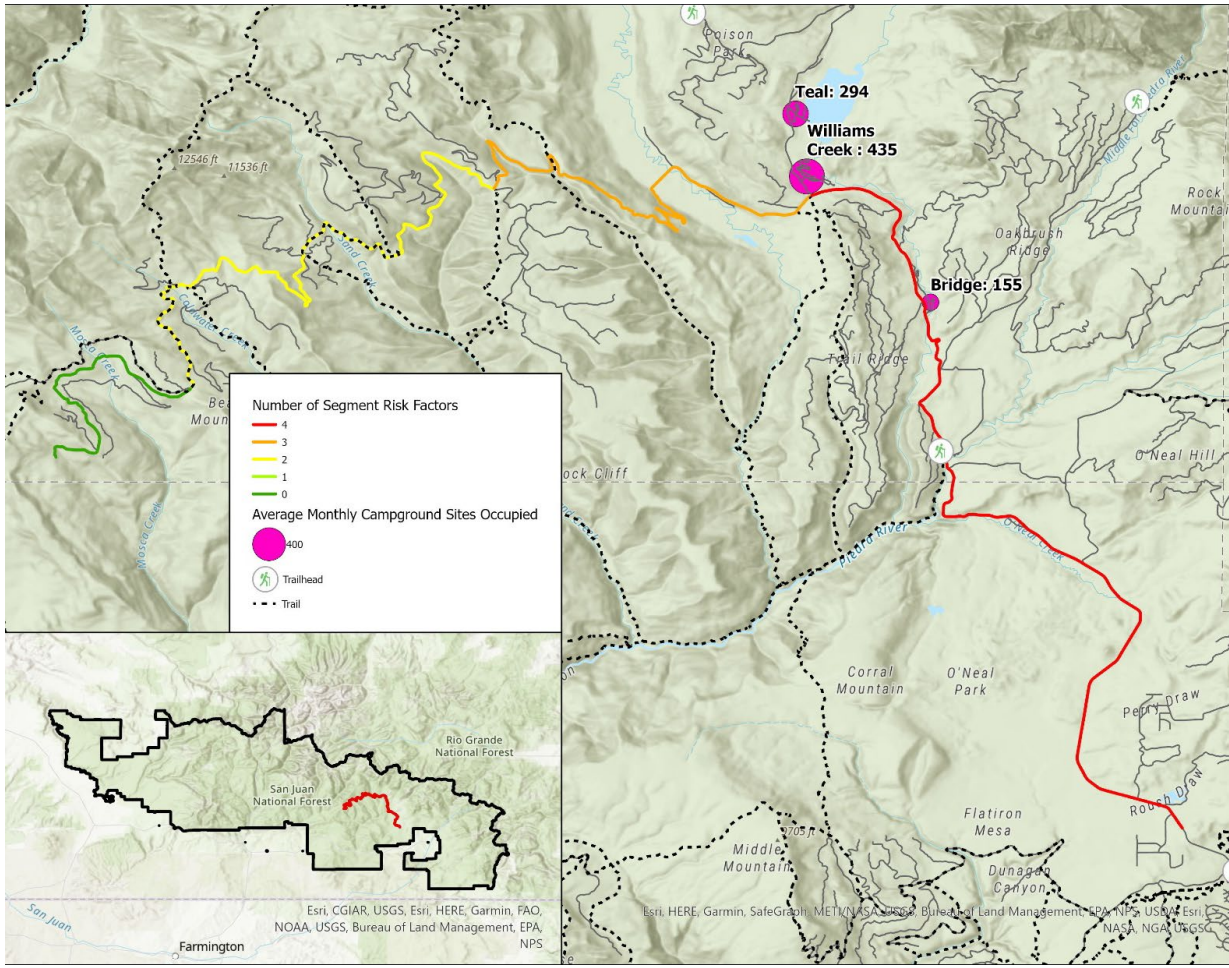
- Centerline data available through Forest Service Geodata Clearinghouse.
- Curvature derived from centerlines using the University of Wisconsin's Curve Finder application.
- Elevation through the United States Geological Survey's (USGS's) National Map (10-meter resolution).
- Other contextual data, including, trails, trailheads, and campground occupancy.



Source: FHWA

Identifying Risk Factors

- Prioritized routes based on key criteria noted in the research.
- Locations of combined horizontal curvature and substantial grade:
  - Horizontal curves with estimated radius less than 300 feet.
  - Vertical grade with a slope estimated at greater than 10 percent.
- Four Forest road risk factors based on systemic review:
  - Operational maintenance level of 3 (suitable for passenger cars) or 4 (moderate degree of user comfort).
  - Functional classification of arterial or collector.
  - Crushed aggregate or gravel surface type.
  - Two travel lanes indicated in USFS centerline records.
- Traffic volumes recording during counts between 2008 and 2015.



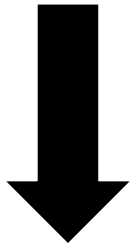
Source: FHWA

Practical Approach – Best Assessment with the Least Data

- Simplify screening process for low data environments.
  - Combined with other existing data as able.
- Target the greatest number of risk factors with common, public datasets.

Source: FHWA

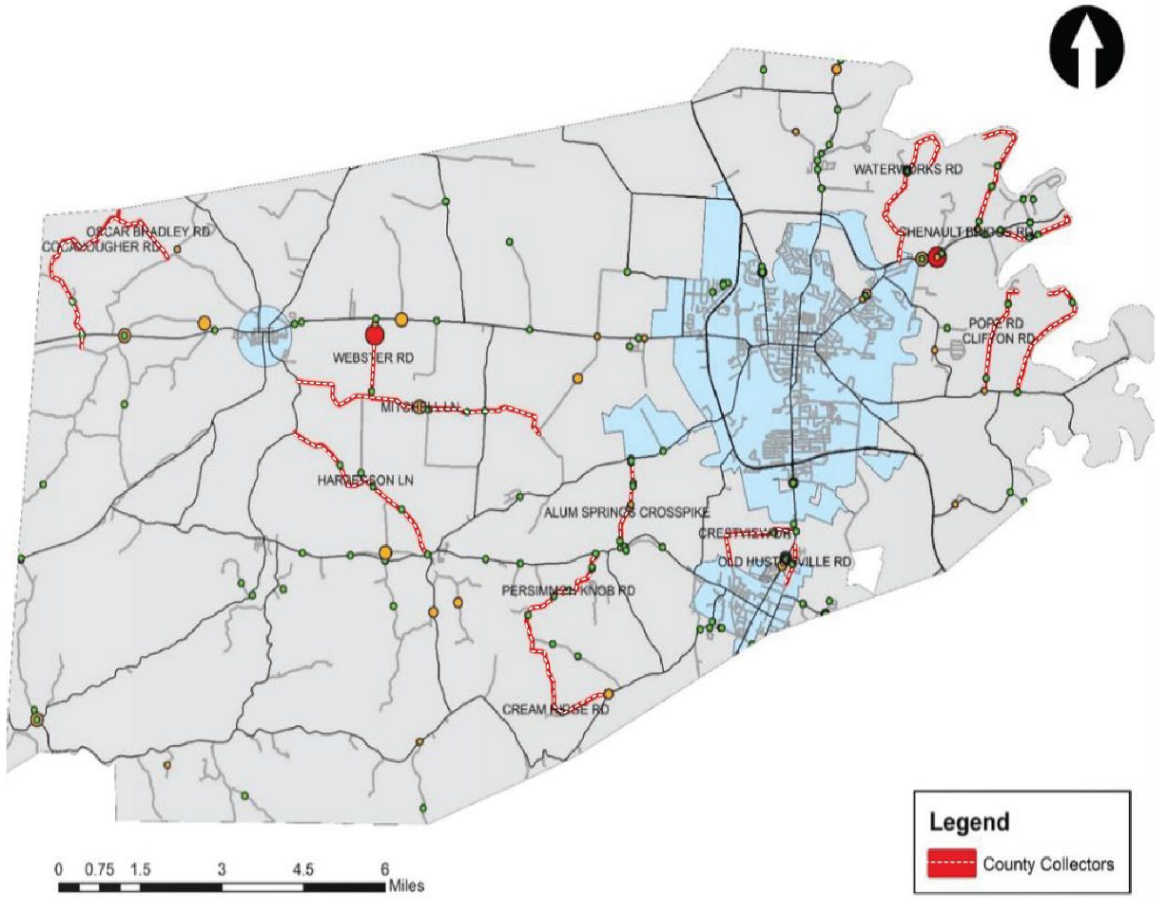
- Centerlines w/ Curve Finder.
- Digital Elevation Models (DEMs).



- Exposure.
- Sharp Curves.
- Steep Grade.
- Limited Sight Distance.
- Narrow Roads and Shoulders.
- Roadside Slopes.
- Roadside Hazards.
- Clear Zone.

Assessing Risk with Local Knowledge

- Kentucky Transportation Cabinet, Kentucky LTAP, University of Kentucky, and FHWA helped counties in Kentucky develop Local Road Safety Plans
- Limited data available (roadway and crash data), what is the best way to assess risk?
- Focused on their “County Collector System”



Source: Boyle County

Assessing Risk with Local Knowledge – Boyle County

- County Judge Executive.
- County Engineer.
- County Sheriff.
- County EMS.
- School Transportation Supervisor.

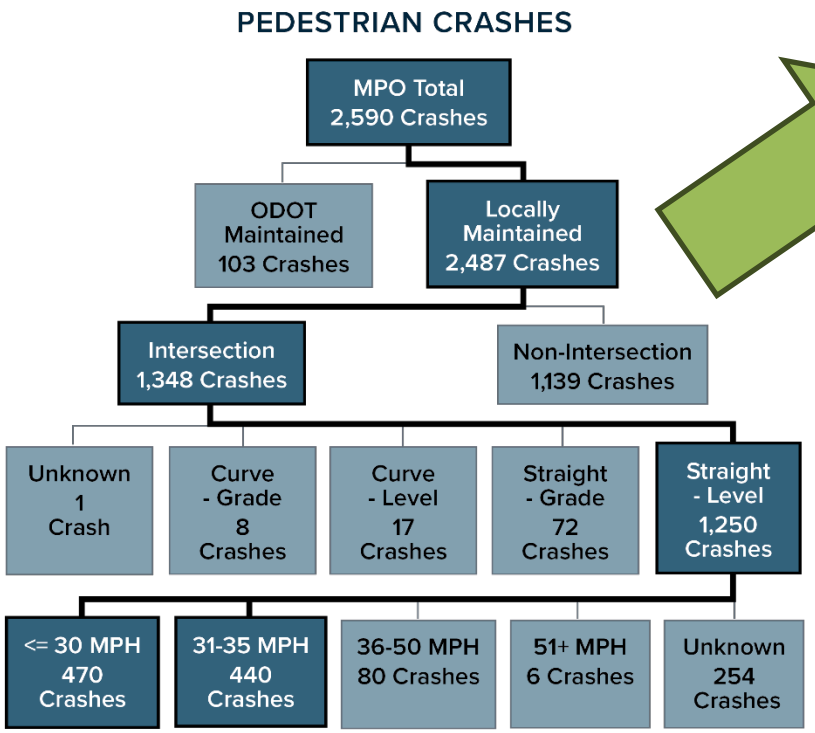
Road Name	Horizontal Curve	Speed	ADT	Vertical Curve	Clear Zone	Road Width	Hazard Score	Hazard Rank
Alum Springs Crosspike	3	3	3	2	3	2	16	1
Harberson Lane	3	3	2	3	2	2	15	2
Waterworks Road	3	3	2	2	3	2	15	2
Oscar Bradley Road	3	3	1	3	2	2	14	4
Cocanougher Road	3	3	1	2	2	3	14	4
Godbey Lane	1	3	2	3	2	2	13	6
Pope Road	2	3	3	2	1	2	13	6
Cream Ridge Road	3	2	1	2	2	2	12	8

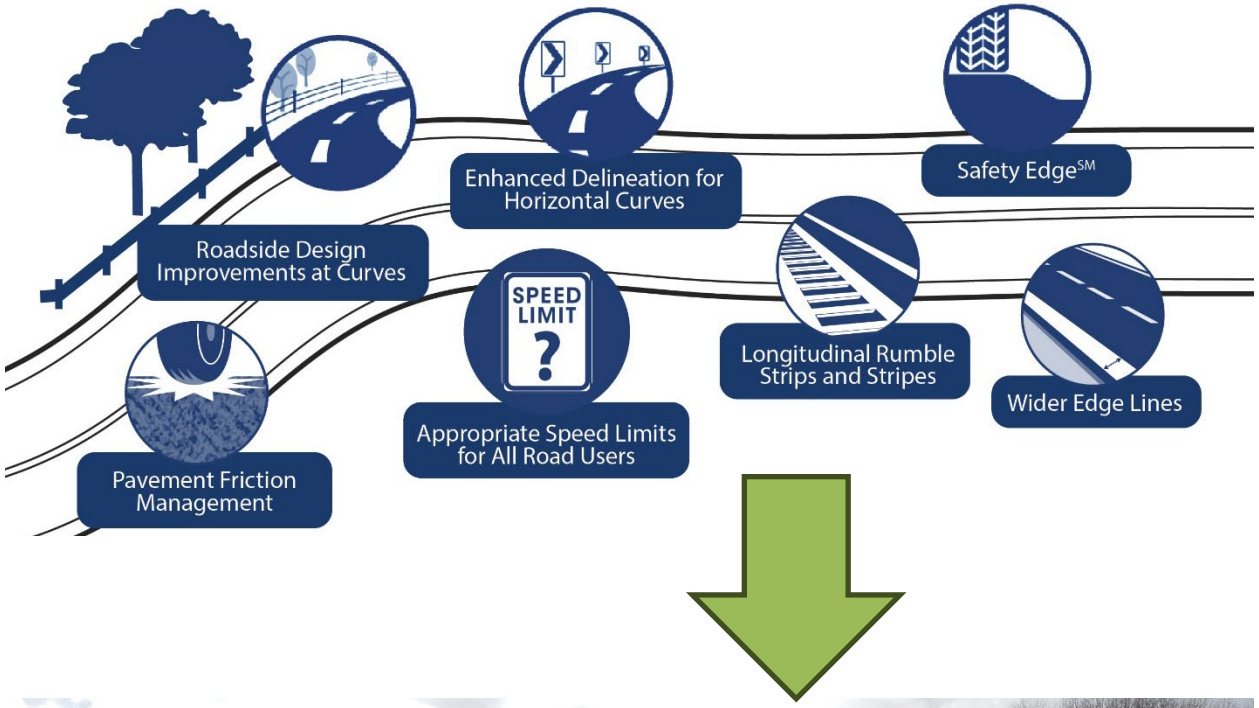
Source: Boyle County

Boyle County High Risk Roads

Source: Boyle County

Road Name	EPDO Rank	Hazard Rank	Final Rating	Final Ranking
Alum Springs Crosspike	1	1	2	1
Harberson Lane	4	2	6	2
Godbey Lane	2	6	8	3
Cream Ridge Road	3	8	11	4
Chenault Bridge Road	4	8	12	5
Waterworks Road	10	2	12	5
Pope Road	7	6	13	7
Wells Landing Road	6	8	14	8
Mitchell Lane	7	8	15	9
Persimmon Knob Road	7	8	15	9
Oscar Bradley Road	12	4	16	11
Cocanougher Road	12	4	16	11
Clifton Road	12	8	20	13
Old Hustonville Road	15	8	23	14
Crestview Drive	11	15	26	15





Source: MORPC

Countermeasure Selection

- Use CMF Clearinghouse, other resources to create a list of applicable countermeasures
- Develop a standardized approach to countermeasure selection

Countermeasure Summary Table by Roadway Departure Objective

Objective	Countermeasure	Target Crash Types: Head-On	Roll over	Fixed Object	Curve	Cost H-M-L	Option on Narrow Roads*	Option on Unpaved Roads	More Details on Page
Keep Vehicles in Lane	Edge Line Markings		●	●	●	L	✓		5
	Center Line Markings	●			●	L			5
	Curve Warning Signs		○	○	●	L	✓	✓	7
	Delineators		○	○	●	L	✓	✓	9
	Shoulder Rumbles		●	●	○	L			11
	Center Line Rumbles	●			○	L			11
	HFST				●	M	✓		10
Reduce Potential for a Crash	Shoulder Widening	○	●	●	●	M-H	✓		13
	SafetyEdge[SM]	●	●		●	L	✓		15
	Center Line Buffer Area	●				L			17
	Removed Fixed Objects			●	○	L-H	✓	✓	14
	Slope Flattening		●		○	M-H	✓	✓	18
Minimize Severity	Roadside Barriers		●	●	○	M-H	✓	✓	19
	Breakway Features		○	●	○	L	✓	✓	21

*For the purpose of this guide, narrow roads are defined as a two-way road with less than 20 feet of total traveled way.

Table Key

● *Primary countermeasure for this type of crash*

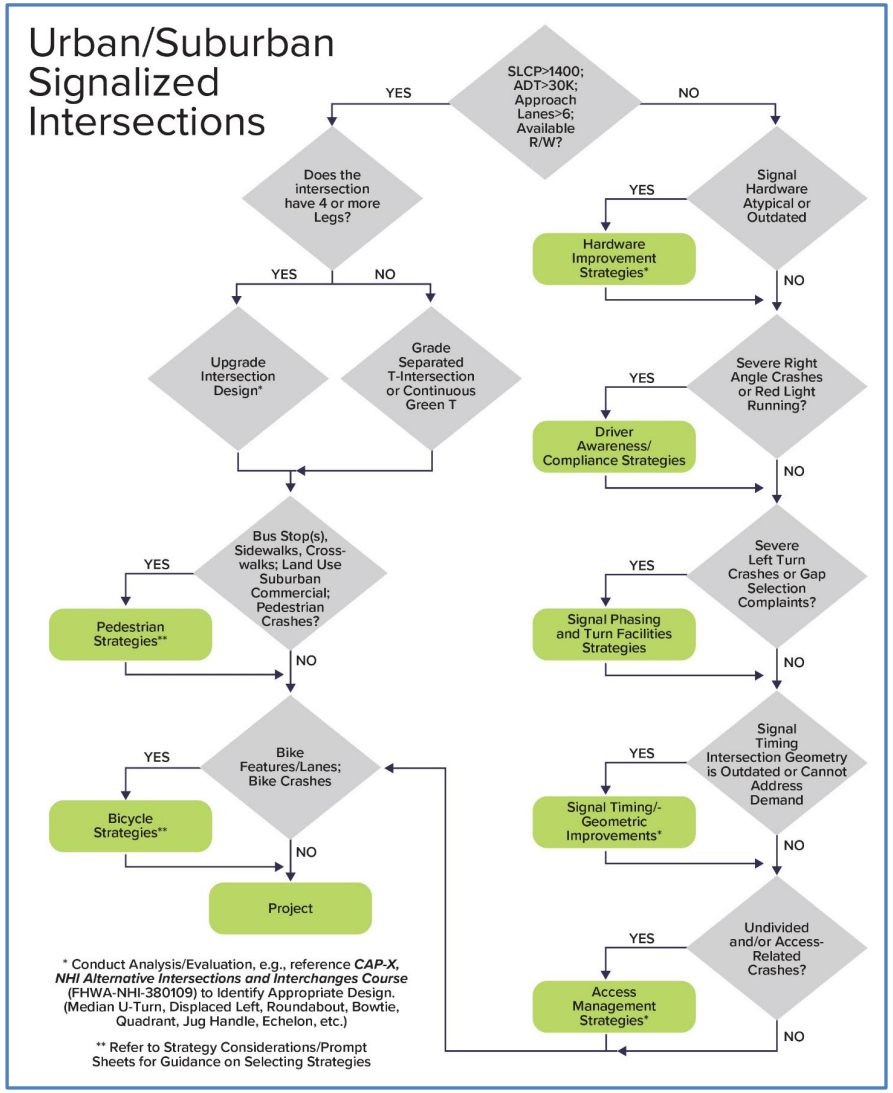
○ *Countermeasure to consider*

L: *Low-cost – up to $5,000 per mile or per curve/location*

M: *Medium-cost – $5,000 to $50,000 per mile or per curve/location*

H: *High-cost – More than $50,000 per mile or per curve/location*

Source: FHWA



Source: Palm Beach County

Prioritizing Systemic Projects

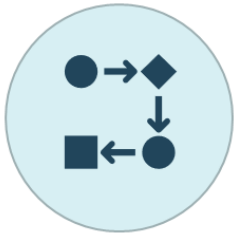
Project ID	Project Type	Description	Environmental or Right-of-Way Impacts	Lives Saved and Serious Injuries Prevented	Cost	BCR	Priority Order
33699	Site-specific	Roundabout at Main Street and Route 104	Moderate	6.1	$2,100,000	8.1	2
45784	Systemic	Chevrons on two-lane rural horizontal curves in District 2	None	30	$800,000	31	1
85142	Systemic	RRFBs at urban mid-block pedestrian crossings in South MPO	Minimum	2.1	$650,000	4.1	3
33559	Systematic	Shoulder rumble strip installation on rural four-lane divided highways that meet criteria	None	1.9	$1,200,000	2.2	4
64741	Site-specific	Road diet on Liberty Avenue in the central business district	Moderate	0.5	$700,000	1.9	5
17458	Systemic	Median cable barriers on unprotected divided freeway segments	None	1.2	$2,450,000	0.9	6
98585	Site-specific	Horizontal and vertical realignment of Route 993 S-curve.	Significant	0.4	$3,000,000	0.2	7

Source: FHWA

Delivering Systemic Projects

- ✓ **Project Bundling**
- ✓ **Indefinite Delivery and Indefinite Quantity (IDIQ) and On-Call Contracts**
- ✓ **Material Procurement**
- ✓ **Quick-Build Applications**
- ✓ **Integrating Systemic Safety into Other Projects and Policies**

Tracking and Evaluation

Benefits of Evaluation per HSIP Evaluation Guide				
				
Understanding the Return on Investments	**Inform Future Decisions**	**Improve Processes**	**Demonstrate Accountability**	**Meet Federal Requirements**

Source: FHWA

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