


2022 Community Safety Report

Village of Seville

NORTHEAST OHIO AREAWIDE COORDINATING AGENCY

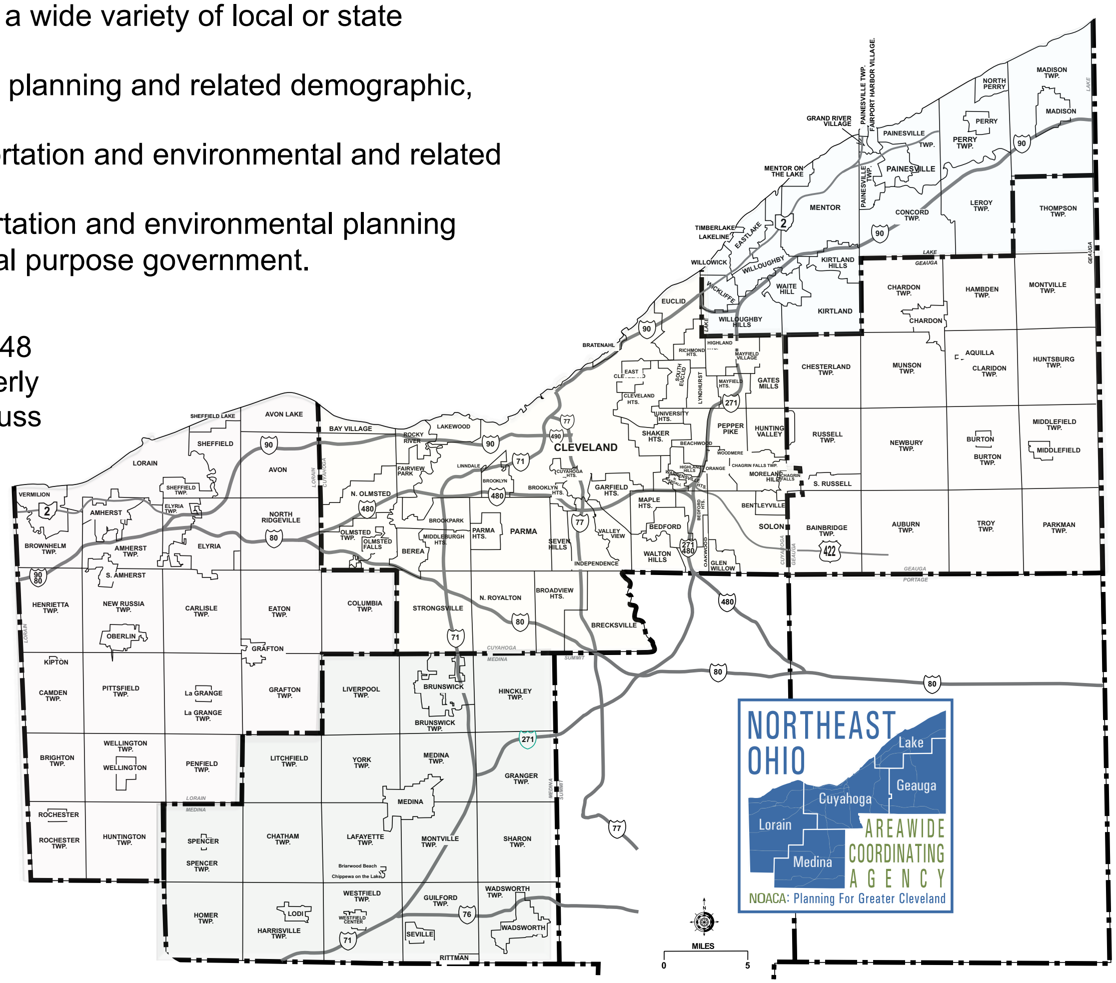
NOACA: Planning For Greater Cleveland

Northeast Ohio Areawide Coordinating Agency

The **Northeast Ohio Areawide Coordinating Agency** (NOACA) is a public organization serving the counties of and municipalities and townships within Cuyahoga, Geauga, Lake, Lorain and Medina (covering an area with 2.1 million people). NOACA is the agency designated or recognized to perform the following functions:

- Serve as the Metropolitan Planning Organization (MPO), with responsibility for comprehensive, cooperative and continuous planning for highways, public transit, and bikeways, as defined in the current transportation law.
- Perform continuous water quality, transportation-related air quality and other environmental planning functions.
- Administer the area clearinghouse function, which includes providing local government with the opportunity to review a wide variety of local or state applications for federal funds.
- Conduct transportation and environmental planning and related demographic, economic and land use research.
- Serve as an information center for transportation and environmental and related planning.
- As directed by the Board, provide transportation and environmental planning assistance to the 172 units of local, general purpose government.

The NOACA Board of Directors is composed of 48 local public officials. The Board convenes quarterly to provide a forum for members to present, discuss and develop solutions to local and areawide issues and make recommendations regarding implementation strategies. As the area clearinghouse for the region, the Board makes comments and recommendations on applications for state and federal grants, with the purpose of enhancing the region's social, physical, environmental and land use/ transportation fabric. NOACA invites you to take part in its planning process. Feel free to participate, to ask questions and to learn more about areawide planning.



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Executive Summary

A Systemic Safety Management approach has recently been incorporated into ongoing NOACA safety programs. This approach uses crash prediction models based on roadway and traffic characteristics for estimating average crash frequency along arterials and major intersections. The Highway Safety Manual (HSM), produced by the American Association of State Highway and Transportation Officials (AASHTO), provides predictive methods for estimating the "expected average crash frequency" of a road network, facility, or individual site, involving vehicles, motorcycles, bicycles, and pedestrians. Combining the identified expected future crash locations with crash history sites will result in safety improvement projects with higher efficacy. The predictive method may also be used in the absence of high-quality historical site-level crash data or where there is no history of reported crashes.

The NOACA systemic safety approach considers 992 centerline miles and 2,993.5 lane-miles of arterial roadways within the region. This safety analysis has separated the arterials by jurisdictional boundaries into 997 distinct segments and also evaluated 529 major intersections based on their roadway and traffic characteristics.

Within the Village of Seville, this analysis considered 2.0 centerline miles and 4.0 lane-miles of arterial roadway which encompass no major intersections. The arterial roadways in Seville make up 0.20% of the total roadway lengths analyzed, which is proportional to Seville having about 0.13% of the NOACA region population.

Due to the recent traffic pattern abnormalities caused by the COVID-19 pandemic, the recorded crash data for 2018 and 2019 were used. During this period, the annual average of recorded crashes along the analyzed arterials was 1.00. The predictive method resulted in 1.00 average annual expected crashes along those arterials and intersections.

The following tables list a prioritization ranking of the selected arterial segments within the Village of Seville based on the estimated average annual crash frequency from highest to lowest.

RANK	ARTERIAL ROAD NAME	FROM	TO
1	SR 3	LAFAYETTE ST	ATLANTIC DR
2	SR 3	HOMESTEAD RD	LAFAYETTE ST

The prioritized sites should be examined together with the observed history of crash locations for investing in safety improvements with higher efficacy.

This safety report includes four parts:

- PART I: Background, Definitions, and Methodology
- PART II: Selected Arterials and Intersections
- PART III: Crash Frequency Prediction
- PART IV: Prioritization of Expected Crash Sites

Part I includes jurisdiction background information, definitions of roadway and intersection types, and the predictive method descriptions.

Part II presents the roadway and traffic characteristics of the analyzed arterials and major intersections.

Part III discusses the estimated crash results.

Part IV provides a prioritized list of arterials and intersections based on the estimated annual predicted crash frequency.

PART I: Background, Definitions, and Methodology

Background

The national Vision Zero initiative envisions a transportation network with zero deaths or serious injuries. One of NOACA's transportation planning goals is to achieve this vision in its five-county region in the future. During the last few years, NOACA has extended the conventional concept for road safety of three E's to **six E's: Education, Engineering, Enforcement, Emergency Response, Evaluation and Equity**. NOACA administers several safety initiatives as part of the agency's Regional Safety Program (RSP) to improve the safety and efficiency of the transportation system.

The primary focus of the RSP is to improve safety by reducing crashes, particularly fatal and serious injury crashes, on all modes of transportation in the NOACA region. This is accomplished in several ways, including:

- Safety Performance Measures: monitor and report on crash trends and progress in meeting regional crash reduction goals
- Safe Routes to School (SRTS): provide assistance and support to communities undertaking SRTS planning or implementation
- Road Safety Audits and Technical Assistance: work with ODOT and local communities to study corridors and intersections and recommend safety improvements
- SAVE Plan Implementation: address the goals and actions in the plan to improve regional transportation safety

The SAVE plan intends to save lives by identifying the high-crash locations and implementing safety treatments at those sites. This plan was developed with the vision that traffic deaths and injuries can be prevented with appropriate planning, policies and programs, with a long-term goal of reducing the number of fatalities and serious injuries by 50% by the year 2040.

The SAVE Plan is a localized companion document that supports the Ohio Department of Transportation's (ODOT's) Strategic Highway Safety Plan (SHSP), which is the cornerstone of the federal Highway Safety Improvement Program (HSIP) in Ohio. The 10 emphasis areas identified for specific action in the SAVE Plan are:

1. Intersection
2. Roadway Departure
3. Young Driver
4. Speed
5. Impaired Driving
6. Older Driver
7. Distracted Driving
8. Pedestrian
9. Motorcycle
10. Bicycle

To complement the current safety plans, a Systemic Safety Management approach has recently been incorporated into ongoing NOACA safety programs. This approach is intended to address crash types that occur with high frequency across the roadway network but that are not concentrated at individual locations. This is because these crashes tend to be overlooked when ranking sites using a crash-history-based safety management approach. As a proactive approach, the Systemic Safety Management enhances analysis for implementation by detecting crash potential at locations that may not have a history of crashes. In particular, even sites with zero crash history can be identified for potential safety improvement. By applying this approach, NOACA will consider the potential for future crashes and crash history when identifying where to make safety improvements.

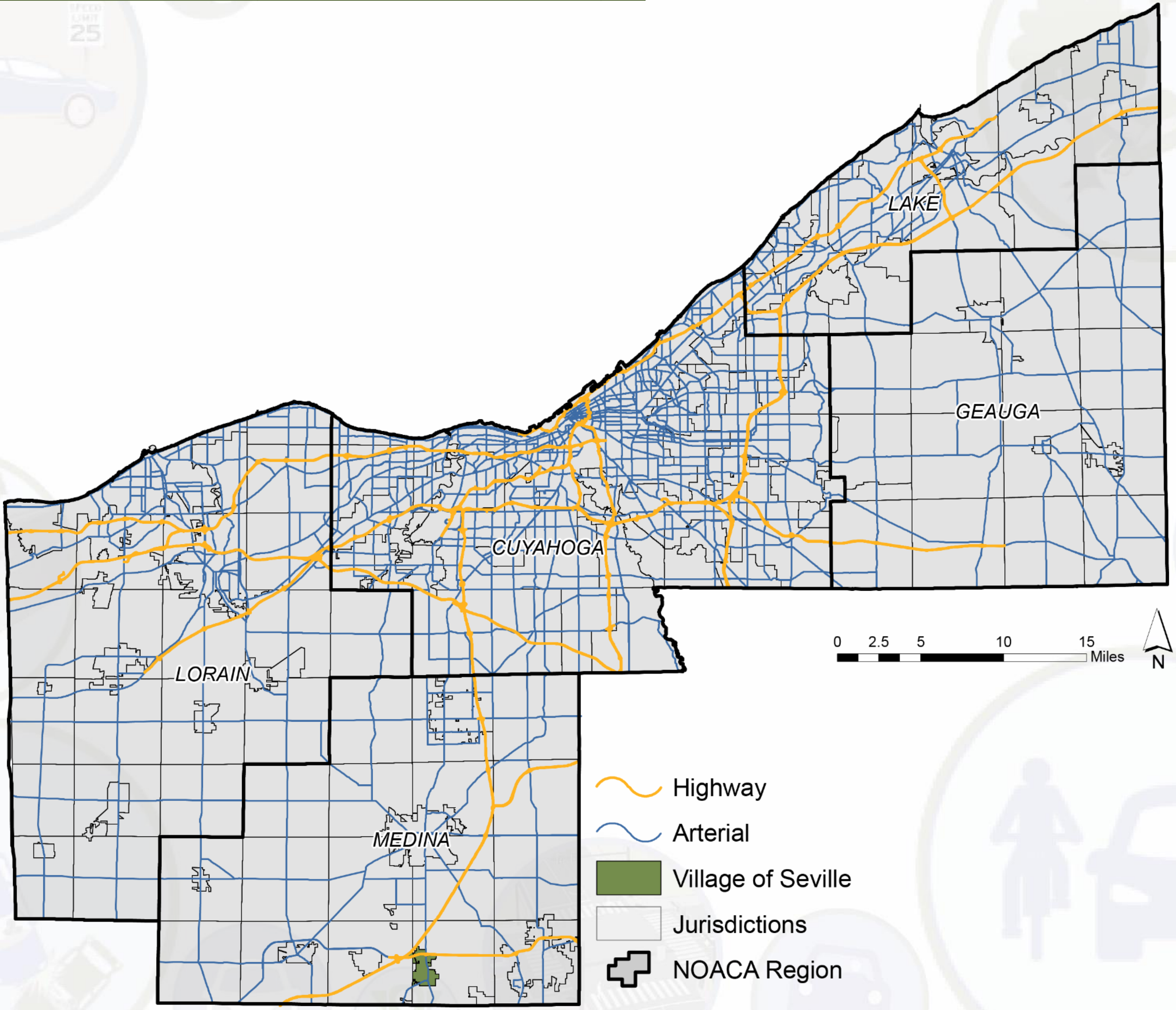
Seville is a Village in Medina County. Seville was platted in 1828. It was named after Seville, in Spain. A post office was established in Seville in 1830.

According to the 2020 Decennial Census, Seville has a population of 2,335 people and 1,038 households. The input data of the NOACA travel forecasting model indicates that the estimated current number of individual employed in the Village of Seville is 3,110.

The Village of Seville includes Interstate 76 (I 76) and State Route 3 (SR 3). Cleveland-Hopkins International Airport is the nearest airport.

Map 1 illustrates the location of the Village of Seville in the NOACA region.

Map 1: Location of the Village of Seville in the NOACA Region



Definitions

This section defines the fundamental terms used in the Highway Safety Manual (HSM) and throughout the report.

- Crash frequency is defined as the number of crashes that occur at a particular site, facility, or network in a one-year period
- Crash estimation refers to any methodology used to forecast or predict the crash frequency
- The predictive method is the methodology used to estimate the "expected average crash frequency" of a roadway segment or intersection under a given geometric design and traffic volume during a year
- Safety Performance Functions (SPFs) are regression equations that estimate the average crash frequency for a specific site type (with specified base conditions)
- Crash Modification Factors (CMFs) represent the relative changes in crash frequency due to a change in one specific condition. A CMF may serve as an estimate of the effect of a particular geometric design or traffic control feature

To select the correct SPF, the following segment and intersection types are used for arterial roadways and intersections, respectively.

Roadway Segment Types

- **Two-lane undivided arterial (2U)** – a roadway consisting of two lanes with a continuous cross-section providing two directions of travel in which the lanes are not physically separated by either distance or a barrier

- **Three-lane arterials (3T)** – a roadway consisting of three lanes with a continuous cross-section providing two directions of travel in which the center lane is a two-way left-turn lane (TWLTL)

- **Four-lane undivided arterials (4U)** – a roadway consisting of four lanes with a continuous cross-section providing two directions of travel in which the lanes are not physically separated by either distance or a barrier

- **Four-lane divided arterials (i.e., including a raised or depressed median) (4D)** – a roadway consisting of two directional lanes with a continuous cross-section providing two directions of travel in which the lanes are physically separated by either distance or a barrier.

- **Five-lane arterials including a center TWLTL (5T)** – a roadway consisting of five lanes with a continuous cross-section providing two directions of travel in which the center lane is a two-way left-turn lane (TWLTL)

Intersection Types

- **Three-leg intersection with stop control (3ST)** – an intersection of an urban or suburban arterial and a minor road. A stop sign is provided on the minor road approach to the intersection only
- **Three-leg signalized intersection (3SG)** – an intersection of an urban or suburban arterial and a minor road. Signalized control is provided at the intersection by traffic lights
- **Four-leg intersection with stop control (4ST)** – an intersection of an urban or suburban arterial and two minor roads. A stop sign is provided on both the minor road approaches to the intersection
- **Four-leg signalized intersection (4SG)** – an intersection of an urban or suburban arterial and two minor roads. Signalized control is provided at the intersection by traffic lights

Predictive Models for Urban and Suburban Arterials and Intersections

The input data needed for the predictive crash modeling include:

- Traffic volume
- Basic roadway characteristics: number of lanes, presence of median dividers, and number of driveways
- Safety Performance Function coefficients (SPFs), provided by the Highway Safety Manual

The essential equation used to determine the number of predicted annual crashes for a given arterial segment or intersection is as follows:

$$N_{predictedrs} = C_r \times (N_{br} + N_{pedr} + N_{biker})$$

Where:

$N_{predictedrs} = Predicted\ annual\ average\ crash\ frequency\ of\ an\ individual\ roadway\ segment\ or\ intersection$

$C_r = Calibration\ factor\ for\ roadway\ segments\ of\ a\ specific\ type\ developed\ for\ use\ for\ a\ particular\ geographical\ area$

$$N_{br} = Predicted\ average\ crash\ frequency\ of\ an\ individual\ roadway\ segment\ or\ intersection\ (excluding\ vehicle\ /pedestrian\ and\ vehicle/bicycle\ collisions)$$

$$N_{biker} = Predicted\ average\ frequency\ of vehicle/bicycle\ collisions\ for\ an\ individual\ roadway\ segment\ or\ intersection$$

$$N_{pedr} = Predicted\ average\ frequency\ of vehicle/pedestrian\ collisions\ for\ an\ individual\ roadway\ segment\ or\ intersection$$

N_{br}, N_{pedr}, and N_{biker} are determined using several different SPFs for crash types shown in Tables 1 and 2.

The calculation of predicted average crash frequency involves multiple steps and equations for different crash type such as mode and severity. Individual SPFs with unique coefficients are used to calculate crash subtotals as shown in Table 1. These predicted crash subtotals are then added together to determine an individual roadway segment's total predicted average crash frequency.

Table 1: Crash Types for Roadway Segments

NON-DRIVEWAY				**DRIVEWAY**		**VEHICLE-PEDESTRIAN COLLISIONS**	**VEHICLE-BICYCLE COLLISIONS**
MULTIPLE-VEHICLE COLLISIONS		**SINGLE-VEHICLE COLLISIONS**		**MULTIPLE-VEHICLE COLLISIONS**			
FATAL & INJURY	PROPERTY DAMAGE ONLY	FATAL & INJURY	PROPERTY DAMAGE ONLY	FATAL & INJURY	PROPERTY DAMAGE ONLY		

The intersection crashes types, shown in Table 2, are similar, only without a calculation for driveways.

Table 2: Crash Types for Intersections

MULTIPLE-VEHICLE COLLISIONS		**SINGLE-VEHICLE COLLISIONS**		**VEHICLE-PEDESTRIAN COLLISIONS**	**VEHICLE-BICYCLE COLLISIONS**
FATAL & INJURY	PROPERTY DAMAGE ONLY	FATAL & INJURY	PROPERTY DAMAGE ONLY		

Appendix B at the end of this report contains the SPFs and coefficients from the Highway Safety Manual for each crash type.

A Predictive Method for Estimating Average Crash Frequency and Severity

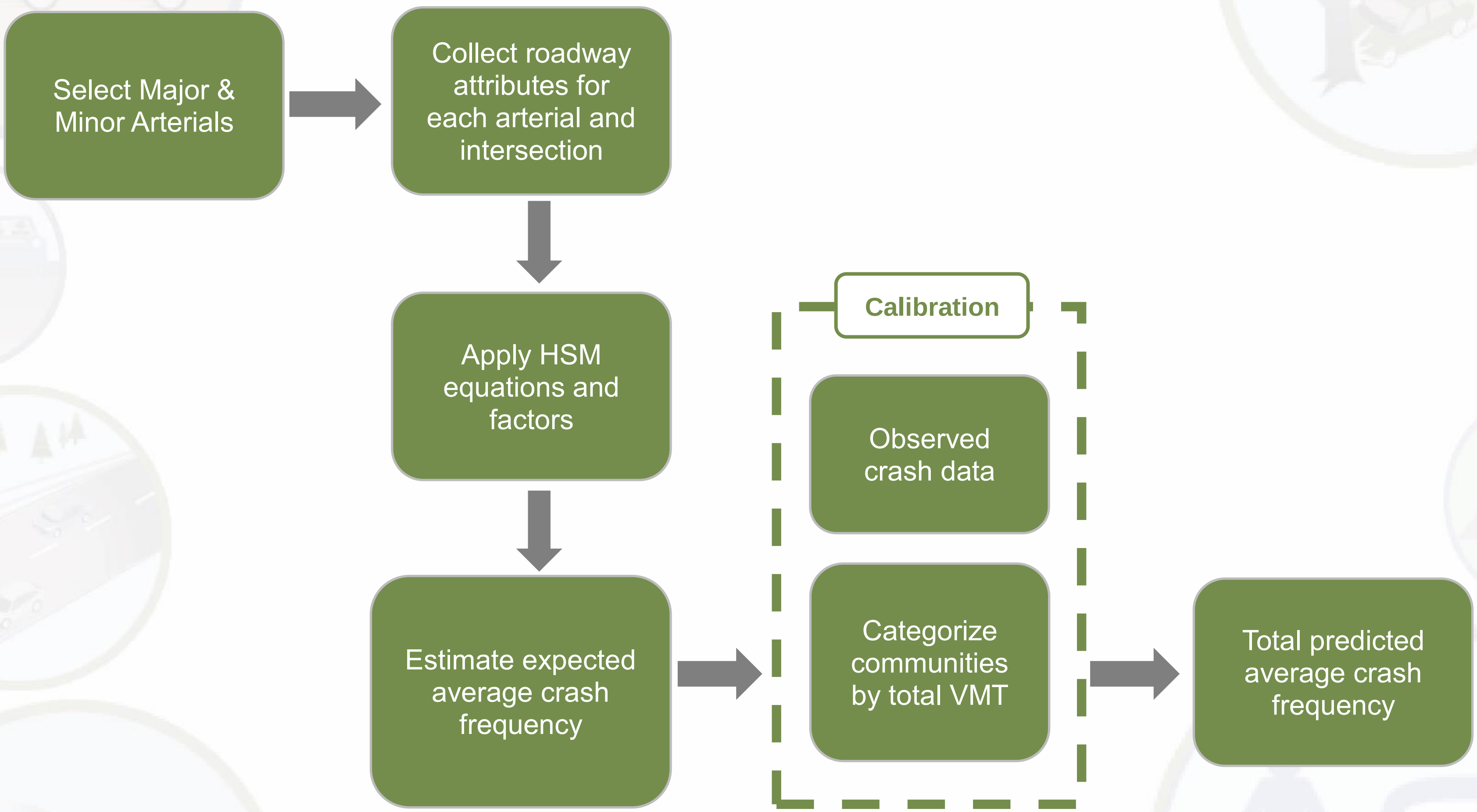
The predictive method described below provides estimated annual crash frequency and severity along arterials and at major intersections by using some approaches from the Highway Safety Manual. These estimates are not solely based on observed historical crash data, but rather incorporate roadway and traffic characteristics to provide an estimate of expected average crash frequency. This can assist decision makers on where to invest in the prioritized safety improvements with higher efficacy.

The roadway and traffic input data include:

- Road segment type
- Average Two-Way Daily Traffic volume (ADT)
- Number of lanes
- Number of driveways (access points serving land uses)
- Vehicle Miles Traveled (VMT)

Figure 1 illustrates the overall crash frequency prediction process.

Figure 1: Crash Frequency Prediction Process



PART II: Selected Arterials and Intersections

The road network within the boundaries of the Village of Seville was reviewed and 2 arterial segments and no intersections were identified for analysis. Each record in Table 3 represents an arterial segment. The tables display the SPF input data of roadway name and termini, segment type, length (miles), number of driveways, and ADT volume.

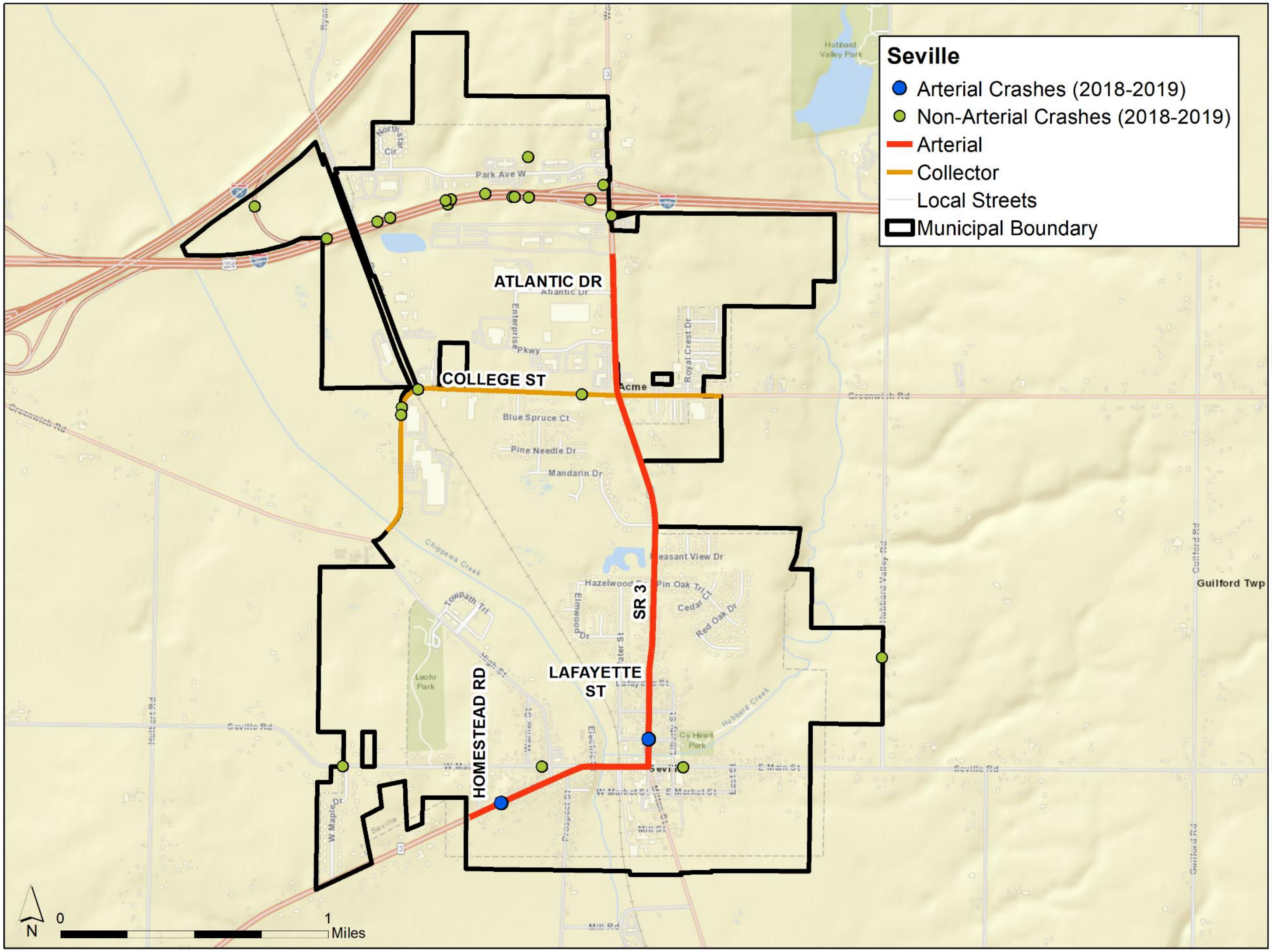
Table 3: Selected Arterial Segments

ROAD NAME	FROM	TO	SEGMENT TYPE	LENGTH (MILES)	NUMBER OF DRIVEWAYS	ADT	AVERAGE RECORDED CRASHES (2018 & 2019)
SR 3	HOMESTEAD RD	LAFAYETTE ST	2U	0.86	40	9,502	1.00
SR 3	LAFAYETTE ST	ATLANTIC DR	2U	1.14	60	18,612	0.00

- Note 1: Arterial road segments were selected to be consistent with the NOACA 2020 pavement reports
- Note 2: ADT volumes were derived from the 2020 scenario of the NOACA travel forecasting model
- Note 3: Google satellite imagery was used for estimating the number of driveways, since a detailed driveway inventory with land uses does not currently exist for the region
- Note 4: Major and minor roads at intersections were selected based upon ADT volumes
- Note 5: Only the intersections where two arterials meet were considered for this analysis
- Note 6: Pedestrian activity is assumed to be “low” for all intersections

Map 2 illustrates the arterials and intersections in the Village of Seville that are included in this analysis. Observed 2018-2019 crash locations are also shown.

Map 2: Arterials Segments in the Village of Seville



PART III: Crash Frequency Prediction

The developed SPFs were used to estimate the annual average crash frequency for each of the selected arterials and intersections. Due to a lack of comprehensive data for the crash modification factors (CMFs), the calibration factor, C_r, was derived from two sources:

- The recorded crash data of 2018 and 2019
- The total of daily auto and truck VMT of arterials

The process of calculating the calibration factors is as follows:

- Cities and villages within each of the five counties are grouped based on a set of VMT ranges. The VMT ranges are determined based on generating a normal distribution of communities.
- The ratio of the total observed to total predicted crashes is calculated for all the selected arterials and intersections within each city and village.
- Within each VMT range, the median value of the above ratios is selected as the calibration factor for those jurisdictions in the associated VMT group.
- The calibration factor is then applied to each arterial segment and intersection within a community to estimate the final annual average crash frequency.

Table 4 displays the daily arterial VMT ranges for communities of Medina County and their associated calibration factors.

Table 4: Daily Arterial VMT Ranges and Calibration Factors for Jurisdictions of Medina County

DAILY ARTERIAL VMT RANGE	JURISDICTIONS INCLUDED	CALIBRATION FACTOR
< 30,000	Seville	0.10
> 30,000	Brunswick, Medina, Wadsworth	4.01

Table 5 provide the predicted crashes by arterial segment. **These estimated average annual crash frequencies are the calibrated and aggregated values of motorized and nonmotorized collisions.**

Table 5: Estimated Average Annual Crash Frequency for Selected Arterial Segments

ROAD NAME	FROM	TO	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
SR 3	HOMESTEAD RD	LAFAYETTE ST	0.86	0.24
SR 3	LAFAYETTE ST	ATLANTIC DR	1.14	0.76

Table 6 display breakouts of the predicted nonmotorized crashes by arterial segment. **The nonmotorized crashes include the calibrated total value of vehicle-bicycle and vehicle-pedestrian collisions.**

Table 6: Estimated Average Annual Nonmotorized Crash Frequency for Selected Arterials

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
SR 3	0.86	0.00
SR 3	1.14	0.01

PART IV: Prioritization of Expected Crash Sites

This Part includes Table 7 which tabulate a prioritized ranking of the selected arterials based on the estimated average annual crash frequency from highest to lowest.

Table 7: Selected Arterials Ranked by Expected Average Annual Crash Frequency

RANK	ROAD NAME	FROM	TO
1	SR 3	LAFAYETTE ST	ATLANTIC DR
2	SR 3	HOMESTEAD RD	LAFAYETTE ST

Map 3 highlights the sites in the Village of Seville prioritized above. The arterial segments highlighted in various colors from red to blue represent the highest estimated average annual arterial segment crash frequency.

Map 3: Arterial and Intersection Prioritization Sites

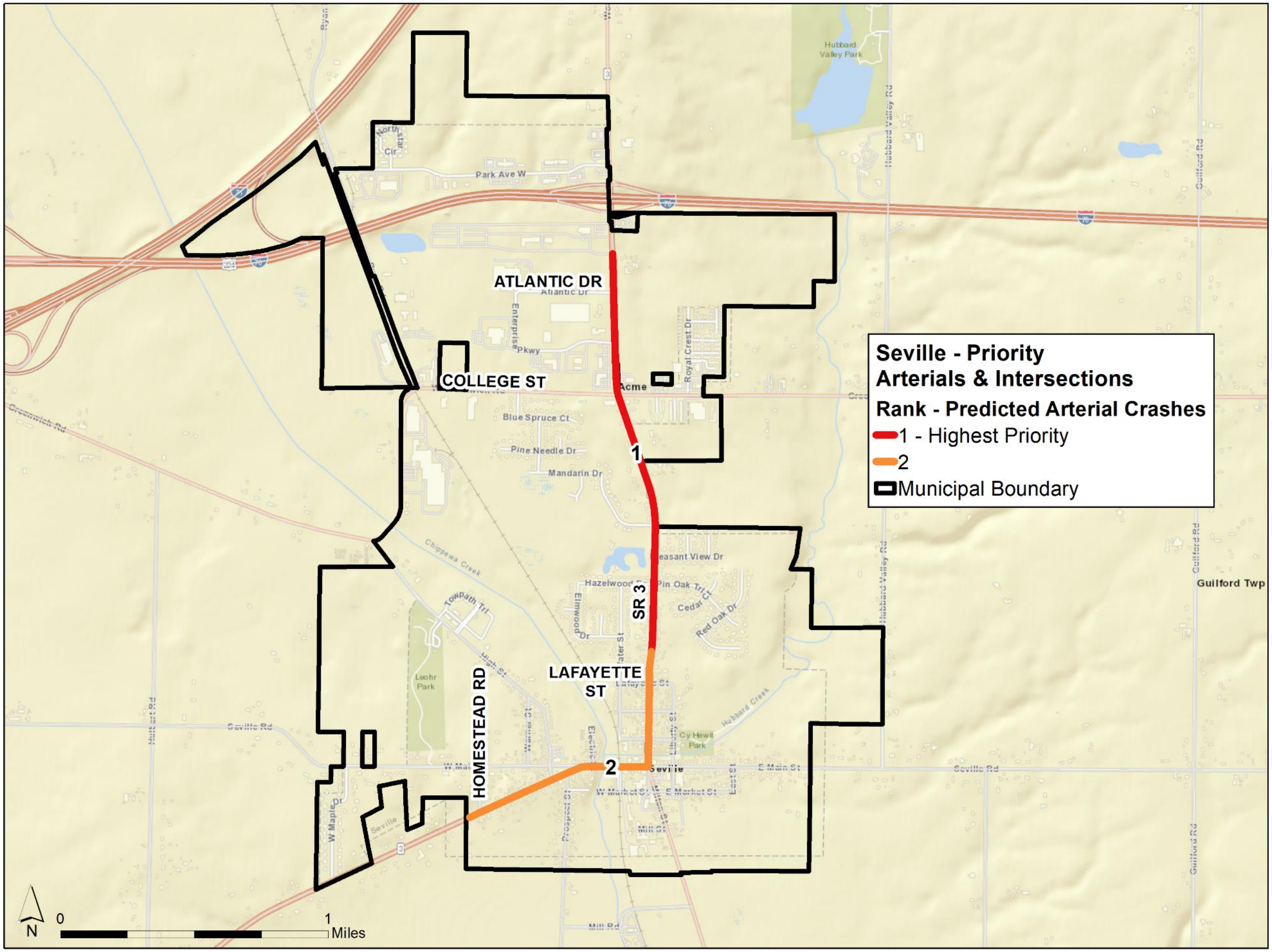


Table 8 summarizes the total annual average of 2018 and 2019 recorded crash data and the total expected annual average crash frequency for the selected arterials in the Village of Seville.

Table 8: Comparison of History and Predicted Annual Average Crash Frequency

SELECTED ARTERIALS AND INTERSECTIONS IN THE VILLAGE OF SEVILLE	
TOTAL RECORDED AVERAGE ANNUAL CRASH DATA	TOTAL ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
1.00	1.00

The prioritized sites should be examined in tandem with the observed history of crash locations for investing in safety improvements with higher efficacy. Additionally, certain safety features or traffic calming measures can be incorporated into the SPFs to forecast how improvements can affect expected crashes (e.g., adding medians, turning lanes, or automated speed enforcement). A roadway with a low number of reported crashes may also be worthy of examination based upon a high expected average annual crash frequency. This could indicate a need for further investigation into the road segments for other factors that affect crashes before choosing where to make safety investments. Appendix C contains proven countermeasures compiled by the Federal Highway Administration (FHWA) to assist in the selection of safety improvements.

If recorded crashes are HIGHER than estimated crashes…	then this may be due to roadway hazards and conditions not yet captured in the SPFs or human error during vehicle operation.
If recorded crashes are LOWER than estimated crashes…	then those segments may have incorporated safety countermeasures that are not captured in the SPFs.

Appendix A: Outputs of Safety Performance Functions

The following tables contain the outputs of the Highway Safety Manual safety performance functions before calibration for the selected arterial segments in the Village of Seville.

Table A-1: Predicted Average Vehicle Crashes of Arterials (Excluding Pedestrians and Bicycles)

ROAD NAME	LENGTH (MI)	NON-DRIVEWAY				DRIVEWAY	
		MULTIPLE-VEHICLE PREDICTED CRASHES PER YEAR		SINGLE-VEHICLE PREDICTED CRASHES PER YEAR		MULTIPLE-VEHICLE PREDICTED CRASHES PER YEAR	
		FATAL AND INJURY	PROPERTY DAMAGE ONLY	FATAL AND INJURY	PROPERTY DAMAGE ONLY	FATAL AND INJURY	PROPERTY DAMAGE ONLY
SR 3	0.86	0.299	0.718	0.141	0.471	0.205	0.429
SR 3	1.14	1.210	2.961	0.219	0.963	0.601	1.260

Table A-2: Predicted Average Pedestrian and Bicycle Crashes of Arterials

ROAD NAME	LENGTH (MI)	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
SR 3	0.86	0.011	0.009
SR 3	1.14	0.036	0.029

Appendix B: Highway Safety Manual Coefficient Tables and Functions

The following equations and tables are extracted from Chapter 12 of the Highway Safety Manual (2010).

Arterials

Multiple-Vehicle Non-Driveway Crashes

$$N_{brmv} = exp(a + b \times ln(ADT) + ln(\mathrm{L}))$$

Where:

$N_{brmv} =$ *Predicted average crash frequency of an individual roadway segment for multiple vehicle nondriveway crashes*

$\mathrm{ADT} =$ *Average Daily Two Way Traffic Volume*

$\mathrm{L} =$ *Number of Lanes*

Table B-1: SPF Coefficients for Multiple-Vehicle Non-Driveway Crashes on Roadway Segments

ROAD TYPE	TOTAL CRASHES		FATAL AND INJURY CRASHES		PROPERTY DAMAGE ONLY CRASHES	
	INTERCEPT (a)	ADT (b)	INTERCEPT (a)	ADT (b)	INTERCEPT (a)	ADT (b)
2U	-15.22	1.68	-16.22	1.66	-15.62	1.69
3T	-12.40	1.41	-16.45	1.69	-11.95	1.33
4U	-11.63	1.33	-12.08	1.25	-12.53	1.38
4D	-12.34	1.36	-12.76	1.28	-12.81	1.38
5T	-9.70	1.17	-10.47	1.12	-9.97	1.17

$$N_{brmv(FI)} = N_{brmv}\left(\frac{N'_{brmv(FI)}}{N'_{brmv(FI)} + N'_{brmv(PDO)}}\right)$$

Where:

$N'_{bmrv(FI)} = preliminary\ fatal\ and\ injury\ predicted\ crash\ frequency\ for\ multiple\ vehicle\ nondriveway\ crashes$

$N'_{brmv(PDO)} = preliminary\ property\ damage\ only\ predicted\ crash\ frequency\ for\ multiple\ vehicle\ nondriveway\ crashes$

The *N'* values use the same formula as N_{brmv} but replace the *a* and *b* coefficients with the respective values for fatal and injury crashes and property damage only crashes from Table B-1.

Finally, to ensure $N_{brmv} = N_{brmv(FI)} + N_{brmv(PDO)}$, the following equation is used to calculate $N_{brmv(PDO)}$.

$$N_{brmv(PDO)} = N_{brmv} - N_{brmv(FI)}$$

Single-Vehicle Crashes

$$N_{brsv} = exp(a + b \times ln(ADT) + ln(\mathrm{L}))$$

Where:

$N_{brsv} = Predicted\ average\ crash\ frequency\ of\ an\ individual\ roadway\ segment\ for\ single\ vehicle\ crashes$

$\mathrm{ADT} = Average\ Daily\ Two\ Way\ Traffic\ Volume$

$\mathrm{L} = Number\ of\ Lanes$

Table B-2: SPF Coefficients for Single-Vehicle Crashes on Roadway Segments

ROAD TYPE	TOTAL CRASHES		FATAL AND INJURY CRASHES		PROPERTY DAMAGE ONLY CRASHES	
	INTERCEPT (a)	ADT (b)	INTERCEPT (a)	ADT (b)	INTERCEPT (a)	ADT (b)
2U	-5.47	0.56	-3.96	0.23	-6.51	0.64
3T	-5.74	0.54	-6.37	0.47	-6.29	0.56
4U	-7.99	0.81	-7.37	0.61	-8.50	0.84
4D	-5.05	0.47	-8.71	0.66	-5.04	0.45
5T	-4.82	0.54	-4.43	0.35	-5.83	0.61

$$N_{brsv(FI)} = N_{brsv}\left(\frac{N'_{brsv(FI)}}{N'_{brsv(FI)} + N'_{brsv(PDO)}}\right)$$

Where:

$N'_{bmsv(FI)} = preliminary\ fatal\ and\ injury\ predicted\ crash\ frequency\ for\ single\ vehicle\ crashes$

$N'_{brsv(PDO)} = \ preliminary\ property\ damage\ only\ predicted\ crash\ frequency\ for\ single\ vehicle\ crashes$

The *N'* values use the same formula as N_{brsv} but replace the *a* and *b* coefficients with the respective values for fatal and injury crashes and property damage only crashes from Table B-2.

Finally, to ensure N_{brsv} = $N_{brsv(FI)} + N_{brsv(PDO)}$, the following equation is used to calculate $N_{brsv(PDO)}$.

$$N_{brsv(PDO)} = N_{brsv} - N_{brsv(FI)}$$

Multiple-Vehicle Driveway Crashes

The function below is used to calculate the number of predicted multiple-vehicle driveway crashes. The values for N_j and t are taken from Table B-3 below.

$$N_{brdwy} = \sum_{\substack{\text{all} \\ \text{driveway} \\ \text{types}}} n_j \times N_j \times \left(\frac{ADT}{15{,}000}\right)^{(t)}$$

Where:

$N_{brdwy} =$ *Predicted average crash frequency of an individual roadway segment for multiple vehicle driveway crashes*

$n_j =$ *Number of driveways along a roadway segment*

$N_j =$ *Number of driveway related collisions per driveway per year coefficient*

$ADT =$ *Average Daily Two Way Traffic Volume*

$t =$ *Regression coefficient for traffic volume adjustment*

Table B-3: SPF Coefficients for Multiple-Vehicle Driveway Crashes on Roadway Segments

DRIVEWAY TYPE (j)	2U	3T	4U	4D	5T
NUMBER OF DRIVEWAY-RELATED COLLISIONS PER DRIVEWAY PER YEAR (N_j)					
MAJOR COMMERCIAL	0.158	0.102	0.182	0.033	0.165
MINOR COMMERCIAL	0.050	0.032	0.058	0.011	0.053
MAJOR INDUSTRIAL / INSTITUTIONAL	0.172	0.110	0.198	0.036	0.181
MINOR INDUSTRIAL / INSTITUTIONAL	0.023	0.015	0.026	0.005	0.024
MAJOR RESIDENTIAL	0.083	0.053	0.096	0.018	0.087
MINOR RESIDENTIAL	0.016	0.010	0.018	0.003	0.016
OTHER	0.025	0.016	0.029	0.005	0.027
REGRESSION COEFFICIENT FOR ADT (t)					
ALL DRIVEWAYS	1.000	1.000	1.172	1.106	1.172
PROPORTION OF FATAL AND INJURY CRASHES (f_{dwy})					
ALL DRIVEWAYS	0.323	0.243	0.342	0.284	0.269
PROPORTION OF PROPERTY DAMAGE ONLY CRASHES					
ALL DRIVEWAYS	0.677	0.757	0.658	0.716	0.731

$$N_{brdwy(FI)} = N_{brdwy} \times f_{dwy}$$

Where:

$f_{dwy} = proportion\ of\ fatal\ and\ injury\ crashes\ coefficient$ from Table B-3.

To ensure $N_{brdwy} = N_{brdwy(FI)} + N_{brdwy(PDO)}$, the following equation is used to calculate $N_{brdwy(PDO)}$:

$$N_{brdwy(PDO)} = N_{brdwy} - N_{brdwy(FI)}$$

The final calculation for total (motorized) vehicle crashes along arterials is a sum of the three types of crashes detailed above:

$$N_{br} = N_{brmv} + N_{brsv} + N_{brdwy}$$

Bicycle and Pedestrian Crashes

To calculate predicted pedestrian crashes, the vehicle crashes are multiplied by the appropriate pedestrian crash adjustment factor in Table B-4 (f_{pedr}).

$$N_{pedr} = N_{br} \times f_{pedr}$$

Table B-4: Pedestrian Crash Adjustment Factor for Roadway Segments

ROAD TYPE	POSTED SPEED 30 MPH OR LOWER	POSTED SPEED GREATER THAN 30 MPH
2U	0.036	0.005
3T	0.041	0.013
4U	0.022	0.009
4D	0.067	0.019
5T	0.030	0.023

Similarly, the bicycle crash adjustment factors in Table B-5 are used to calculate predicted bicycle crashes.

$$N_{biker} = N_{br} \times f_{biker}$$

Table B-5: Bicycle Crash Adjustment Factor for Roadway Segments

ROAD TYPE	POSTED SPEED 30 MPH OR LOWER	POSTED SPEED GREATER THAN 30 MPH
2U	0.018	0.004
3T	0.027	0.007
4U	0.011	0.002
4D	0.013	0.005
5T	0.050	0.012

Intersections

Multiple-Vehicle Intersection Crashes

$$N_{bimv} = exp(a + b \times ln(ADT_{maj}) + c \times ln(ADT_{min}))$$

Where:

$N_{bimv} =$ *Predicted average crash frequency of multiple vehicle crashes for an intersection*

$ADT_{maj} =$ *Average Daily Two Way Traffic Volume for the major road at an intersection*

$ADT_{min} =$ *Average Daily Two Way Traffic Volume for the minor road at an intersection*

Table B-6: SPF Coefficients for Multiple-Vehicle Crashes at Intersections

INTERSECTION TYPE	TOTAL CRASHES			FATAL AND INJURY CRASHES			PROPERTY DAMAGE ONLY CRASHES		
	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)
3ST	-13.36	1.11	0.41	-14.01	1.16	0.30	-15.38	1.20	0.51
3SG	-12.13	1.11	0.26	-11.58	1.02	0.17	-13.24	1.14	0.30
4ST	-8.90	0.82	0.25	-11.13	0.93	0.28	-8.74	0.77	0.23
4SG	-10.99	1.07	0.23	-13.14	1.18	0.22	-11.02	1.02	0.24

$$N_{bimv(FI)} = N_{bimv}\left(\frac{N'_{bimv(FI)}}{N'_{bimv(FI)} + N'_{bimv(PDO)}}\right)$$

Where:

$N'_{bimv(FI)} = preliminary\ fatal\ and\ injury\ predicted\ crash\ frequency\ for\ \text{multiple vehicle crashes}\ at\ intersections$

$N'_{bimv(PDO)} = preliminary\ property\ damage\ only\ predicted\ crash\ frequency\ for\ \text{multiple vehicle crashes}\ at\ intersections$

The *N'* values use the same formula as N_{bimv} but replace the *a*, *b*, and *c* coefficients with the respective values for fatal and injury crashes and property damage only crashes from Table B-6.

Finally, to ensure $N_{bimv} = N_{bimv(FI)} + N_{bimv(PDO)}$, the following equation is used to calculate $N_{bimv(PDO)}$.

$$N_{bimv(PDO)} = N_{bimv} - N_{bimv(FI)}$$

Single-Vehicle Intersection Crashes

$$N_{bisv} = exp(a + b \times ln(ADT_{maj}) + c \times ln(ADT_{min}))$$

Where:

$N_{bisv} =\ Predicted\ average\ crash\ frequency\ of\ single\ vehicle\ crashes\ at\ an\ intersection$

$ADT_{maj} = Average\ Daily\ Two\ Way\ Traffic\ Volume\ for\ the\ major\ road\ at\ an\ intersection$

$ADT_{min} = Average\ Daily\ Two\ Way\ Traffic\ Volume\ for\ the\ minor\ road\ at\ an\ intersection$

Table B-7: SPF Coefficients for Single-Vehicle Crashes at Intersections

INTERSECTION TYPE	TOTAL CRASHES			FATAL AND INJURY CRASHES			PROPERTY DAMAGE ONLY CRASHES		
	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)	INTERCEPT (a)	ADT_{maj} (b)	ADT_{min} (c)
3ST	-6.81	0.16	0.51				-8.36	0.25	0.55
3SG	-9.02	0.42	0.40	-9.75	0.27	0.51	-9.08	0.45	0.33
4ST	-5.33	0.33	0.12				-7.04	0.36	0.25
4SG	-10.21	0.68	0.27	-9.25	0.43	0.29	-11.34	0.78	0.25

To calculate fatal and injury crashes at 3SG and 4SG intersections, the following function is used:

$$N_{bisv(FI)} = N_{bisv}\left(\frac{N'_{bisv(FI)}}{N'_{bisv(FI)} + N'_{bisv(PDO)}}\right)$$

Where:

$N'_{bisv(FI)} = preliminary\ fatal\ and\ injury\ predicted\ crash\ frequency\ for\ multiple\ vehicle\ crashes\ at\ intersections$

$N'_{bisv(PDO)} = preliminary\ property\ damage\ only\ predicted\ crash\ frequency\ for\ multiple\ vehicle\ crashes\ at\ intersections$

The *N'* values use the same formula as N_{bisv} but replace the *a*, *b*, and *c* coefficients with the respective values for fatal and injury crashes and property damage only crashes from Table B-7.

Table B-8 is used for Single-Vehicle fatal and injury crashes at stop-sign-controlled intersections because there are no regression coefficents for these types of intersections.

$$N_{bisv(FI)} = N_{bisv} \times f_{bisv}$$

Where:

$f_{bisv} = proportion\ of\ fatal\ and\ injury\ crashes$

Table B-8: Factors for Single-Vehicle Fatal and injury Crashes at Stop-Controlled Intersections

INTERSECTION TYPE	ADJUSTMENT FACTOR
3ST	0.31
4ST	0.28

Finally, to ensure $N_{bisv} = N_{bisv(FI)} + N_{bisv(PDO)}$, the following equation is used to calculate $N_{bisv(PDO)}$:

$$N_{bisv(PDO)} = N_{bisv} - N_{bisv(FI)}$$

The final calculation for total (motorized) vehicle crashes at intersections is a sum of the multiple-vehicle and single-vehicle crashes detailed above:

$$N_{bi} = N_{bimv} + N_{bisv}$$

Bicycle and Pedestrian Intersection Crashes

$$N_{bikei} = N_{bi} \times f_{bikei}$$

Table B-9: Bicycle Crash Adjustment Factor for Intersections

INTERSECTION TYPE	BICYCLE CRASH ADJUSTMENT FACTOR
3ST	0.016
3SG	0.011
4ST	0.018
4SG	0.015

$$N_{pedi} = N_{bi} \times f_{pedi}$$

Table B-10: Pedestrian Crash Adjustment Factor for Stop-Controlled Intersections

INTERSECTION TYPE	PEDESTRIAN CRASH ADJUSTMENT FACTOR
3ST	0.021
4ST	0.022

$$N_{pedbase} = exp(a + b \times ln(ADT_{total}) + c \times \ln\left(\frac{ADT_{min}}{ADT_{maj}}\right) + d \times \ln(PedVol) + e \times n_{lanesx})$$

Where:

$ADT_{total}(= ADT_{maj} + ADT_{min})$ *Average Daily Traffic volume for the major and minor roads*

$PedVol$ = *sum of daily pedestrian volumes crossing all intersection legs*

n_{lanesx} = *maximum number of traffic lanes crossed by a pedestrian at the intersection*

Table B-11: Pedestrian Crash Adjustment Factor for Signal-Controlled Intersections

INTERSECTION TYPE	INTERCEPT (a)	ADT_{total} (b)	ADT_{min}/ADT_{maj} (c)	PedVol (d)	n_{lanesx} (e)
3SG	-6.60	0.05	0.24	0.41	0.09
4SG	-9.53	0.40	0.26	0.45	0.04

Table B-12: Pedestrian Crash Adjustment Factor for Signal-Controlled Intersections

GENERAL LEVEL OF PEDESTRIAN ACTIVITY	3SG	4SG
HIGH	1,700	3,200
MEDIUM-HIGH	750	1,500
MEDIUM	400	700
MEDIUM-LOW	120	240
LOW	20	50

Crash Modification Factors

The Highway Safety Manual includes the following roadway and arterial features as crash modification factors (CMFs) that can affect expected crashes beyond the roadway characteristics discussed above. These characteristics include the following:

Segment CMFs:

- On-Street Parking
- Roadside Fixed Objects
- Width of Median (if present)
- Lighting
- Automated Speed Enforcement

Intersection CMFs:

- Left Turn Lanes
- Left Turn Signal Phasing
- Right Turn Lanes
- Right Turn on Red
- Lighting
- Red Light Cameras
- Schools
- Bus Stops
- Alcohol Sales Establishments

The scope of this report does not include a detailed roadway inventory of the specific characteristics associated with the crash modification factors. Therefore, all CMF values were assumed to be equal to 1 for the purposes of this report, having no affect on the predicted crash frequency calculations.

These CMF characteristics, however, could be identified and taken into account for a more detailed future analysis of specific roadway segments or intersections, should a jurisdiction desire to do so.

Appendix C: FHWA Proven Safety Countermeasures

The Federal Highway Administration (FHWA) details 28 safety strategies that have been proven to reduce fatal and serious injury crashes. A short summary of each countermeasure is listed below. Detailed information can be found at https://safety.fhwa.dot.gov/provencountermeasures/. FHWA resources can provide guidance when determining how to improve safety at the priority locations listed in Part IV of this report as well as roadways and intersections with a history of high recorded crashes.

The categories for the tables of countermeasures have been determined by FHWA.

Table C-1: Speed Management

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Speed Safety Cameras	Cameras that measure vehicle speeds and capture photographs or video of traffic over a specified speed threshold	47-54%
	Variable Speed Limits	Installing electronic signs to change the speed limits when road conditions change (e.g., congestion, crashes, weather/visibility)	34%
	Appropriate Speed Limits for All Road Users	Studying and updating speed limits for roads which are not limited access highways to protect vulnerable road users	26%

Table C-2: Roadway Departure

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Wider Edge Lines	Increasing the width of edge lines for greater visibility of travel lanes and upcoming road alignment	22-37%
	Enhanced Delineation for Horizontal Curves	These markings indicate upcoming curves for drivers. Strategies include: • Pavement markings • In-lane curve warning pavement markings • Retroreflective strips on sign posts • Delineators • Chevron signs • Larger, fluorescent, and/or retroreflective signs • Dynamic curve warning signs • Sequential dynamic chevrons	15-38%
	Longitudinal Rumble Strips and Stripes	Rumble Strips are milled or raised features outside travel lanes to indicate with sound or vibrations a driver has drifted out of the lane Rumble Stripes are rumble strips combined with painted markings to increase visibility of the strips	13-51% (Shoulder) 44-64% (Center Line)
	SafetyEdge[SM]	These devices create a 30-degree slope at the roadway edge during paving to eliminate a vertical edge as the shoulder soil wears away	11-21%

Table C-2: Roadway Departure (continued)

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Roadside Design Improvements at Curves	FHWA lists six design improvements to reduce crashes at curves, which can be implemented together or individually • Safe Recovery Areas ○ Clear zone ○ Slope flattening ○ Adding or widening shoulders • Severity Reduction ○ Cable barrier ○ Metal-beam guardrail ○ Concrete barrier	22-44%
	Median Barriers	Median barriers separate opposing traffic and create divided highways to reduce head-on and cross-directional crashes Types of Medians: • Cable barriers • Metal-beam guardrails • Concrete barriers	97%

Table C-3: Intersections

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Backplates with Reflective Borders	Yellow reflective borders around traffic signals increase visibility at all times of the day and in various conditions	15%

Table C-3: Intersections (continued)

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Corridor Access Management	Access management is the design and control of entry and exit points along roadways. FHWA provides the following strategies to improve interactions for all road users at a variety of access points: • Reduce density through driveway closure, consolidation, or relocation • Manage spacing of intersection and access points • Limit allowable movements at driveways (such as right-in/right-out only) • Place driveways on an intersection approach corner rather than a corner, which is expected to have fewer total crashes • Implement raised medians that preclude across-roadway movements • Use designs such as roundabouts or reduced left-turn conflicts (such as restricted crossing U-turn, median U-turns, etc.) • Provide turn lanes (i.e., left-only, right-only, or interior two-way left) • Use lower-speed, one-way or two-way off-arterial circulation roads	5-23% (Rural) 25-31% (Urban)
	Left- and Right-Turn Lanes at Two-Way Stop-Controlled Intersections	Turning lane installations along a major road at an intersection with stop-controlled access for the minor road where there are large turning volumes or a history of turn-related crashes	28-48% (Left Turn) 14-26% (Right Turn)
	Reduced Left-Turn Conflict Intersections	Updating intersection geometric design to reduce left-turn conflicts. The two recommended proven designs are Restricted Crossing U-Turn (RCUT) and Median U-Turn (MUT).	54-63% (RCUT) 30% (MUT)

Table C-3: Intersections (continued)

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Roundabouts	Roundabouts are intersections with circular design and yield-based entry, which reduce speeds and road-user conflict while also keeping traffic flowing	78-82%

	Systemic Application of Multiple Low-Cost Countermeasures at Stop-Controlled Intersections	Suggested low-cost countermeasures include:
		• On the Through Approach
		  ○ Doubled-up (left and right), oversized advance intersection warning signs, with supplemental street name plaques (can also include flashing beacon)
		  ○ Retroreflective sheeting on sign posts
		  ○ Enhanced pavement markings that delineate through lane edge lines
		• On the Stop Approach
		  ○ Doubled-up (left and right), oversized advance ”Stop Ahead“ intersection warning signs (can also include flashing beacon)
		  ○ Doubled-up (left and right), oversized stop signs
		  ○ Retroreflective sheeting on sign posts
		  ○ Properly placed stop bar
		  ○ Removal of vegetation, parking, or obstructions that limit sight distance
		  ○ Double arrow warning sign at stem of T-intersections
			10-27%

	Yellow Change Intervals	This countermeasure involves reviewing traffic signal timing to adjust the length of yellow signals so that the yellow is neither too long nor too short	8-14%

Table C-4: Pedestrian/Bicyclist

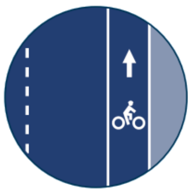
SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Crosswalk Visibility Enhancement	Enhancements include high-visibility crosswalks, improved crosswalk lighting, and enhanced signage and pavement markings	25-42%
	Bicycle Lanes	These facilities provide separation between motorized traffic and bicycles and can involve road paint or a vertical barrier	30-49%
	Rectangular Rapid Flashing Beacons (RRFB)	RRFBs are flashing signals usually activated by a push button to alert motorists to the presence of a crosswalk	47%
	Leading Pedestrian Interval	Traffic signals are reprogrammed to provide several seconds of pedestrian crossing before motorists receive a green light	13%
	Medians and Pedestrian Refuge Island in Urban and Suburban Areas	Medians create separation between traffic flowing in opposite directions. A pedestrian refuge provides space within a median for pedestrians to wait safely after partially crossing a road.	46% (Median) 56% (Refuge Island)

Table C-4: Pedestrian/Bicyclist (continued)

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Pedestrian Hybrid Beacons	Pedestrian hybrid beacons are devices that remain ”dark“ until a pedestrian pushes the call button to activate the beacon. This initiates a yellow to red flashing light sequence, which directs motorists to slow and come to a stop. These are often used at higher speed roadways, longer road segments without intersections, or where insufficient gaps in traffic exist	55% (Pedestrian) 15-29% (Total)
	Road Diets (Roadway Reconfiguration)	This countermeasure adjusts the number of lanes and lane widths to reduce speeds and increase safety perceptions for all road users. A typical example involves changing a four-lane undivided roadway into three-lanes: one traffic lane in each direction, a center turning lane, and possible bicycle lanes	19-47%
	Walkways	Spaces for people walking or using wheelchairs: • Sidewalks • Shared-use paths • Pedestrian Walkways separated from roadways	65-89%

Table C-5: Crosscutting

SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Pavement Friction Management	This strategy involves understanding pavement friction conditions using Continuous Pavement Friction Measurement (CPFM) equipment and subsequently selecting appropriate locations to install High Friction Surface Treatment (HFST)	20-63%
	Lighting	Providing vertical and horizontal lighting both to reduce fatal crashes and improve the sense of safety for pedestrians	28-42%
	Local Road Safety Plans (LSRP)	LSRPs can help local jurisdictions to identify and prioritize locally owned roadways for safety enhancements that are sensitive to local conditions and funding abilities.	17-35%
	Road Safety Audits (RSAs)	An RSA is conducted by a cross-discipline or cross-departmental team independent from a particular roadway project to examine all factors across all road users and compile them into a report. A response is required from the roadway owner before project work can proceed.	10-60%

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1299 Superior Avenue E
Cleveland, Ohio 44114
www.noaca.org