



2022 Community Safety Report

City of Lorain



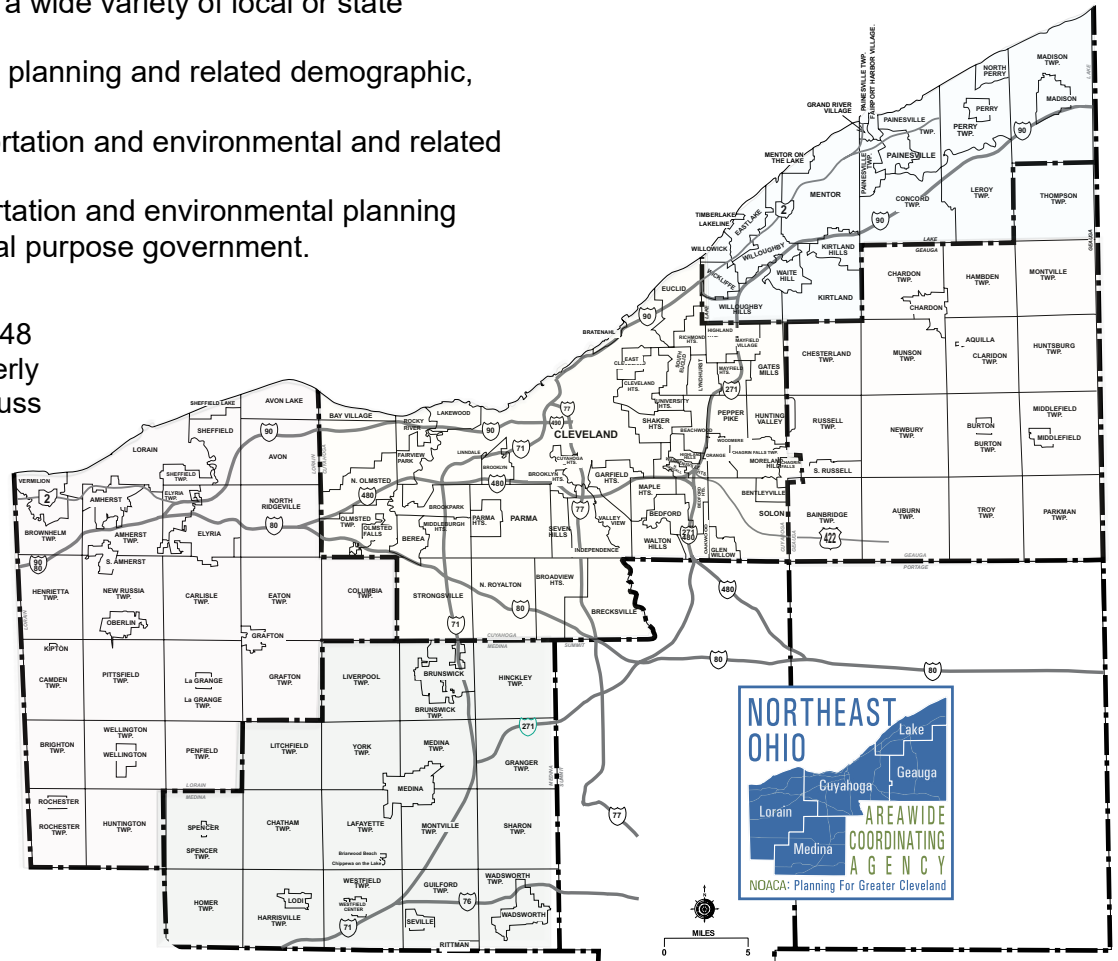
Northeast Ohio Areawide
Coordinating Agency

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 City of Lorain, this analysis considered 33.5 centerline miles and 109.6 lane-miles of arterial roadway which encompass eighteen major intersections. The arterial roadways in Lorain make up 3.37% of the total roadway lengths analyzed, which is proportional to Lorain having about 3.75% 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 526.00. The predictive method resulted in 474.97 average annual expected crashes along those arterials and intersections. The lower expected crash value may be explained by roadway conditions not yet captured in the expected crash calculations or human error during the actual crashes.

The following tables list a prioritization ranking of the selected arterials and intersections within the City of Lorain based on the estimated average annual crash frequency from highest to lowest.

RANK	ARTERIAL ROAD NAME	FROM	TO
1	US 6	VERMILION ECL	W OF US-6 / SR-611
2	SR 58 (N LEAVITT RD)	COOPER FOSTER PARK RD	SR-611
3	BAUMHART RD	LORAIN SCL	W ERIE AVE (US-6)
4	SR 611	HENDERSON DR	LORAIN ECL
5	SR 611	ELYRIA AVE	COLORADO AVE

RANK	ARTERIAL ROAD NAME	FROM	TO
6	US 6	ARKANSAS AVE	E OF ROOT RD
7	OBERLIN AVE	COOPER FOSTER PARK RD	MEISTER RD
8	BROADWAY AVE	W 39TH ST	E 28TH ST (SR-57)
9	SR 57 (GROVE AVE)	ELYRIA NCL	E 36TH ST
10	US 6	LEAVITT RD (SR-58)	SR-57 (BROADWAY)

RANK	INTERSECTION	MAJOR ROAD	MINOR ROAD
1	SR 58 (N LEAVITT RD) - COOPER-FOSTER PARK RD	SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD
2	SR 611 - COLORADO AVE	SR 611	COLORADO AVE
3	BROADWAY AVE - COOPER-FOSTER PARK RD	BROADWAY AVE	COOPER-FOSTER PARK RD
4	SR 58 (N LEAVITT RD) - SR 611	SR 58 (N LEAVITT RD)	SR 611
5	BROADWAY AVE - SR 57 (E 28TH ST)	BROADWAY AVE	SR 57 (E 28TH 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.

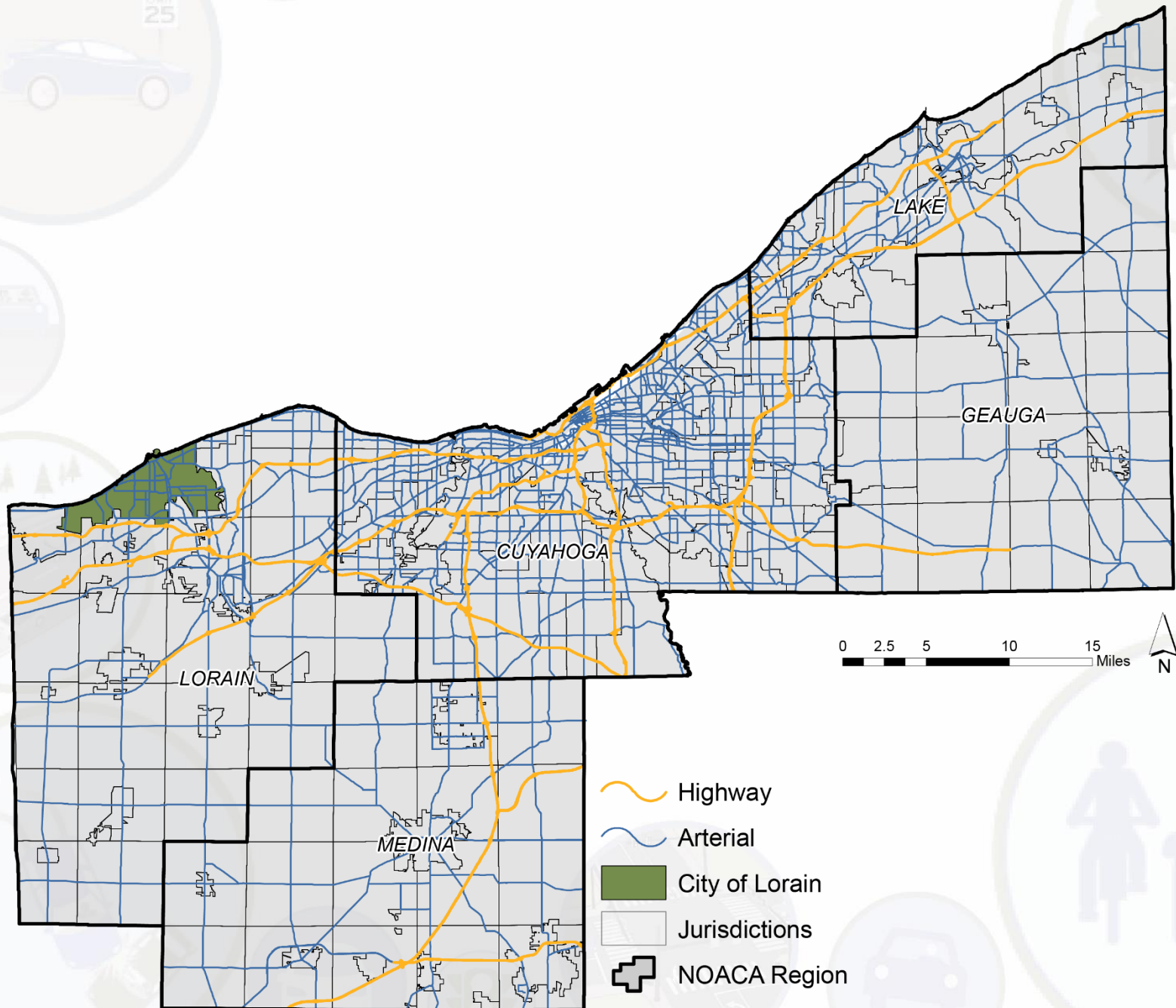
The City of Lorain is located on Lake Erie at the mouth of the Black River, approximately 30 miles west of Cleveland. The city was the former home to the American Ship Building Company Lorain Yard, Ford Motor Company Lorain Assembly Plant, and United States Steel Corporation's sprawling steel mill on the city's south side.

According to the 2020 Decennial Census, the population of Lorain is 65,211 people and 26,595 households. The input data of the NOACA travel forecasting model indicates that the estimated current number of individuals employed in the City of Lorain is 20,925.

The City of Lorain includes U.S. Route 6 (US 6), State Route 2 (SR 2), State Route 611 (SR 611), State Route 58 (SR 58), and State Route 57 (SR 57). Cleveland-Hopkins International Airport is the nearest airport.

Map 1 illustrates the location of the City of Lorain in the NOACA region.

Map 1: Location of the City of Lorain 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

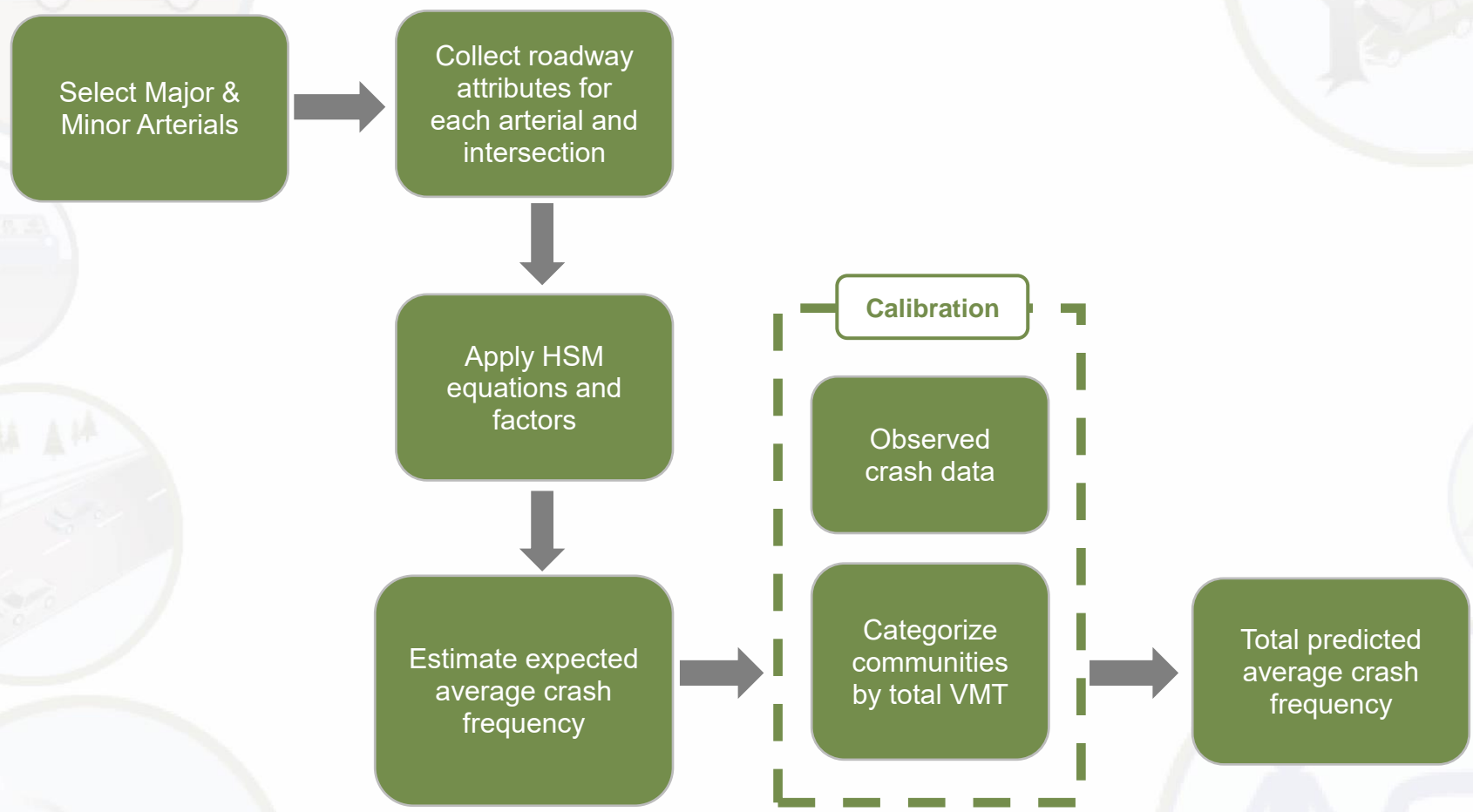
The predictive method described below provides estimated annual crash frequency and severity along arterials and at major intersections by using some approaches from the Highway Safety Manual. These estimates are not solely based on observed historical crash data, but rather incorporate roadway and traffic 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 City of Lorain was reviewed and 32 arterial segments and 18 intersections were identified for analysis. Each record in Tables 3 and 4 represents an arterial segment or intersection, respectively. 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)
BAUMHART RD	LORAIN SCL	W ERIE AVE (US-6)	4D	1.42	20	19,349	9.50
BROADWAY AVE	W 39TH ST	E 28TH ST (SR-57)	4U	0.78	50	9,749	26.50
COLORADO AVE	ERIE ST (US-6)	HENDRICKS DR / KANSAS AVE	2U	0.89	45	3,996	7.50
COOPER-FOSTER PARK RD	AMHERST ECL	NORTH RIDGE RD	4U	0.15	20	6,702	5.00
COOPER-FOSTER PARK RD	NORTH RIDGE RD	BROADWAY AVE	2U	1.09	20	5,902	7.00
COOPER-FOSTER PARK RD	OAK POINT RD	LORAIN ECL	2U	0.21	10	499	6.00
ELYRIA AVE	E 39TH ST	HENDERSON DR (SR-611)	2U	1.24	80	5,011	28.50
KOLBE RD	Longbrook Rd	ERIE AVE (US-6)	2U	0.97	35	5,506	9.00
MAIN ST	AMHERST NCL	Longbrook Dr	2U	0.18	0	5,760	3.00
MIDDLE RIDGE RD	OLD WEST RIDGE RD (N OF SR-2 RAMPS)	COOPER FOSTER PARK	4U	0.35	15	11,962	7.00
NORTH RIDGE RD	E OF S PEARL ST	GLADYS AVE	4U	0.23	20	7,645	3.00

Table 3: Selected Arterial Segments (continued)

ROAD NAME	FROM	TO	SEGMENT TYPE	LENGTH (MILES)	NUMBER OF DRIVEWAYS	ADT	AVERAGE RECORDED CRASHES (2018 & 2019)
OBERLIN AVE	COOPER FOSTER PARK RD	MEISTER RD	4U	1.61	150	4,894	36.50
OBERLIN AVE	MEISTER RD	ERIE AVE (US-6)	2U	1.74	150	2,879	37.00
SR 57 (BROADWAY AVE)	E 28TH ST (SR-57)	E 14TH ST	4U	1.00	20	2,741	18.00
SR 57 (BROADWAY AVE)	E 14TH ST	US-6 (ERIE AVE)	4U	0.80	30	1,424	12.00
SR 57 (E 28TH ST)	FULTON RD	BROADWAY AVE	4U	0.61	10	6,743	6.00
SR 57 (E 28TH ST)	GROVE AVE (SR-57)	FULTON RD	4U	1.72	15	767	25.00
SR 57 (GROVE AVE)	ELYRIA NCL	E 36TH ST	4D	1.02	5	14,521	13.50
SR 57 (GROVE AVE)	E 36TH ST	E 28TH ST (SR-57)	4U	0.52	5	7,955	15.00
SR 58 (N LEAVITT RD)	COOPER FOSTER PARK RD	SR-611	4U	2.34	100	10,716	78.50
SR 58 (N LEAVITT RD)	SR-611	W ERIE AVE (US-6)	2U	0.57	60	5,256	9.50
SR 611	W 21ST ST	W ERIE AVE (US-6)	2U	0.44	40	1,896	1.00
SR 611	W ERIE AVE (US-6)	LEAVITT RD (SR-58)	4U	1.14	45	3,621	2.00
SR 611	LEAVITT RD (SR-58)	HAMILTON AVE	4U	1.03	45	7,511	15.50
SR 611	HAMILTON AVE	ELYRIA AVE	2U	0.95	40	8,429	41.50
SR 611	ELYRIA AVE	COLORADO AVE	4U	0.81	40	12,837	19.50

Table 3: Selected Arterial Segments (continued)

ROAD NAME	FROM	TO	SEGMENT TYPE	LENGTH (MILES)	NUMBER OF DRIVEWAYS	ADT	AVERAGE RECORDED CRASHES (2018 & 2019)
SR 611	HENDERSON DR	LORAIN ECL	2U	1.38	45	12,567	36.50
US 6	VERMILION ECL	W OF US-6 / SR-611	4U	3.04	100	10,312	14.50
US 6	PUEBLO DR	LEAVITT RD (SR-58)	4U	1.07	40	5,248	3.00
US 6	LEAVITT RD (SR-58)	SR-57 (BROADWAY)	4U	1.44	40	6,769	13.00
US 6	BROADWAY (SR-57)	ARKANSAS AVE	4D	0.27	20	2,556	4.50
US 6	ARKANSAS AVE	E OF ROOT RD	2U	2.46	100	5,530	12.00

Table 4: Selected Intersections

MAJOR ROAD	MINOR ROAD	INTERSECTION TYPE	ADT OF MAJOR ROAD	ADT OF MINOR ROAD
BROADWAY AVE	COOPER-FOSTER PARK RD	4SG	11,962	7,354
BROADWAY AVE	SR 57 (E 28TH ST)	4SG	9,750	6,744
ELYRIA AVE	SR 57 (E 28TH ST)	4SG	5,011	6,744
ELYRIA AVE	SR 611	4SG	5,011	12,838
NORTH RIDGE RD	OBERLIN AVE	4SG	2,006	737
OBERLIN AVE	COOPER-FOSTER PARK RD	4SG	4,895	6,703
OBERLIN AVE	SR 611	4SG	2,879	7,512

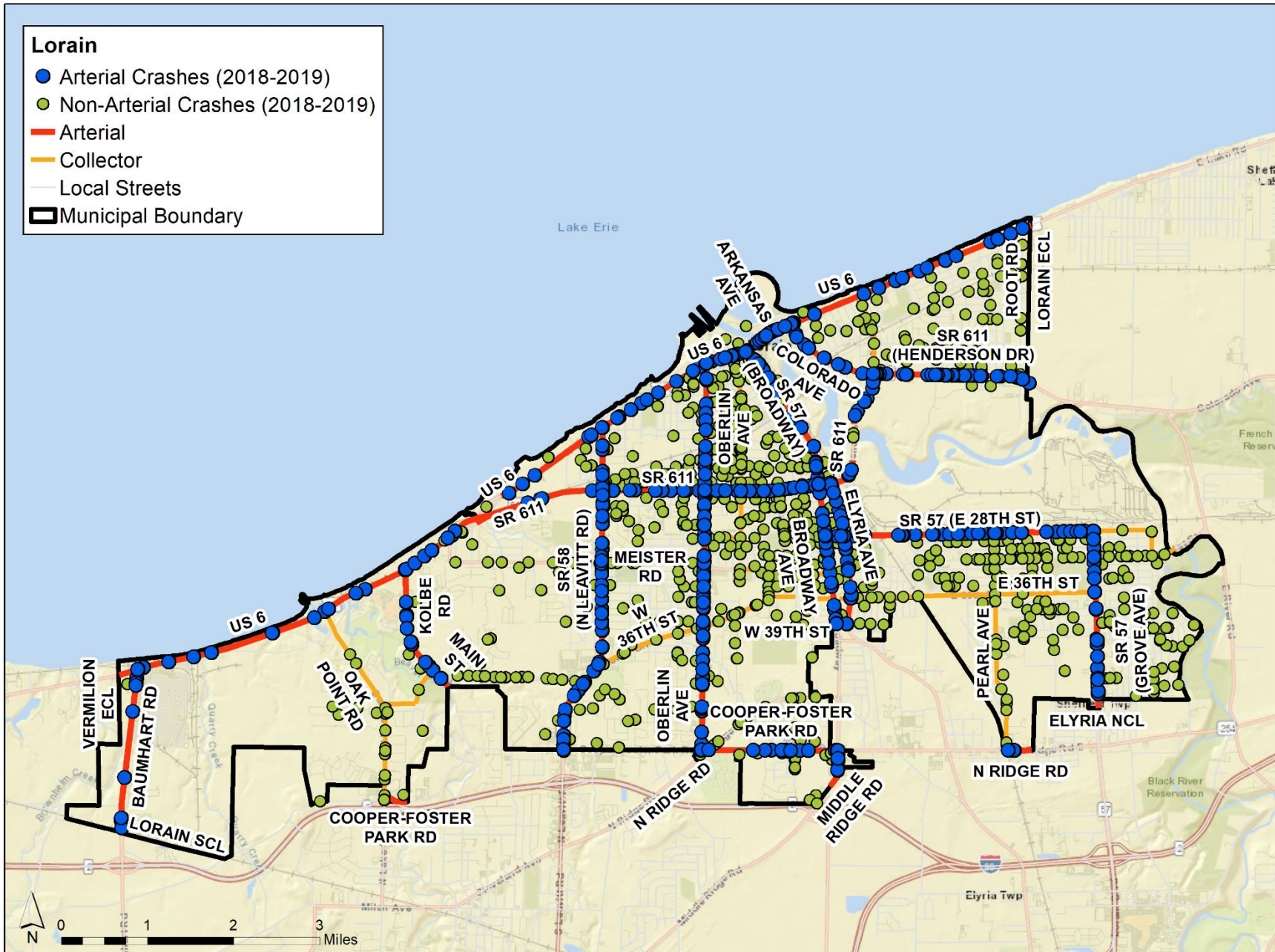
Table 4: Selected Intersections (continued)

MAJOR ROAD	MINOR ROAD	INTERSECTION TYPE	ADT OF MAJOR ROAD	ADT OF MINOR ROAD
OBERLIN AVE	US 6	4SG	2,879	6,769
SR 57 (BROADWAY AVE)	SR 611	4SG	2,741	8,429
SR 57 (GROVE AVE)	SR 57 (E 28TH ST)	4SG	1,152	7,955
SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD	4SG	17,749	6,036
SR 58 (N LEAVITT RD)	SR 611	4SG	10,716	4,764
SR 611	COLORADO AVE	4SG	12,568	12,838
US 6	BAUMHART RD	3SG	10,312	9,130
US 6	BROADWAY AVE	4SG	6,769	1,280
US 6	COLORADO AVE	4SG	5,530	3,302
US 6	KOLBE RD	3SG	10,312	1,957
US 6	SR 58 (N LEAVITT RD)	4SG	6,769	5,257

- 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 City of Lorain that are included in this analysis. Observed 2018-2019 crash locations are also shown.

Map 2: Arterials and Intersections in the City of Lorain



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 5 displays the daily arterial VMT ranges for communities of Lorain County and their associated calibration factors.

Table 5: Daily Arterial VMT Ranges and Calibration Factors for Jurisdictions of Lorain County

DAILY ARTERIAL VMT RANGE	JURISDICTIONS INCLUDED	CALIBRATION FACTOR
< 30,000	Avon Lake, Sheffield Lake	5.32
30,000-150,000	Amherst, Avon, Grafton, North Ridgeville, Sheffield	5.49
> 150,000	Elyria, Lorain	4.79

Tables 6 and 7 provide the predicted crashes by arterial and intersection respectively. **These estimated average annual crash frequencies are the calibrated and aggregated values of motorized and nonmotorized collisions.**

Table 6: Estimated Average Annual Crash Frequency for Selected Arterial Segments

ROAD NAME	FROM	TO	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
BAUMHART RD	LORAIN SCL	W ERIE AVE (US-6)	1.42	25.85
BROADWAY AVE	W 39TH ST	E 28TH ST (SR-57)	0.78	13.20
COLORADO AVE	ERIE ST (US-6)	HENDRICKS DR / KANSAS AVE	0.89	4.52
COOPER-FOSTER PARK RD	AMHERST ECL	NORTH RIDGE RD	0.15	2.19
COOPER-FOSTER PARK RD	NORTH RIDGE RD	BROADWAY AVE	1.09	6.62
COOPER-FOSTER PARK RD	OAK POINT RD	LORAIN ECL	0.21	0.19
ELYRIA AVE	E 39TH ST	HENDERSON DR (SR-611)	1.24	8.63
KOLBE RD	Longbrook Rd	ERIE AVE (US-6)	0.97	6.22
MAIN ST	AMHERST NCL	Longbrook Dr	0.18	0.91
MIDDLE RIDGE RD	OLD WEST RIDGE RD (N OF SR-2 RAMPS)	COOPER FOSTER PARK	0.35	6.77
NORTH RIDGE RD	E OF S PEARL ST	GLADYS AVE	0.23	3.25
OBERLIN AVE	COOPER FOSTER PARK RD	MEISTER RD	1.61	13.84
OBERLIN AVE	MEISTER RD	ERIE AVE (US-6)	1.74	7.88
SR 57 (BROADWAY AVE)	E 28TH ST (SR-57)	E 14TH ST	1.00	2.99
SR 57 (BROADWAY AVE)	E 14TH ST	US-6 (ERIE AVE)	0.80	1.28

Table 6: Estimated Average Annual Crash Frequency for Selected Arterial Segments (continued)

ROAD NAME	FROM	TO	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
SR 57 (E 28TH ST)	FULTON RD	BROADWAY AVE	0.61	5.06
SR 57 (E 28TH ST)	GROVE AVE (SR-57)	FULTON RD	1.72	1.19
SR 57 (GROVE AVE)	ELYRIA NCL	E 36TH ST	1.02	13.03
SR 57 (GROVE AVE)	E 36TH ST	E 28TH ST (SR-57)	0.52	5.02
SR 58 (N LEAVITT RD)	COOPER FOSTER PARK RD	SR-611	2.34	39.61
SR 58 (N LEAVITT RD)	SR-611	W ERIE AVE (US-6)	0.57	5.15
SR 611	W 21ST ST	W ERIE AVE (US-6)	0.44	1.39
SR 611	W ERIE AVE (US-6)	LEAVITT RD (SR-58)	1.14	5.28
SR 611	LEAVITT RD (SR-58)	HAMILTON AVE	1.03	11.47
SR 611	HAMILTON AVE	ELYRIA AVE	0.95	10.21
SR 611	ELYRIA AVE	COLORADO AVE	0.81	17.67
SR 611	HENDERSON DR	LORAIN ECL	1.38	22.72
US 6	VERMILION ECL	W OF US-6 / SR-611	3.04	46.44
US 6	PUEBLO DR	LEAVITT RD (SR-58)	1.07	7.54
US 6	LEAVITT RD (SR-58)	SR-57 (BROADWAY)	1.44	12.92

Table 6: Estimated Average Annual Crash Frequency for Selected Arterial Segments (continued)

ROAD NAME	FROM	TO	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
US 6	BROADWAY (SR-57)	ARKANSAS AVE	0.27	0.66
US 6	ARKANSAS AVE	E OF ROOT RD	2.46	16.36

Table 7: Estimated Average Annual Crash Frequency for Selected Intersections

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
BROADWAY AVE	COOPER-FOSTER PARK RD	15.52
BROADWAY AVE	SR 57 (E 28TH ST)	12.29
ELYRIA AVE	SR 57 (E 28TH ST)	6.18
ELYRIA AVE	SR 611	7.18
NORTH RIDGE RD	OBERLIN AVE	1.45
OBERLIN AVE	COOPER-FOSTER PARK RD	6.02
OBERLIN AVE	SR 611	3.61
OBERLIN AVE	US 6	3.52
SR 57 (BROADWAY AVE)	SR 611	3.54
SR 57 (GROVE AVE)	SR 57 (E 28TH ST)	1.52
SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD	22.42

Table 7: Estimated Average Annual Crash Frequency for Selected Intersections (continued)

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
SR 58 (N LEAVITT RD)	SR 611	12.52
SR 611	COLORADO AVE	18.59
US 6	BAUMHART RD	9.11
US 6	BROADWAY AVE	5.74
US 6	COLORADO AVE	5.79
US 6	KOLBE RD	5.96
US 6	SR 58 (N LEAVITT RD)	7.95

Tables 8 and 9 display breakouts of the predicted nonmotorized crashes by arterial and intersection, respectively. **The nonmotorized crashes include the calibrated total value of vehicle-bicycle and vehicle-pedestrian collisions.**

Table 8: Estimated Average Annual Nonmotorized Crash Frequency for Selected Arterials

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
BAUMHART RD	1.42	0.61
BROADWAY AVE	0.78	0.14
COLORADO AVE	0.89	0.04
COOPER-FOSTER PARK RD	0.15	0.02

Table 8: Estimated Average Annual Nonmotorized Crash Frequency for Selected Arterials (continued)

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
COOPER-FOSTER PARK RD	1.09	0.06
COOPER-FOSTER PARK RD	0.21	0.00
ELYRIA AVE	1.24	0.08
KOLBE RD	0.97	0.06
MAIN ST	0.18	0.01
MIDDLE RIDGE RD	0.35	0.07
NORTH RIDGE RD	0.23	0.04
OBERLIN AVE	1.61	0.15
OBERLIN AVE	1.74	0.07
SR 57 (BROADWAY AVE)	1.00	0.03
SR 57 (BROADWAY AVE)	0.80	0.01
SR 57 (E 28TH ST)	0.61	0.06
SR 57 (E 28TH ST)	1.72	0.01
SR 57 (GROVE AVE)	1.02	0.31
SR 57 (GROVE AVE)	0.52	0.05
SR 58 (N LEAVITT RD)	2.34	0.43

Table 8: Estimated Average Annual Nonmotorized Crash Frequency for Selected Arterials (continued)

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
SR 58 (N LEAVITT RD)	0.57	0.05
SR 611	0.44	0.01
SR 611	1.14	0.06
SR 611	1.03	0.12
SR 611	0.95	0.09
SR 611	0.81	0.19
SR 611	1.38	0.20
US 6	3.04	0.51
US 6	1.07	0.08
US 6	1.44	0.14
US 6	0.27	0.02
US 6	2.46	0.15

Table 9: Estimated Average Annual Nonmotorized Crash Frequency for Selected Intersections

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
BROADWAY AVE	COOPER-FOSTER PARK RD	0.33
BROADWAY AVE	SR 57 (E 28TH ST)	0.28
ELYRIA AVE	SR 57 (E 28TH ST)	0.19
ELYRIA AVE	SR 611	0.24
NORTH RIDGE RD	OBERLIN AVE	0.06
OBERLIN AVE	COOPER-FOSTER PARK RD	0.19
OBERLIN AVE	SR 611	0.17
OBERLIN AVE	US 6	0.16
SR 57 (BROADWAY AVE)	SR 611	0.17
SR 57 (GROVE AVE)	SR 57 (E 28TH ST)	0.16
SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD	0.42
SR 58 (N LEAVITT RD)	SR 611	0.27
SR 611	COLORADO AVE	0.40
US 6	BAUMHART RD	0.14
US 6	BROADWAY AVE	0.14

Table 9: Estimated Average Annual Nonmotorized Crash Frequency for Selected Intersections (continued)

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
US 6	COLORADO AVE	0.16
US 6	KOLBE RD	0.09
US 6	SR 58 (N LEAVITT RD)	0.20

PART IV: Prioritization of Expected Crash Sites

This Part includes Tables 10 and 11 which tabulate a prioritized ranking of the selected arterials and intersections based on the estimated average annual crash frequency from highest to lowest.

Table 10: Selected Arterials Ranked by Expected Average Annual Crash Frequency

RANK	ROAD NAME	FROM	TO
1	US 6	VERMILION ECL	W OF US-6 / SR-611
2	SR 58 (N LEAVITT RD)	COOPER FOSTER PARK RD	SR-611
3	BAUMHART RD	LORAIN SCL	W ERIE AVE (US-6)
4	SR 611	HENDERSON DR	LORAIN ECL
5	SR 611	ELYRIA AVE	COLORADO AVE
6	US 6	ARKANSAS AVE	E OF ROOT RD
7	OBERLIN AVE	COOPER FOSTER PARK RD	MEISTER RD
8	BROADWAY AVE	W 39TH ST	E 28TH ST (SR-57)
9	SR 57 (GROVE AVE)	ELYRIA NCL	E 36TH ST
10	US 6	LEAVITT RD (SR-58)	SR-57 (BROADWAY)

Table 11: Selected Intersections Ranked by Expected Average Annual Crash Frequency

RANK	MAJOR ROAD	MINOR ROAD
1	SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD
2	SR 611	COLORADO AVE
3	BROADWAY AVE	COOPER-FOSTER PARK RD
4	SR 58 (N LEAVITT RD)	SR 611
5	BROADWAY AVE	SR 57 (E 28TH ST)

Map 3 highlights the sites in the City of Lorain prioritized above. The arterial segments highlighted in various colors from red to blue represent the highest estimated average annual arterial segment crash frequency. The purple circles represent the estimated average annual intersection crash frequency, with larger circles indicating higher rankings.

Map 3: Arterial and Intersection Prioritization Sites

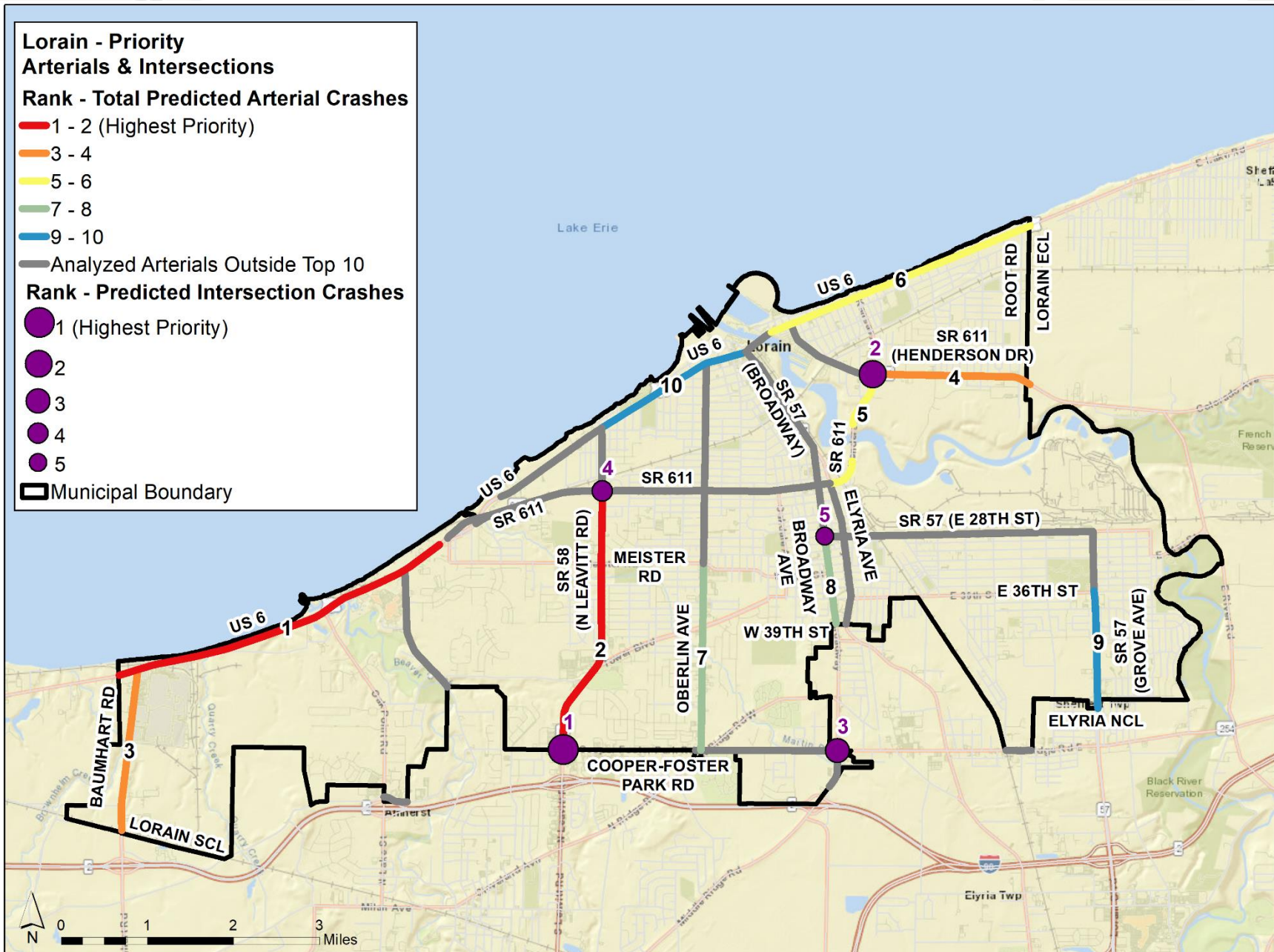


Table 12 summarizes the total annual average of 2018 and 2019 recorded crash data and the total expected annual average crash frequency for the selected arterials and intersections in the City of Lorain.

Table 12: Comparison of History and Predicted Annual Average Crash Frequency

SELECTED ARTERIALS AND INTERSECTIONS IN THE CITY OF LORAIN	
TOTAL RECORDED AVERAGE ANNUAL CRASH DATA	TOTAL ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
526.00	474.97

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. For example, the US 6 segment from Columbia Road to City of Lorain Eastern City Line has the highest number of expected annual average crash frequency but only an average of fifteen observed annual crashes. Some of the other arterial segments, such as Elyria Avenue and segments of SR 611, have higher numbers of average observed crashes but do not appear in the priority list above. 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 and intersections in the City of Lorain.

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
BAUMHART RD	1.42	1.181	3.016	0.159	0.783	0.038	0.095
BROADWAY AVE	0.78	0.451	0.950	0.123	0.327	0.299	0.576
COLORADO AVE	0.89	0.074	0.172	0.117	0.273	0.097	0.203
COOPER-FOSTER PARK RD	0.15	0.054	0.109	0.019	0.045	0.077	0.148
COOPER-FOSTER PARK RD	1.09	0.172	0.407	0.159	0.435	0.064	0.133
COOPER-FOSTER PARK RD	0.21	0.001	0.001	0.014	0.014	0.003	0.006
ELYRIA AVE	1.24	0.149	0.351	0.173	0.444	0.216	0.452
KOLBE RD	0.97	0.137	0.322	0.139	0.370	0.104	0.217
MAIN ST	0.18	0.027	0.064	0.026	0.071	0.000	0.000
MIDDLE RIDGE RD	0.35	0.261	0.564	0.063	0.176	0.114	0.220

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

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
NORTH RIDGE RD	0.23	0.098	0.201	0.031	0.078	0.090	0.173
OBERLIN AVE	1.61	0.396	0.761	0.162	0.369	0.400	0.770
OBERLIN AVE	1.74	0.084	0.193	0.208	0.426	0.232	0.487
SR 57 (BROADWAY AVE)	1.00	0.119	0.213	0.069	0.137	0.027	0.052
SR 57 (BROADWAY AVE)	0.80	0.042	0.069	0.036	0.061	0.019	0.036
SR 57 (E 28TH ST)	0.61	0.223	0.448	0.076	0.185	0.039	0.075
SR 57 (E 28TH ST)	1.72	0.042	0.063	0.051	0.076	0.005	0.009
SR 57 (GROVE AVE)	1.02	0.586	1.454	0.095	0.496	0.007	0.017
SR 57 (GROVE AVE)	0.52	0.234	0.479	0.072	0.183	0.024	0.045
SR 58 (N LEAVITT RD)	2.34	1.523	3.245	0.391	1.067	0.669	1.287
SR 58 (N LEAVITT RD)	0.57	0.074	0.175	0.080	0.211	0.170	0.356
SR 611	0.44	0.011	0.024	0.047	0.080	0.041	0.086
SR 611	1.14	0.192	0.356	0.094	0.201	0.084	0.162

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

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 611	1.03	0.431	0.877	0.137	0.344	0.198	0.382
SR 611	0.95	0.271	0.648	0.151	0.481	0.182	0.380
SR 611	0.81	0.660	1.439	0.152	0.432	0.331	0.636
SR 611	1.38	0.763	1.846	0.242	0.906	0.304	0.638
US 6	3.04	1.886	3.999	0.495	1.340	0.639	1.230
US 6	1.07	0.287	0.557	0.113	0.261	0.116	0.223
US 6	1.44	0.530	1.063	0.179	0.439	0.156	0.300
US 6	0.27	0.016	0.034	0.008	0.061	0.004	0.010
US 6	2.46	0.349	0.823	0.352	0.940	0.298	0.624

Table A-2: Predicted Average Vehicle Crashes at Intersections (Excluding Pedestrians and Bicycles)

MAJOR ROAD	MINOR ROAD	MULTIPLE-VEHICLE PREDICTED CRASHES PER YEAR		SINGLE-VEHICLE PREDICTED CRASHES PER YEAR	
		FATAL AND INJURY	PROPERTY DAMAGE ONLY	FATAL AND INJURY	PROPERTY DAMAGE ONLY
BROADWAY AVE	COOPER-FOSTER PARK RD	0.938	2.079	0.046	0.109
BROADWAY AVE	SR 57 (E 28TH ST)	0.723	1.653	0.041	0.091
ELYRIA AVE	SR 57 (E 28TH ST)	0.329	0.837	0.031	0.053
ELYRIA AVE	SR 611	0.378	0.974	0.036	0.061
NORTH RIDGE RD	OBERLIN AVE	0.069	0.194	0.012	0.016
OBERLIN AVE	COOPER-FOSTER PARK RD	0.320	0.816	0.030	0.052
OBERLIN AVE	SR 611	0.175	0.486	0.024	0.035
OBERLIN AVE	US 6	0.171	0.474	0.024	0.034
SR 57 (BROADWAY AVE)	SR 611	0.169	0.475	0.024	0.034
SR 57 (GROVE AVE)	SR 57 (E 28TH ST)	0.059	0.192	0.016	0.016
SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD	1.432	2.967	0.052	0.142
SR 58 (N LEAVITT RD)	SR 611	0.750	1.677	0.039	0.091
SR 611	COLORADO AVE	1.122	2.494	0.054	0.127
US 6	BAUMHART RD	0.570	1.076	0.077	0.149
US 6	BROADWAY AVE	0.328	0.769	0.023	0.048

Table A-2: Predicted Average Vehicle Crashes at Intersections (Excluding Pedestrians and Bicycles) (continued)

MAJOR ROAD	MINOR ROAD	MULTIPLE-VEHICLE PREDICTED CRASHES PER YEAR		SINGLE-VEHICLE PREDICTED CRASHES PER YEAR	
		FATAL AND INJURY	PROPERTY DAMAGE ONLY	FATAL AND INJURY	PROPERTY DAMAGE ONLY
US 6	COLORADO AVE	0.317	0.782	0.027	0.050
US 6	KOLBE RD	0.434	0.669	0.034	0.087
US 6	SR 58 (N LEAVITT RD)	0.445	1.074	0.033	0.065

Table A-3: Predicted Average Pedestrian and Bicycle Crashes of Arterials

ROAD NAME	LENGTH (MI)	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
BAUMHART RD	1.42	0.100	0.026
BROADWAY AVE	0.78	0.025	0.005
COLORADO AVE	0.89	0.005	0.004
COOPER-FOSTER PARK RD	0.15	0.004	0.001
COOPER-FOSTER PARK RD	1.09	0.007	0.005
COOPER-FOSTER PARK RD	0.21	0.000	0.000
ELYRIA AVE	1.24	0.009	0.007
KOLBE RD	0.97	0.006	0.005
MAIN ST	0.18	0.001	0.001

Table A-3: Predicted Average Pedestrian and Bicycle Crashes of Arterials (continued)

ROAD NAME	LENGTH (MI)	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
MIDDLE RIDGE RD	0.35	0.013	0.003
NORTH RIDGE RD	0.23	0.006	0.001
OBERLIN AVE	1.61	0.026	0.006
OBERLIN AVE	1.74	0.008	0.007
SR 57 (BROADWAY AVE)	1.00	0.006	0.001
SR 57 (BROADWAY AVE)	0.80	0.002	0.001
SR 57 (E 28TH ST)	0.61	0.009	0.002
SR 57 (E 28TH ST)	1.72	0.002	0.000
SR 57 (GROVE AVE)	1.02	0.050	0.013
SR 57 (GROVE AVE)	0.52	0.009	0.002
SR 58 (N LEAVITT RD)	2.34	0.074	0.016
SR 58 (N LEAVITT RD)	0.57	0.005	0.004
SR 611	0.44	0.001	0.001
SR 611	1.14	0.010	0.002
SR 611	1.03	0.021	0.005
SR 611	0.95	0.011	0.008

Table A-3: Predicted Average Pedestrian and Bicycle Crashes of Arterials (continued)

ROAD NAME	LENGTH (MI)	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
SR 611	0.81	0.033	0.007
SR 611	1.38	0.024	0.019
US 6	3.04	0.086	0.019
US 6	1.07	0.014	0.003
US 6	1.44	0.024	0.005
US 6	0.27	0.003	0.001
US 6	2.46	0.017	0.014

Table A-4: Predicted Average Pedestrian and Bicycle Crashes at Intersections

MAJOR ROAD	MINOR ROAD	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
BROADWAY AVE	COOPER-FOSTER PARK RD	0.328	0.048
BROADWAY AVE	SR 57 (E 28TH ST)	0.277	0.038
ELYRIA AVE	SR 57 (E 28TH ST)	0.190	0.019
ELYRIA AVE	SR 611	0.245	0.022
NORTH RIDGE RD	OBERLIN AVE	0.061	0.004
OBERLIN AVE	COOPER-FOSTER PARK RD	0.188	0.018

Table A-4: Predicted Average Pedestrian and Bicycle Crashes at Intersections (continued)

MAJOR ROAD	MINOR ROAD	PEDESTRIAN PREDICTED CRASHES PER YEAR	BICYCLE PREDICTED CRASHES PER YEAR
OBERLIN AVE	SR 611	0.165	0.011
OBERLIN AVE	US 6	0.158	0.011
SR 57 (BROADWAY AVE)	SR 611	0.173	0.011
SR 57 (GROVE AVE)	SR 57 (E 28TH ST)	0.159	0.004
SR 58 (N LEAVITT RD)	COOPER-FOSTER PARK RD	0.423	0.069
SR 58 (N LEAVITT RD)	SR 611	0.268	0.038
SR 611	COLORADO AVE	0.400	0.057
US 6	BAUMHART RD	0.141	0.021
US 6	BROADWAY AVE	0.136	0.018
US 6	COLORADO AVE	0.157	0.018
US 6	KOLBE RD	0.093	0.013
US 6	SR 58 (N LEAVITT RD)	0.204	0.024

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

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

Where:

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

ADT = Average Daily Two Way Traffic Volume

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:

$N'_{brmv(FI)}$ = 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

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

Where:

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

ADT = Average Daily Two Way Traffic Volume

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:

$N'_{brsv(FI)}$ = 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 multiple vehicle crashes at intersections

$N'_{bimv(PDO)}$ = preliminary property damage only predicted crash frequency for 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 coefficients 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	<p>These markings indicate upcoming curves for drivers. Strategies include:</p> <ul style="list-style-type: none"> • 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	<p>Rumble Strips are milled or raised features outside travel lanes to indicate with sound or vibrations a driver has drifted out of the lane</p> <p>Rumble Stripes are rumble strips combined with painted markings to increase visibility of the strips</p>	<p>13-51% (Shoulder)</p> <p>44-64% (Center Line)</p>
	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	<p>FHWA lists six design improvements to reduce crashes at curves, which can be implemented together or individually</p> <ul style="list-style-type: none"> • Safe Recovery Areas <ul style="list-style-type: none"> ○ Clear zone ○ Slope flattening ○ Adding or widening shoulders • Severity Reduction <ul style="list-style-type: none"> ○ Cable barrier ○ Metal-beam guardrail ○ Concrete barrier 	22-44%
	Median Barriers	<p>Median barriers separate opposing traffic and create divided highways to reduce head-on and cross-directional crashes</p> <p>Types of Medians:</p> <ul style="list-style-type: none"> • 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	<p>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:</p> <ul style="list-style-type: none"> • 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 	<p>5-23% (Rural)</p> <p>25-31% (Urban)</p>
	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	<p>28-48% (Left Turn)</p> <p>14-26% (Right Turn)</p>
	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).	<p>54-63% (RCUT)</p> <p>30% (MUT)</p>

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	<p>Suggested low-cost countermeasures include:</p> <ul style="list-style-type: none"> • On the Through Approach <ul style="list-style-type: none"> ○ 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 <ul style="list-style-type: none"> ○ 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)








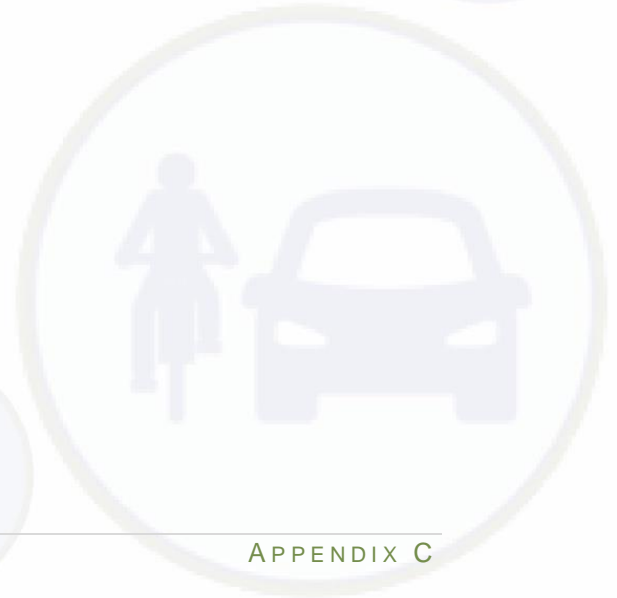
SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Pedestrian Hybrid Beacons	Pedestrian hybrid beacons are devices that remain "dark" until a pedestrian pushes the call button to activate the beacon. This initiates a yellow to red flashing light sequence, which directs motorists to slow and come 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: <ul style="list-style-type: none"> • 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