



2022 Community Safety Report

City of Elyria



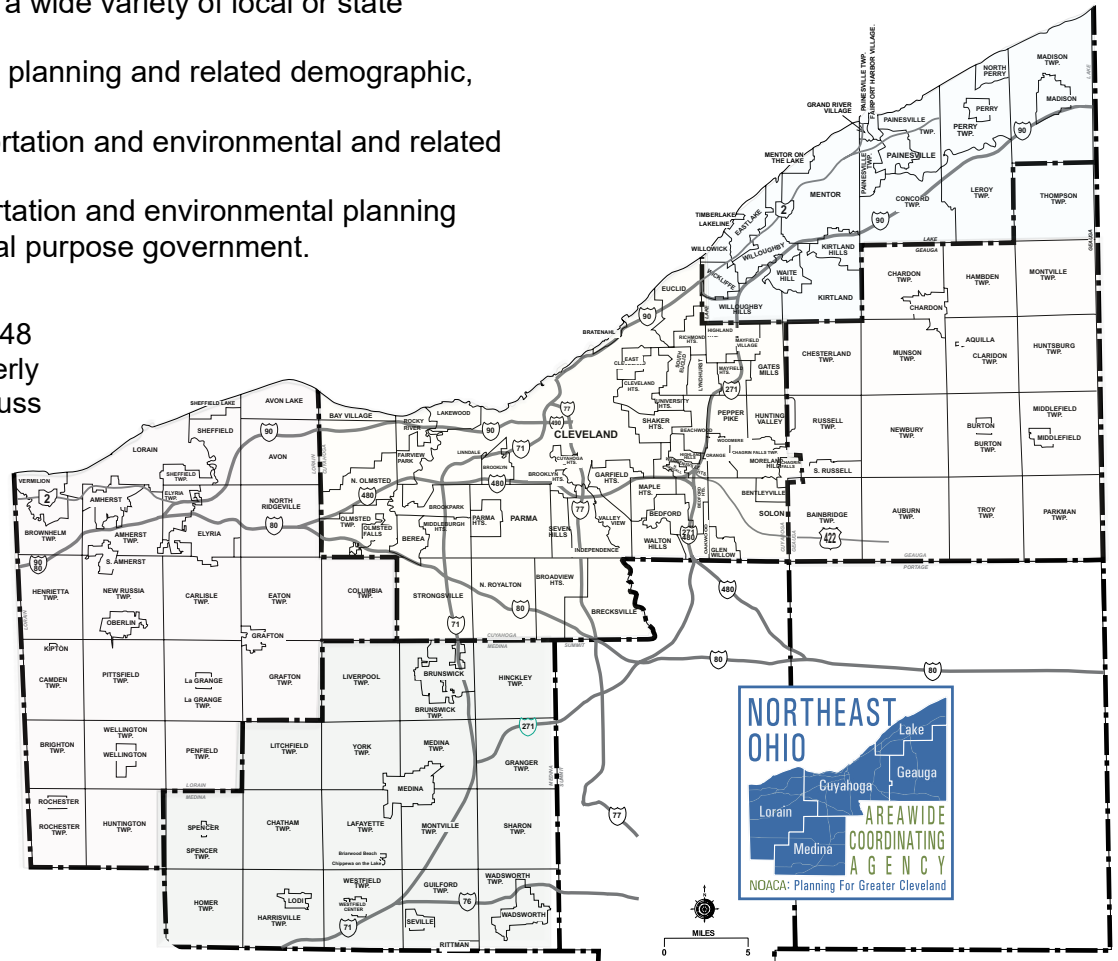
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Coordinating Agency

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.

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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 Elyria, this analysis considered 20.6 centerline miles and 67.7 lane-miles of arterial roadway which encompass seventeen major intersections. The arterial roadways in Elyria make up 2.07% of the total roadway lengths analyzed, which is proportional to Elyria having about 3.03% 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 584.00. The predictive method resulted in 614.16 average annual expected crashes along those arterials and intersections. The larger expected crash value may be explained by existing safety countermeasures which are not captured in the expected crash calculations.

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

RANK	ARTERIAL ROAD NAME	FROM	TO
1	SR 57	LORAIN BLVD / SR-113	0.22 MI N OF I-90
2	SR 57	CLEVELAND ST (US-20)	LORAIN BLVD / SR-113
3	SR 301 (ABBE RD N)	SR-57	BURNS RD
4	LAKE AVE	PARKVIEW CT	ERIE ST
5	CLEVELAND ST	GULF ST	US-20 / SR-57 (JFK MEMORIAL PKWY)

RANK	ARTERIAL ROAD NAME	FROM	TO
6	LAKE AVE	ERIE ST	PARMELY AVE
7	US 20 (CENTER RIDGE RD)	SR-57 (JFK MEMORIAL PKWY)	ELYRIA ECL
8	SR 301 (ABBE RD N)	BURNS RD	ANTIOCH DR / COLLEGE DR
9	LORAIN BLVD	SR-57 / SR-113	WEST RIVER RD
10	SR 113	SR-57 (LORAIN BLVD)	CLEMENS AVE

RANK	INTERSECTION	MAJOR ROAD	MINOR ROAD
1	LORAIN BLVD - SR 57	LORAIN BLVD	SR 57
2	SR 57 - CLEVELAND ST	SR 57	CLEVELAND ST
3	SR 57 - SR 301 (ABBE RD N)	SR 57	SR 301 (ABBE RD N)
4	BROAD ST - CEDAR ST	BROAD ST	CEDAR ST
5	BROAD ST - E BRIDGE ST	BROAD ST	E BRIDGE ST
6	SR 113 - LAKE AVE	SR 113	LAKE AVE
7	BROAD ST - EAST AVE	BROAD ST	EAST AVE
8	EAST AVE - 2ND ST	EAST AVE	2ND ST
9	BROAD ST - MIDDLE AVE	BROAD ST	MIDDLE AVE
10	MIDDLE AVE - 2ND ST	MIDDLE AVE	2ND 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 Elyria is the county seat of Lorain County and located at the forks of the Black River. The city is named for its founder, Herman Ely and is home to Lorain County Community College.

According to the 2020 Decennial Census, the population of Elyria is 52,656 people and 22,954 households. The input data of the NOACA travel forecasting model indicates that the estimated current number of individuals employed in the City of Elyria is 28,841.

The City of Elyria includes US Route 20, the Ohio Turnpike, State Route 2 (SR 2), State Route 113 (SR 113), State Route 301 (SR 301), and State Route 57 (SR 57). Lorain County Transit is based in Elyria. The Elyria Amtrak Station provides train transportation and Greyhound bus service is also in the city. Cleveland-Hopkins International Airport is the nearest airport.

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

Map 1: Location of the City of Elyria 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

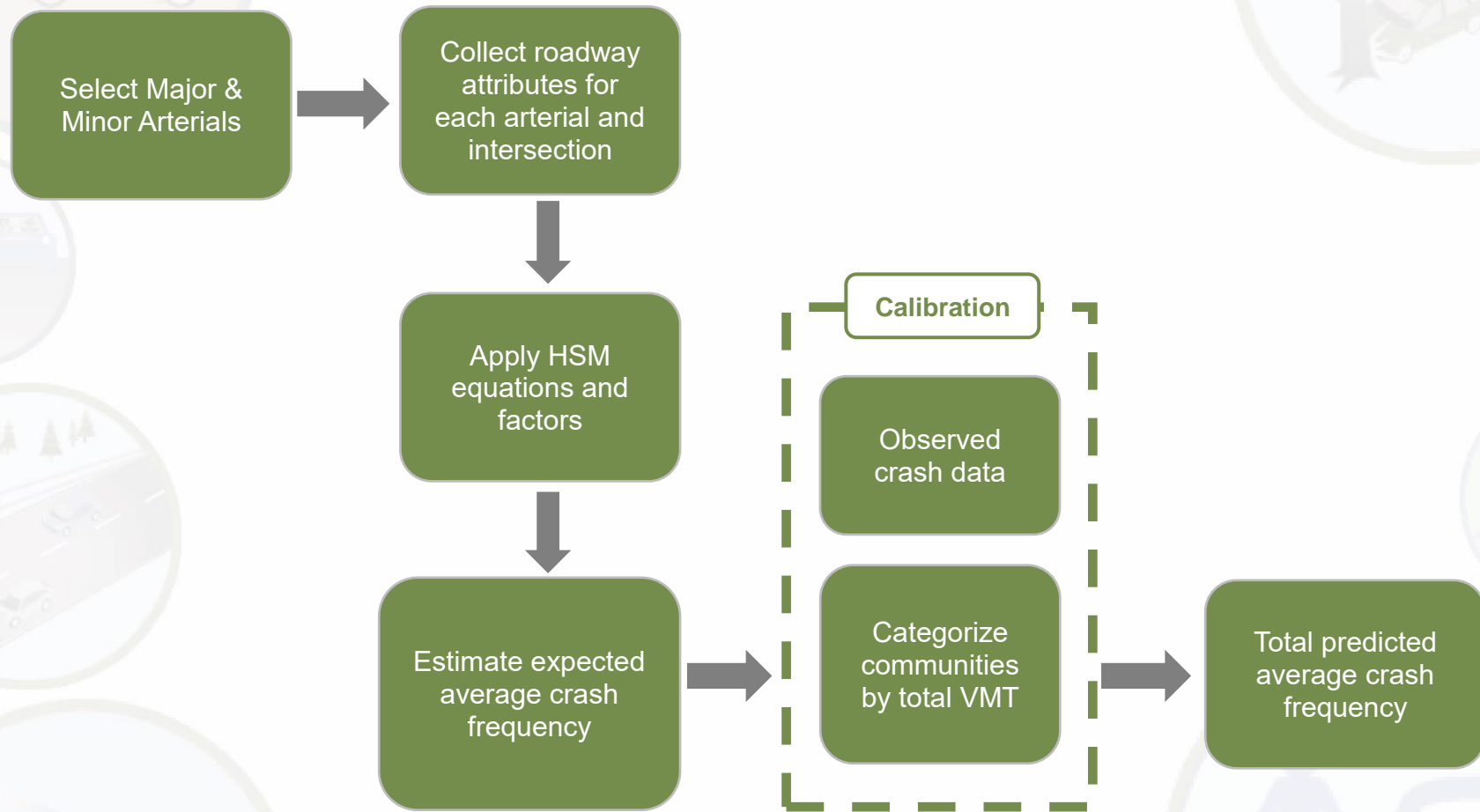
The predictive method described below provides estimated annual crash frequency and severity along arterials and at major intersections by using some approaches from the Highway Safety Manual. These estimates are not solely based on observed historical crash data, but rather incorporate roadway and traffic 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 Elyria was reviewed and 26 arterial segments and 17 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)
2ND ST	CEDAR ST	MIDDLE AVE	4U	0.26	15	4,742	1.00
BROAD ST	WEST AVE	EAST BRIDGE ST	2U	0.56	10	11,690	22.00
BROAD ST	EAST OF US-20 / SR-57	ELYRIA ECL	2U	0.29	20	6,903	4.00
CEDAR ST	2ND ST	E BROAD ST	4U	0.08	5	4,582	6.00
CLEVELAND ST	GULF ST	US-20/SR-57 (JFK MEMORIAL PKWY)	4U	0.99	70	7,920	35.50
E BRIDGE ST	EAST BROAD ST	GULF RD / CLEVELAND ST	4U	0.48	15	10,315	12.50
EAST AVE	16TH ST	EAST BROAD ST	2U	1.15	110	5,378	20.50
LAKE AVE	PARKVIEW CT	ERIE ST	4U	0.56	40	18,414	19.00
LAKE AVE	ERIE ST	PARMELY AVE	4U	1.02	50	8,419	20.00
LORAIN BLVD	SR-57 / SR-113	WEST RIVER RD	4D	0.78	10	15,707	12.00
LOWELL ST	LORAIN BLVD	WEST RIVER RD	2U	0.15	7	237	0.00

Table 3: Selected Arterial Segments (continued)

ROAD NAME	FROM	TO	SEGMENT TYPE	LENGTH (MILES)	NUMBER OF DRIVEWAYS	ADT	AVERAGE RECORDED CRASHES (2018 & 2019)
MIDDLE AVE	E BROAD ST	OBERLIN RD / 17TH ST	2U	1.16	60	6,615	34.50
N GATEWAY BLVD	ERIE ST	WEST RIVER RD	3T	0.39	15	7,095	13.00
OBERLIN RD	ELYRIA SCL	MIDDLE AVE	4U	0.64	45	9,026	5.50
S GATEWAY BLVD	WEST RIVER RD N OF FILBERT ST	WEST RIVER RD	2U	0.83	30	2,672	11.00
SR 113	SR-57 (LORAIN BLVD)	CLEMENS AVE	4D	1.08	0	11,898	7.00
SR 301 (ABBE RD N)	SR-57	BURNS RD	4U	1.62	60	12,698	57.50
SR 301 (ABBE RD N)	BURNS RD	ANTIOCH DR / COLLEGE DR	4U	0.46	40	11,982	12.00
SR 57	CLEVELAND ST (US-20)	LORAIN BLVD / SR-113	4D	2.71	0	17,925	130.50
SR 57	LORAIN BLVD / SR-113	0.22 MI N OF I-90	4D	1.69	0	60,249	104.00
SR 57	0.22 MI N OF I-90	ELYRIA NCL	4D	0.31	0	18,767	6.50
US 20 (CENTER RIDGE RD)	SR-57 (JFK MEMORIAL PKWY)	ELYRIA ECL	4U	0.43	20	15,629	27.50
W RIDGE RD	FOX CHASE DR	ELYRIA NCL	2U	0.84	40	1,513	6.50
W RIDGE RD	OLD WEST RIDGE RD	ELYRIA NCL	2U	0.30	40	2,605	2.00
W RIVER RD	CARLISLE TWP NCL	3RD ST	2U	1.19	80	3,371	6.00
W RIVER RD	3RD ST	FREMONT ST	2U	0.59	80	4,531	8.00

Table 4: Selected Intersections

MAJOR ROAD	MINOR ROAD	INTERSECTION TYPE	ADT OF MAJOR ROAD	ADT OF MINOR ROAD
BROAD ST	CEDAR ST	4SG	11,691	4,582
BROAD ST	E BRIDGE ST	3SG	11,691	10,315
BROAD ST	EAST AVE	4SG	7,586	5,378
BROAD ST	MIDDLE AVE	3ST	7,586	3,314
EAST AVE	2ND ST	4SG	5,378	4,742
LORAIN BLVD	LAKE AVE	4SG	2,143	16,868
LORAIN BLVD	SR 57	4SG	60,250	17,927
LOWELL ST	LORAIN BLVD	3SG	238	7,385
LOWELL ST	W RIVER RD	3ST	238	1,540
MIDDLE AVE	2ND ST	4SG	3,314	4,742
N GATEWAY BLVD	LAKE AVE	4SG	2,053	16,868
SR 113	LAKE AVE	3SG	11,899	8,419
SR 57	CLEVELAND ST	4SG	29,745	15,629
SR 57	SR 301 (ABBE RD N)	3SG	17,927	12,699

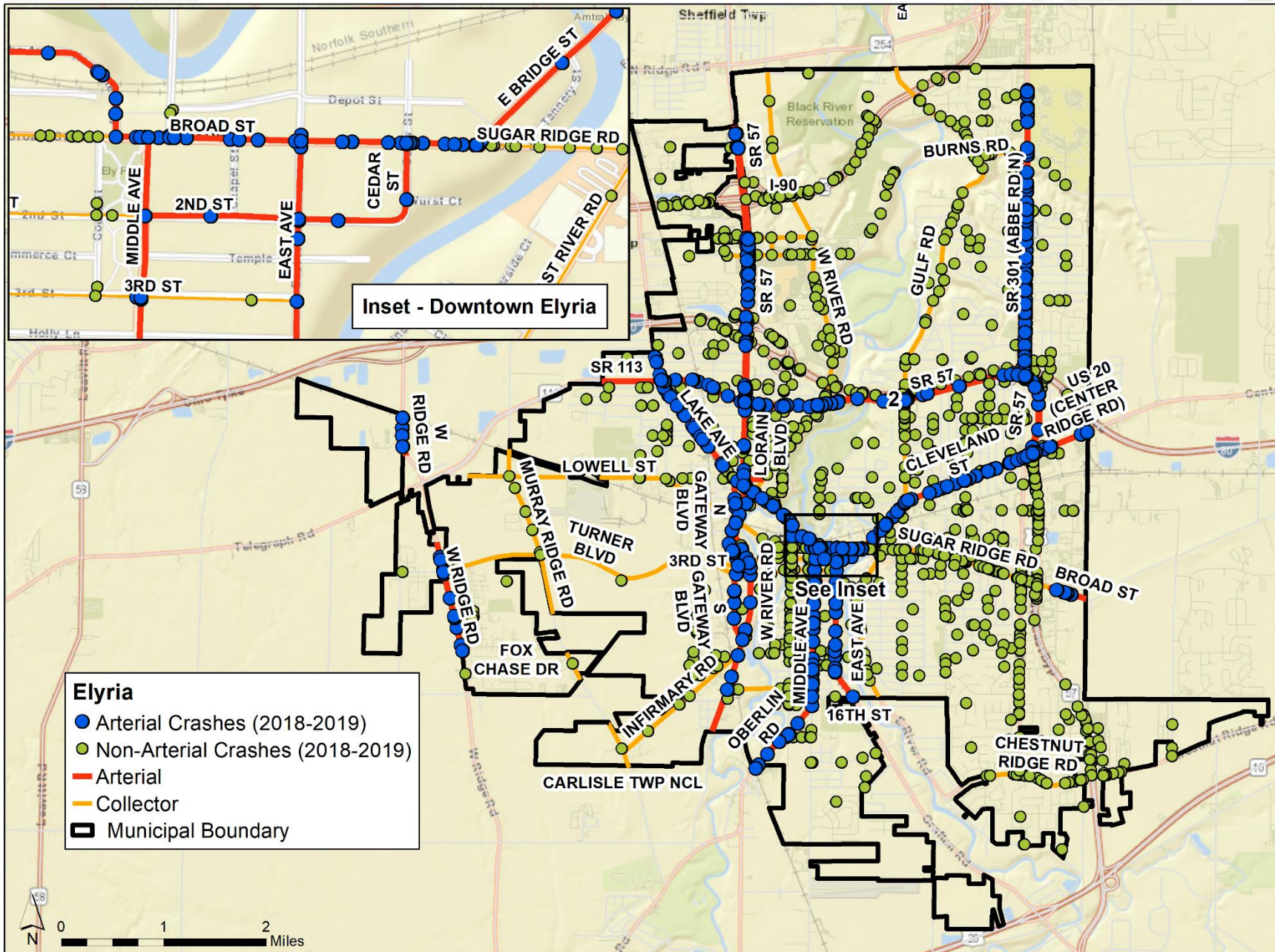
Table 4: Selected Intersections (continued)

MAJOR ROAD	MINOR ROAD	INTERSECTION TYPE	ADT OF MAJOR ROAD	ADT OF MINOR ROAD
W RIVER RD	LAKE AVE	4SG	1,540	16,868
W RIVER RD	N GATEWAY BLVD	4SG	2,530	2,053
W RIVER RD	S GATEWAY BLVD	3SG	4,530	2,672

- 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 Elyria that are included in this analysis. Observed 2018-2019 crash locations are also shown.

Map 2: Arterials and Intersections in the City of Elyria



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
2ND ST	CEDAR ST	MIDDLE AVE	0.26	1.82
BROAD ST	WEST AVE	EAST BRIDGE ST	0.56	7.64
BROAD ST	EAST OF US-20 / SR-57	ELYRIA ECL	0.29	2.91
CEDAR ST	2ND ST	E BROAD ST	0.08	0.55
CLEVELAND ST	GULF ST	US-20 / SR-57 (JFK MEMORIAL PKWY)	0.99	13.52
E BRIDGE ST	EAST BROAD ST	GULF RD / CLEVELAND ST	0.48	7.26
EAST AVE	16TH ST	EAST BROAD ST	1.15	10.17
LAKE AVE	PARKVIEW CT	ERIE ST	0.56	21.11
LAKE AVE	ERIE ST	PARMELY AVE	1.02	13.40
LORAIN BLVD	SR-57 / SR-113	WEST RIVER RD	0.78	11.07
LOWELL ST	LORAIN BLVD	WEST RIVER RD	0.15	0.08
MIDDLE AVE	E BROAD ST	OBERLIN RD / 17TH ST	1.16	10.06
N GATEWAY BLVD	ERIE ST	WEST RIVER RD	0.39	3.40
OBERLIN RD	ELYRIA SCL	MIDDLE AVE	0.64	10.19
S GATEWAY BLVD	WEST RIVER RD N OF FILBERT ST	WEST RIVER RD	0.83	2.61

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

ROAD NAME	FROM	TO	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
SR 113	SR-57 (LORAIN BLVD)	CLEMENS AVE	1.08	10.88
SR 301 (ABBE RD N)	SR-57	BURNS RD	1.62	32.57
SR 301 (ABBE RD N)	BURNS RD	ANTIOCH DR / COLLEGE DR	0.46	11.10
SR 57	CLEVELAND ST (US-20)	LORAIN BLVD / SR-113	2.71	43.91
SR 57	LORAIN BLVD / SR-113	0.22 MI N OF I-90	1.69	124.20
SR 57	0.22 MI N OF I-90	ELYRIA NCL	0.31	5.31
US 20 (CENTER RIDGE RD)	SR-57 (JFK MEMORIAL PKWY)	ELYRIA ECL	0.43	11.72
W RIDGE RD	FOX CHASE DR	ELYRIA NCL	0.84	1.74
W RIDGE RD	OLD WEST RIDGE RD	ELYRIA NCL	0.30	1.53
W RIVER RD	CARLISLE TWP NCL	3RD ST	1.19	5.65
W RIVER RD	3RD ST	FREMONT ST	0.59	5.23

Table 7: Estimated Average Annual Crash Frequency for Selected Intersections

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
BROAD ST	CEDAR ST	13.59
BROAD ST	E BRIDGE ST	10.71
BROAD ST	EAST AVE	8.99
BROAD ST	MIDDLE AVE	5.83
EAST AVE	2ND ST	6.12
LORAIN BLVD	LAKE AVE	3.29
LORAIN BLVD	SR 57	104.46
LOWELL ST	LORAIN BLVD	0.42
LOWELL ST	W RIVER RD	0.62
MIDDLE AVE	2ND ST	3.73
N GATEWAY BLVD	LAKE AVE	3.16
SR 113	LAKE AVE	10.31
SR 57	CLEVELAND ST	48.03
SR 57	SR 301 (ABBE RD N)	17.66

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

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
W RIVER RD	LAKE AVE	2.41
W RIVER RD	N GATEWAY BLVD	2.33
W RIVER RD	S GATEWAY BLVD	2.83

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
2ND ST	0.26	0.02
BROAD ST	0.56	0.07
BROAD ST	0.29	0.03
CEDAR ST	0.08	0.01
CLEVELAND ST	0.99	0.15
E BRIDGE ST	0.48	0.08
EAST AVE	1.15	0.09

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

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
LAKE AVE	0.56	0.23
LAKE AVE	1.02	0.15
LORAIN BLVD	0.78	0.26
LOWELL ST	0.15	0.00
MIDDLE AVE	1.16	0.09
N GATEWAY BLVD	0.39	0.07
OBERLIN RD	0.64	0.11
S GATEWAY BLVD	0.83	0.02
SR 113	1.08	0.25
SR 301 (ABBE RD N)	1.62	0.35
SR 301 (ABBE RD N)	0.46	0.12
SR 57	2.71	1.03
SR 57	1.69	2.91
SR 57	0.31	0.12
US 20 (CENTER RIDGE RD)	0.43	0.13

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

ROAD NAME	LENGTH (MI)	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
W RIDGE RD	0.84	0.02
W RIDGE RD	0.30	0.01
W RIVER RD	1.19	0.05
W RIVER RD	0.59	0.05

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

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
BROAD ST	CEDAR ST	0.28
BROAD ST	E BRIDGE ST	0.16
BROAD ST	EAST AVE	0.22
BROAD ST	MIDDLE AVE	0.21
EAST AVE	2ND ST	0.17
LORAIN BLVD	LAKE AVE	0.24
LORAIN BLVD	SR 57	1.69
LOWELL ST	LORAIN BLVD	0.10
LOWELL ST	W RIVER RD	0.02

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

MAJOR ROAD	MINOR ROAD	ESTIMATED AVERAGE ANNUAL NONMOTORIZED CRASH FREQUENCY
MIDDLE AVE	2ND ST	0.14
N GATEWAY BLVD	LAKE AVE	0.24
SR 113	LAKE AVE	0.15
SR 57	CLEVELAND ST	0.84
SR 57	SR 301 (ABBE RD N)	0.23
W RIVER RD	LAKE AVE	0.24
W RIVER RD	N GATEWAY BLVD	0.09
W RIVER RD	S GATEWAY BLVD	0.07

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	SR 57	LORAIN BLVD / SR-113	0.22 MI N OF I-90
2	SR 57	CLEVELAND ST (US-20)	LORAIN BLVD / SR-113
3	SR 301 (ABBE RD N)	SR-57	BURNS RD
4	LAKE AVE	PARKVIEW CT	ERIE ST
5	CLEVELAND ST	GULF ST	US-20 / SR-57 (JFK MEMORIAL PKWY)
6	LAKE AVE	ERIE ST	PARMELY AVE
7	US 20 (CENTER RIDGE RD)	SR-57 (JFK MEMORIAL PKWY)	ELYRIA ECL
8	SR 301 (ABBE RD N)	BURNS RD	ANTIOCH DR / COLLEGE DR
9	LORAIN BLVD	SR-57 / SR-113	WEST RIVER RD
10	SR 113	SR-57 (LORAIN BLVD)	CLEMENS AVE

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

RANK	MAJOR ROAD	MINOR ROAD
1	LORAIN BLVD	SR 57
2	SR 57	CLEVELAND ST
3	SR 57	SR 301 (ABBE RD N)
4	BROAD ST	CEDAR ST
5	BROAD ST	E BRIDGE ST
6	SR 113	LAKE AVE
7	BROAD ST	EAST AVE
8	EAST AVE	2ND ST
9	BROAD ST	MIDDLE AVE
10	MIDDLE AVE	2ND ST

Map 3 highlights the sites in the City of Elyria 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

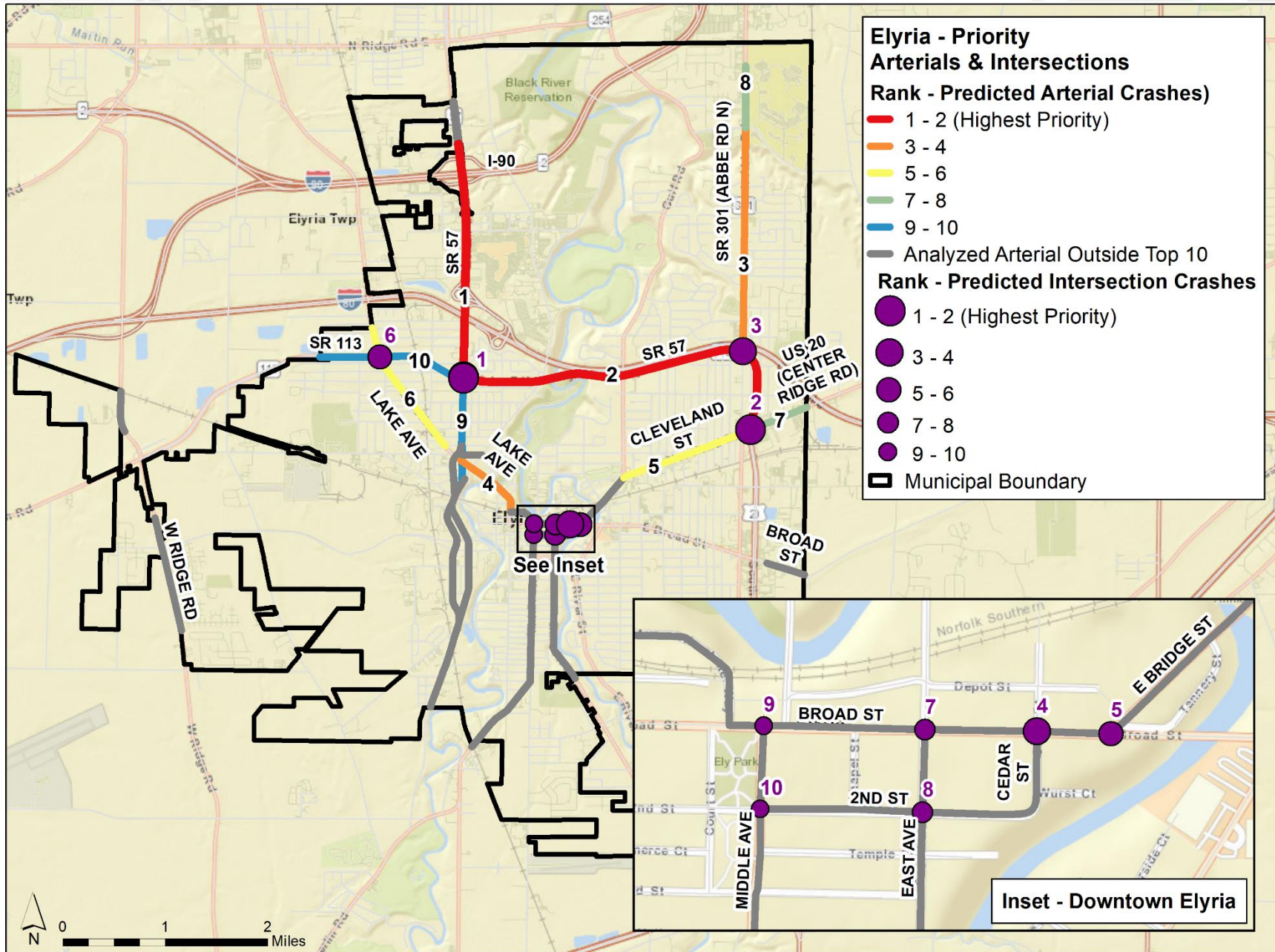


Table 12 summarizes the total annual average of 2018 and 2019 recorded crash data and the total expected annual average crash frequency for the selected arterials and intersections in the City of Elyria.

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

SELECTED ARTERIALS AND INTERSECTIONS IN THE CITY OF ELYRIA	
TOTAL RECORDED AVERAGE ANNUAL CRASH DATA	TOTAL ESTIMATED AVERAGE ANNUAL CRASH FREQUENCY
584.00	623.06

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 SR 57 segment from Lorain Blvd/SR 113 to North of I-90 has the second highest number of average recorded crashes and the highest expected annual average crash frequency; however, some of the other arterial segments, such as Middle Avenue and Broad Street, have a higher number 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

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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 Elyria.

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
2ND ST	0.26	0.061	0.118	0.026	0.058	0.039	0.074
BROAD ST	0.56	0.275	0.663	0.097	0.351	0.063	0.132
BROAD ST	0.29	0.059	0.141	0.044	0.129	0.074	0.156
CEDAR ST	0.08	0.018	0.035	0.008	0.017	0.012	0.024
CLEVELAND ST	0.99	0.443	0.907	0.136	0.347	0.328	0.632
E BRIDGE ST	0.48	0.298	0.632	0.078	0.212	0.096	0.185
EAST AVE	1.15	0.156	0.367	0.163	0.431	0.318	0.667
LAKE AVE	0.56	0.713	1.631	0.132	0.409	0.504	0.971
LAKE AVE	1.02	0.492	1.016	0.146	0.377	0.252	0.485
LORAIN BLVD	0.78	0.496	1.240	0.076	0.393	0.015	0.038

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
LOWELL ST	0.15	0.000	0.000	0.008	0.006	0.001	0.002
MIDDLE AVE	1.16	0.221	0.525	0.174	0.500	0.214	0.448
N GATEWAY BLVD	0.39	0.092	0.340	0.044	0.106	0.028	0.086
OBERLIN RD	0.64	0.337	0.701	0.096	0.251	0.246	0.473
S GATEWAY BLVD	0.83	0.035	0.081	0.097	0.193	0.043	0.090
SR 113	1.08	0.480	1.167	0.088	0.482	0.000	0.000
SR 301 (ABBE RD N)	1.62	1.302	2.835	0.302	0.856	0.490	0.942
SR 301 (ABBE RD N)	0.46	0.344	0.743	0.083	0.231	0.305	0.587
SR 57	2.71	2.043	5.176	0.288	1.445	0.000	0.000
SR 57	1.69	6.066	17.345	0.391	1.520	0.000	0.000
SR 57	0.31	0.248	0.631	0.034	0.169	0.000	0.000
US 20 (CENTER RIDGE RD)	0.43	0.447	1.000	0.091	0.272	0.208	0.400
W RIDGE RD	0.84	0.014	0.031	0.083	0.130	0.033	0.068

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
W RIDGE RD	0.30	0.012	0.028	0.035	0.068	0.056	0.118
W RIVER RD	1.19	0.074	0.173	0.149	0.325	0.145	0.304
W RIVER RD	0.59	0.060	0.141	0.080	0.197	0.195	0.409

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
BROAD ST	CEDAR ST	0.824	1.816	0.040	0.097
BROAD ST	E BRIDGE ST	0.663	1.290	0.085	0.164
BROAD ST	EAST AVE	0.512	1.213	0.035	0.071
BROAD ST	MIDDLE AVE	0.296	0.591	0.089	0.198
EAST AVE	2ND ST	0.332	0.828	0.029	0.053
LORAIN BLVD	LAKE AVE	0.146	0.434	0.026	0.032
LORAIN BLVD	SR 57	7.620	13.272	0.113	0.452

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
LOWELL ST	LORAIN BLVD	0.011	0.013	0.021	0.021
LOWELL ST	W RIVER RD	0.006	0.008	0.035	0.077
MIDDLE AVE	2ND ST	0.187	0.504	0.023	0.036
N GATEWAY BLVD	LAKE AVE	0.139	0.415	0.025	0.031
SR 113	LAKE AVE	0.652	1.238	0.077	0.155
SR 57	CLEVELAND ST	3.230	6.282	0.082	0.258
SR 57	SR 301 (ABBE RD N)	1.068	2.246	0.107	0.217
W RIVER RD	LAKE AVE	0.099	0.309	0.022	0.024
W RIVER RD	N GATEWAY BLVD	0.113	0.314	0.017	0.024
W RIVER RD	S GATEWAY BLVD	0.195	0.285	0.032	0.066

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
2ND ST	0.26	0.003	0.001
BROAD ST	0.56	0.008	0.006
BROAD ST	0.29	0.003	0.002
CEDAR ST	0.08	0.001	0.000
CLEVELAND ST	0.99	0.025	0.006
E BRIDGE ST	0.48	0.013	0.003
EAST AVE	1.15	0.011	0.008
LAKE AVE	0.56	0.039	0.009
LAKE AVE	1.02	0.025	0.006
LORAIN BLVD	0.78	0.043	0.011
LOWELL ST	0.15	0.000	0.000
MIDDLE AVE	1.16	0.010	0.008
N GATEWAY BLVD	0.39	0.009	0.005
OBERLIN RD	0.64	0.019	0.004
S GATEWAY BLVD	0.83	0.003	0.002
SR 113	1.08	0.042	0.011

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 301 (ABBE RD N)	1.62	0.061	0.013
SR 301 (ABBE RD N)	0.46	0.021	0.005
SR 57	2.71	0.170	0.045
SR 57	1.69	0.481	0.127
SR 57	0.31	0.021	0.005
US 20 (CENTER RIDGE RD)	0.43	0.022	0.005
W RIDGE RD	0.84	0.002	0.001
W RIDGE RD	0.30	0.002	0.001
W RIVER RD	1.19	0.006	0.005
W RIVER RD	0.59	0.005	0.004

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
BROAD ST	CEDAR ST	0.017	0.042
BROAD ST	E BRIDGE ST	0.009	0.024
BROAD ST	EAST AVE	0.018	0.027
BROAD ST	MIDDLE AVE	0.025	0.019
EAST AVE	2ND ST	0.018	0.019
LORAIN BLVD	LAKE AVE	0.040	0.010
LORAIN BLVD	SR 57	0.030	0.322
LOWELL ST	LORAIN BLVD	0.020	0.001
LOWELL ST	W RIVER RD	0.003	0.002
MIDDLE AVE	2ND ST	0.018	0.011
N GATEWAY BLVD	LAKE AVE	0.041	0.009
SR 113	LAKE AVE	0.008	0.023
SR 57	CLEVELAND ST	0.028	0.148
SR 57	SR 301 (ABBE RD N)	0.009	0.040

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
W RIVER RD	LAKE AVE	0.043	0.007
W RIVER RD	N GATEWAY BLVD	0.013	0.007
W RIVER RD	S GATEWAY BLVD	0.008	0.006

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.

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

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_{dwj})					
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)








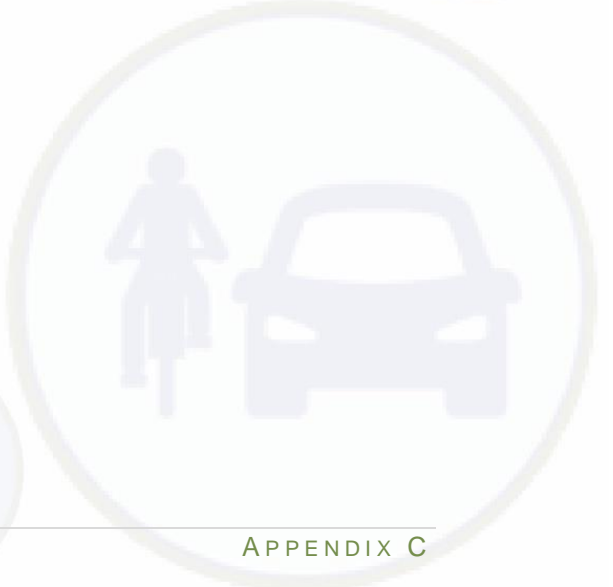
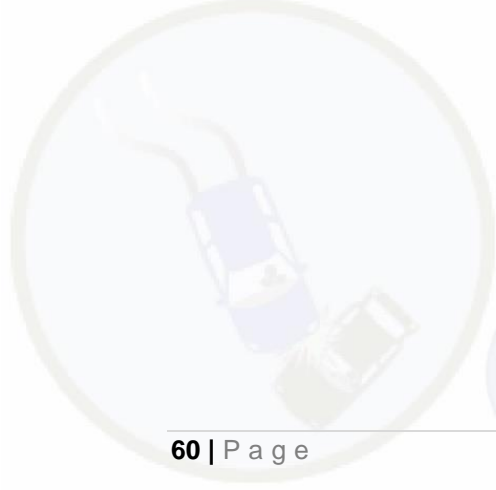
SAFETY COUNTERMEASURE		DESCRIPTION	CRASH REDUCTION RATE
	Pedestrian Hybrid Beacons	Pedestrian hybrid beacons are devices that remain "dark" until a pedestrian pushes the call button to activate the beacon. This initiates a yellow to red flashing light sequence, which directs motorists to slow and come 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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