Updates to Risk Factors for SHSP Emphasis Areas

Pedestrian Crashes

PREPARED FOR

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PREPARED BY

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Purpose & Background

The Massachusetts Department of Transportation (MassDOT) is updating the risk-based network screening maps in the IMPACT tool to incorporate recent crash data and build on lessons learned from previous analyses. This document describes the updated systemic analysis performed by VHB for pedestrian crashes using crash data from 2017 through 2021. For this analysis, VHB used the default "Pedestrian" query[1] in the MassDOT IMPACT tool. The definition reads as: any crash involving "Non-motorist" in the "Person Type" field and a "pedestrian" in the "Non-Motorist Type" field.[2]

Note that the purpose of this report is to identify the factors most correlated with the frequency and severity of pedestrian involved crashes; causality was not directly investigated. As such, agencies interested in developing targeted countermeasure programs are encouraged to perform some initial investigation into causality of the target crash in their jurisdiction. This will allow the agency to develop targeted countermeasures.

Data Analysis and Focus Crash Types

To establish context, VHB first used the MassDOT IMPACT "Test of Proportions" tool[3] to summarize fatal injury (K) and suspected serious injury (A) of pedestrian crashes. To identify overrepresented crash attributes, VHB compared KA pedestrian crashes to all KA crashes in the State. Where the proportion for a given attribute is statistically larger than the proportion for the comparison group, that attribute is flagged as a potential risk factor. Statistical overrepresentation is checked by building 95 percent confidence intervals around the proportion using sampling errors. Figure 1 and Figure 2 show how the lower and upper bounds, respectively, are calculated based on the proportion of crashes (*p*) and the number of crashes in the sample (*N*). If the lower bound of pedestrian KA crashes is larger than the upper bound of the comparison group, the attribute was considered "overrepresented" for the data.

$$95\%\ Confidence\ Interval, Lower\ Bound\ =\ p - 1.96 * \sqrt{\frac{p(1-p)}{N}}$$

Figure 1. Calculation of the lower bound of the 95 percent confidence interval for the proportion of crashes with an attribute.

$$95\%\ Confidence\ Interval, Upper\ Bound\ =\ p + 1.96 * \sqrt{\frac{p(1-p)}{N}}$$

Figure 2. Calculation of the upper bound of the 95 percent confidence interval for the proportion of crashes with an attribute.

Table 1 summarizes notable overrepresentations found in the analysis. VHB included the following data elements in their analysis:

- Access Control.

[1] https://www.mass.gov/info-details/impact-emphasis-area-definitions
[2] MassDOT. *Impact Emphasis Area Definitions.* Available at: https://www.mass.gov/info-details/impact-emphasis-area-definitions. Accessed May, 2023.
[3] https://apps.impact.dot.state.ma.us/sat/TestofProportions

- Age of Driver – Oldest Known.
- Age of Driver – Youngest Known.
- Age of Non-Motorist – Oldest Known.
- Age of Non-Motorist – Youngest Known.
- Average Annual Daily Traffic.
- City/Town Name.
- County Name.
- Crash Day of Week.
- Crash Hour of Day.
- Crash Month.
- Crash Severity.
- Crash Status.
- Crash Year.
- Curb.
- Driver Contributing Circumstances.
- Driver Distracted By.
- Facility Type.
- Federal Functional Class.
- First Harmful Event.
- First Harmful Event Location.
- FMCSA Reportable.
- Functional Class.
- Geocoding Method.
- Hit and Run.
- Jurisdiction.
- Left Shoulder Type-linked.
- Left Shoulder Width-linked.
- Left Sidewalk Width-linked.
- Light Conditions.
- Locality.
- Manner of Collision.
- MassDOT District.

- Max Injury Severity Reported.
- Median Type.
- Median Width.
- Most Harmful Event.
- Non-Motorist Action.
- Non-Motorist Location.
- Non-Motorist Type.
- Number of Peak Hour Lanes.
- Number of Travel Lanes.
- Number of Vehicles.
- Operation.
- Opposite Number of Travel Lanes.
- Police Agency Type.
- Right Shoulder Type-linked.
- Right Shoulder Width-linked.
- Right Sidewalk Width-linked.
- Road Contributing Circumstances.
- Road Surface Condition.
- Roadway Junction Type.
- RPA Abbreviation.
- School Bus Related.
- Speed Limit.
- State Police Troops.
- Structural Conditions.
- Surface Type.
- Surface Width-linked.
- Terrain Type.
- Total Fatalities.
- Total Lanes.
- Total of Non-Fatal Injuries.
- Traffic Control Device Function.
- Traffic Control Device Type.

- Trafficway Description.
- Truck Route.
- Urban Area.
- Urban Location Type.
- Urban Type.
- Vehicle Actions Prior to Crash.
- Vehicle Configuration.
- Vehicle Emergency Use.
- Vehicle Sequence of Events.
- Vehicle Towed from Scene.
- Vehicle Travel Direction.
- Weather Conditions.
- Work Zone Related.

Table 1. Summary of Key Overrepresentation Findings.

Crash Field	Crash Attribute	Percent of Pedestrian KA Crashes	Percent of All KA Crashes
Access Control	No access control	89.2%	79.2%
Age of Driver – Youngest Known (crash level)	45-54	14.9%	12.5%
	55-64	13.7%	8.5%
	65-74	9.5%	4.5%
	75-84	5.1%	2.2%
Crash Hour of Day	5:00-5:59 PM	10.4%	7.2%
	6:00-6:59 PM	9.0%	6.5%
	7:00-7:59 PM	7.0%	5.3%
	8:00-8:59 PM	7.5%	5.1%
Crash Month	January	9.3%	7.0%
	February	8.8%	6.1%
	November	10.8%	8.4%
	December	11.4%	8.0%
Light Conditions	Dark- lighted roadway	36.7%	26.4%
Weather Conditions	Rain	12.5%	9.4%
Urban Type	Large Urbanized Area	88.1%	85.1%
Operation	One-way Traffic	7.4%	5.4%
Speed Limit	20	3.1%	1.4%
	25	7.2%	4.6%
	30	23.4%	16.8%
Curb	Both sides	69.4%	44.2%
Median Type	Raised median	4.2%	2.8%

Crash Field	Crash Attribute	Percent of Pedestrian KA Crashes	Percent of All KA Crashes
Functional Class	Rural minor arterial or urban principal	29.9%	22.6%
Left Shoulder Type-linked	No Shoulder	69.9%	64.2%
Right Shoulder Type-linked	No Shoulder	69.0%	49.6%
Driver Contributing Circumstances	Glare	3.1%	0.7%
	Inattention	10.6%	6.0%
	Other Improper Action	5.1%	3.0%
	Visibility Obstructed	3.2%	0.7%
Hit and Run	Yes, hit and run	6.8%	3.0%
Roadway Junction Type	Driveway	3.1%	1.9%
	T-Intersection	18.4%	15.7%
Traffic Control Device Type	Traffic control signal	17.3%	13.3%
	Warning Signs	1.8%	0.9%

From a safety management perspective, it is notable that there was an overrepresentation of pedestrian crashes in large, urbanized areas, likely due to the higher number of pedestrians present. A higher proportion of KA pedestrian crashes was also observed on roadways with no access control, roadways that have lower speed limits (20 – 30 mph), roadways with no shoulder, and roadways classified as rural minor arterials or urban principal arterials. Additionally, a higher proportion of KA crashes were observed at driveways and T-intersections, particularly, at the intersections with warning signs or traffic control signals. These crashes were more prevalent among older drivers and were more likely to occur during dark hours and under wet weather conditions.

MassDOT should consider these findings when identifying potential countermeasures for increasing pedestrian safety. The National Highway Traffic Safety Administration's (NHTSA) *Countermeasures that Work*[4] includes several countermeasures targeting pedestrian safety including Safe Routes to School (SRTS) program, pedestrian safety zones, reducing and enforcing speed limits, and conspicuity enhancement. While these are notable results, they should not restrict the analysis from focusing on all pedestrian crashes. Ultimately, the focus crash type for this analysis is all pedestrian crashes.

[4] https://www.nhtsa.gov/book/countermeasures/countermeasures-work/pedestrian-safety

Crash Tree and Focus Facility Type

After concluding that the pedestrian focus crash type should include all pedestrian crashes, VHB developed crash trees to identify focus facility types and gain insight into pedestrians involved in severe collisions. Figure 3 shows the crash tree. As expected, most of the severe pedestrian crashes occur on roads with no access control. Of those, more than half occur on roadway segments – primarily on principal arterials, minor arterials, and major collectors. Additionally, nearly 38 percent of those occur at traditional roadway intersections. Of those, more than half are at stop-controlled or uncontrolled intersections and approximately 39 percent are at signalized intersections.

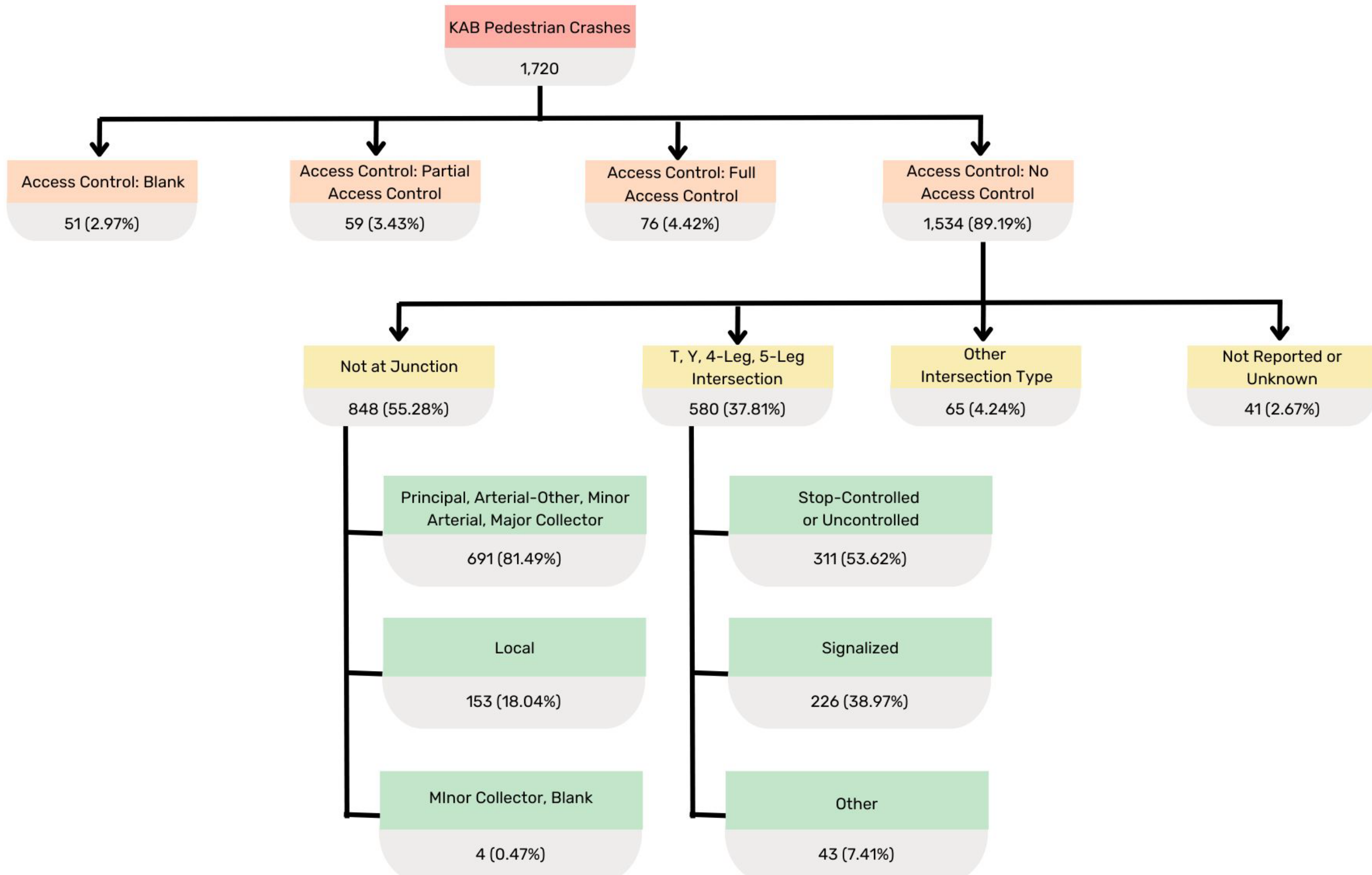

Figure 3. Crash tree summarizing KA Pedestrian crashes in Massachusetts.

Based on the crash tree in Figure 3, VHB recommends the following focus facility types:

- Pedestrian KA crashes at Principal Arterials
- Pedestrian KA crashes at Minor Arterials
- Pedestrian KA crashes at Major Collectors
- Pedestrian KA crashes at all intersections (except roundabouts, other circular intersections, and non-conventional intersections)

Risk Factor Analysis

After identifying focus crash types and trends, VHB proceeded with the risk factor analysis. The following sections describe the methodology, data, and results of this analysis.

Methodology

Due to the binary nature of the crash severity outcome of interest, the project team used binary logistic regression. This probabilistic modeling technique assesses the probability that an event has occurred (i.e., a KA pedestrian crash) on a given segment or intersection based on the model inputs. Agresti (2007) provides more background information on this method.[5] When modeling, VHB began with road exposure variables and added additional variables one at a time, monitoring the coefficients to ensure the inclusion of a variable did not result in large changes in magnitude. Additionally, VHB included variables with p-values upwards of 0.25 assuming the magnitude of the results made sense. VHB did not select a strict level of significance, as Hauer notes this could lead to misunderstanding or outright disregard for potentially noteworthy results.[6] The model estimates coefficients for each independent variable which are used to calculate Odds Ratios. An Odds Ratio greater than 1.0 indicates a positive correlation between the variable and the probability of a crash; an Odds Ratio less than 1.0 indicates a negative correlation between the variable and the probability of a crash.

Data

VHB used ArcGIS to manage and integrate data for this analysis. VHB aggregated data at the segment and intersection level. Due to limitations with crash data acquisition, VHB excluded the City of Boston from the analysis. MassDOT provided VHB with various sources of data, as described in the following sections.

Crash Data

VHB obtained road segment and intersection data from MassDOT and identified the segments and intersections which fit into the focus facility characteristics. If one or more KA pedestrian crash occurred on a given segment (e.g., within 100 feet as calculated in GIS) or an intersection (e.g., within 125 feet radius) at any time between 2017 and 2021, VHB assigned that segment or intersection with a “1”; those segments or intersections without an observed crash received a value of “0.”

[5] Agresti, A. (2007). An Introduction to Categorical Data Analysis. Second Edition. John Wiley & Sons, Inc., New York.
[6] Hauer, E. (2004). The harm done by tests of significance. *Accident Analysis & Prevention*, *36*(3), 495-500.

Roadway Data

VHB downloaded the Massachusetts statewide Road Inventory 2021 file, available at https://geo-massdot.opendata.arcgis.com/datasets/342e8400ba3340c1bf5bf2b429ad8294/about. Based on discussions with MassDOT, VHB filtered the roadway data in ArcGIS using mileage counted (equal to 1), jurisdiction (not equal to null), and facility type (less than 7) to identify unique segments that were counted for the Highway Performance Monitoring System (HPMS). Filtering the roadway inventory in this way prevented potential double-counting of mileage and VMT for divided roads and roads with overlapping route numbers. MassDOT provided VHB with updated traffic volume data, which VHB integrated using GIS. Finally, somewhat simplified the roadway data by dissolving on common roadway characteristics, including route and street name, town, surface width, shoulder width and type, presence of curbing, traffic volume, etc.

Intersection Data

VHB received the Massachusetts statewide intersection data from a working version of the intersection inventory managed by MassDOT. Based on discussion with MassDOT, VHB filtered out roundabouts, any other circular intersections, or non-conventional intersections from the modeling database. Finally, the modeling dataset included all signalized intersections, stop-controlled (two-way and all-way), yield controlled, and uncontrolled intersections.

School Location Data

VHB obtained primary and secondary school location data from the Massachusetts Bureau of Geographic Information (MassGIS) open data portal (https://www.mass.gov/info-details/massgis-data-massachusetts-schools-pre-k-through-high-school). VHB identified if any schools were present within a half mile of each segment.

College and University Data

VHB accessed college and university location data from the MassGIS open data portal (https://www.mass.gov/info-details/massgis-data-colleges-and-universities). Although these data contain several categories of trade schools and other atypical technical training institutions, VHB only included "Colleges, universities, and professional schools," "Fine arts schools," "Junior colleges," and "Other technical and trade schools" for the purposes of this analysis. VHB identified if any schools were present within a half mile geographical boundary of each segment and a quarter mile radius of each intersection

Land Use Data

The proximity of origins and destinations that encourage pedestrian travel can be obtained from a dense mix of different land uses. VHB employed an approximation of land-use mix described by Frank, Andersen, and Schmid (2004) using the intersection-level land use data provided by MassDOT[7].

$$Land\ Use\ Mix = -\sum_{i=1}^{n} \rho_i \frac{\ln \rho_i}{\ln n}$$

Figure 4: Calculation of Land-use mix from Frank, Andresen, and Schmid (2004).

[7] Frank, L.D., Andresen, M.A. and Schmid, T.L., (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American journal of preventive medicine*, *27*(2), pp.87-96.

Where:

ρ_i = proportion of estimated area attributed to land use i.

n = number of land uses within quarter mile radius of an intersection.

This metric assesses the distribution of four land-use types—residential, commercial, industrial, and institutional—within a quarter mile radius of an intersection. A totally uniform land use within the quarter mile buffer would produce a value of "0," whereas a completely even distribution of all four land uses would produce a value of "1."

Additional Data

VHB obtained several additional data sources for integration into the data set, including census and American Community Survey (ACS) data, public health data from the Massachusetts Department of Public Health (DPH), environmental justice (EJ) data provided by Environmental Justice Community Block Group Data Update, EJScreen data, disadvantaged community data from the USDOT, climate and economic justice data from U.S. Climate Resilience Toolkit, social vulnerability data from Centers for Disease Control and Prevention (CDC), and land cover data provided by MassDOT. Note that, regarding EJ data, the reports may change if the final layers were used but they were not available at the time the analyses were performed. The version of Massachusetts 2020 Environmental Justice Block Group data available at the time of the analysis was a preliminary version that was later updated with a final.

Results

The following sections describe the results of the binary logistic regression modeling effort. To account for unobserved influences on the segments due to road facilities and traffic exposure, VHB established a base model that included the natural log of the length of the segment. Before including additional variables in the binary logistic, VHB developed a correlation matrix of input variables. Highly correlated variables are indicators of potential complications in the model development process. The following sections include correlation matrices for each model.

Pedestrian KA Crashes at Principal Arterials

The binary logistic regression model for pedestrian KA crashes at principal arterials is summarized in Table 2. As expected, crash probability increases with increased exposure, as shown by the odds ratios for the natural log of segment length.

The model shows odds ratios greater than one for segments with AADTs or 8,000 or more veh/day, curb on both sides, and three of more total lanes, indicating wider, busier roads are at an elevated risk for severe pedestrian crashes. Dense, more urban segments are correlated with a higher risk for pedestrians, as illustrated by the odds ratios greater than one for walking potential of "Medium" or "High", the presence of a college within a half mile, transit presence within a quarter mile, total block group population over 3000 people, and proximity to commercial, mixed-use commercial, mixed use residential, and multifamily residential zoning within 100 feet. Bike trails within a half mile are correlated with less risk of a severe pedestrian crash, likely indicating more pedestrian infrastructure options for pedestrians. Disadvantaged community traits, like the presence of one Environmental Justice (EJ) flag or more and higher percentiles of low life expectancy were correlated with higher risk of severe pedestrian crashes.

Table 2. Binary Logistic Regression Model Results- Pedestrian KA Crashes on Principal Arterials.

Variable (Number)	Odds Ratio	Standard Error	z-value	P>|z|	95% Confidence Interval	
Curb is on both sides (1)	1.46	0.24	2.29	0.02	1.06	2.02
Natural Log of the length of the segment (2)	1.91	0.15	8.28	0.00	1.64	2.22
AADT over 8,000 veh/day (3)	3.07	0.89	3.89	0.00	1.74	5.41
Three or more total lanes on the segment (4)	1.46	0.19	2.90	<0.01	1.13	1.89
Walking potential is "Medium" or "High" (5)	2.29	0.67	2.82	0.01	1.29	4.07
Bike trails present within a half mile (6)	0.78	0.11	-1.80	0.07	0.59	1.02
Colleges present within a half mile (7)	1.49	0.21	2.80	0.01	1.13	1.97
Transit present within a quarter mile (8)	1.45	0.19	2.86	<0.01	1.13	1.88
Segment within 100 ft of area zoned as "Commercial" (9)	2.57	0.40	6.12	0.00	1.90	3.48
Segment within 100 ft of area zoned as "Mixed Use Commercial" (10)	2.01	0.62	2.26	0.02	1.10	3.67
Segment within 100 ft of area zoned as "Mixed Use Residential" (11)	1.48	0.20	2.87	<0.01	1.13	1.94
Segment within 100 ft of area zoned as "Residential Multifamily" (12)	1.49	0.18	3.26	<0.01	1.17	1.89
Total population of the Block Groups is over 3000 people (13)	2.25	0.71	2.57	0.01	1.21	4.17
One or more EJ flags are present (14)	1.30	0.18	1.91	0.06	0.99	1.70
Percentile of low life expectancy for the census tract the segment is in (15)	1.95	0.48	2.72	0.01	1.20	3.14
Constant (16)	0.00133	0.00055	-16.09	0.00	0.00059	0.00298

Note: Number of observations = 43,043; Log likelihood = -1659.5094; Pseudo R2 = 0.0874; LR chi2(15) = 317.98; Prob > chi2 = 0.0000.

Table 3 presents a correlation matrix identifying correlation between any two variables. There is no significant correlation between any of the variables. The highest correlation was between variables 13 (total population of the Block Groups is over 3000 people) and 14 (one or more EJ flags are present); however, model results were stable when included, so VHB elected to keep both variables in the model.

Table 3. Correlation Matrix for Binary Logistic Regression Model of Pedestrian KA crashes at Principal Arterials.

Variable No	1	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000												
3	0.194	1.000											
4	0.182	0.160	1.000										
5	0.369	0.146	0.106	1.000									
6	0.134	0.051	0.035	0.103	1.000								
7	0.206	0.065	0.078	0.144	0.069	1.000							
8	0.318	0.164	0.074	0.176	0.234	0.153	1.000						
9	0.205	0.145	0.112	0.254	0.064	0.076	0.096	1.000					
10	0.009	-0.010	0.031	-0.003	-0.011	0.026	-0.030	0.034	1.000				
11	0.061	0.003	-0.049	0.040	0.026	0.048	0.066	0.108	0.055	1.000			
12	-0.059	-0.044	-0.026	-0.076	-0.037	-0.010	-0.038	-0.051	0.000	-0.003	1.000		
13	0.322	0.089	0.128	0.268	0.080	0.225	0.178	0.192	0.028	0.101	-0.055	1.000	
14	0.220	0.038	0.070	0.271	-0.105	0.136	-0.060	0.195	0.019	0.075	-0.081	0.386	1.000

Pedestrian KA Crashes at Minor Arterials

The binary logistic regression model for pedestrian KA crashes at minor arterials is summarized in Table 4. As expected, crash probability increases with increased exposure, as shown by the odds ratios for the natural log of segment length.

The model shows odds ratios greater than one for wide and busy segments, specifically those with AADTs or 10,000 or more veh/day, curb on both sides, curbed median, two-way traffic operation, and more than ten feet of sidewalk are at an elevated risk for severe pedestrian crashes. Dense, more urban segments are correlated with more risk, as illustrated by the odds ratios greater than one for walking potential of "High", transit presence within a quarter mile, and proximity to commercial, mixed use residential, and multifamily residential zoning within 100 feet. Disadvantaged community traits, like 25% or more of the households in the block group the segment is being Limited English households, median household income in the block group the segment is in being under $100,000, and a higher percentage of Black or African American population are correlated with higher risk of severe pedestrian crashes. Proximity to open land zoning within 100 feet is also correlated with higher risk.

Table 4. Binary Logistic Regression Model Results- Pedestrian KA Crashes on Minor Arterials.

Variable (Number)	Odds Ratio	Standard Error	z-value	P>|z|	95% Confidence Interval	
Natural log of the length of the segment (1)	1.61	0.12	6.39	0.00	1.39	1.86
Median is curbed (2)	2.04	0.51	2.87	<0.01	1.25	3.32
Curbs is on both sides (3)	1.31	0.20	1.79	0.07	0.97	1.76
Traffic is Two way on the segment (4)	2.61	0.90	2.79	0.01	1.33	5.11
AADT is over 10,000 veh/day (5)	1.44	0.17	3.10	<0.01	1.14	1.82
Sidewalk is over 10 feet wide (6)	1.42	0.21	2.32	0.02	1.06	1.90
Walking potential is "High" (7)	1.79	0.25	4.09	0.00	1.35	2.36
Transit is present within a quarter mile (8)	2.13	0.28	5.73	0.00	1.64	2.76
Median Household income in the Block Group is under $100,000 (9)	1.57	0.24	2.95	<0.01	1.16	2.13
25% or more of the households in the block group the segment is in are Limited English households (10)	1.55	0.29	2.37	0.02	1.08	2.24
Segment is within 100 ft of area zoned as "Commercial" (11)	2.03	0.26	5.50	0.00	1.58	2.61
Segment is within 100 ft of area zoned as "Mixed Use Residential" (12)	1.63	0.23	3.56	0.00	1.25	2.14
Segment is within 100 ft of area zoned as "Open Land" (13)	1.48	0.17	3.41	<0.01	1.18	1.85
Segment is within 100 ft of area zoned as "Residential Multifamily" (14)	1.31	0.16	2.22	0.03	1.03	1.66
Percentage of Black or African American residents in the census tract the segment is in (15)	6.16	3.21	3.48	0.00	2.21	17.11
Constant (16)	0.00084	0.00036	-16.67	0.00	0.00037	0.00193

Note: Number of observations = 86,634; Log likelihood = -1935.0833; Pseudo R2 = 0.0933; LR chi2(15) = 398.10; Prob > chi2 = 0.0000.

Table 5 is a correlation matrix identifying correlation between any two variables. There is no significant correlation between any of the variables. The highest correlation was between variables 3 (curbs is on both sides) and 6 (sidewalk is over 10 feet wide); however, model results were stable when included, so VHB elected to keep both variables in the model.

Table 5. Correlation Matrix for Binary Logistic Regression Model of Pedestrian KA crashes at Principal Arterials.

Variable No	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	1.000													
3	0.090	1.000												
4	-0.021	-0.078	1.000											
5	0.097	0.188	-0.002	1.000										
6	-0.047	0.459	-0.074	0.082	1.000									
7	0.056	0.310	-0.146	0.041	0.337	1.000								
8	0.052	0.303	-0.066	0.144	0.305	0.016	1.000							
9	0.027	0.163	-0.037	-0.045	0.152	0.233	-0.025	1.000						
10	0.007	0.179	-0.091	0.018	0.257	0.246	0.103	0.122	1.000					
11	0.081	0.252	-0.094	0.120	0.215	0.261	0.140	0.174	0.132	1.000				
12	-0.010	0.101	0.031	-0.008	0.139	0.128	0.041	0.074	0.086	0.142	1.000			
13	-0.013	-0.084	0.025	-0.035	-0.050	-0.001	-0.077	0.032	0.010	0.040	0.007	1.000		
14	-0.042	0.212	0.012	0.028	0.212	0.123	0.142	0.135	0.064	0.093	0.110	-0.020	1.000	
15	0.028	0.211	-0.047	0.100	0.232	0.292	0.140	0.176	0.185	0.116	0.037	-0.010	0.097	1.000

Pedestrian KA Crashes at Major Collectors

The binary logistic regression model for pedestrian KA crashes at major collectors is summarized in Table 6. As expected, crash probability increases with increased exposure, as shown by the odds ratios for the natural log of segment length.

The model shows odds ratios greater than one for busy segments, specifically those with AADTs or 3,000 or more veh/day, speed limit over 25 mph, and more than five feet of sidewalk are at an elevated risk for severe pedestrian crashes. More suburban area segments are correlated with more risk, as illustrated by the odds ratios greater than one for segments with alcohol sold within a quarter mile, less than 25 transit stops within a square mile, a traffic proximity over 300 as calculated in the EJScreen analysis within a square mile of the segment, and proximity to commercial, recreation, open land, and other residential zoning within 100 feet. The percentile of linguistic isolation in the block group, an indicator of a disadvantaged community, is correlated with a higher risk of severe pedestrian crashes.

Table 6. Binary Logistic Regression Model Results- Pedestrian KA Crashes on Major Collectors.

Variable (Number)	Odds Ratio	Standard Error	z-value	P>|z|	95% Confidence Interval	
The Natural Log of the length of the segment (1)	1.73	0.23	4.17	0.00	1.34	2.24
Speed Limit over 25 mph (2)	2.36	1.09	1.86	0.06	0.95	5.83
AADT over 3000 veh/day (3)	2.21	0.61	2.85	<0.01	1.28	3.80
Sidewalk is over 5 feet wide (4)	2.88	0.74	4.14	0.00	1.75	4.75
Alcohol is sold within a quarter mile (5)	1.71	0.42	2.19	0.03	1.06	2.77
Less than 25 transit stops per square mi in the block group the segment is in (6)	1.83	0.66	1.68	0.09	0.90	3.70
Percentage of population that is linguistically isolated (7)	3.75	3.51	1.41	0.16	0.60	23.54
Traffic Proximity is over 300 as calculated in the EJScreen analysis (8)	1.37	0.35	1.22	0.22	0.82	2.28
Segment is within 100 ft of area zoned as "Commercial" (9)	1.91	0.42	2.98	<0.01	1.25	2.93
Segment is within 100 ft of area zoned as "Recreation" (10)	3.31	2.03	1.96	0.05	1.00	10.99
Segment is within 100 ft of area zoned as "Open Land" (11)	1.36	0.27	1.54	0.12	0.92	2.02
Segment is within 100 ft of area zoned as "Residential Other" (12)	3.27	1.96	1.98	0.05	1.01	10.56
Constant (13)	0.00023	0.00017	-11.39	0.00	0.00006	0.00098

Note: Number of observations = 66,858; Log likelihood = -736.80655; Pseudo R2 = 0.0740; LR chi2(12) = 117.84; Prob > chi2 = 0.0000.

Table 7 is a correlation matrix identifying correlation between any two variables. There is no significant correlation between any of the variables. The highest correlation was between variables 4 (sidewalk is over 5 feet wide) and 5 (alcohol is sold within a quarter mile); however, model results were stable when included, so VHB elected to keep both variables in the model.

Table 7. Correlation Matrix for Binary Logistic Regression Model of Pedestrian KA crashes at Major Collectors.

Variable No	2	3	4	5	6	7	8	9	10	11	12
2	1.000										
3	-0.008	1.000									
4	-0.031	0.266	1.000								
5	-0.045	0.157	0.401	1.000							
6	-0.042	-0.161	-0.331	-0.201	1.000						
7	-0.047	0.176	0.375	0.277	-0.176	1.000					
8	0.004	0.220	0.379	0.293	-0.186	0.271	1.000				
9	-0.038	0.092	0.202	0.380	-0.075	0.188	0.169	1.000			
10	0.014	-0.057	-0.067	-0.033	0.029	-0.039	-0.072	-0.033	1.000		
11	0.000	-0.078	-0.130	-0.039	0.081	-0.009	-0.094	0.060	0.027	1.000	
12	0.017	-0.028	-0.043	-0.037	0.017	-0.026	-0.054	0.001	0.017	0.014	1.000

Pedestrian KA Crashes at Intersections

The binary logistic regression model for pedestrian KA crashes at intersections is summarized in Table 8. The model shows that odds ratios are greater than one for busy intersections, and the odds ratios get higher with higher ranges of traffic volume on the major or minor approaches. Additionally, four legged intersections, signalized intersections, or intersections with three or more through lanes on major roads showed an elevated risk for severe pedestrian crashes. Intersections in urban areas are found to be correlated with more risk, as illustrated by the odds ratios greater than one for intersections with alcohol sold or at least one or more transit stops within a quarter mile radius. Towns where the intersections are located meeting three environmental justice criteria also experienced increasingly higher severe pedestrian crashes. Intersections with a higher proportion of impervious land cover demonstrated a higher likelihood of pedestrian crashes. Lastly, severe pedestrian crashes are more likely to occur on intersections with a higher proportion of industrial land use or a higher land-use mix due to the closer proximity of origin and destination.

Table 8: Binary Logistic Regression Model Results- Pedestrian KA Crashes at Intersections.

Variable	Odds Ratio	Standard Error	z-value	P>|z|	95% Confidence Interval	
Major AADT between 3,000 and 5,999 Vehicles per Day (1)	1.864	0.486	2.390	0.017	1.118	3.106
Major AADT between 6,000 and 11,999 Vehicles per Day (2)	3.509	0.875	5.030	0.000	2.152	5.721
Major AADT 12,000 and above Vehicles per Day (3)	5.739	1.427	7.030	0.000	3.525	9.341
Minor AADT 1,000 and above Vehicles per Day (4)	1.598	0.243	3.080	0.002	1.185	2.153
3 or more through lanes on major road (5)	1.544	0.173	3.880	0.000	1.240	1.923
All three EJ criteria are present (6)	1.579	0.156	4.630	0.000	1.301	1.916
Indicator of at least one or more alcohol shops within 0.25 mi (7)	1.504	0.175	3.510	0.000	1.197	1.888
Indicator of at least one or more transit stops within 0.25 mi (8)	1.168	0.106	1.710	0.087	0.978	1.394
Indicator of 4-leg intersection (9)	1.437	0.132	3.950	0.000	1.200	1.720
Indicator of signalized intersection (10)	1.526	0.173	3.740	0.000	1.223	1.905
Indicator of urban area (11)	3.702	3.735	1.300	0.195	0.512	26.747
Proportion of impervious land (12)	6.088	1.584	6.940	0.000	3.656	10.137
Land use mix (13)	2.339	0.678	2.930	0.003	1.325	4.127
Proportion of institutional land use (14)	2.031	0.832	1.730	0.084	0.910	4.533
Constant (15)	0.000	0.000	-9.130	0.000	0.000	0.001

Note: Number of observations = 50,720; Log likelihood = -3025.2613; Pseudo R2 = 0.1345; LR chi2(14) = 940.07; Prob > chi2 = 0.0000.

Table 9 is a correlation matrix identifying correlation between any two variables. The highest correlation was between variable 12 (proportion of impervious land) with both 6 (All three EJ criteria are present) and 7 (indicator of at least one or more alcohol shops within 0.25 mi); however, model results were stable when included, so VHB elected to keep both variables in the model.

Table 9: Correlation Matrix for Binary Logistic Regression Model of Pedestrian KA crashes at intersections.

Variable No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1													
2	-0.417	1												
3	-0.343	-0.343	1											
4	0.126	0.026	0.062	1										
5	-0.143	-0.047	0.318	-0.005	1									
6	0.016	0.013	0.118	0.013	0.101	1								
7	-0.059	0.030	0.187	0.082	0.131	0.301	1							
8	-0.009	0.008	0.155	0.219	0.072	0.260	0.296	1						
9	-0.008	0.009	0.066	0.065	0.085	0.125	0.122	0.084	1					
10	-0.127	0.009	0.247	0.079	0.356	0.108	0.155	0.106	0.321	1				
11	0.078	0.109	0.106	0.319	0.054	0.144	0.161	0.120	0.039	0.059	1			
12	0.011	0.047	0.174	0.126	0.129	0.578	0.578	0.467	0.162	0.158	0.288	1		
13	-0.063	0.044	0.135	0.016	0.109	0.089	0.220	0.069	0.019	0.108	0.094	0.191	1	
14	-0.032	0.033	0.052	-0.010	0.032	0.070	0.054	0.055	0.004	0.065	0.008	0.054	0.509	1

Conclusions and Recommendations

The purpose of this analysis is to identify segment-level risk factors for fatal and serious injury pedestrian crashes. Instead of using the coefficients in the binary logistic regressions results from, VHB recommends that MassDOT assign risk scores between 0 and 1 based on the character of the risk factor. VHB and MassDOT made this decision to avoid overly weighting any one risk factor, especially considering potential data issues with the risk factor data which may cause biases. Table 10 to Table 13 summarize the suggested risk scoring schema for pedestrian KA crashes on principal arterials, minor arterials, major collectors, and intersections, respectively.

Table 10. Segment-level risk factors for Pedestrian KA Crashes on Principal Arterials.

Risk Factor for Pedestrian KA Crashes	Suggested Scoring
Curb is on both sides	1 if true; 0 otherwise.
Natural Log of the length of the segment	No score
AADT over 8,000 veh/day	1 if true; 0 otherwise.
There are 3 or more total lanes on the segment	1 if true; 0 otherwise.
Walking potential is “Medium” or “High”	1 if true; 0 otherwise.
Bike trails are present within a half mile	0 if true; 1 otherwise.
Colleges are present within a half mile	1 if true; 0 otherwise.
Transit is present within a quarter mile	1 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Commercial”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Mixed Use Commercial”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Mixed Use Residential”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Residential Multifamily”	0.25 if true; 0 otherwise.
Total population of the Block Groups is over 3000 people	1 if true; 0 otherwise.
One or more EJ flags are present	1 if true; 0 otherwise.
Percentile of low life expectancy for the census tract the segment is in	Continuous from 0 to 1 for range of values
Maximum potential score for a town:	**11.00**

Table 11. Segment-level risk factors for Pedestrian KA Crashes on Minor Arterials.

Risk Factor for Pedestrian KA Crashes	Suggested Scoring
Natural log of the length of the segment	No score
Median is curbed	1 if true; 0 otherwise.
Curbs is on both sides	1 if true; 0 otherwise.
Traffic is Two way on the segment	1 if true; 0 otherwise.
AADT is over 10,000 veh/day	1 if true; 0 otherwise.
Sidewalk is over 10 feet wide	1 if true; 0 otherwise.
Walking potential is "High"	1 if true; 0 otherwise.
Transit is present within a quarter mile	1 if true; 0 otherwise.
Median Household income in the Block Group is under $100,000	1 if true; 0 otherwise.
25% or more of the households in the block group the segment is in are Limited English households	1 if true; 0 otherwise.
Segment is within 100 ft of area zoned as "Commercial"	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as "Mixed Use Residential"	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as "Open Land"	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as "Residential Multifamily"	0.25 if true; 0 otherwise.
Percentage of Black or African American residents in the census tract the segment is in	Continuous from 0 to 1 for range of values
Maximum potential score for a town:	**11.00**

Table 12. Segment-level risk factors for Pedestrian KA Crashes on Major Collectors.

Risk Factor for Pedestrian KA Crashes	Suggested Scoring
The Natural Log of the length of the segment	No score
Speed Limit over 25 mph	1 if true; 0 otherwise.
AADT over 3000 veh/day	1 if true; 0 otherwise.
Sidewalk is over 5 feet wide	1 if true; 0 otherwise.
Alcohol is sold within a quarter mile	1 if true; 0 otherwise.
Less than 25 transit stops per square mi in the block group the segment is in	1 if true; 0 otherwise.
Percentage of population that is linguistically isolated	Continuous from 0 to 1 for range of values
Traffic Proximity is over 300 as calculated in the EJScreen analysis	1 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Commercial”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Recreation”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Open Land”	0.25 if true; 0 otherwise.
Segment is within 100 ft of area zoned as “Residential Other”	0.25 if true; 0 otherwise.
Maximum potential score for a town:	**8.00**

Table 13: Intersection-level risk factors for Pedestrian KA crashes.

Risk Factor for Pedestrian KA Crashes	Suggested Risk Scoring
Major AADT between 3,000 and 5,999 Vehicles per Day	0.33 if true; else
Major AADT between 6,000 and 11,999 Vehicles per Day	0.66 if true; else
Major AADT 12,000 and above Vehicles per Day	1 if true; 0 otherwise
Minor AADT 1,000 and above Vehicles per Day	1 if true; 0 otherwise
3 or more through lanes on major road	1 if true; 0 otherwise
All three EJ criteria are present	0.33 if 1; 0.66 if 2; 1 if 3; 0 otherwise
Indicator of at least one or more alcohol shops within 0.25mi	1 if true; 0 otherwise
Indicator of at least one or more transit stops within 0.25mi	1 if true; 0 otherwise
Indicator of 4 leg intersection	1 if true; 0 otherwise
Indicator of signalized intersection	1 if true; 0 otherwise
Indicator of urban area	1 if true; 0 otherwise
Proportion of impervious land	Use the proportion (0 to 1)
Land use mix	Use the proportion (0 to 1)
Proportion of institutional land use	Use the proportion (0 to1)
Maximum potential score for an intersection:	**12.00**

Table 14 provides an example application of the risk factors on a hypothetical segment on principal arterials. To balance prioritization across the different risk scoring schemes, VHB recommends normalizing the segment risk scores against the total possible score for each schema – producing a normalized risk score for each segment ranging from 0 to 100. The example segment has a total risk score of 7.99 out of 11, resulting in a normalized risk score of 72.6 percent. Table 15 presents an example application of risk factors at a hypothetical intersection. The example intersection has a total risk score of 9.42 out of 12.0, resulting in a normalized risk score of 78.5 percent.

Table 14. Example Risk Score Calculation for Pedestrian KA Crashes at a Segment.

Variable	**Segment Characteristic**	**Risk Factor**	**Risk Score**
Curb is on both sides	True	1 if true; 0 otherwise.	0
AADT over 8,000 veh/day	AADT is 9,000 veh/day	1 if true; 0 otherwise.	1
There are 3 or more total lanes on the segment	Segment has 4 lanes	1 if true; 0 otherwise.	1
Walking potential is "Medium" or "High"	Walking potential is "Low"	1 if true; 0 otherwise.	0
Bike trails are present within a half mile	Bike trails present within a half mile	1 if true; 0 otherwise.	1
Colleges are present within a half mile	College present within a half mile	1 if true; 0 otherwise.	1
Transit is present within a quarter mile	Transit is present within a quarter mile	1 if true; 0 otherwise.	1
Segment is within 100 ft of area zoned as "Commercial"	Segment is 50 feet from an area zoned as "Commercial"	0.25 if true; 0 otherwise.	0.25
Segment is within 100 ft of area zoned as "Mixed Use Commercial"	Segment is 75 feet from an area zoned as "Mixed Use Commercial"	0.25 if true; 0 otherwise.	0.25
Segment is within 100 ft of area zoned as "Mixed Use Residential"	Segment is 120 feet from an area zoned as "Mixed Use Residential"	0.25 if true; 0 otherwise.	0
Segment is within 100 ft of area zoned as "Residential Multifamily"	Segment is 1,000 feet from an area zoned as "Residential Multifamily"	0.25 if true; 0 otherwise.	0
Total population of the Block Group the segment is in is over 3,000 people	Total population of the Block Group the segment is in is 4,000	1 if true; 0 otherwise.	1
One or more EJ flags are present	2 EJ flags are present	1 if true; 0 otherwise.	1
Percentile of low life expectancy for the census tract the segment is in	Percentile of low life expectancy for the census tract the segment is in is 50%	Continuous from 0 to 1 for range of values. Values range from 0% to 98%.	0.49
		Total Risk Score:	7.99
		Risk Percent Score (Out of 11):	72.6%

Table 15. Example Risk Score Calculation for Pedestrian KA Crashes at an Intersection.

Variable	Segment Characteristic	Risk Factor	Risk Score
Major AADT between 3,000 and 5,999 Vehicles per Day	Major AADT 7,500 veh/day	0.33 if true; else	
Major AADT between 6,000 and 11,999 Vehicles per Day	Major AADT 7,500 veh/day	0.66 if true; else	0.66
Major AADT 12,000 and above Vehicles per Day	Major AADT 7,500 veh/day	1 if true; 0 otherwise	
Minor AADT 1,000 and above Vehicles per Day	Minor AADT 1,500 veh/day	1 if true; 0 otherwise	1
3 or more through lanes on major road	4 lanes	1 if true; 0 otherwise	1
All three EJ criteria are present	2 EJ criteria present	0.33 if 1; 0.66 if 2; 1 if 3; 0 otherwise	0.66
Indicator of at least one or more alcohol shops within 0.25mi	True	1 if true; 0 otherwise	1
Indicator of at least one or more transit stops within 0.25mi	True	1 if true; 0 otherwise	1
Indicator of 4 leg intersection	True	1 if true; 0 otherwise	1
Indicator of signalized intersection	True	1 if true; 0 otherwise	1
Indicator of urban area	True	1 if true; 0 otherwise	1
Proportion of impervious land	0.4	Use the proportion (0 to 1)	0.4
Land use mix	0.6	Use the proportion (0 to 1)	0.6
Proportion of institutional land use	0.1	Use the proportion (0 to1)	0.1
		Total Risk Score:	**9.42**
		Risk Percent Score (Out of 12):	**78.5**

MassDOT ranked the segments and intersections at both the Statewide and MPO levels using the normalized risk score and the percentile score of ranking (rank kind equal to weak) function in ArcGIS. For each normalized risk score, a percentile rank for the given score was computed relative to all the normalized risk scores. If there are repeated occurrences of the same normalized risk score, then the percentile rank corresponds to values that are less than or equal to the given score. The advantage of the weak ranking approach is that it guarantees that the highest normalized score will receive a percentile rank of 100 percent. For pedestrian crashes at segments, normalized risk scores range from 0 to 0.887. The maximum value (0.887) received a percentile rank of 100 and other values received a percentile rank accordingly. For example, a segment with a normalized risk score of 0.60, the calculated state percentile rank was 85.61, and fell in the secondary risk category. MassDOT then assigned risk categories using the computed ranks. For example, segments/intersections ranked in the top 5 percentile (95 through 100) were categorized as “Primary Risk Site” and segments/intersections ranked in the next 10 percentile (85 through 95) were categorized as “Secondary Risk Site”; the remaining segments/intersections were not categorized. In instances where there are large, repeated occurrences of the same normalized risk score, the percentage of segments/intersections computed for top 5% or next 10% may not be equal to 5 or 10%. This is a byproduct of the weak ranking approach.

Table 16 and Table 17 show the distribution of focus facility type segments with the normalized risk score (presented as percentages) across these categories for Statewide and MPO rankings, respectively. Similarly, Table 18 and Table 19 show the distribution of intersections with the normalized risk score (presented as percentages) across these categories for Statewide and MPO rankings, respectively. Note the goal was to see a higher proportion of target crashes for primary and secondary risk sites than proportion of segments/intersections. Figure 5 is a map of the risk segments ranked statewide, while Figure 6 is a map of the risk segments ranked by MPO. Similarly, Figure 7 is a map of the risk intersections ranked statewide, while Figure 8 is a map of the risk intersections ranked by MPO.

There are a total of 2,035 segments in the primary risk category (top 5 percent), that captured 18.27 percent of the severe pedestrian crashes. Similarly, there are 4,063 segments in the secondary risk category (next top 10 percent), which captured an additional 21.21 percent of the severe pedestrian crashes. The highest number of primary risk category segments were in Boston Region MPO (890 segments), followed by Pioneer Valley Planning Commission (201 segments) and Southeastern Regional Planning and Economic Development District (167 segments).

There are a total of 2,706 intersections in the primary risk category (top 5 percent), that captured 28.34 percent of the severe pedestrian crashes at intersections. Similarly, there are 5,411 intersections in the secondary risk category (next top 10 percent), which captured an additional 24.90 percent of the severe pedestrian crashes. The highest number of primary risk category intersections were in Boston Region MPO (1,195 intersections), followed by Pioneer Valley Planning Commission (283 intersections) and Southeastern Regional Planning and Economic Development District (233 intersections).

Table 16. Statewide Risk Categories by Segments.

State	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored State Segments	Percent of Target Crashes
MA	Primary Risk Site	69.1%	88.7%	2,035	5.01%	18.27%
	Secondary Risk Site	59.5%	69.1%	4,063	9.99%	21.21%

Table 17. Distribution of Risk Segments my MPO.

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored MPO Towns	Percent of Target Crashes in MPO
Berkshire Regional Planning Commission	Primary Risk Site	68.8%	88.3%	81	5.75%	16.00%
	Secondary Risk Site	54.5%	67.2%	132	9.38%	20.00%
Boston Region MPO	Primary Risk Site	70.2%	88.6%	890	5.12%	19.54%
	Secondary Risk Site	62.5%	70.2%	1,721	9.90%	15.49%
Cape Cod Commission	Primary Risk Site	53.4%	79.3%	129	5.04%	11.11%
	Secondary Risk Site	42.7%	53.3%	257	10.04%	24.07%
Central Massachusetts Regional Planning Commission	Primary Risk Site	68.7%	87.1%	161	5.19%	22.22%
	Secondary Risk Site	57.1%	68.7%	305	9.83%	31.75%
Franklin Regional Council of Governments	Primary Risk Site	56.3%	69.3%	55	6.97%	55.56%
	Secondary Risk Site	44.9%	55.8%	64	8.11%	11.11%
Martha's Vineyard Commission	Primary Risk Site	44.8%	54.5%	12	7.23%	20.00%
	Secondary Risk Site	40.6%	43.8%	15	9.04%	0.00%
Merrimack Valley Planning Commission	Primary Risk Site	70.7%	88.1%	99	5.11%	18.33%
	Secondary Risk Site	60.0%	70.1%	197	10.16%	25.00%
Montachusett Regional Planning Commission	Primary Risk Site	64.5%	82.4%	108	5.04%	9.38%
	Secondary Risk Site	53.8%	64.4%	215	10.04%	21.88%
Nantucket Planning and Economic Development Commission	Primary Risk Site	56.3%	65.9%	11	7.43%	0.00%
	Secondary Risk Site	53.1%	55.0%	16	10.81%	0.00%
Northern Middlesex Council of Governments	Primary Risk Site	73.4%	86.9%	83	5.27%	11.63%
	Secondary Risk Site	64.0%	72.9%	155	9.84%	25.58%

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored MPO Towns	Percent of Target Crashes in MPO
Pioneer Valley Planning Commission	Primary Risk Site	70.1%	88.7%	201	5.02%	17.43%
	Secondary Risk Site	59.5%	70.0%	403	10.06%	19.27%
Old Colony Planning Council	Primary Risk Site	68.8%	85.5%	115	5.39%	14.86%
	Secondary Risk Site	58.2%	68.7%	209	9.80%	31.08%
Southeastern Regional Planning and Economic Development District	Primary Risk Site	69.6%	85.7%	167	5.06%	15.93%
	Secondary Risk Site	60.7%	69.6%	335	10.15%	22.12%

Table 18. Statewide Risk Categories by Intersections.

State	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Intersections	Percent of Scored State Intersections	Percent of Target Crashes
MA	Primary Risk Site	68.04%	92.33%	2,706	5.00%	28.34%
	Secondary Risk Site	58.27%	68.04%	5,411	10.00%	24.90%

Table 19. Distribution of Risk Intersections my MPO.

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Intersections	Percent of Scored MPO Intersections	Percent of Target Crashes in MPO
Berkshire Regional Planning Commission	Primary Risk Site	61.15%	87.53%	65	5.04%	37.50%
	Secondary Risk Site	49.07%	61.10%	129	10.01%	25.00%
Boston Region MPO	Primary Risk Site	72.16%	92.33%	1,195	5.00%	27.03%
	Secondary Risk Site	63.16%	72.16%	2,388	10.00%	23.92%
Cape Cod Commission	Primary Risk Site	54.36%	87.47%	149	5.00%	10.00%
	Secondary Risk Site	46.68%	54.36%	298	10.01%	30.00%
Central Massachusetts Regional Planning Commission	Primary Risk Site	60.17%	88.33%	215	5.02%	34.38%
	Secondary Risk Site	47.14%	60.01%	428	9.99%	37.50%
Franklin Regional Council of Governments	Primary Risk Site	51.52%	75.40%	46	5.02%	16.67%
	Secondary Risk Site	43.68%	51.20%	92	10.04%	50.00%
Martha's Vineyard Commission	Primary Risk Site	48.12%	53.30%	8	5.67%	0.00%
	Secondary Risk Site	43.36%	47.55%	14	9.93%	100.00%
Merrimack Valley Planning Commission	Primary Risk Site	63.68%	82.52%	143	5.01%	26.67%
	Secondary Risk Site	53.94%	63.58%	286	10.02%	17.78%

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Intersections	Percent of Scored MPO Intersections	Percent of Target Crashes in MPO
Montachusett Regional Planning Commission	Primary Risk Site	56.36%	84.52%	112	5.02%	18.75%
	Secondary Risk Site	49.01%	56.31%	223	10.00%	43.75%
Nantucket Planning and Economic Development Commission	Primary Risk Site	47.97%	54.94%	7	5.04%	0.00%
	Secondary Risk Site	46.28%	47.66%	14	10.07%	0.00%
Northern Middlesex Council of Governments	Primary Risk Site	62.91%	81.62%	123	5.03%	41.18%
	Secondary Risk Site	53.85%	62.87%	244	9.98%	20.59%
Pioneer Valley Planning Commission	Primary Risk Site	60.66%	87.88%	283	5.01%	26.76%
	Secondary Risk Site	49.71%	60.65%	564	9.99%	30.99%
Old Colony Planning Council	Primary Risk Site	61.46%	90.20%	134	5.03%	20.51%
	Secondary Risk Site	51.84%	61.45%	266	9.99%	38.46%
Southeastern Regional Planning and Economic Development District	Primary Risk Site	61.87%	90.31%	233	5.02%	23.08%
	Secondary Risk Site	55.21%	61.81%	464	9.99%	27.69%

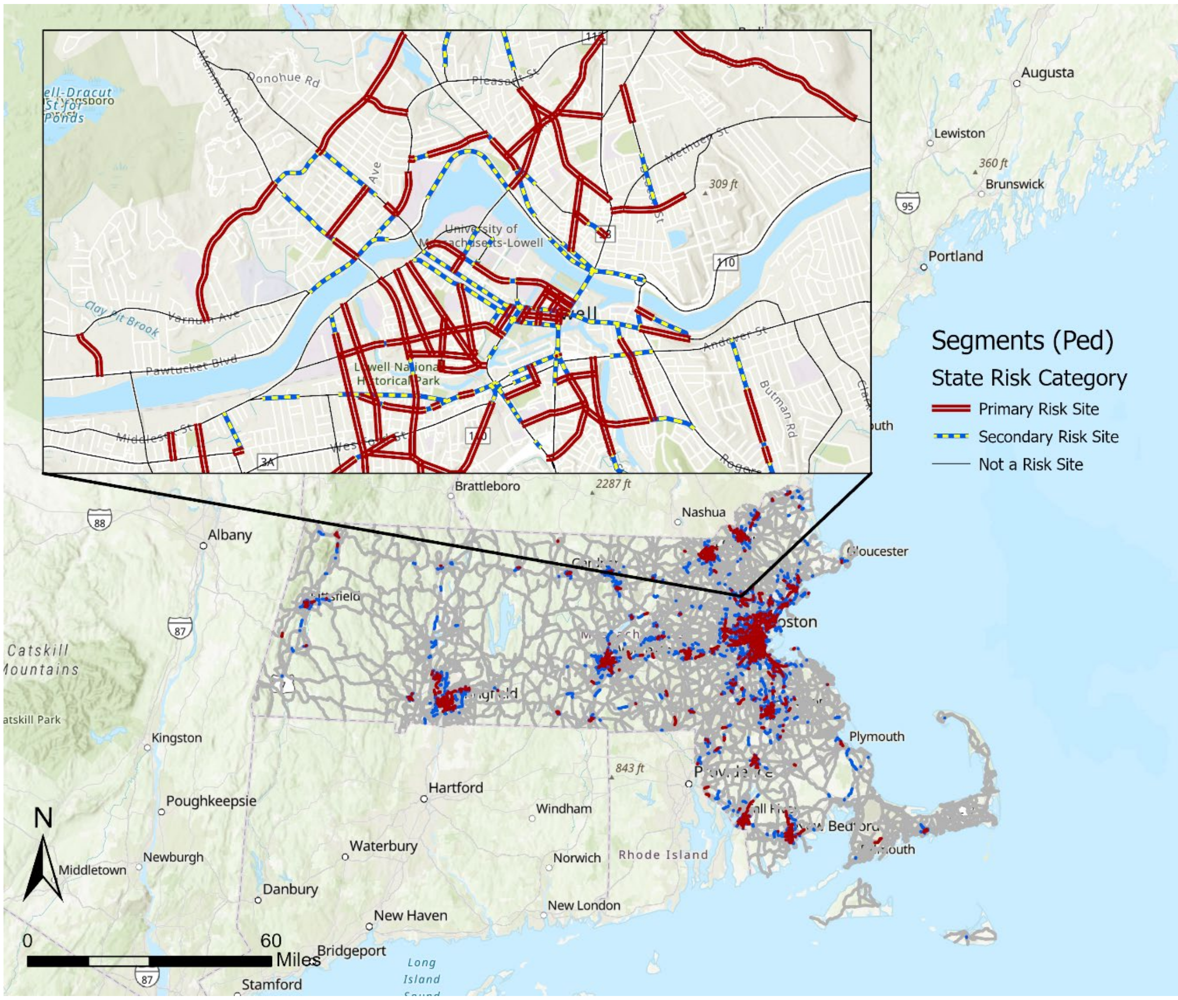

Figure 5. Map depicting the primary and secondary risk segments for severe pedestrian crashes, ranked statewide.

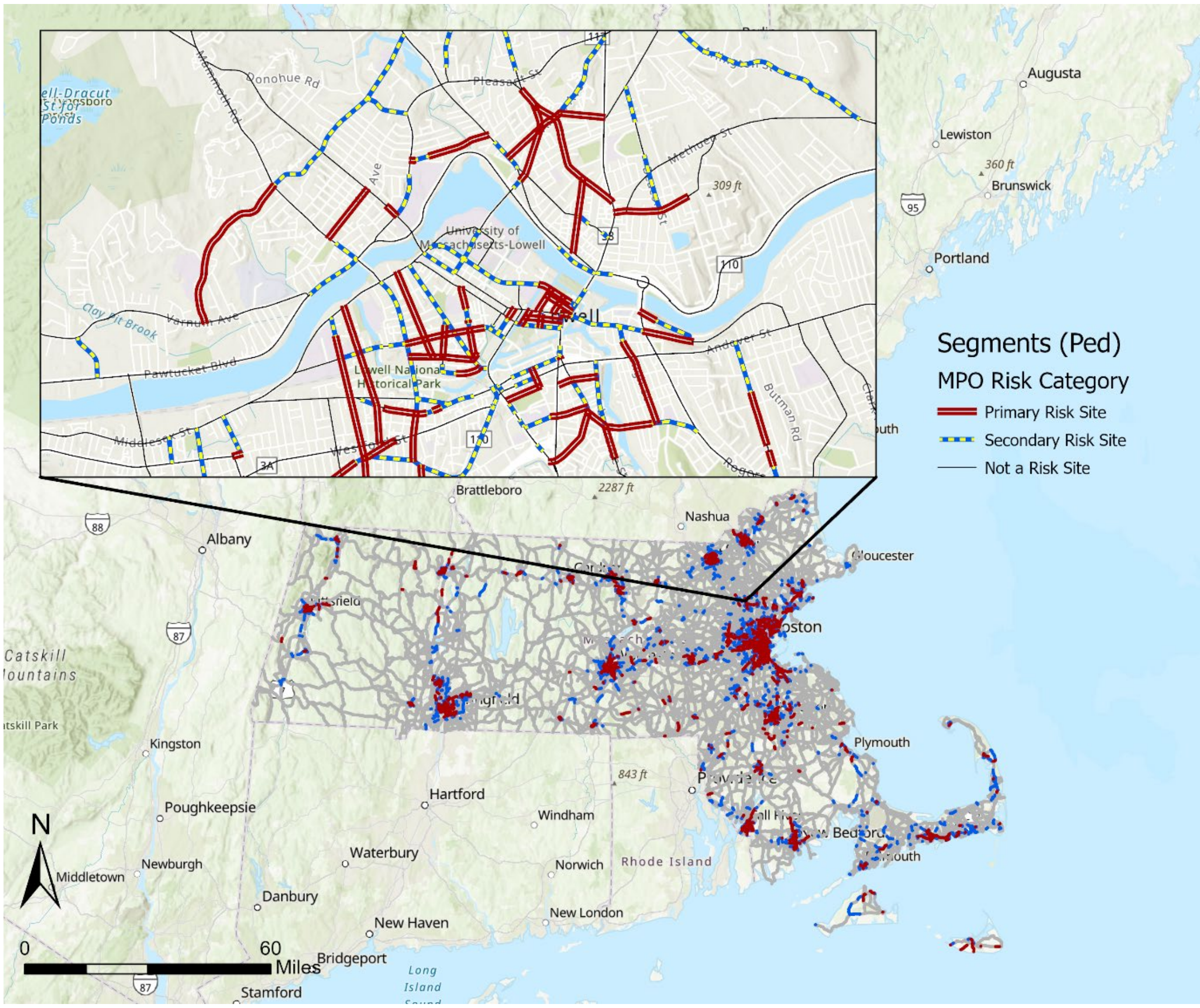

Figure 6. Map depicting the primary and secondary risk segments for severe pedestrian crashes, ranked by MPO.

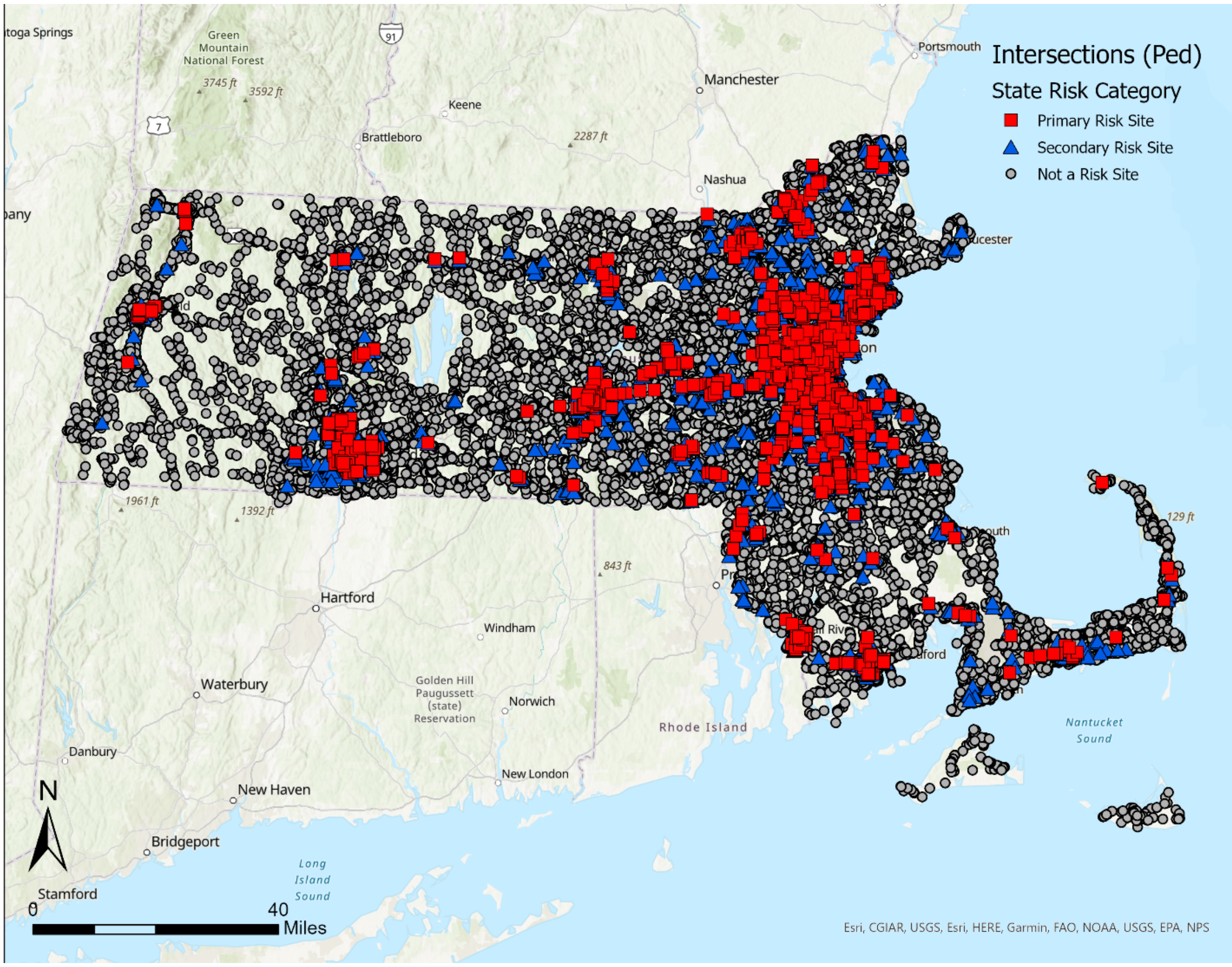

Figure 7. Map depicting the primary and secondary risk intersections for severe pedestrian crashes, ranked statewide.

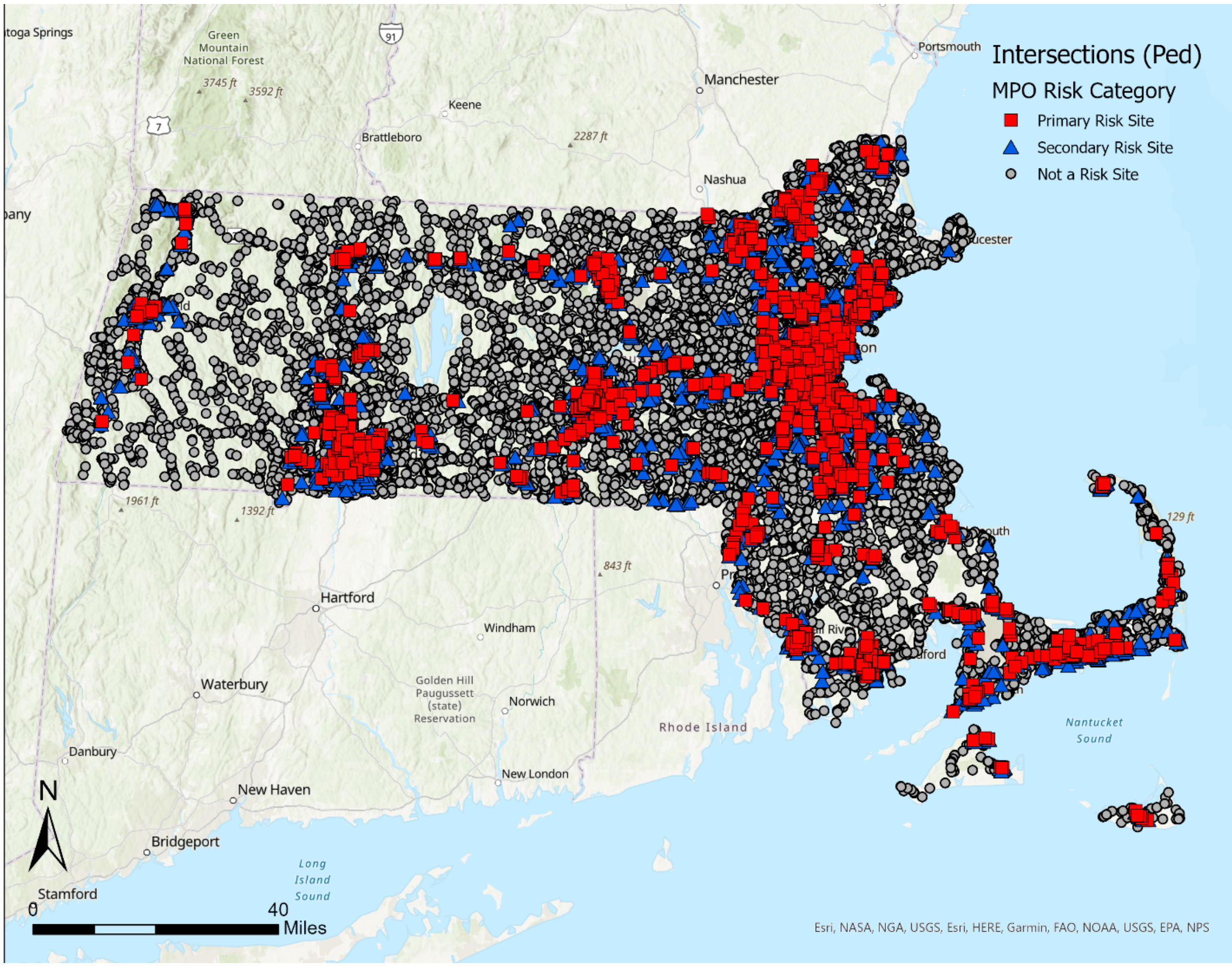

Figure 8. Map depicting the primary and secondary risk intersections for severe pedestrian crashes, ranked by MPO.