Updates to Risk Factors for SHSP Emphasis Areas

Intersection Angle Crashes

PREPARED FOR

Massachusetts Department of Transportation

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 Intersection angle crashes using crash data from 2017 through 2021. For this analysis, VHB first used the default "Intersection" query[1] in the MassDOT IMPACT tool. The definition reads as: a crash where the Roadway Junction Type is reported to be "Four-way intersection", "T-intersection", "Y-intersection", or "Five-point or more".[2] The angle crash data was then extracted by filtering First Harmful Events to "Collisions with motor vehicle in traffic" and Manner of Collision to "Angle".

Note that the purpose of this report is to identify the factors most correlated with the frequency and severity of angle 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 checked "Test of Proportions" to summarize fatal injury (K) and suspected serious injury (A) of intersection angle crashes. To identify overrepresented crash attributes, VHB compared KA intersection angle 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 angle 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 the analysis:

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[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 March, 2023.

- Access Control.
- Age of Driver – Oldest Known.
- Age of Driver – Youngest Known.
- Age of Non-Motorist – Oldest Known.
- Age of Non-Motorist – Youngest Known.
- 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.
- Jurisdiction.
- Left Shoulder Type-linked.
- Left Shoulder Width-linked.
- Light Conditions.
- Locality.
- Manner of Collision.
- MassDOT District.
- Max Injury Severity Reported.
- Median Type.
- Most Harmful Event.

- Number of Travel Lanes.
- Operation.
- Opposite Number of Travel Lanes.
- Right Shoulder Type-linked.
- Right Shoulder Width-linked.
- Road Contributing Circumstances.
- Road Surface Condition.
- Roadway Junction Type.
- Speed Limit.
- Terrain Type.
- Total Fatalities.
- Total Lanes.
- Traffic Control Device Type.
- Trafficway Description.
- Urban Type.
- Weather Conditions.

Table 1. Summary of Key Overrepresentation Findings

Crash Field	Crash Attribute	Percent of Angle KA Crashes	Percent of All KA Crashes
Age of Driver - Oldest Known	55-64	21.57%	13.82%
	65-74	15.59%	9.98%
	75-84	8.91%	5.08%
	>84	2.87%	1.49%
Age of Driver-Youngest Known	16-17	4.57%	2.82%
	18-20	15.47%	10.75%
Access Control	No Access Control	94.61%	73.98%
Average Annual Daily Traffic (AADT)	2,000 - 4,999	14.54%	12.93%
	5,000 - 9,999	19.34%	13.87%
	10,000 - 14,999	15.53%	11.56%
Curb	Both sides	58.50%	31.48%
Driver Contributing Circumstances	Disregarded traffic signs, signals, road markings	9.85%	2.16%
	Failed to yield right of way	19.14%	3.30%
	No improper driving	37.13%	23.24%

Crash Field	Crash Attribute	Percent of Angle KA Crashes	Percent of All KA Crashes
Driver Distracted By	Not Distracted	48.02%	37.73%
Facility Type	Mainline roadway	97.60%	95.14%
Federal Functional Class	Major Collector	14.60%	11.48%
	Minor Arterial	37.87%	28.88%
	Principal Arterial - Other	34.53%	21.54%
Jurisdiction	City or Town accepted road	74.21%	57.64%
Left Shoulder Type-linked	No Shoulder	70.69%	60.84%
Lighting Condition	Daylight	71.51%	46.33%
Median Type	None	88.45%	71.42%
	Raised Median	4.04%	2.01%
Number of Travel Lanes	2	84.58%	74.36%
Right Shoulder Type-linked	No Shoulder	62.72%	40.15%
Road Surface Condition	Dry	82.53%	76.83%
Roadway Junction Type	Five-point or more	1.17%	0.26%
	Four-way intersection	58.21%	9.85%
	T-intersection	37.16%	9.81%
Speed Limit	30	21.98%	16.82%
Total Lanes	2	78.72%	65.27%
Traffic Control Device Type	Flashing traffic control signal	2.93%	0.81%
	Stop signs	42.38%	6.95%
	Traffic control signal	32.88%	7.25%
Trafficway Description	Two-way, divided, unprotected median	20.63%	15.61%
	Two-way, not divided	69.75%	60.15%
Urban Type	Large Urbanized Area	88.63%	82.98%

From a safety management perspective, it is notable that intersection angle crashes are overrepresented on major collectors and arterials (minor and principal arterial-other), city or town-owned roads, and two-lane undivided roads or divided with unprotected median. These crashes were also overrepresented on roadways with no access control, no left or right shoulder, and curbing on both sides. Moreover, intersection angle crashes are overrepresented where roads are located in large, urbanized areas with lower speed limits (30 mph), intersection configuration is five point or more, four-way, or T-intersection and traffic control is stop signs, flashing signs, or signals. Intersections with average annual daily traffic (AADT) between 2,000 and 15,000 also experienced higher frequency of angle crashes. These crashes are more prevalent during the daytime on dry road surfaces. Severe intersection angle crashes involving older (55 years and above) and younger (16-20 years) individuals are also overrepresented. Additionally, there are several driver-related contributing circumstances which point to behavioral issues, including disregarding traffic control and failing to yield the right of way. While these are notable results, they should not restrict the analysis from focusing on all intersection angle crashes. These results should be considered when developing projects and countermeasures at angle crash risk sites. Ultimately, the focus crash type for this analysis is all angle crashes.

Crash Tree and Focus Facility Type

After concluding that focus crash type should include all KA angle crashes, VHB developed a crash tree to identify the intersection geometry and traffic control under which severe angle crashes tend to occur most often. Figure 3 shows the crash tree developed. It is evident that angle crashes are most common at stop-controlled and signalized intersections compared to intersections with other traffic controls. Both three- and four-legged intersections in urban areas were prone to angle crashes. Finally, VHB performed risk factor analysis for KA angle crashes on all intersections (except roundabouts, other circular intersections, and non-conventional intersections).

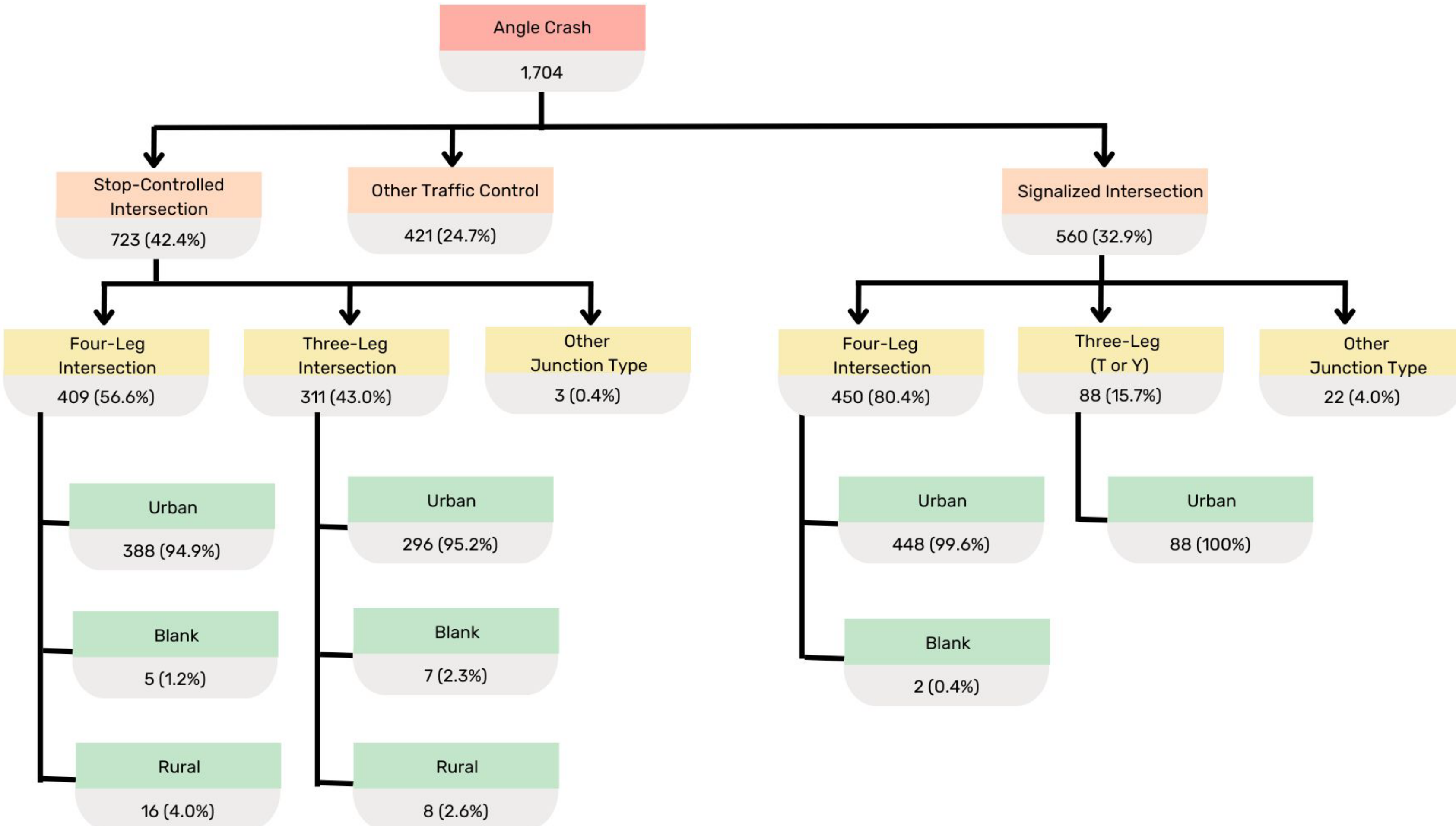

Figure 3: Crash Tree Summarizing KA Angle Crashes at Intersections in Massachusetts.

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 angle crash) at a given intersection based on the model inputs. Agresti (2007) provides more background information on this method.[3] 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 0.10 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.[4] 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 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 intersection angle crash data from MassDOT IMPACT Test of Proportions tool and identified the intersections which fit into the focus facility characteristics. The angle crash data was extracted by filtering First Harmful Events to “Collisions with motor vehicle in traffic” and Manner of Collision to “Angle”. If one or more KA angle crashes occurred at a given intersection (e.g., within 125 feet radius) at any time between 2017 and 2021, VHB assigned that intersection with a “1”; those without an observed KA angle crash received a value of “0.”

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, stop-controlled (two-way and all-way), yield-controlled, and uncontrolled intersections.

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

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

"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 quarter mile radius of each intersection.

Land Use Data

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[5].

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

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

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 Massachusetts Executive Office of Energy and Environmental Affairs (EEA), EJScreen data, disadvantaged community data from the USDOT, climate and economic justice data from U.S. Climate Resilience Toolkit, and 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. Before including variables in the binary logistic model, VHB developed a correlation matrix of input variables to verify low correlation between variables. Highly correlated variables are indicators of potential complications in the model development process. The following section includes the correlation matrix for the final model.

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[5] 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.

Angle KA Crashes at Intersections

Table 2 documents the binary logistic regression model results for angle KA crashes at intersections. This model excludes intersections in Boston due to known under-reporting issues with the crash data. The dependent variable for the model was the occurrence of a KA angle crash at an intersection: 1 if a crash occurred; 0 otherwise. Although the modeling effort tested various continuous and binary variables, all statistically significant variables included in the final model are binary – meaning the variable is equal to 1 if the condition is true for the intersection and 0 otherwise. Table 2 presents odds ratios, standard error, z-value, p-value, and 95 percent confidence intervals for each variable included in the final model.

The binary logistic regression model results for angle KA crashes at intersections are summarized in Table 2. The model shows that odds ratios are greater than one for busier intersections. The odds ratios get higher with increasing ranges of traffic volume on the major roads and the highest odds ratio is observed when vehicles per day is above 9,000. Higher traffic volume on the minor road approach also showed a higher likelihood of angle crashes, as indicated by a greater odds ratio for the traffic volume on minor roads 1,500 vehicles per day and above. Additionally, four or more-legged intersections or intersections with three or more through lanes on major roads are at an elevated risk for severe angle crashes due to having more conflict points. Moreover, both stop-controlled (two-way and all-way) intersections and signalized intersections have a higher likelihood of severe angle crashes. Lastly, towns (where the intersections are located) that meet three environmental justice criteria also experienced increasingly higher severe angle crashes.

Table 2: Binary Logistic Regression Model Results- Angle KA Crashes at Intersections.

Variables	Odds Ratio	Standard Error	z-value	P>|z|	95% Confidence Interval	
Major AADT between 3,000 and 5,999 Vehicles per Day (1)	1.507	0.231	2.680	0.007	1.116	2.035
Major AADT between 6,000 and 8,999 Vehicles per Day (2)	2.346	0.353	5.660	0.000	1.746	3.151
Major AADT 9,000 and above Vehicles per Day (3)	3.194	0.460	8.070	0.000	2.409	4.234
Minor AADT 1,500 and above Vehicles per Day (4)	1.903	0.132	9.250	0.000	1.660	2.180
Respective town meets three environmental justice criteria (5)	1.660	0.106	7.970	0.000	1.466	1.881
Three or more through lanes on major road (6)	1.896	0.167	7.280	0.000	1.596	2.253
Indicator of two-way stop-controlled intersection (7)	2.645	0.272	9.450	0.000	2.162	3.236
Indicator of all-way stop-controlled intersection (8)	1.885	0.432	2.770	0.006	1.204	2.953
Indicator for signalized intersection (9)	2.753	0.365	7.630	0.000	2.122	3.571
Indicator for four or more-legged intersection (10)	3.131	0.222	16.110	0.000	2.725	3.598
Constant	0.002	0.000	-40.410	0.000	0.001	0.002
Note: Number of observations = 50,720; Log likelihood = -4618.2608; Pseudo R2 = 0.1407; LR chi2(10) = 1512.08; Prob > chi2 = 0.0000.						

Table 3 presents the correlation matrix identifying correlation between any two variables. There is no significant correlation between any of the variables. The highest correlation is between variables 1 (Major AADT between 3,000 and 5,999 vehicles per day) and 3 (Major AADT 9,000 and above vehicles per day); 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 Angle KA crashes at Intersections.

Variable No	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.327	1.000								
3	-0.433	-0.340	1.000							
4	-0.091	0.005	0.215	1.000						
5	0.016	0.010	0.109	-0.018	1.000					
6	-0.143	-0.067	0.297	0.106	0.101	1.000				
7	-0.030	0.011	0.036	0.023	-0.010	-0.034	1.000			
8	0.064	-0.012	-0.067	0.053	0.049	-0.031	-0.136	1.000		
9	-0.127	-0.011	0.239	0.308	0.108	0.356	-0.278	-0.036	1.000	
10	-0.010	-0.003	0.076	0.151	0.127	0.093	0.061	0.208	0.339	1.000

Conclusions and Recommendations

The purpose of this analysis is to identify intersection-level risk factors for fatal and serious injury angle crashes. Instead of using the coefficients in the binary logistic regression results from the model, 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 4 summarizes the suggested risk scoring schema for severe angle crashes at intersections.

Table 4: Intersection-level risk factors for angle KA crashes at intersections.

Variable	Suggested Scoring
Major AADT	Continuous from 0 to 1 for the range of major AADT values (10 to 166,255)
Minor AADT 1,500 and above Vehicles per Day	1 if true; 0 otherwise
Respective town meets three environmental justice criteria	1 if true; 0 otherwise
Three or more through lanes on major road	1 if true; 0 otherwise
Indicator of two-way stop-controlled intersection	1 if true; else
Indicator of all-way stop-controlled intersection	0.75 if true; else
Indicator for signalized intersection	1 if true; 0 otherwise
Indicator for four or more-legged intersection	1 if true; 0 otherwise
Maximum potential score for an intersection:	**6.00**

Table 5 presents an example application of risk factors at a hypothetical intersection. To balance prioritization across the different risk scoring schemes, VHB recommends normalizing the intersection risk scores against the total possible score for each schema – producing a normalized risk score for each intersection ranging from 0 to 100. The example intersection has a total risk score of 4.12 out of 6, resulting in a normalized risk score of 68.7 percent.

Table 5: Example Risk Score Calculation for Angle KA Crashes at Intersections.

Variable	Intersection Characteristic	Risk Factor	Risk Score
Major AADT	Major AADT is 20,000 veh/day	Continuous from 0 to 1 for the range of major AADT values	0.12
Minor AADT 1,500 and above Vehicles per Day	Minor AADT 2,000 veh/day	1 if true; 0 otherwise	1
Respective town meets three environmental justice criteria	Meets two EJ criteria	1 if true; 0 otherwise	0
Three or more through lanes on major road	True	1 if true; 0 otherwise	1
Indicator of two-way stop-controlled intersection	False	1 If true; else	0
Indicator of all-way stop-controlled intersection	False	0.75 if true; else	0
Indicator for signalized intersection	True	1 if true; 0 otherwise	1
Indicator for four or more-legged intersection	True	1 if true; 0 otherwise	1
		Total Risk Score:	**4.12**
		Risk Percentage (Out of 6):	**68.67%**

Generally, the model and risk factors produce results that were expected by the VHB and MassDOT team. Several factors point toward increased exposure for severe intersection angle crashes (e.g., higher AADT on major and minor approaches, three or more through lanes, and four or more-legged intersection), which is expected to be correlated with a higher angle crash frequency. Additionally, several factors measure intersection control types (e.g., two-way stop controlled, all-way stop controlled, and signalized) indicating stopping requirements of the vehicles approaching an intersection from different legs. Moreover, intersections meeting EJ criteria for the town they are located in point toward the correlation of infrastructure and severe angle crash frequency.

MassDOT ranked the 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 intersection angle crashes, normalized risk scores range from 0.000025 to 1.00. The maximum value (1.00) received a percentile rank of 100 and other values received a percentile rank accordingly. For example, intersection with a risk score of 0.68, the calculated percentile rank was 94.27, and fell in the secondary risk category. MassDOT then assigned risk categories using the computed ranks. For example, intersections ranked in the top 5 percentile (95 through 100) were categorized as “Primary Risk Intersection” and intersections ranked in the next 10 percentile (85 through 95) were categorized as ”Secondary Risk Intersection”; the remaining intersections were not categorized. In instances where there are large, repeated occurrences of the same normalized risk score, the percentage of intersections computed for top 5 percent or next 10 percent may not be equal to 5 or 10 percent. This is a byproduct of the weak ranking approach.

Table 6 and Table 7 show the distribution of intersections and crashes 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 intersections (e.g., top 5 percent intersection capturing 12 percent crashes). Similarly, Figure 5 is a map of the risk intersections ranked Statewide, while Figure 6 is a map of the risk intersections ranked by MPO. These figures indicate the intersections in the State that may deserve a higher-level of attention to reduce statewide angle crashes at intersections. There are a total of 2,706 intersections in the primary risk category (top 5 percent), that captured 27.10 percent of the severe angle crashes at intersections. Similarly, there are 5,412 intersections in the secondary risk category (next top 10 percent), which captured an additional 27.53 percent of the severe angle crashes. The highest number of primary risk category intersections were in Boston Region MPO (1,195 intersections), followed by Pioneer Valley Planning Commission (286 intersections) and Southeastern Regional Planning and Economic Development District (233 intersections). The towns that have a higher number of intersections experiencing severe angle crashes (primary risk intersections) include Springfield (236 intersections), Boston (204 intersections), New Bedford (191 intersections), Worcester (165 intersections), Lowell (123 intersections), Fall River (121 intersections), and Cambridge (120 intersections).

Table 6. Statewide Risk Categories.

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	66.48%	100.00%	2,706	5.00%	27.10%
	Secondary Risk Site	55.40%	66.48%	5,412	10.00%	27.53%

Table 7. Distribution of Risk Intersections by 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	62.65%	82.54%	67	5.20%	21.43%
	Secondary	46.38%	62.53%	127	9.85%	50.00%
Boston Region MPO	Primary	67.95%	100.00%	1,195	5.00%	28.87%
	Secondary	56.80%	67.92%	2,388	10.00%	25.64%
	Primary	61.01%	82.84%	150	5.04%	31.11%

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
Cape Cod Commission	Secondary	45.60%	61.01%	297	9.97%	33.33%
Central Massachusetts Regional Planning Commission	Primary	66.21%	99.64%	215	5.02%	30.43%
	Secondary	52.58%	66.19%	428	9.99%	20.87%
Franklin Regional Council of Governments	Primary	56.47%	79.34%	47	5.13%	33.33%
	Secondary	42.04%	56.21%	95	10.37%	33.33%
Martha's Vineyard Commission	Primary	44.10%	63.01%	12	8.51%	0.00%
	Secondary	39.64%	41.84%	10	7.09%	0.00%
Merrimack Valley Planning Commission	Primary	69.63%	99.53%	143	5.01%	19.05%
	Secondary	52.09%	68.72%	286	10.02%	33.33%
Montachusett Regional Planning Commission	Primary	62.20%	99.47%	113	5.07%	17.14%
	Secondary	45.81%	62.20%	240	10.76%	45.71%
Nantucket Planning and Economic Development Commission	Primary	44.38%	50.97%	7	5.04%	0%
	Secondary	34.28%	43.04%	14	10.07%	0%
Northern Middlesex Council of Governments	Primary	72.36%	99.77%	123	5.03%	34.48%
	Secondary	55.51%	72.27%	245	10.02%	24.14%
Pioneer Valley Planning Commission	Primary	74.65%	99.97%	286	5.07%	29.37%
	Secondary	58.49%	74.59%	562	9.96%	28.67%
Old Colony Planning Council	Primary	65.79%	98.66%	134	5.03%	29.46%
	Secondary	53.76%	65.77%	266	9.99%	31.25%
Southeastern Regional Planning and Economic Development District	Primary	74.46%	99.75%	233	5.02%	18.12%
	Secondary	61.28%	74.40%	466	10.04%	25.36%

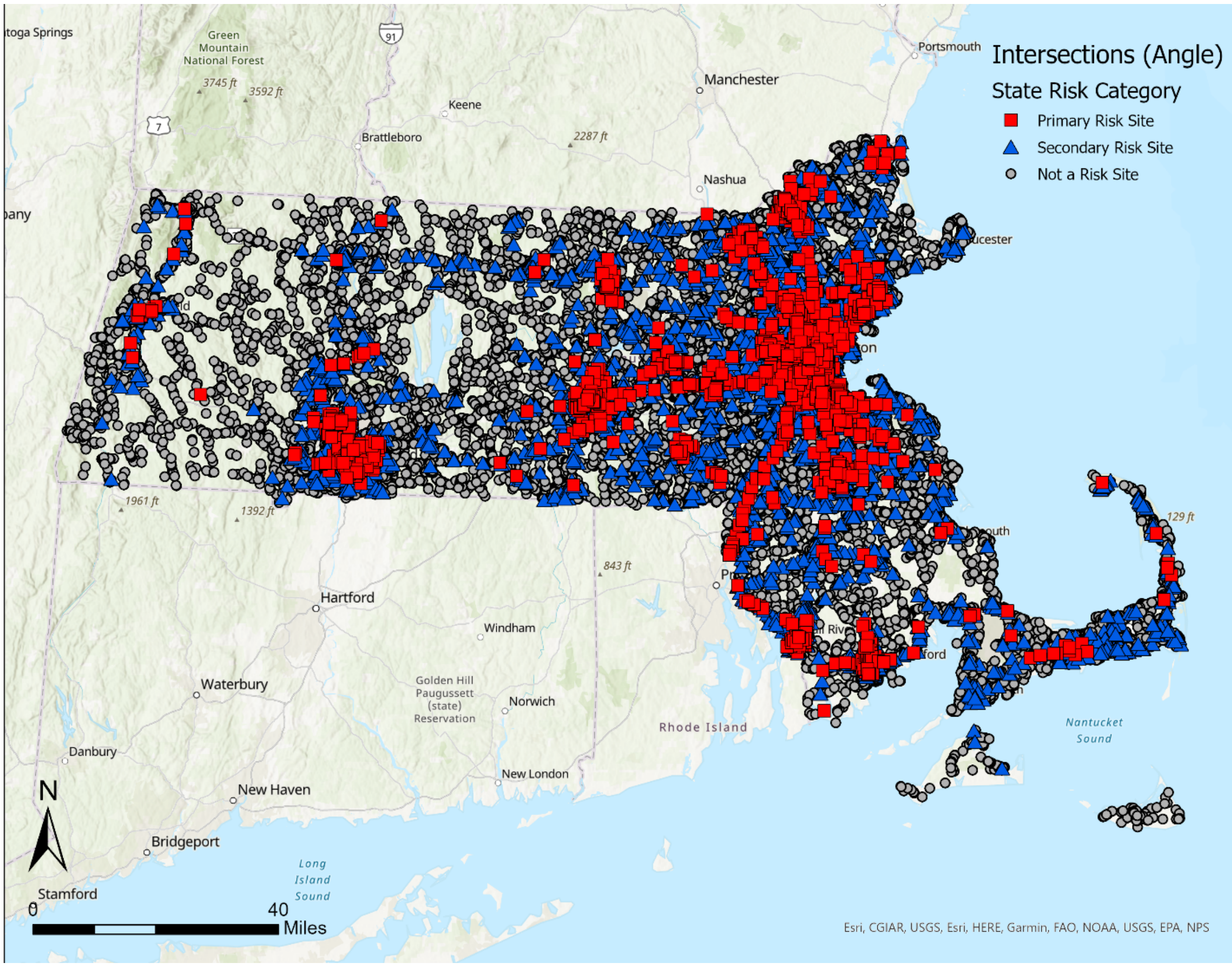

Figure 5. Map depicting the primary and secondary risk intersections for severe angle crashes, ranked statewide.

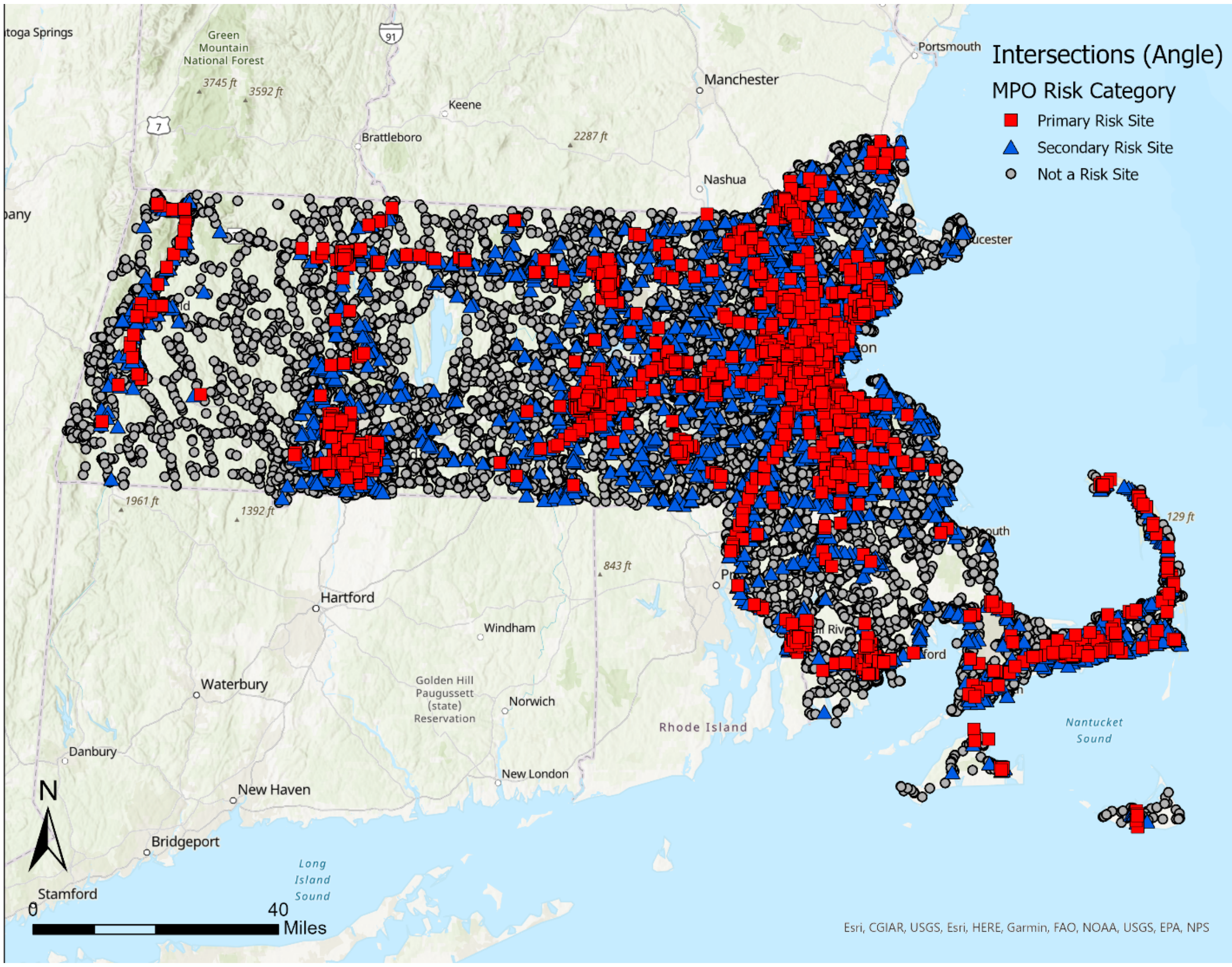

Figure 6. Map depicting the primary and secondary risk intersections for severe angle crashes, ranked by MPO.