Updates to Risk Factors for SHSP Emphasis Areas

Occupant Protection (Unbelted Vehicle Occupants)

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 occupant protection crashes using crash data from 2017 through 2021. For this analysis, VHB used the default "Occupant Protection" query[1] in the MassDOT IMPACT tool. The definition reads as: any crash in which the "Person Type" field is either "Driver" or "Passenger", the "Protective System Use" field is "No", and the "Vehicle Configuration" field for one or more of the vehicles involved in the crash includes "Passenger car" or "Light truck (van, mini-van, pick-up or sport utility)".[2]

Note that the purpose of this report is to identify the factors most correlated with the frequency and severity of occupant protection-related 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 occupant protection crashes. To identify overrepresented crash attributes, VHB compared KA occupant protection 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 occupant protection 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:

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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.

[3] https://apps.impact.dot.state.ma.us/sat/TestofProportions

- Access Control.
- Age of Driver – Oldest known.
- Age of Driver – Youngest Known.
- Age of Non-Motorist – Oldest Known.
- Age of Non-Motorist – Youngest Known.
- County Name.
- Crash Day of Week.
- Crash Month.
- 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.
- Manner of Collision.
- Max Injury Severity Reported.
- Median Type.
- Operation.
- Opposite Number of Travel Lanes.
- Right Shoulder Type-linked.
- Right Shoulder Width-linked.
- Road Contributing Circumstance.
- Road Surface Condition.
- Roadway Junction Type.
- Speed Limit.

- Terrain Type.
- 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 Occupant Protection KA Crashes	Percent of All KA Crashes
Access Control	Full Access Control	20.65%	15.03%
Traffic Control Device Type	No controls	82.64%	71.77%
Age of Driver – Oldest Known	18-20	5.80%	3.72%
	21-24	8.96%	6.67%
	25-34	21.25%	17.66%
Crash Day of Week	Saturday	18.30%	16.09%
Curb	None	51.66%	40.86%
Functional Class	Interstate	14.08%	9.85%
First Harmful Event	Collision with embankment	1.88%	1.09%
	Collision with guardrail	6.83%	4.03%
	Collision with median barrier	2.22%	1.02%
	Collision with parked motor vehicle	6.31%	3.83%
	Collision with tree	15.32%	7.43%
	Collision with unknown fixed object	3.50%	2.02%
	Collision with utility pole	9.73%	5.13%
Jurisdiction	MassDOT	36.65%	32.69%
Light Conditions	Dark - lighted roadway	30.80%	26.43%
	Dark - roadway not lighted	16.30%	9.60%
Manner of Collision	Head-on	12.97%	10.98%
	Single vehicle crash	52.60%	42.37%
Median Type	Positive Barrier - Semi-rigid	6.83%	5.27%
	Positive Barrier - Unspecified	8.11%	5.47%
Total Lanes	6	11.48%	7.72%
Right Shoulder Type-linked	Hardened bituminous mix or penetration	36.48%	30.55%
	Stable - Unruttable compacted subgrade	13.01%	10.63%
Right Shoulder Width-linked	10	13.52%	9.56%
	12	5.80%	3.64%
Left Shoulder Type-linked	Hardened bituminous mix or penetration	18.77%	13.43%

Crash Field	Crash Attribute	Percent of Occupant Protection KA Crashes	Percent of All KA Crashes
Left Shoulder Width-linked	4	12.93%	8.28%
Driver Contributing Circumstances	Driving too fast for conditions	3.37%	2.45%
	Exceeded authorized speed limit	7.08%	4.04%
	Failure to keep in proper lane or running off road	9.14%	5.87%
	Operating vehicle in erratic, reckless, careless, negligent or aggressive manner	13.87%	8.57%
	Over-correcting/over-steering	1.53%	0.99%
	Physical impairment	2.55%	1.61%
Driver Distracted By	Other activity (searching, eating, personal hygiene, etc.)	4.14%	2.86%
	Passenger	0.80%	0.39%
Road Surface Condition	Wet	17.49%	14.71%
Road Contributing Circumstances	None	80.12%	77.40%
Roadway Junction Type	Not at junction	72.10%	59.26%
Trafficway Description	Two-way, divided, positive median barrier	19.24%	16.13%

From a safety management perspective, it is notable that KA occupant protection crashes were overrepresented on interstates with full access control and where no traffic control devices are present. Similarly, these crashes were overrepresented on two-way divided roadways with a median barrier, outside junction area, on roadways with wider shoulder, on segments with 6 total lanes, and roadways under State DOT jurisdiction. All these factors included here indicate roadways where higher speeds may be observed. And the higher speed led to higher severity of crashes. No specific road contribution circumstances were overrepresented; however, wet road surface condition was. Not surprisingly, different types of erratic driving behavior were overrepresented in the driver contributing circumstances field and include driving too fast for conditions, exceeding the authorized speed limit, failure to keep in the proper lane or running off the road, operating vehicle in erratic, reckless, careless, negligent or aggressive manner, over-correcting/over-steering, and physical impairment. A higher proportion of drivers involved in these crashes were also distracted by passengers and other activities that include searching, eating, and personal hygiene. Single-vehicle and head-on crashes were overrepresented in these crashes. A higher proportion of collisions with embankments, guardrails, median barriers, parked motor vehicles, trees, unknown fixed objects, and utility poles were observed among occupant protection crashes. Younger driver populations were also overrepresented in occupant protection crashes with a higher proportion observed among drivers between 18 to 34 years of age. In addition to that, such crashes were also overrepresented during nighttime and on Saturdays. Generally, these findings indicate that these fatalities are more likely to occur on otherwise “safer” designs because those designs are correlated with high-speed travel.

MassDOT should consider these findings when identifying potential restraint use countermeasures including communications and outreach. The National Highway Traffic Safety Administration’s (NHTSA)

Countermeasures that Work[4] includes several examples including state and local primary enforcement seat belt use laws, increased seat belt use law penalties, short term, high-visibility seat belt law enforcement, integrated nighttime seat belt enforcement, and strengthening child/youth occupant restraint laws. While these are notable results, they should not restrict the analysis from focusing on all occupant protection crashes. These results should be considered when developing projects and countermeasures at occupant protection risk sites. Ultimately, the focus crash type for this analysis is all occupant protection crashes.

Crash Tree and Focus Facility Type

After concluding that the occupant protection focus crash type should include all occupant protection crashes, VHB developed a crash tree to identify the roadway conditions, lighting conditions, and functional classifications under which severe occupant protection crashes tend to occur most often. Figure 3 shows the crash tree. It is evident that the majority of KA crashes related to occupant protection took place in urban areas. Although most of these crashes occurred outside of junctions, a significant portion of these also happened within junctions. Among the crashes that occurred outside the junction area, the majority of those occurred during nighttime or limited lighting conditions. For the daytime crashes where no curbs were present, interstates experienced the greatest number of occupant protection KA crashes. This was followed by local streets, which experienced a high proportion of occupant protection KA crashes even though the speed limits may be low, indicating a higher frequency of unbelted drivers on these roads.

[4] https://www.nhtsa.gov/book/countermeasures/countermeasures-work/seat-belts-and-child-restraints

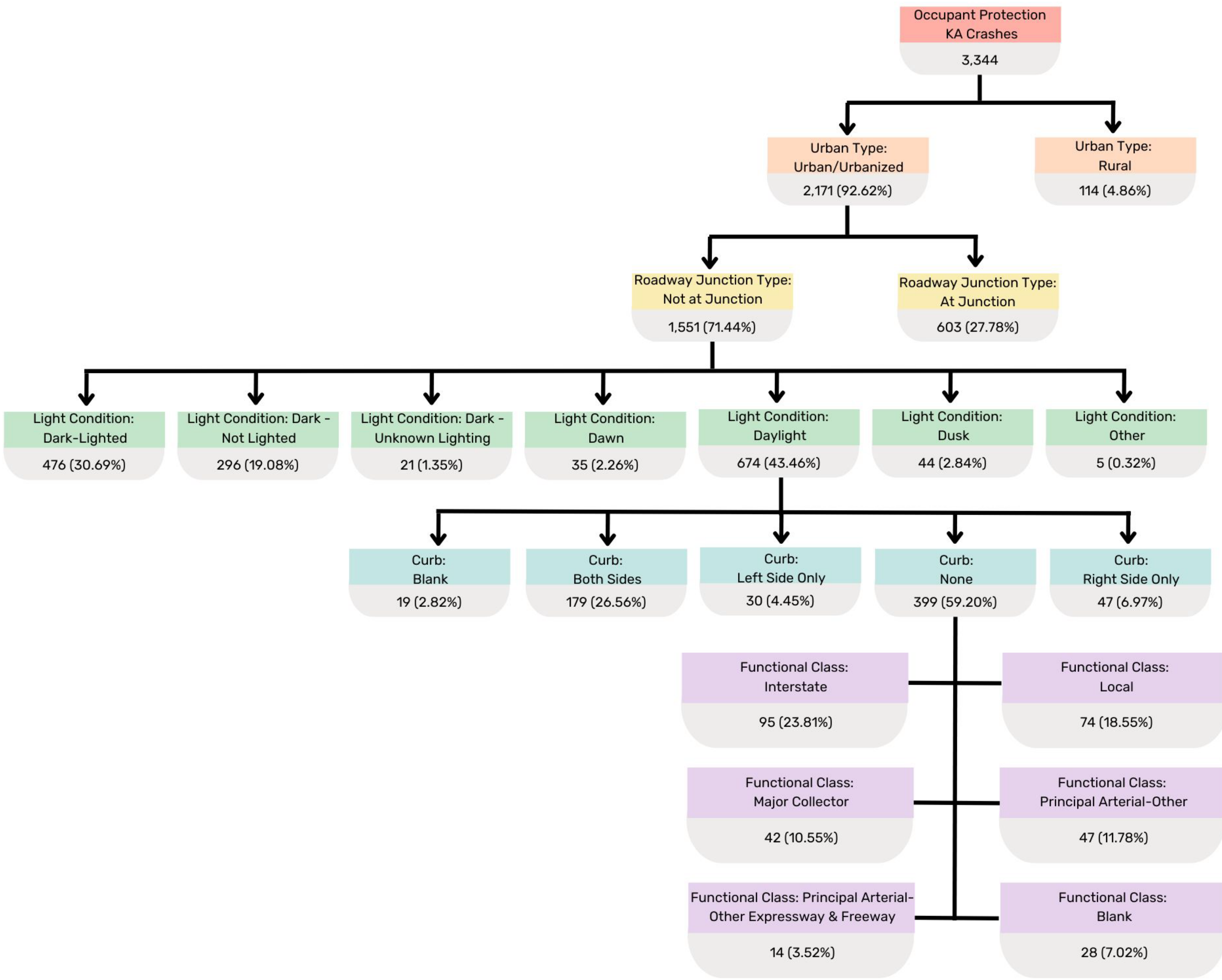

Figure 3. Crash tree summarizing KA occupant protection crashes in Massachusetts.

While the analysis above points towards some potential focus for this emphasis area (e.g., urban area, not at a junction, interstate, no curbs), occupant protection crashes are best addressed directly using educational campaigns. As a result, VHB recommends performing a town-based analysis of occupant protection crashes. This allows for the prioritization of towns for the reception of grants and encouragement for occupant protection safety campaigns.

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

Negative binomial regression is a standard approach to crash frequency modeling given that crash frequency data are typically overdispersed count data. As such, VHB used a negative binomial count regression modeling approach to identify community-level characteristics associated with higher frequencies of occupant protection KA crashes. Negative binomial regression is commonly used in transportation safety as it applies to over-dispersed count data (i.e., the variance exceeds the mean of the observed data). The dependent variable in the model is the number of occupant protection KA crashes, making a count model appropriate for the data. The functional form of the negative binomial regression model is shown in Figure 4.[5]

$$\lambda_i = e^{\beta X_i + \varepsilon_i}$$

Figure 4. Negative binomial regression functional form.

Where:

> $e^{\varepsilon i}$ = gamma-distributed error term with a mean equal to one and variance equal to α.
>
> λ_i = expected number of occupant protection KA crashes at location i.
>
> β = vector of estimated parameters.
>
> X_i = vector of independent variables that characterize location i and influence occupant protection KA crash frequency.

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]

Data

VHB used ArcGIS to manage and integrate data for this analysis. VHB aggregated data at the city and town level. In Massachusetts, all roads and geographic areas are covered by town jurisdiction. Due to

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[5] Lord, D., Mannering, F., 2010. The Statistical Analysis of Crash-Frequency Data: A Review and Assessment of Methodological Alternatives. Transp. Res. Part A Policy Pract. 44 5 , 291–305. doi:10.1016/j.tra.2010.02.001
[6] Hauer, E. (2004). The harm done by tests of significance. *Accident Analysis & Prevention*, *36*(3), 495-500.

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 occupant protection crashes by town using the MassDOT IMPACT Test of Proportions tool. VHB then joined these totals to the town-level data set.

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. VHB aggregated the roadway data at the town-level, including summing total centerline miles and centerline miles for each Federal Functional Class.

Driver License Data

MassDOT provided driver license data by age, town, and zip code for 2021. VHB used spatial analysis to assign driver license zip codes to the relevant town, joining the driver license totals by age. VHB then calculated the average number of licensed drivers by age group for each town and integrated with town-level data.

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 then used spatial analysis to determine the total number of schools in each town.

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.

Citation Data

VHB obtained traffic citation count data by town for a five-year period between 2015 and 2019. These data included total citations, as well as subsets of counts for speeding-, seat belt-, impaired driving-, and distraction-related traffic citations.

Seat Belt Survey Data

VHB and MassDOT obtained the 2018-22 Massachusetts Safety Belt Usage Observation Study reports which summarizes the results of seatbelt surveys across the State. Instead of relying on data from a specific year, VHB utilized aggregated average data spanning from 2018 to 2022. This approach was chosen due to the limited number of observations in certain cities, which could result in driver belt use rates that may not accurately represent those cities. Additionally, there were a few cities for which belt use rates were unavailable. In such cases, we substituted the belt use rate using the county level data.

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), alcohol shop location data, healthy aging data from DPH, and environmental justice (EJ) data provided by Environmental Justice Community Block Group Data Update. 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. VHB used spatial analysis tools to integrate these data.

Results

The following sections describe the results of the negative binomial regression modeling effort.

Variables of Interest

To account for unobserved influences due to road facilities and traffic exposure, VHB established a base model that included the natural log of the mile years (i.e., the product of five years of data and total centerline mileage in the town) – this accounts for exposure. Before including additional variables in the negative binomial, VHB developed a correlation matrix of input variables. Highly correlated variables are indicators of potential complications in the model development process. Although VHB considered all potential variables in this matrix, Table 2 shows the correlation matrix for the following 12 variables (listed here) included in the final occupant protection model. Note the maximum correlation between any two variables is -0.55, below the standard value of 0.7, above which there are concerns of serial correlation.

1. Population density is between 50 and 200 residents per square mile in the city or town.
2. Population density is between 200 and 1,500 residents per square mile in the city or town.
3. Population density is greater than 1,500 residents per square mile in the city or town.
4. Indicator that the proportion of centerline mileage in the city/town that is interstate[7] is greater than 0.04.
5. Indicator that the proportion of centerline mileage in the city/town that is rural or urban principal arterial[8] is greater than 0.05.
6. Indicator that annual impaired driving citations per centerline mile is greater than 0.5.
7. Indicator that annual distracted driving citations per centerline mile is greater than 0.25.
8. Indicator that the proportions of driver seat belt use less than 0.8.
9. Indicator that the weighted average posted speed limit for known speed limit segments is greater than 30 mph.
10. Indicator that all three EJ indicators are present in the city/town.
11. Indicator that the proportion of the younger population (age 15-24) is greater than 0.10.
12. Indicator that the proportion of older drivers (age 65+) is greater than 0.20.

[7] Federal functional class 1.
[8] Federal functional class 2.

Table 2. Correlation matrix of input variables.

Variables	Pop Density: 50-200	Pop Density: 200-1500	Pop Density: >1500	Functional Class 1	Function al Class 2	Impaired Citations	Distracted Citations	Unbelted survey	Average Speed	EJ-3	Younger Population	Older Population
Pop Density: 50-200	1.000											
Pop Density: 200-1500	-0.432	1.000										
Pop Density: >1500	-0.211	-0.548	1.000									
Functional Class 1	0.013	0.105	-0.079	1.000								
Functional Class 2	0.114	0.087	-0.164	-0.150	1.000							
Impaired Citations	-0.309	0.382	0.196	0.085	-0.002	1.000						
Distracted Citations	-0.264	-0.031	0.449	0.171	-0.065	0.395	1.000					
Unbelted survey	-0.005	0.002	-0.049	-0.015	0.176	0.021	-0.034	1.000				
Average Speed	0.090	0.228	-0.337	0.094	-0.003	0.042	-0.110	0.117	1.000			
EJ-3	-0.116	-0.278	0.520	-0.088	-0.015	0.174	0.439	0.038	-0.318	1.000		
Younger Population	-0.112	0.275	0.036	0.064	-0.037	0.283	0.140	-0.072	0.113	-0.031	1.000	
Older Population	0.055	0.010	-0.098	0.010	0.102	0.001	-0.058	0.028	0.074	-0.115	-0.021	1.000

Model Results

Table 3 documents the negative binomial regression results and presents coefficients, standard error, z-value, p-value, and 95 percent confidence intervals for each variable included in the final model. The model predicts the number of KA occupant protection crashes expected in a town. The natural log of the product of centerline mileage and 5 years of crash data were included in the model to offset exposure for each town. The independent variables include a mix of population, roadway, citation, and environmental justice variables.

Town population density provides some overall level of exposure for the town – towns with high relative population densities experienced a higher frequency of severe occupant protection crashes. Towns meeting three environmental justice criteria also experienced increasingly higher severe occupant protection crashes, indicating that these areas should be targeted for occupant protection campaigns. The high proportion of interstate mileage suggests a correlation between high-speed and more severe outcomes for occupant protection crashes, while the high proportion of principal arterials may be associated with a lower level of design, increased stops, and increased conflicts. Similarly, towns with higher average speed limits also experienced severe occupant protection crashes. The proportion of driver seat belt use provides some direct measure of the level of unbelted driving in the town, while the impaired and distracted driving citation metrics provide an additional surrogate level of exposure for risky driving behaviors. Not surprisingly, towns with a lower level of seat belt use demonstrated a higher likelihood of severe occupant protection crashes. Towns with a higher proportion of both younger (15-24 years) and older (65+ years) populations also experienced more of these crashes supporting a lower seat belt use rate among the younger population[9] and higher likelihood of severity to older population when seat belts are not used[10].

[9] Seat Belt & Car Seat Statistics. https://www.valuepenguin.com/car-insurance/seat-belt-statistics
[10] Characteristics of Crash Injuries Among Young, Middle-Aged, and Older Drivers. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/810857

Table 3. Negative binomial count regression model results.

Variable (Number)	Coefficient	Standard Error	z-value	P>|z|	95% Confidence Interval	
Intercept	-6.990	0.277	-25.271	<0.001	-7.533	-6.447
Population Density is between 50 and 200 Persons per Square Mile	0.775	0.267	2.907	0.004	0.252	1.298
Population Density is between 200 and 1,500 Persons per Square Mile	1.217	0.252	4.836	<0.001	0.723	1.711
Population Density is greater than 1,500 Persons per Square Mile	1.423	0.261	5.458	<0.001	0.911	1.935
Proportion of Centerline Mileage in the City/Town that is Interstate is Greater than 0.04	0.280	0.091	3.064	0.002	0.102	0.458
Proportion of Centerline Mileage in the City/Town that is Rural or Urban Principal Arterial is Greater than 0.05	0.209	0.093	2.244	0.025	0.027	0.391
Annual Impaired Driving Citations per Centerline Mile is greater than 0.5	0.463	0.105	4.388	<0.001	0.257	0.669
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	0.205	0.083	2.468	0.014	0.042	0.368
Proportion of Driver Seat Belt Use less than 0.8	0.195	0.073	2.666	0.008	0.052	0.338
Weighted Average Posted Speed Limit for Known Speed Limit Segments is greater than 30 mph	0.312	0.147	2.123	0.034	0.024	0.600
All three EJ indicators present in City/Town	0.408	0.128	3.180	0.001	0.157	0.659
Proportion of Younger Population (age 15-24) is greater than 0.10	0.336	0.091	3.700	<0.001	0.158	0.514
Proportion of Older Drivers (age 65+) is greater than 0.20	0.139	0.075	1.853	0.064	-0.008	0.286
Natural Log of the Product of Centerline Mileage and Years – Offset	1.000	NA	NA	NA	NA	NA
alpha	0.143					

Note: Number of observations = 349; AIC=1622.2, Log likelihood = -797.083.

Conclusions and Recommendations

The purpose of this analysis is to identify town-level risk factors for fatal and serious injury occupant protection crashes. Instead of using the coefficients in the negative binomial regressions results from Table 3, 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. Where a binary predictive variable was used, binary risk scores are applied. From a modeling perspective, the cutoffs for the binary variables were determined by using visual representations of the data and smaller bins to find the cutoffs which make the most sense.

Table 4. Town-level risk factors for occupant protection KA Crashes.

Risk Factor for Occupant Protection KA Crashes	**Suggested Scoring**
Population Density is between 50 and 200 Persons per Square Mile	0.33 if true; else
Population Density is between 200 and 1,500 Persons per Square Mile	0.66 if true; else
Population Density is greater than 1,500 Persons per Square Mile	1 if true; 0 otherwise
Proportion of Centerline Mileage in the City/Town that is Interstate is Greater than 0.04	1 if true; 0 otherwise
Proportion of Centerline Mileage in the City/Town that is Rural or Urban Principal Arterial is Greater than 0.05	1 if true; 0 otherwise
Annual Impaired Driving Citations per Centerline Mile is greater than 0.5	1 if true; 0 otherwise
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	1 if true; 0 otherwise
Proportion of Driver Seat Belt Use less than 0.8	1 if true; 0 otherwise
Weighted Average Posted Speed Limit for Known Speed Limit Segments is greater than 30 mph	1 if true; 0 otherwise
All three EJ indicators present in City/Town	1 if true; 0 otherwise
Proportion of the Younger Population (age 15-24) is greater than 0.10	1 if true; 0 otherwise
Proportion of Older Drivers (age 65+) is greater than 0.20	1 if true; 0 otherwise
Maximum potential score for a town:	**10.0**

Table 5 provides an example application of the risk factors of a hypothetical town. To provide context for these risk factor scores in relation to other emphasis areas, MassDOT can normalize the cumulative score by dividing by the total potential score for a town. This would generate a risk score out of 100 percent for each town. Under this approach, the normalized risk score for the example town is 66.6 percent (6.66 divided by 10.0).

Table 5. Example risk score calculation for occupant protection crashes.

Variable	Town Characteristic	Risk Factor	Risk Score
Population Density is between 50 and 200 Persons per Square Mile	Population density of 750	0.33 if true; else	0
Population Density is between 200 and 1,500 Persons per Square Mile	Population density of 750	0.66 if true; else	0.66
Population Density is greater than 1,500 Persons per Square Mile	Population density of 750	1 if true; 0 otherwise	0
Proportion of Centerline Mileage in the City/Town that is Interstate is Greater than 0.04	Proportion is 0.06	1 if true; 0 otherwise	1
Proportion of Centerline Mileage in the City/Town that is Rural or Urban Principal Arterial is Greater than 0.05	Proportion is 0.04	1 if true; 0 otherwise	0
Annual Impaired Driving Citations per Centerline Mile is greater than 0.5	Proportion is 0.4	1 if true; 0 otherwise	0
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	Proportion is 0.28	1 if true; 0 otherwise	1
Proportion of Driver Seat Belt Use less than 0.8	Proportion is 0.70	1 if true; 0 otherwise	1
Weighted Average Posted Speed Limit for Known Speed Limit Segments is greater than 30 mph	Speed is 33.15 mph	1 if true; 0 otherwise	1
All three EJ indicators present in City/Town	Town meets 2 EJ criteria	1 if true; 0 otherwise	0
Proportion of Younger Population (age 15-24) is greater than 0.10	Proportion is 0.15	1 if true; 0 otherwise	1
Proportion of Older Drivers (age 65+) is greater than 0.20	Proportion is 0.23	1 if true; 0 otherwise	1
Total Risk Score:			6.66
Risk Percent Score (Out of 10.0):			66.6%

Generally, the model and risk factors produce results that were expected by the VHB and MassDOT team. Several factors point toward increased unbelted driver exposure (e.g., higher population density, younger person population, and older person population), which is expected to be correlated with higher occupant protection crash frequency. Not surprisingly, a lower proportion of seat belt use was associated with a higher proportion of such crashes. Additionally, several factors measure the surrogate level of risk in the town, indicating an increased likelihood of risk-taking behavior that is likely to be present in the unbelted driver population (e.g., impaired driving citations and distracted driving citations). Moreover, two risk factors point toward the correlation of infrastructure and occupant protection-related crash frequency: the presence of principal arterials and historically underinvested areas (correlated with EJ community status). Two more infrastructure-related risk factors correlated with higher severity occupant protection crashes are the presence of high-speed facilities (interstates) and higher average speed. A higher proportion of younger drivers increased the likelihood of occupant protection crashes as younger drivers have historically the lowest seat belt use rate. Similarly, a higher proportion of older drivers also increased the likelihood of such crashes due to a crash being more severe when older drivers are not restrained.

MassDOT ranked the towns 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 occupant protection-related crashes, normalized risk scores range from 0.0 to 0.87. The maximum value (0.87) received a percentile rank of 100 and other values received a percentile rank accordingly. For example, for a town with a normalized risk score of 0.70, the calculated state percentile rank was 97.44, and fell in the primary risk category. MassDOT then assigned risk categories using the computed ranks. For example, towns ranked in the top 5 percentile (95 through 100) were categorized as "Primary Risk Town" and towns ranked in the next 10 percentile (85 through 95) were categorized as "Secondary Risk Town"; the remaining towns were not categorized. In instances where there are large, repeated occurrences of the same normalized risk score, the percentage of segments 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 towns 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 towns. Similarly, Figure 5 is a map of the risk towns ranked statewide, while Figure 6 is a map of the risk towns ranked by MPO. These figures indicate the towns in the State that may deserve a higher-level of attention to reduce statewide occupant protection-related crashes. There are a total of 22 towns in the primary risk category (top 5 percent, in this case 6.27 percent), that captured 21.45 percent of the severe occupant protection-related crashes. Similarly, there are 33 towns in the secondary risk category (next top 10 percent), which captured an additional 13.65 percent of the severe occupant protection-related crashes. The towns that are in the primary risk category for severe occupant protection-related crashes are Holyoke, Fall River, Freetown, Woburn, Rockland, Dedham, Methuen, Revere, West Bridgewater, Brockton, Abington, Bourne, Somerset, Raynham, Framingham, Waltham, Haverhill, Worcester, Salem, Springfield, Newburyport, and Stoughton. Seven of these towns were under Boston Region MPO, and four of these were under Pioneer Valley Planning Commission. A higher number of secondary risk category towns for occupant protection-related crashes were also under these two MPOs.

Table 6. Statewide risk categories.

State	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Towns	Percent of Scored State Towns	Percent of Target Crashes
MA	Primary Risk Site	70.00%	86.60%	22	6.27%	21.45%
	Secondary Risk Site	66.60%	66.60%	33	9.40%	13.65%

Table 7. Distribution of risk towns my MPO.

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Towns	Percent of Scored MPO Towns	Percent of Target Crashes in MPO
Berkshire Regional Planning Commission	Primary	66.60%	66.60%	2	6.25%	29.82%
	Secondary	56.60%	63.30%	3	9.38%	33.33%
Boston Region MPO	Primary	70.00%	80.00%	7	7.22%	16.06%
	Secondary	66.60%	66.60%	9	9.28%	7.65%
Cape Cod Commission	Primary	76.60%	76.60%	1	6.67%	13.14%
	Secondary	46.60%	46.60%	4	26.67%	24.82%
Central Massachusetts Regional Planning Commission	Primary	66.60%	80.00%	7	17.50%	56.08%
	Secondary	23.30%	63.30%	33	82.50%	43.92%
Franklin Regional Council of Governments	Primary	53.30%	53.30%	2	7.69%	21.88%
	Secondary	46.60%	46.60%	2	7.69%	34.38%
Martha's Vineyard Commission	Primary	46.60%	46.60%	1	14.29%	33.33%
	Secondary	43.30%	43.30%	2	28.57%	22.22%
Merrimack Valley Planning Commission	Primary	80.00%	80.00%	1	6.67%	11.97%
	Secondary	70.00%	70.00%	2	13.33%	27.46%
Montachusett Regional Planning Commission	Primary	56.60%	66.60%	5	22.73%	34.91%
	Secondary	20.00%	53.30%	17	77.27%	65.09%
Nantucket Planning and Economic Development Commission	Primary	36.60%	36.60%	1	100.00%	100.00%
	Secondary	N/A	N/A	0	0%	0%
Northern Middlesex Council of Governments	Primary	60.00%	60.00%	2	22.22%	52.38%
	Secondary	36.60%	56.60%	7	77.78%	47.62%
Pioneer Valley Planning Commission	Primary	60.00%	80.00%	4	9.30%	53.56%
	Secondary	56.60%	56.60%	4	9.30%	6.37%
Old Colony Planning Council	Primary	80.00%	80.00%	1	5.88%	23.33%
	Secondary	70.00%	76.60%	3	17.65%	18.33%
Southeastern Regional Planning and Economic Development District	Primary	76.60%	86.60%	2	7.41%	9.04%
	Secondary	66.60%	70.00%	10	37.04%	36.17%

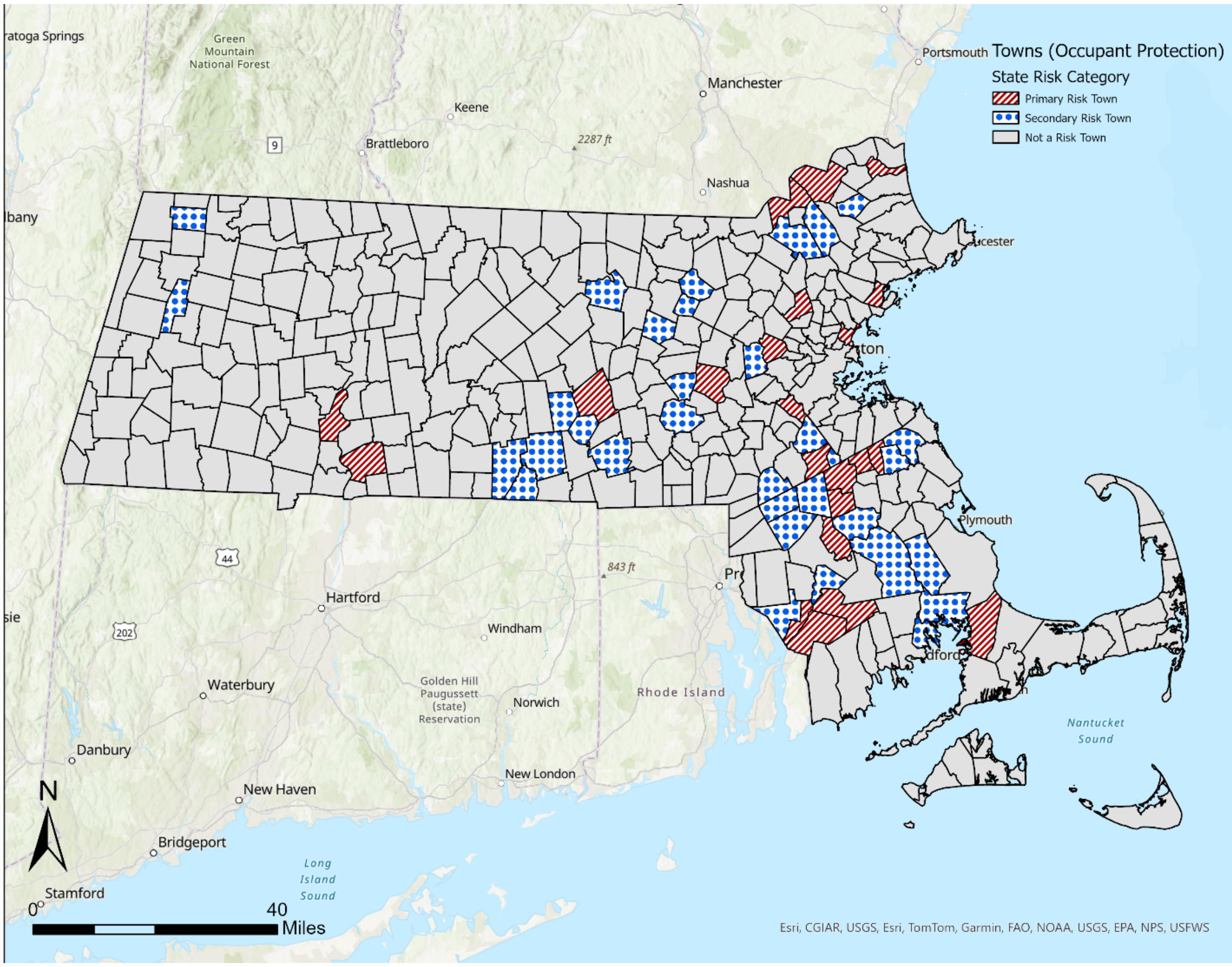

Figure 5. Map depicting the primary and secondary risk towns for severe occupant protection crashes, ranked statewide.

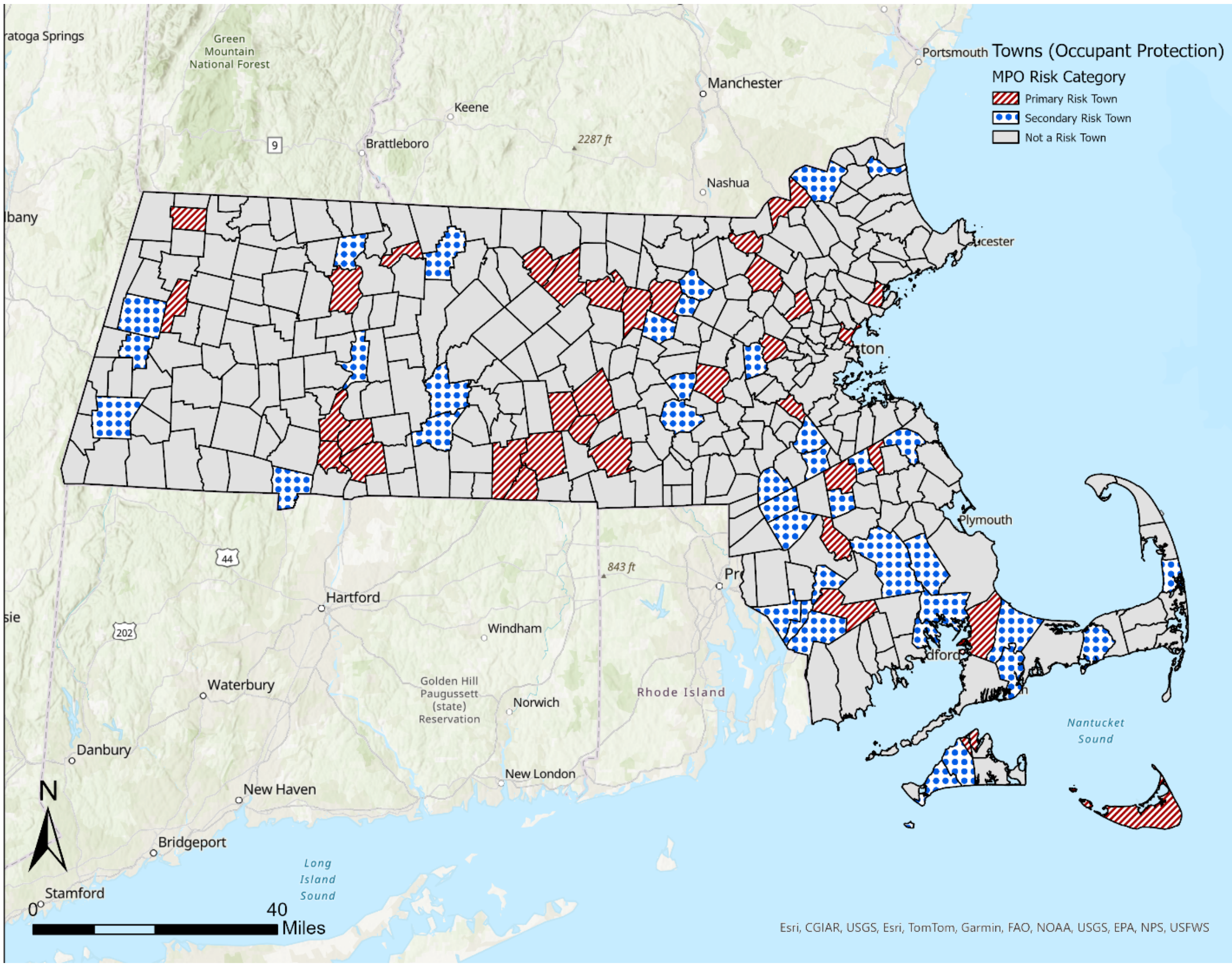

Figure 6. Map depicting the primary and secondary risk towns for severe occupant protection crashes, ranked by MPO.