Updates to Risk Factors for SHSP Emphasis Areas

Distracted Driving

PREPARED FOR

Massachusetts Department of Transportation

PREPARED BY

vhb

REPORT DATE: March 29, 2023

UPDATED: February 16, 2024

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 distracted driving crashes using crash data from 2017 through 2021. For this analysis, VHB used the default "Distracted Driving" query[1] in the MassDOT IMPACT tool. The definition reads as: any crash in which one or more of the drivers is reported with a "Driver Distracted Type" of "Manually operating an electronic device", "Talking on hands-free electronic device", "Talking on hand-held electronic device", "Other activity, electronic device", "Other activity (searching, eating, personal hygiene, etc.)", "Passenger", or "External distraction (outside the vehicle)".[2]

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

---

[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 Distracted Driving KA Crashes	Percent of All KA Crashes
Access Control	No access control	85.45%	79.22%
Traffic Control Device Type	No controls	76.93%	71.77%
County Name	Berkshire	3.87%	2.13%
Facility Type	Mainline roadway	96.59%	94.79%
Functional Class	Local	17.18%	13.13%
First Harmful Event	Collision with utility pole	8.82%	5.13%
First Harmful Event Location	Shoulder - paved	3.10%	1.41%
Jurisdiction	City or Town accepted road	66.72%	60.77%
Manner of Collision	Rear-end	18.58%	13.08%
Max Injury Severity Reported	Suspected Serious Injury (A)	52.01%	44.31%
Median Type	None	80.96%	75.76%
Total Lanes	2	74.92%	67.50%
Left Shoulder Type-linked	No Shoulder	70.12%	64.16%
Driver Contributing Circumstances	Distracted	11.21%	1.47%
	Inattention	8.84%	6.02%
	Operating vehicle in erratic, reckless, careless, negligent or aggressive manner	11.44%	8.57%
	Physical impairment	2.92%	1.61%
Driver Distracted By	External distraction (outside the vehicle)	13.60%	1.30%
	Manually operating an electronic device	11.43%	1.05%
	Other activity (searching, eating, personal hygiene, etc.)	28.37%	2.86%
	Other activity, electronic device	4.93%	0.48%
	Passenger	3.94%	0.39%
	Talking on hand-held electronic device	1.58%	0.18%
Roadway Junction Type	Not at junction	65.63%	59.26%
Urban Type	Large Urban Cluster	3.25%	1.54%

Crash Field	Crash Attribute	Percent of Distracted Driving KA Crashes	Percent of All KA Crashes
	Rural	6.50%	3.78%

From a safety management perspective, it is notable that a large proportion of these crashes occurred on roadways with no access control and no traffic control devices. These crashes were also overrepresented on two-lane roads, where a median was not present, falls into the jurisdiction of city or town accepted roads, and roads that are within large urban clusters or rural. Additionally, rear-end crashes are overrepresented along with collisions with utility poles as the first harmful event. Not surprisingly, different types of distractions were overrepresented in the driver contributing circumstances field and include distracted, inattention, operating vehicle in erratic, reckless, careless, negligent or aggressive manner, and physical impairment. Drivers were also distracted by external distractions (outside the vehicle), manually operating an electronic device, talking on hand-held electronic device, passenger, and other activity (searching, eating, personal hygiene, electronic device, etc.).

MassDOT should consider these findings when identifying potential distracted driver countermeasures. The National Highway Traffic Safety Administration's (NHTSA) *Countermeasures that Work*[4] includes several examples of effective campaigns targeting distracted driving including graduated driver licensing (GDL) requirements for beginning drivers, cell phone and text messaging laws, high-visibility cell phone/text messaging enforcement, and general distraction laws. While these are notable results, they should not restrict the analysis from focusing on all distracted driver crashes. Agencies interested in infrastructure projects targeting distracted driving should focus on the lane departure and intersection risk maps. These results should be considered when developing projects and countermeasures at distracted driver risk sites. Ultimately, the focus crash type for this analysis is all distracted driving crashes.

Crash Tree and Focus Facility Type

After concluding that the distracted driving focus crash type should include all distracted driving crashes, VHB developed a crash tree to identify the roadway conditions and driver distraction types under which severe distracted driving crashes tend to occur most often. Figure 3 shows the crash tree. It is evident that the majority of KA crashes related to distracted driving took place in urban areas. Although most of these crashes occurred outside of junctions, a significant portion of these also happened within junctions. The primary cause of driver distractions was engaging in various other activities such as searching, eating, personal hygiene, and more. In instances where other distractions were involved, the crashes were predominantly single-vehicle crashes, followed by head-on and angle collisions. Note that,"Driver distracted by" is a vehicle-level variable and as multiple vehicles were involved in many crashes, there were multi-vehicle crashes where one of the drivers were not distracted. This resulted in "Not Distracted" outcome in this category.

[4] https://www.nhtsa.gov/book/countermeasures/countermeasures-work/distracted-driving

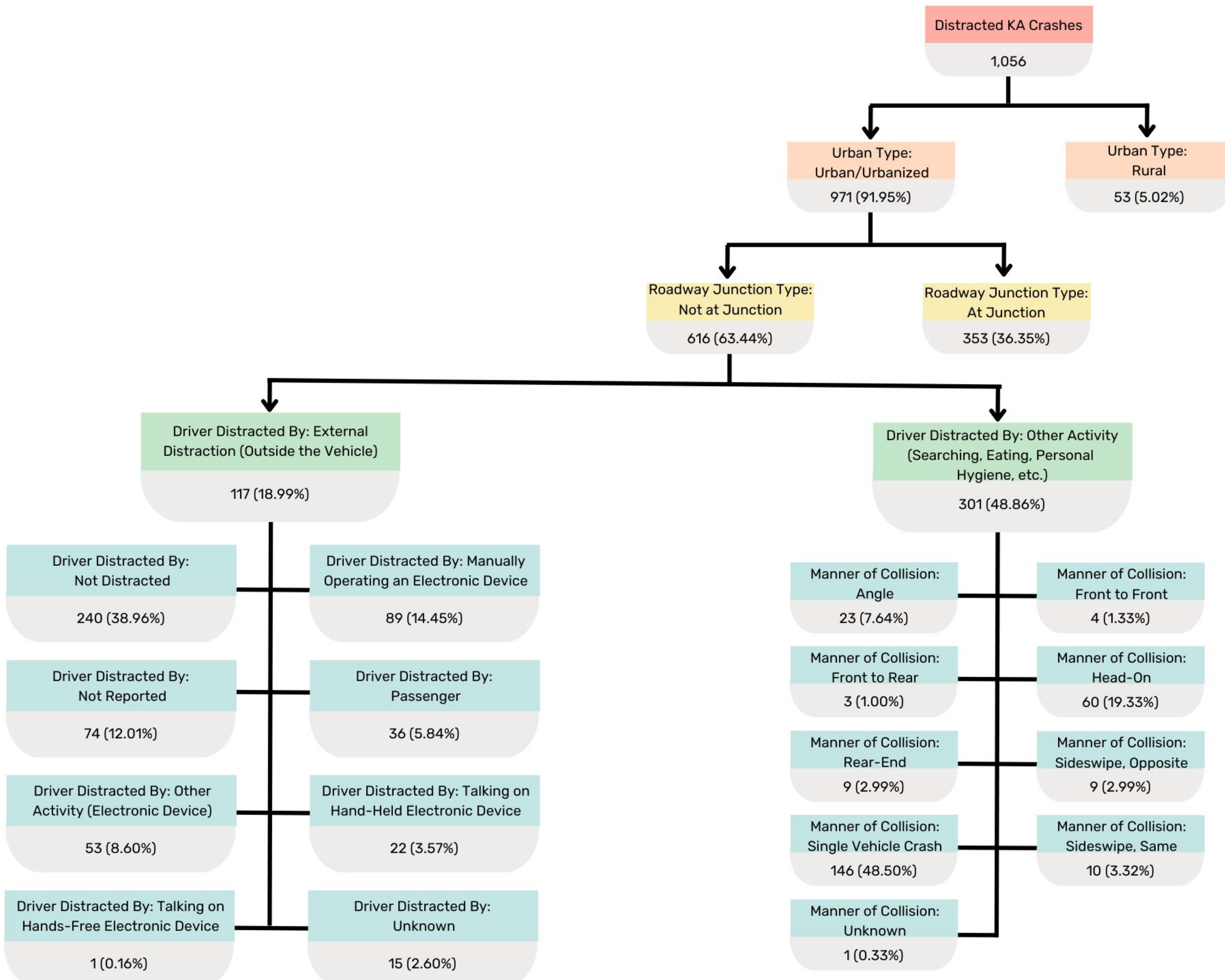

Figure 3. Crash tree summarizing KA distracted driving crashes in Massachusetts.

While the analysis above points towards some potential focus for this emphasis area (e.g., urban area, not at a junction, other distractions), distracted driving crashes are best addressed directly using educational campaigns. As a result, VHB recommends performing a town-based analysis of distracted driving crashes. This allows for the prioritization of towns for the reception of grants and encouragement for distracted driving 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 distracted driving-related 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 distracted driving-related 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 distracted driving-related KA crashes at location i.

β = vector of estimated parameters.

X_i = vector of independent variables that characterize location i and influence distracted driving-related 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 jurisdictions. Due to

---

[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 distracted driver 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. VHB then used spatial analysis to determine the total number of colleges and universities in each town.

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. VHB then aggregated these totals annual for each town and normalized against centerline mileage.

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, seatbelt use survey data at the county level, 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). 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. In the base model, VHB added variables that are not highly correlated one by one and observed their significance level and how it impacted the parameter estimates of other variables. Repeting this process resulted in a list of variables that significantly impact the dependent variable, but are not highly correlated among themselves. Although VHB considered all potential variables in this matrix, Table 2 shows the correlation matrix for the 12 variables (listed here) included in the final distracted driver model. Note the maximum correlation between any two variables is -0.58, below the standard value of 0.7, above which there are concerns of serial correlation.

1. Population density between 50 and 200 residents per square mile in the city or town.
2. Population density between 200 and 1000 residents per square mile in the city or town.
3. Population density greater than 1000 residents per square mile in the city or town.
4. Indicator that the town meets any two EJ criteria.
5. Indicator that the town meets all three EJ criteria.
6. Indicator that the proportion of centerline mileage that is Federal Functional Class Principal Arterial – Freeways & Expressways[7] is greater than 0.10.
7. Indicator that the proportion of centerline mileage that is Federal Functional Class Major Collector[8] is greater than 0.20.
8. Indicator that the annual distracted driving citations per centerline mile is greater than 0.25.
9. Indicator that the annual impaired driving citations per centerline mile is greater than 0.60.
10. Indicator that the proportion of unbelted drivers observed the residing county’s seatbelt survey is less than 80 percent.
11. Indicator that the proportion of licensed drivers aged 15 to 24 in the town is greater than 0.10.
12. Weighted average posted speed limit for known speed limit segments.

---

[7] Federal functional class 2.
[8] Federal functional class 5.

Table 2. Correlation Matrix of Input Variables.

Variables	Pop Density: 50-200	Pop Density: 200-1000	Pop Density: >1000	EJ-2	EJ-3	Functional Class 2	Functional Class 5	Impaired Citations	Distracted Citations	Unbelted survey	Licensed drivers-Young	Average Speed
Pop Density: 50-200	1.000											
Pop Density: 200-1000	-0.354	1.000										
Pop Density: >1000	-0.275	-0.582	1.000									
EJ-2	-0.155	0.011	0.228	1.000								
EJ-3	-0.116	-0.245	0.421	-0.137	1.000							
Functional Class 2	0.201	-0.097	-0.129	-0.013	-0.017	1.000						
Functional Class 5	0.154	0.078	-0.249	-0.142	-0.138	0.018	1.000					
Impaired Citations	-0.309	0.269	0.296	0.210	0.174	-0.087	-0.096	1.000				
Distracted Citations	-0.264	-0.090	0.459	-0.023	0.439	-0.065	-0.155	0.395	1.000			
Unbelted survey	-0.070	0.094	-0.004	0.005	0.082	0.038	0.047	0.119	0.077	1.000		
Licensed drivers-Young	-0.112	0.211	0.103	-0.047	-0.031	-0.098	-0.076	0.283	0.140	0.063	1.000	
Average Speed	0.298	0.121	-0.433	-0.134	-0.278	0.237	0.018	-0.161	-0.156	-0.002	-0.037	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 distracted driving 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 distracted driving-related crashes. Towns meeting two or three environmental justice criteria also experienced increasingly higher severe distracted driving-related crashes, indicating that these areas should be targeted for anti-distracted driving educational campaigns. The high proportion of freeway and expressway mileage suggests a correlation between high-speed and more severe outcomes for distracted driving crashes, while the high proportion of major collectors may be associated with a lower level of design, increased stops, and increased conflicts. Similarly, towns with higher average speed limits also experienced severe distracted driving-related crashes. The distracted driving citation metric provides some direct measure of the level of distracted driving in the town, while the impaired citation metrics provide an additional surrogate level of exposure for risky driving behaviors. Not surprisingly, towns with a lower level of seat belt use also demonstrated a higher likelihood of severe distracted driving-related crashes – as a low-level of seat belt use is a surrogate for elevated risk taking behavior by drivers. Towns with a higher proportion of younger population also experienced more of these crashes supporting a higher likelihood of distracted driving behavior among the younger population.

Table 3. Negative Binomial Count Regression Model Results.

Variable (Number)	Coefficient	Standard Error	z-value	P>|z|	95% Confidence Interval	
Intercept	-8.290	0.636	-13.038	<0.001	-9.537	-7.043
Population Density is between 50 and 200 Persons per Square Mile	0.658	0.337	1.954	0.051	-0.003	1.319
Population Density is between 200 and 1,000 Persons per Square Mile	1.050	0.317	3.313	<0.001	0.429	1.671
Population Density is greater than 1,000 Persons per Square Mile	1.198	0.338	3.542	<0.001	0.536	1.860
Town Meets Two Environmental Justice Criteria	0.349	0.109	3.194	<0.001	0.135	0.563
Town Meets Three Environmental Justice Criteria	0.886	0.154	5.774	<0.001	0.584	1.188
Proportion of Functional Class 2 (Freeway and Expressway) Mileage is 0.10 or greater	0.426	0.219	1.946	0.052	-0.003	0.855
Proportion of Functional Class 5 (Collectors) Mileage is 0.20 or greater	0.246	0.136	1.808	0.071	-0.021	0.513
Annual Impaired Driving Citations per Centerline Mile is greater than 0.60	0.301	0.119	2.521	0.012	0.068	0.534
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	0.218	0.111	1.968	0.049	0.000	0.436
Proportion of Driver Seat Belt Use Less than 0.80	0.247	0.090	2.748	0.006	0.071	0.423
Proportion of Younger Population (age 15-24) is Greater than 0.10	0.299	0.115	2.603	0.009	0.074	0.524
Weighted Average Posted Speed Limit for Known Speed Limit Segments	0.031	0.015	2.071	0.038	0.002	0.060
Natural Log of the product of Centerline Mileage and Years – Offset	1.000	NA	NA	NA	NA	NA
alpha	0.147					

Note: Number of observations = 349; AIC=1216, Log likelihood = -594.0165.

Conclusions and Recommendations

The purpose of this analysis is to identify town-level risk factors for fatal and serious injury distracted driving 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 Distracted Driver KA Crashes.

Risk Factor for Distracted Driver 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 1,000 Persons per Square Mile	0.66 if true; else
Population Density is greater than 1,000 Persons per Square Mile	1 if true; 0 otherwise.
Town Meets Two Environmental Justice Criteria	0.5 if true; else
Town Meets Three Environmental Justice Criteria	1 if true; 0 otherwise
Proportion of Functional Class 2 (Freeway and Expressway) Mileage is 0.10 or greater	1 if true; 0 otherwise
Proportion of Functional Class 5 (Collectors) Mileage is 0.20 or greater	1 if true; 0 otherwise
Annual Impaired Driving Citations per Centerline Mile is greater than 0.60	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 0.80	1 if true; 0 otherwise
Proportion of Younger Population (age 15-24) is Greater than 0.10	1 if true; 0 otherwise
Weighted Average Posted Speed Limit for Known Speed Limit Segments	Continuous from 0 to 1 for the range of values
Maximum potential score for a town:	**9.0**

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 51.6 percent (4.64 divided by 9.0).

Table 5. Example Risk Score Calculation for Distracted Driving 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 1,000 Persons per Square Mile	Population density of 750	0.66 if true; else	0.66
Population Density is greater than 1,000 Persons per Square Mile	Population density of 750	1 if true; 0 otherwise.	0
Town Meets Two Environmental Justice Criteria	Town meets two EJ criteria	0.5 if true; else	0.5
Town Meets Three Environmental Justice Criteria	Town meets two EJ criteria	1 if true; 0 otherwise	0
Proportion of Functional Class 2 (Freeway and Expressway) Mileage is 0.10 or greater	Proportion is 0.12	1 if true; 0 otherwise	1
Proportion of Functional Class 5 (Collectors) Mileage is 0.20 or greater	Proportion is 0.15	1 if true; 0 otherwise	0
Annual Impaired Driving Citations per Centerline Mile is greater than 0.60	Proportion is 0.50	1 if true; 0 otherwise	0
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	Proportion is 0.30	1 if true; 0 otherwise	1
Proportion of Driver Seat Belt Use Less than 0.80	Proportion is 0.91	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
Weighted Average Posted Speed Limit for Known Speed Limit Segments	Average speed of 38.3 mph and range of 26.5 to 51.2 mph	Continuous from 0 to 1 for the range of values	0.48
Total Risk Score:			4.64
Risk Percent Score (Out of 9.0):			51.6%

Generally, the model and risk factors produce results that were expected by the VHB and MassDOT team. Several factors point toward increased distracted driver exposure (e.g., higher population density, and younger person population), which is expected to be correlated with higher distracted driving crash frequency. 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 distracted driver population (e.g., lower seat belt use rate, impaired driving citations, and distracted driving citations) [9, 10]. Moreover, two risk factors point toward the correlation of infrastructure and distracted driving crash frequency: the presence of low-speed facilities (e.g., major collector) and historically underinvested infrastructure (correlated with EJ community status). Two more infrastructure-related risk factors correlated with higher severity distracted driving-related crashes are the presence of high-speed facilities (freeway, and expressway mileage) and higher average speed.

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

[9] Distracted Driving: A Literature Review. https://apps.ict.illinois.edu/projects/getfile.asp?id=9155

[10] Analyzing the Effect of Distractions and Impairments on Young Driver Safety Using Naturalistic Driving Study Data. https://ascelibrary.org/doi/10.1061/JTEPBS.TEENG-7265

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 distracted driving-related crashes, normalized risk scores range from 0.00095 to 0.785. The maximum value (0.785) received a percentile rank of 100 and other values received a percentile rank accordingly. For example, a town with a normalized risk score of 0.70, the calculated state percentile rank was 98.58, 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 distracted driving-related crashes. Note that, it may be more appropriate to utilize statewide ranking for towns, particularly for the ones that are in the MPOs/RPAs with few towns, as the results for these towns may be skewed. There are a total of 18 towns in the primary risk category (top 5 percent), that captured 17.28 percent of the severe distracted driving-related crashes. Similarly, there are 35 towns in the secondary risk category (next top 10 percent), which captured additional 26.44 percent of the severe distracted driving-related crashes. The towns that are in the primary risk category for severe distracted driving-related crashes are Holyoke, Fall River, Lenox, Freetown, Rockland, Leominster, Methuen, Revere, East Brookfield, West Bridgewater, Brockton, East Bridgewater, Bourne, Bridgewater, Haverhill, Worcester, Stoughton, and Lakeville. Five of these towns were under Boston Region MPO, and three of these were under Pioneer Valley Planning Commission. A higher number of secondary risk category towns for distracted driving-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	63.93%	78.51%	18	5.13%	17.28%
	Secondary Risk Site	52.94%	63.11%	35	9.97%	26.44%

Table 7. Distribution of Risk Towns by 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	62.24%	65.18%	2	6.25%	28.21%
	Secondary	45.10%	50.98%	3	9.38%	20.51%
Boston Region MPO	Primary	59.01%	70.59%	5	5.15%	11.28%
	Secondary	53.04%	58.02%	10	10.31%	31.71%
Cape Cod Commission	Primary	78.51%	78.51%	1	6.67%	13.21%
	Secondary	43.82%	46.87%	2	13.33%	11.32%
Central Massachusetts Regional Planning Commission	Primary	68.95%	71.56%	2	5.00%	21.70%
	Secondary	55.27%	62.86%	4	10.00%	19.81%
Franklin Regional Council of Governments	Primary	43.05%	47.16%	2	7.69%	0.00%
	Secondary	36.94%	40.21%	2	7.69%	31.58%
Martha's Vineyard Commission	Primary	52.41%	52.41%	1	14.29%	33.33%
	Secondary	46.66%	46.66%	1	14.29%	0.00%
Merrimack Valley Planning Commission	Primary	72.17%	72.17%	1	6.67%	28.79%
	Secondary	58.46%	63.93%	2	13.33%	31.82%
Montachusett Regional Planning Commission	Primary	47.44%	68.41%	2	9.09%	27.27%
	Secondary	39.53%	40.28%	2	9.09%	2.27%
Nantucket Planning and Economic Development Commission	Primary	31.17%	31.17%	1	100.00%	100.00%
	Secondary	N/A	N/A	0	0%	0%
Northern Middlesex Council of Governments	Primary	57.20%	57.20%	1	11.11%	32.50%
	Secondary	48.65%	48.65%	1	11.11%	12.50%
Pioneer Valley Planning Commission	Primary	53.63%	68.53%	3	6.98%	38.74%
	Secondary	45.63%	52.94%	4	9.30%	14.41%
Old Colony Planning Council	Primary	69.69%	69.69%	1	5.88%	8.54%
	Secondary	66.49%	68.12%	2	11.76%	39.02%
Southeastern Regional Planning and Economic Development District	Primary	70.39%	71.25%	2	7.41%	3.75%
	Secondary	61.60%	69.04%	3	11.11%	17.50%

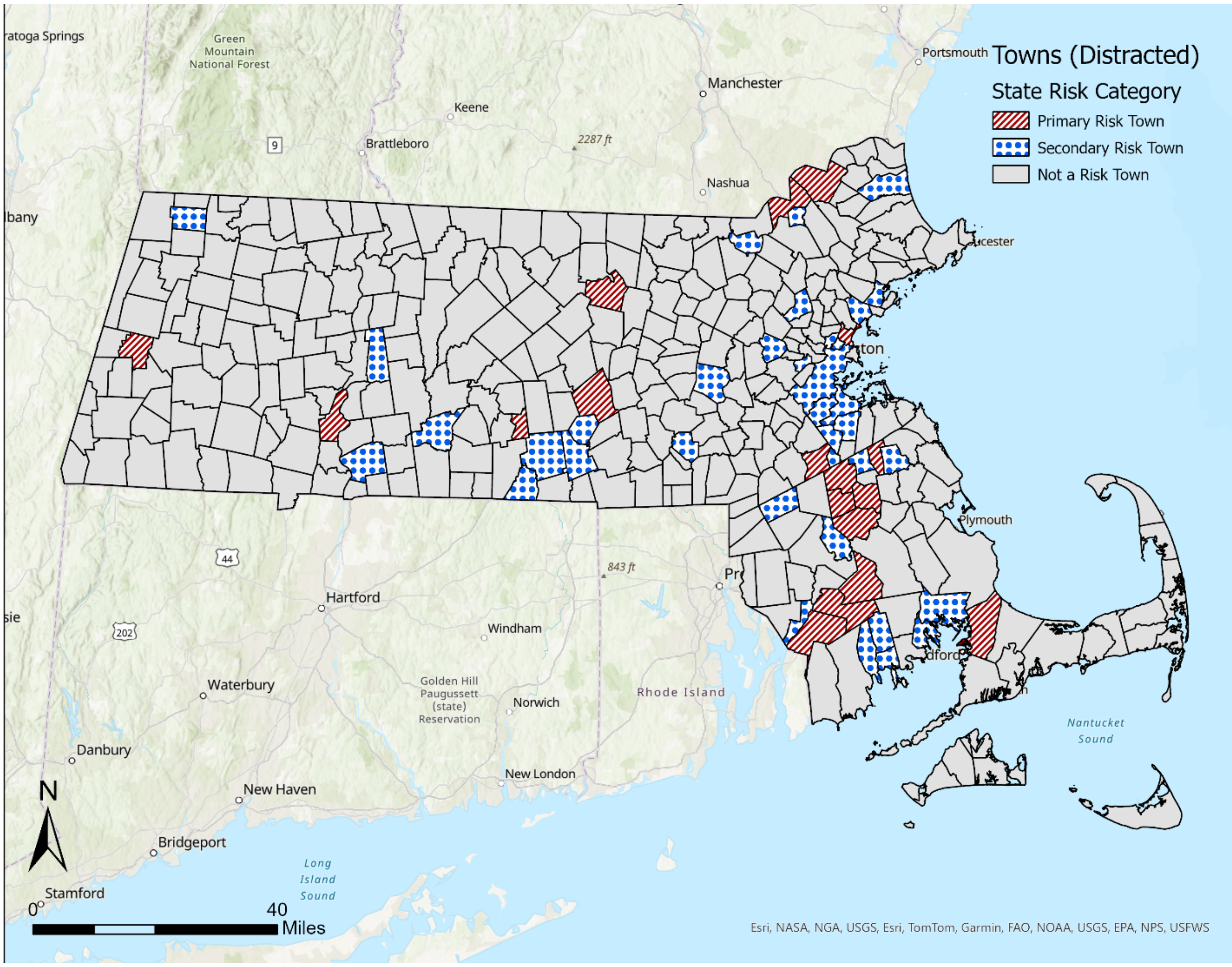

Figure 5. Map depicting the primary and secondary risk towns for severe distracted driving crashes, ranked statewide.

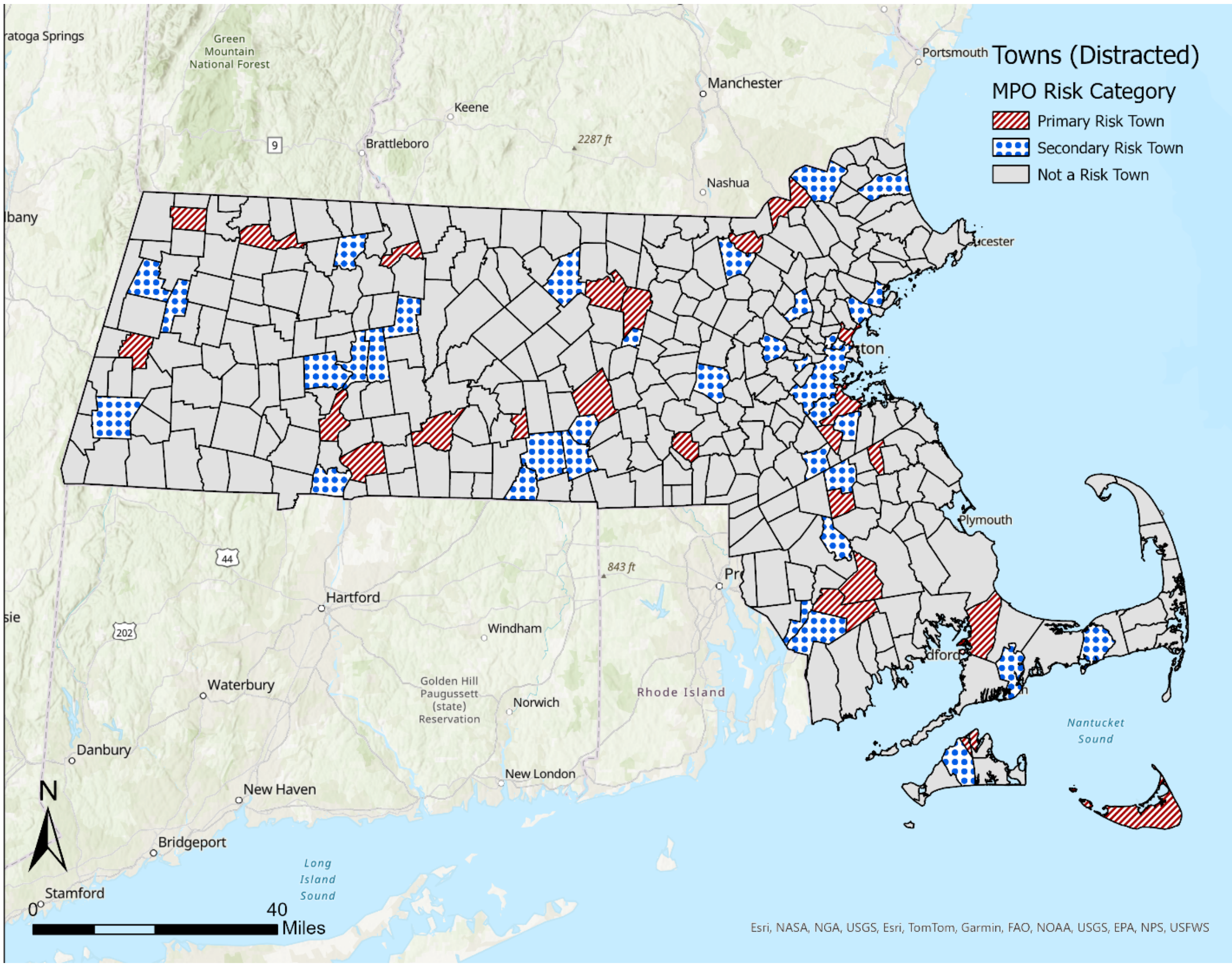

Figure 6. Map depicting the primary and secondary risk towns for severe distracted driving crashes, ranked by MPO.