MassDOT IMPACT Phase II - Identification of Risk Factors for SHSP Emphasis Areas

Occupant Protection (Unbelted Vehicle Occupants)

PREPARED FOR

Massachusetts Department of Transportation

PREPARED BY

REPORT DATE: AUGUST 2021

Purpose & Background

The Massachusetts Department of Transportation (MassDOT) was awarded a grant by the United States Department of Transportation (USDOT) under its Safety Data Initiative (SDI) competition. MassDOT's work under this grant includes the creation of a Safety Analysis Module in their online IMPACT tool. One feature in this module will be a mapping component which will include crash-based and systemic network screening maps. As part of this work, MassDOT is identifying focus crash types, facility types, and risk factors for their Strategic Highway Safety Plan (SHSP) Emphasis Areas. This report is part of the SDI project and summarizes the risk factor analysis performed for occupant protection crashes (i.e., involving an unbelted vehicle occupant). It also describes a method to identify risk factors using negative binomial regression, which is one potential method to identify risk factors under the SDI grant. Reports for other emphasis areas describe different methods used to adapt to the needs of those areas.

This analysis is a community-based analysis. This report summarizes the ability to assess a city or town's risk of experiencing a high frequency of unbelted fatalities and serious injuries. MassDOT and its safety partners can use these results to prioritize cities and towns for targeted education and enforcement campaigns. Further, the analysis identifies overrepresented roadway characteristics present among severe unbelted crashes which will be used to identify segment-level risk factors for further prioritization of segments. Additionally, this report includes specific information about historical unbelted crashes, which will point safety stakeholders towards other emphasis areas to identify sites where engineering countermeasures may reduce the frequency and severity of these crashes.

Focus Crash Types

As part of the 2018 Strategic Highway Safety Plan (SHSP)[1], Massachusetts identified Occupant Protection as an emphasis area due to 102 related highway fatalities occurring between 2012 and 2016, the third highest total for emphasis areas within the SHSP. Massachusetts has known issues with safety belt usage, as the SHSP points out[1]:

- Massachusetts's seat belt usage rate of 81.6 percent was one of the lowest in the United States in 2018.
- 78 percent of men were observed using safety belts, as opposed to 87 percent of women.
- 68 percent of pickup truck occupants were observed wearing seat belts, as opposed to 84 percent of passenger cars.

Given that unbelted vehicle occupants can be significantly harmed in any crash, MassDOT and VHB opted to not further identify a focus crash type, thus defining a focus crash type as any severe crash in which a vehicle occupant was not belted. VHB then used the MassDOT IMPACT Crash Data Portal to query for unbelted crashes using the following steps:

1. Using the Data Query and Visualization Tool, query person-level data to identify when the "prtc_sys_use_descr" field equals "None used – vehicle occupant" between the years 2013 and 2017.
2. Export resulting person-level data from IMPACT.
3. IMPACT exports person level data with the crash data tied to each person, so if there are 4 people tied to a crash, each person has the same crash-level data attributes but their person-level data attributes differ. To condense the person-level data export to crash-level, VHB used Microsoft

[1] https://www.mass.gov/doc/massachusetts-shsp-2018/download

Excel's "Remove Duplicates" function to remove duplicate crash entries with the "Crash Number" field.

4. Remove crashes with non-motorists.

This query resulted in a total of 47,119 unbelted persons in 33,298 crashes, 547 of which were fatal crashes and 2,008 were incapacitating injury crashes between 2013 and 2017. VHB compared the distribution of unbelted fatal and incapacitating injury (KA) crashes to the distribution of all unbelted crashes (KABCO) across a series of crash-level characteristics. There is some concern that unbelted behavior is underreported for less severe crashes, so there may be some bias in these results which is difficult to quantify. 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 unbelted crashes KA crashes was 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.

The following sections document these comparisons and highlight the key takeaways for systemic risk factor analysis. The goal of these sections is to summarize the typical characteristics of severe unbelted crashes. Attributes bolded in the tables are statistically overrepresented. Safety stakeholders can use this information to identify other emphasis areas for which engineering countermeasures should be considered (i.e., roadway departures, intersections) based on common crash types. Stakeholders can also use information about who is involved in unbelted crashes to target education and enforcement campaigns.

Manner of Collision and First Harmful Event

Table 1 shows the comparison of unbelted KA crashes and unbelted KABCO crashes distributed by manner of collision. Single-vehicle crashes represent the largest percentage of both unbelted KA and KABCO crashes; however, single-vehicle is over-represented in unbelted KA crashes (51.0 percent) compared to KABCO crashes (26.7 percent). Similarly, head-on crashes are over-represented, accounting for 4.6 percent of KABCO crashes compared to 12.6 percent of KA crashes. Both of these manner of collision results point towards unbelted KA crashes being correlated with lane departure crashes.

To further investigate this relationship, Table 2 compares the distribution of some notable first harmful event categories for unbelted KA and KABCO crashes. There is significant overrepresentation for fixed object crashes, including collisions with trees, utility poles, overturns, and collisions with barriers. This further supports the conclusion from Table 1 that there is a correlation between severe lane departure and unbelted crashes. As such, stakeholders interested in engineering countermeasures which could reduce severe unbelted crash frequency and severity should consider developing projects using the Lane Departure emphasis area risk factor map.

Table 1. Summary of unbelted crashes by manner of collision.

Manner of Collision	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Single Vehicle Crash	**1,304**	**51.0%**	**0.99%**	**8,896**	**26.7%**	**0.24%**
Angle	455	17.8%	0.76%	7,861	23.6%	0.23%
Head-On	**321**	**12.6%**	**0.66%**	**1,545**	**4.6%**	**0.12%**
Rear-End	310	12.1%	0.65%	8,163	24.5%	0.24%
Sideswipe, Same Direction	85	3.3%	0.35%	4,162	12.5%	0.18%
Sideswipe, Opposite Direction	46	1.8%	0.26%	1,239	3.7%	0.10%
Not Reported	18	0.7%	0.17%	222	0.7%	0.04%
Other, Unknown, or Reported but Invalid	13	0.5%	0.14%	772	2.3%	0.08%
Rear to Rear	2	0.1%	0.06%	399	1.2%	0.06%
Front to Front	1	0.0%	0.04%	13	0.0%	0.01%
Front to Rear	0	0.0%	0.00%	26	0.1%	0.02%

Table 2. Notable first harmful events for unbelted crashes.

Notable First Harmful Events[2]	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Collision with Tree	**382**	**15.0%**	**0.71%**	**1,605**	**4.8%**	**0.12%**
Collision with Utility Pole	**239**	**9.4%**	**0.58%**	**1,805**	**5.4%**	**0.12%**
Collision with Guardrail	**139**	**5.4%**	**0.45%**	**916**	**2.8%**	**0.09%**
Collision with Curb	**95**	**3.7%**	**0.37%**	**678**	**2.0%**	**0.08%**
Overturn/Rollover	**93**	**3.6%**	**0.37%**	**314**	**0.9%**	**0.5%**
Collision with Other	**65**	**2.5%**	**0.31%**	**549**	**1.6%**	**0.07%**
Collision with Median Barrier	**57**	**2.2%**	**0.29%**	**284**	**0.9%**	**0.05%**
Collision with Embankment	**49**	**1.9%**	**0.28%**	**324**	**1.0%**	**0.05%**

[2] This table does not include all crashes, just the crashes in the notable first harmful event categories.

Intersection Related and Junction Type

Table 3 details the relationship of KA crashes to specific intersection types. Table 3 indicates that unbelted KA crashes tend to be segment-based and less related to an intersection. This supports the results in Table 1 and Table 2 and suggests that more severe unbelted crashes tend to be related to lane departure, and potentially at higher speeds between intersections.

Table 3. Summary of unbelted crashes by junction type.

Junction Type	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Not at Junction	**1,781**	**69.7%**	**0.91%**	**20,829**	**62.6%**	**0.3%**
T-Intersection	277	10.8%	0.62%	4,612	13.9%	0.2%
Four-way Intersection	253	9.9%	0.59%	4,235	12.7%	0.2%
Y-Intersection	61	2.4%	0.30%	670	2.0%	0.1%
Driveway	50	2.0%	0.27%	1,218	3.7%	0.1%
Off-ramp	51	2.0%	0.28%	468	1.4%	0.1%
On-ramp	34	1.3%	0.23%	363	1.1%	0.1%
Not Reported	25	1.0%	0.19%	337	1.0%	0.1%
Traffic Circle	11	0.4%	0.13%	232	0.7%	0.0%
Unknown/Other	6	0.2%	0.10%	208	0.6%	0.0%
Five-point or More	6	0.2%	0.10%	101	0.3%	0.0%
Railway Grade Crossing	0	0.0%	0.00%	21	0.1%	0.0%
Reported but Invalid	0	0.0%	0.00%	4	0.0%	0.0%

Lighting Condition and Time of Day

Table 4 underscores that unbelted KA crashes are much more likely to occur during dark - no lighting conditions than KABCO crashes. Related to previous tables, this could be an indication of dark lighting conditions interacting with lane departure circumstances; darkness may limit visibility or complicate situations for drivers. As such, stakeholders interested in engineering countermeasures to target severe unbelted crash frequency and severity could consider strategies to improve visibility (e.g., signing and pavement marking enhancements). Table 5 reflects this trend, as 39.7 percent of KA unbelted crashes occur between 8 pm and 6 am, as opposed to 26.5 percent of KABCO unbelted crashes.

Table 4. Summary of unbelted crashes by lighting condition.

Lighting Condition	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Daylight	1,293	50.6%	0.99%	20,450	61.4%	0.27%
Dark - lighted roadway	**740**	**29.0%**	**0.90%**	**8,387**	**25.2%**	**0.24%**
Dark - roadway not lighted	**390**	**15.3%**	**0.71%**	**2,284**	**6.9%**	**0.14%**
Dusk	42	1.6%	0.25%	526	1.6%	0.07%
Dawn	59	2.3%	0.30%	871	2.6%	0.09%
Dark - unknown roadway lighting	23	0.9%	0.19%	297	0.9%	0.05%
Not reported	7	0.3%	0.10%	122	0.4%	0.03%
Other	1	0.0%	0.04%	86	0.3%	0.03%
Unknown	0	0.0%	0.00%	275	0.8%	0.05%

Table 5. Summary of unbelted crashes by hour of day.

Hour of Day	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
12 AM - Midnight	**133**	**5.2%**	**0.44%**	**1,084**	**3.3%**	**0.10%**
1 AM	**148**	**5.8%**	**0.46%**	**1,001**	**3.0%**	**0.09%**
2 AM	**99**	**3.9%**	**0.38%**	**849**	**2.5%**	**0.09%**
3 AM	**71**	**2.8%**	**0.33%**	**485**	**1.5%**	**0.07%**
4 AM	43	1.7%	0.25%	388	1.2%	0.06%
5 AM	39	1.5%	0.24%	422	1.3%	0.06%
6 AM	52	2.0%	0.28%	755	2.3%	0.08%
7 AM	104	4.1%	0.39%	1,447	4.3%	0.11%
8 AM	79	3.1%	0.34%	1,435	4.3%	0.11%
9 AM	72	2.8%	0.33%	1,388	4.2%	0.11%
10 AM	91	3.6%	0.37%	1,430	4.3%	0.11%
11 AM	104	4.1%	0.39%	1,649	5.0%	0.12%
12 PM - Noon	108	4.2%	0.40%	1,854	5.6%	0.13%
1 PM	127	5.0%	0.43%	1,811	5.4%	0.12%
2 PM	140	5.5%	0.45%	2,255	6.8%	0.14%
3 PM	147	5.8%	0.46%	2,459	7.4%	0.14%
4 PM	139	5.4%	0.45%	2,370	7.1%	0.14%
5 PM	138	5.4%	0.45%	2,337	7.0%	0.14%
6 PM	131	5.1%	0.44%	1,798	5.4%	0.12%
7 PM	106	4.1%	0.39%	1,475	4.4%	0.11%
8 PM	115	4.5%	0.41%	1,223	3.7%	0.10%
9 PM	**137**	**5.4%**	**0.45%**	**1,275**	**3.8%**	**0.11%**
10 PM	**111**	**4.3%**	**0.40%**	**1,097**	**3.3%**	**0.10%**
11 PM	**119**	**4.7%**	**0.42%**	**997**	**3.0%**	**0.09%**

Unknown	2	0.1%	0.06%	14	0.0%	0.01%

Person-Level and Vehicle-Level Data

VHB reviewed the person-level data to identify who was not wearing their seat belt in severe collisions. Of 3,432 unbelted persons involved in KA crashes, 2,319 (67.6 percent) were drivers and 1,113 (32.4 percent) were passengers. Additionally, 64.4 percent were reported as male and 32.8 percent were reported as female (2.8 percent were not reported). Table 6 further explores the gender gap in seat belt use in all KA crashes. Female drivers are more likely than males in KA crashes to be belted, and this proportion increases if there are other occupants in the car, particularly female occupants. Only 78 percent of male drivers in KA crashes were belted if they were the sole person in the vehicle or if they were in a car with only other men. The presence of a female in the car increased the likelihood of a male being belted during a KA crash from 78 percent to 86 percent.

Table 6. Number of vehicles by drivers seat belt use and driver and occupant genders.

Known Driver Protective System Used	Sole Occupant (% of Female or Male Drivers)	Male Occupants Only (% of Female or Male Drivers)	Female Occupants Only (% of Female or Male Drivers)	Both Gender Occupants (% of Female or Male Drivers)
Female Driver Belted	3,074 (85%)	516 (89%)	689 (92%)	259 (93%)
Female Driver Unbelted	522 (15%)	63 (11%)	57 (8%)	20 (7%)
Male Driver Belted	4,764 (78%)	618 (78%)	965 (86%)	263 (85%)
Male Driver Unbelted	1,351 (22%)	178 (22%)	155 (14%)	45 (15%)

Table 7 shows the distribution of unbelted persons by age. Note that almost half (48.6 percent) were persons aged 29 or younger, indicating there is a significant issue with safety belt usage among younger drivers. Additionally, persons aged 17-29 accounted for 42.2 percent of KA unbelted persons compared to only 29.1 percent of all persons in KA crashes. Table 8 provides a summary of the age of persons in the vehicle with unbelted KA persons. This is further supported by the average age gap between unbelted and other persons, which shows small differences in age for unbelted persons aged 17 to 29. VHB also looked for correlations between unbelted persons and the presence of a child in the car but found few crashes which involved such instances.

Table 7. Summary of unbelted persons in KA crashes by age.

Age Range	Number of KA Unbelted Persons	Percent of KA Unbelted Persons	Percent of Persons in All KA Crashes, 2013-2017
16 or younger	220	6.4%	7.0%
17-20	455	13.3%	9.3%
21-24	532	15.5%	9.6%
25-29	461	13.4%	10.2%
30-39	608	17.7%	15.0%
40-49	380	11.1%	13.4%
50-59	390	11.4%	12.7%
60-69	181	5.3%	7.8%
70-79	102	3.0%	3.7%
80-89	51	1.5%	1.7%
90 or older	9	0.3%	0.3%
Unknown	43	1.3%	9.3%

Table 8. Age of others in car with unbelted.

Age Range of Unbelted Person	Number of KA Unbelted Persons	Percent of Unbelted KA Persons in car with Teen (15-20)	Average Age Gap Between Unbelted, Other Occupants |Unbelted-Other|
16 or younger	220	9.2%	16.4
17-20	455	18.1%	3.6
21-24	532	5.7%	5.0
25-29	461	2.1%	9.9
30-39	608	1.7%	13.7
40-49	380	1.5%	15.1
50-59	390	1.0%	19.6
60-69	181	0.5%	19.3
70-79	102	0.0%	15.1
80-89	51	0.0%	8.4
90 or older	9	0.0%	38.7
Unknown	43	8.2%	N/A

Table 9 summarizes the distribution of these persons for passenger cars and light trucks. While passenger car occupants account for the majority (64.6 percent), it's notable that 19.6 percent of occupants are in light trucks, presumably safer vehicles in collisions; however, by not using safety belts the occupants make themselves vulnerable. Finally, VHB reviewed the distribution of the person data by number of occupants in a vehicle. Nearly half of persons (49.3 percent) were the sole occupant of the vehicle, 21.7 percent were in two-occupant vehicles, and 23.1 percent of persons were in vehicles with 3 or more occupants (the remaining balance of 5.9 percent of persons were in vehicles for which the number of occupants were unknown).

Table 9. Summary of unbelted persons in KA crashes by vehicle type.

Vehicle Type	Number of KA Unbelted Persons	Percent of KA Unbelted Persons[3]	Percent of Persons in KA Crashes
Light truck (van, mini-van, pickup, sport utility)	673	19.6%	20.6%
Passenger car	2,216	64.6%	70.6%

Crash-Level Linked Roadway Data

Crash data exported from MassDOT's IMPACT tool include linked roadway inventory data from the geocoding process. VHB reviewed these data to identify overrepresented roadway attributes which can be used as segment-level risk factors. Generally, the results in this section correlate with high-speed facilities. This is because unbelted drivers are at greater risk of severe injury when in a high-speed crash compared to a low-speed crash due to higher energies involved in the collision. This principle has led to FHWA encouraging States to consider the Safe System Approach to highway design and safety management[4].

Roadway Classification Characteristics

Table 10 summarizes the distribution of unbelted crashes by functional class. While urban minor arterials and rural major collectors account for the plurality of KA unbelted crashes (29.2 percent), it is notable that interstate and rural or urban principal arterials are overrepresented, with 12.1 percent of KA crashes each compared to 6.0 percent and 8.6 percent of KABCO crashes, respectively.

Table 10. Summary of unbelted crashes by functional class.

MassDOT Functional Class	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Interstate	**308**	**12.1%**	**0.64%**	**1,984**	**6.0%**	**0.13%**
Rural or urban principal arterial	**310**	**12.1%**	**0.65%**	**2,853**	**8.6%**	**0.15%**
Rural minor arterial or urban principal arterial	480	18.8%	0.77%	6,997	21.0%	0.22%
Urban minor arterial or rural major collector	746	29.2%	0.90%	9,468	28.4%	0.25%
Urban collector or rural minor collector	249	9.7%	0.59%	3,466	10.4%	0.17%
Local	319	12.5%	0.65%	6,175	18.5%	0.21%
Blank	143	5.6%	0.45%	2,355	7.1%	0.14%

Table 11 summarizes the distribution of unbelted crashes by annual average daily traffic (AADT). Note that the higher volume categories are where overrepresentation predominantly occurs, particularly at volumes of 30,000 vehicles per day and greater. These results are likely correlated with the functional class results presented in Table 10, as Interstates and Principal Arterials are the functional classes most likely to carry these higher volumes.

[3] This percentage reflects the proportion of all unbelted KA persons.
[4] https://safety.fhwa.dot.gov/zerodeaths/docs/FHWA_SafeSystem_Brochure_V9_508_200717.pdf.

Table 11. Summary of unbelted crashes by AADT.

AADT	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	468	18.3%	0.77%	7,963	23.9%	0.23%
1-499	71	2.8%	0.33%	870	2.6%	0.09%
500-1,999	220	8.6%	0.55%	3,077	9.2%	0.16%
2,000-4,999	375	14.7%	0.70%	4,817	14.5%	0.19%
5,000-9,999	390	15.3%	0.71%	5,588	16.8%	0.20%
10,000-14,999	261	10.2%	0.60%	3,544	10.6%	0.17%
15,000-19,999	149	5.8%	0.46%	2,208	6.6%	0.14%
20,000-29,999	133	5.2%	0.44%	1,692	5.1%	0.12%
30,000-39,999	66	2.6%	0.31%	654	2.0%	0.08%
40,000-59,999	**117**	**4.6%**	**0.41%**	**815**	**2.4%**	**0.08%**
60,000-99,999	**183**	**7.2%**	**0.51%**	**995**	**3.0%**	**0.09%**
100,000 or Greater	**122**	**4.8%**	**0.42%**	**1,075**	**3.2%**	**0.10%**

Table 12 summarizes the distribution of unbelted crashes by roadway jurisdiction. While the majority of severe unbelted crashes occurred on "Local" (City or Town Accepted) roads, unbelted crashes on MassDOT roads are overrepresented among KA crashes compared to all crashes. Again, this correlates with the findings in the previous tables, as MassDOT maintains a large proportion of the State's high-speed, high-volume facilities, where high-energy collisions occur.

Table 12. Summary of unbelted crashes by roadway jurisdiction.

Jurisdiction	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	143	5.6%	0.45%	2,355	7.1%	0.14%
City or Town accepted road	1,397	54.7%	0.98%	21,835	65.6%	0.26%
Department of Conservation and Recreation	46	1.8%	0.26%	426	1.3%	0.06%
Federal Institutional	1	0.0%	0.04%	1	0.0%	0.00%
Massachusetts Department of Transportation	**941**	**36.8%**	**0.95%**	**8,188**	**24.6%**	**0.24%**
Massachusetts Port Authority	1	0.0%	0.04%	35	0.1%	0.02%
Private	0	0.0%	0.00%	4	0.0%	0.01%
State college or university	0	0.0%	0.00%	6	0.0%	0.01%
State Institutional	0	0.0%	0.00%	1	0.0%	0.00%
State Park or Forest	0	0.0%	0.00%	6	0.0%	0.01%
Unaccepted by city or town	26	1.0%	0.20%	438	1.3%	0.06%

US Air Force	0	0.0%	0.00%	2	0.0%	0.00%
US Army	0	0.0%	0.00%	1	0.0%	0.00%

Table 13 summarizes unbelted crashes by access control on the roadway. Note that while most crashes occurred on roadways with no access control, the proportion of KA unbelted crashes on fully access-controlled roadways is significantly higher than all unbelted crashes. Once again, this correlates with high-speed facilities on which unbelted persons in crashes are more likely to experience a severe injury.

Table 13. Summary of unbelted crashes by access control.

Access Control	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	143	5.6%	0.45%	2,355	7.1%	0.14%
Full Control	**505**	**19.8%**	**0.79%**	**3,263**	**9.8%**	**0.16%**
No Control	1,850	72.4%	0.88%	26,924	80.9%	0.22%
Partial Control	57	2.2%	0.29%	756	2.3%	0.08%

Table 14 shows that for crashes with reported posted speed limits, there is notable overrepresentation at 40 miles per hour and higher, further supporting the correlation between severe injury probability and higher-speed roadways.

Table 14. Summary of unbelted crashes by posted speed limit.

Posted Speed Limit	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	1,222	47.8%	0.99%	18,918	56.8%	0.27%
0 MPH	8	0.3%	0.11%	119	0.4%	0.03%
15 MPH	0	0.0%	0.00%	9	0.0%	0.01%
20 MPH	20	0.8%	0.17%	310	0.9%	0.05%
25 MPH	70	2.7%	0.32%	1,356	4.1%	0.11%
30 MPH	210	8.2%	0.54%	3,698	11.1%	0.17%
35 MPH	193	7.6%	0.52%	2,658	8.0%	0.15%
40 MPH	**184**	**7.2%**	**0.51%**	**1,870**	**5.6%**	**0.13%**
45 MPH	**156**	**6.1%**	**0.47%**	**1,319**	**4.0%**	**0.11%**
50 MPH	69	2.7%	0.32%	709	2.1%	0.08%
55 MPH	**111**	**4.3%**	**0.40%**	**887**	**2.7%**	**0.09%**
60 MPH	**20**	**0.8%**	**0.17%**	**95**	**0.3%**	**0.03%**
65 MPH	**292**	**11.4%**	**0.63%**	**1,348**	**4.0%**	**0.11%**
99 MPH	0	0.0%	0.00%	2	0.0%	0.00%

Cross-Section Characteristics

The linked roadway data characteristics include some fields which convey the cross-sectional characteristics of the road segment the crash was geocoded to. Table 15 summarizes the distribution of unbelted crashes by right shoulder width. While the majority of crashes occurred on roadway segments with shoulders 2 feet wide or less, there is overrepresentation for KA crashes when the shoulder width is 3 feet or wider compared to unbelted crashes of all severities. This is another correlation with high-speed facilities, which are typically designed with relatively wide shoulders.

Table 15. Summary of unbelted crashes by right shoulder width.

Right Shoulder Width	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	155	6.1%	0.47%	2,473	7.4%	0.14%
0'	1,007	39.4%	0.97%	17,557	52.7%	0.27%
1'-2'	**651**	**25.5%**	**0.86%**	**7,329**	**22.0%**	**0.23%**
3'-4'	130	5.1%	0.43%	1,485	4.5%	0.11%
5'-6'	76	3.0%	0.34%	791	2.4%	0.08%
7'-8'	88	3.4%	0.36%	913	2.7%	0.09%
Wider than 8'	**448**	**17.5%**	**0.75%**	**2,750**	**8.3%**	**0.15%**

Table 16 shows the breakdown of crashes by the presence of curbing along the roadway. Both “None” and “Right Side Only” were found to be statistically overrepresented for KA unbelted crashes compared to unbelted crashes of all severities. Notably, curbing is less likely to be present on high-speed, higher classification roadways.

Table 16. Summary of unbelted KA crashes by curbing on the roadside.

Curbing Type	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	189	7.4%	0.52%	2,777	8.3%	0.15%
All Curbs (Divided Highway)	7	0.3%	0.10%	58	0.2%	0.02%
Along Median Only	0	0.0%	0.00%	3	0.0%	0.01%
Both Sides	806	31.5%	0.92%	15,728	47.2%	0.27%
Left Side Only	107	4.2%	0.40%	1,294	3.9%	0.11%
None	**1,276**	**49.9%**	**0.99%**	**11,676**	**35.1%**	**0.26%**
Right Side Only	**170**	**6.7%**	**0.49%**	**1,762**	**5.3%**	**0.12%**

Table 17 shows the distribution of crashes by median type. While most unbelted crashes (both KA and all severity) occurred on roads with no median, crashes on roads with median barrier present were found to be overrepresented for KA unbelted crashes (19.9 percent of KA crashes) compared to all severity unbelted crashes (10.6 percent). Once again, median barrier presence is another feature correlated with high-speed, high classification facilities.

Table 17. Summary of unbelted crashes by median type.

Median Type	Unbelted KA Crashes			Unbelted KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	147	5.8%	0.46%	2,447	7.3%	0.14%
Curbed	88	3.4%	0.36%	1,368	4.1%	0.11%
None	1,803	70.6%	0.90%	25,776	77.4%	0.23%
Positive Barrier - Flexible	0	0.0%	0.00%	6	0.0%	0.01%
Positive Barrier - Rigid	**90**	**3.5%**	**0.36%**	**782**	**2.3%**	**0.08%**
Positive Barrier - Semi-Rigid	**134**	**5.2%**	**0.44%**	**1,236**	**3.7%**	**0.10%**
Positive Barrier - Unspecified	**285**	**11.2%**	**0.62%**	**1,537**	**4.6%**	**0.11%**
Unprotected	8	0.3%	0.11%	146	0.4%	0.04%

Focus Facility Types

Traditional systemic analysis involves the identification of focus facility types – specific functional class, traffic volume, speed limit, and geometric characteristic combinations on which agencies should focus risk factor analysis and countermeasure installation for a focus crash type. However, given the nature of typical countermeasures for occupant protection (targeted education and enforcement), MassDOT and VHB opted to keep the facility type more generic for this analysis (i.e., no focus facility type). As such, the focus will be at the town-level, and each road segment within a town will receive the same town-based risk score.

Risk Factor Analysis

This section describes the methodology, data, and results of the risk factor analysis for unbelted crashes in Massachusetts.

Methodology

Based on discussions with MassDOT, VHB used a negative binomial count regression modeling approach to identify community-level characteristics that are associated with higher frequencies of unbelted-related KA crashes. Negative binomial regression is a commonly used crash prediction method in transportation safety as it applies to over-dispersed count data, a common characteristic of crash data (i.e., the variance exceeds the mean of the observed data). The dependent variable in the model is the number of unbelted KA crashes between 2013 and 2017, making a count model appropriate for the data. The functional form of the negative binomial regression model is shown in Figure 3.[5]

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

Figure 3. Equation. Negative binomial regression functional form.

[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

Where:

$e^{\varepsilon i}$ = gamma distributed error term, where $e^{\varepsilon i}$ is gamma-distributed with a mean equal to one and variance equal to α.

λ_i = expected number of unbelted-related KA crashes at location i.

β = vector of estimated parameters.

X_i = vector of independent variables that characterize location i and influence unbelted-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 noted this could lead to misunderstanding or outright disregard for potentially noteworthy results.[6]

Data

VHB used ArcGIS and Microsoft Excel 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. MassDOT provided VHB with various sources of data, as described in the following sections.

City and Town Data

VHB obtained city and town data from the MassDOT Open Data Portal (https://www.mass.gov/info-details/massgis-data-municipalities). These data were geospatial and included the name of the city/town, boundary, and area in terms of square mileage. These data served as the base modeling data for the analysis – all other data were joined to these data using town name.

Crash Data

Given the analysis was being done at the town level, VHB did not need to perform a spatial join of the crash data. VHB queried unbelted crashes from MassDOT's IMPACT Crash Data Portal as described previously in this report. VHB then joined total unbelted KA crashes for the years 2013 through 2017 to the town data using the city/town name field in the crash data.

Roadway Data

VHB downloaded the Massachusetts statewide roadway inventory as of November 2020, available at https://massdot.maps.arcgis.com/home/item.html?id=10a2766a607345928c6a66ffb479c937. 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 used these data to generate the total centerline mileage, proportion of mileage for functional classifications, and average posted speed limits for each city/town.

[6] Hauer, E. (2004). The harm done by tests of significance. *Accident Analysis & Prevention*, *36*(3), 495-500.

Driver License Data

MassDOT provided driver's license data by age and town for the years 2011 through 2015. VHB used driver's license data for the years 2013-2015 to align with the crash data for this analysis. VHB then calculated the average number of licensed drivers by age group for each town.

School Location Data

VHB obtained primary and secondary school location data from the Massachusetts Bureau of Geographic Information (MassGIS) open data portal (https://massgis.maps.arcgis.com/home/item.html?id=a7ccf184af704f5fbd17d69f935554d6). VHB only included schools with grades 10 through 12 for the purposes of this analysis.

College and University Data

VHB accessed college and university location data from the U.S. Department of Homeland Security's Homeland Infrastructure Foundation-Level Data (HIFLD) repository https://hifld-geoplatform.opendata.arcgis.com/datasets/colleges-and-universities-campuses/explore?location=13.091953%2C0.317215%2C2.75). 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.

Alcohol Sales License Data

MassDOT provided statewide geolocated liquor license data as of November 2019 which identifies the location of active liquor licenses. These data come from the Massachusetts Alcoholic Beverages Control Commission (ABCC). VHB used the Spatial Join tool in ArcGIS to identify the distance to the nearest licensed establishment for a roadway segment.

Environmental Justice Data

Massachusetts Bureau of Geographic Information (MassGIS) developed a geographic information systems (GIS) layer based on 2010 United States Census data for three indicators of high environmental justice (EJ) need neighborhoods:

- **Proportion of non-white population**: Block groups with a proportion of non-white population greater than 25 percent are flagged in this category.
- **Limited English proficiency (LEP) households**: Block groups with a proportion of limited English-speaking households greater than 25 percent are flagged in this category.
- **Median household income**: Block groups with a median household income below $40,673 are flagged in this category.

VHB incorporated these data by indicating which indicators are present within a town or city.

Seat Belt Usage Data

VHB and MassDOT obtained the *2019 Massachusetts Safety Belt Usage Observation Study* report[7] which summarizes the results of seatbelt surveys across the State. The study divided the State into seven regions by County:

- Region 1 – Berkshire, Franklin, Hampshire, and Hampden Counties.
- Region 2 – Worcester County.
- Region 3 – Middlesex County.
- Region 4 – Essex County.
- Region 5 – Suffolk and Norfolk County.
- Region 6 – Bristol County.
- Region 7 – Plymouth and Barnstable Counties.
- Unsampled – Dukes and Nantucket Counties.

Table 18 summarizes the percentage of occupants which were observed to be belted during the study.

Table 18. Summary of percent unbelted occupants in the sample.

Region	Percent of Occupants Unbelted in Sample
Region 1	20.94%
Region 2	23.98%
Region 3	17.36%
Region 4	15.62%
Region 5	16.02%
Region 6	20.54%
Region 7	17.54%

Results

This section describes the results of the negative binomial regression modeling effort. Table 19 documents the results of the final model. VHB reviewed the correlation between independent variables – the maximum correlation between any two variables was 0.55. Additionally, for indicator variables, the minimum number of observations for which a given indicator variable was true was 23 observations. The model predicts the total number of KA unbelted crashes over the five-year study period from 2013 to 2017. To account for mileage and years, the model is offset by the natural log of mile-years, the product of total centerline mileage, and years of crashes (5) for each town.

[7] https://www.mass.gov/doc/2019-massachusetts-safety-belt-usage-observation-survey/download.

Table 19. Negative binomial count regression model results.

Variable (Number)	Coefficient	Standard Error	z-value	P>|z|	95% Confidence Interval	
Natural Log of the product of Centerline Mileage and Years – Offset	1.0	N/A	N/A	N/A	N/A	N/A
All three EJ indicators present in City/Town	0.401	0.136	2.95	0.003	0.134	0.668
Proportion of Licensed Drivers in City/Town 29 or Younger	4.443	1.298	3.42	0.001	1.897	6.989
Proportion of Centerline Mileage in the City/Town that is Interstate is Greater than 0.06[8]	0.407	0.140	2.90	0.004	0.132	0.683
Proportion of Centerline Mileage in the City/Town that is Rural or Urban Principal Arterial is Greater than 0.05[9]	0.418	0.097	4.32	<0.001	0.228	0.607
Population Density is between 500 and 2,000 Persons per Square Mile	0.633	0.087	7.31	<0.001	0.463	0.802
Population Density is between 2,000 and 3,500 Persons per Square Mile	0.808	0.132	6.12	<0.001	0.549	1.066
Population Density is greater than 3,500 Persons per Square Mile	0.554	0.168	3.29	0.001	0.224	0.884
Proportion of City/Town Citations for Unbelted is greater than 0.025	0.473	0.075	6.34	<0.001	0.327	0.619
Weighted Average Posted Speed Limit for Known Speed Limit Segments is greater than 35 Miles per Hour	0.264	0.079	3.36	0.001	0.110	0.418
Constant	-6.281	0.260	-24.19	<0.001	-6.790	-5.772
Alpha	0.180	0.031			0.129	0.252

Note: Number of observations = 347; Log likelihood = -837.24905; Pseudo R2 = 0.0952; LR chi2(9) = 176.14; Prob > chi2 = <0.0001.

The negative binomial regression model described in Table 19 predicts the number of KA unbelted crashes expected in a town. The independent variables include a mix of roadway, population, citation, and environmental justice variables. The correlation with the presence of all three EJ indicators in a town suggests the need to target hard-hit communities with education and enforcement campaigns. The positive correlation between the proportion of drivers aged 29 or younger and KA crash frequency is supported by the crash data summary which found that nearly half of unbelted persons in severe crashes

[8] Functional Classification = 1

[9] Functional Classification = 2

were aged 29 or younger. The population density results suggest higher density cities and towns are expecting more severe unbelted crashes (for reference, the average population density for the sample is 1,280 and median is 539). For citation data, the towns with higher rates of unbelted citations are a surrogate measure for unbelted driving frequency. Finally, the functional classification and weighted average posted speed limit variables suggest a logical correlation with higher speeds – if the town has higher speed roads, they are expected to have higher energy collisions, which are especially dangerous for unbelted drivers. Notably, those functional classifications were found to be overrepresented for KA unbelted crashes. These findings are supported by the overrepresented roadway linked crash data attributes.

Conclusions and Recommendations

The purpose of this analysis is to identify town-level risk factors for fatal and serious injury unbelted crashes in Massachusetts, as well as segment level risk factors for further prioritization for enforcement and other strategies. VHB recommends that MassDOT disregard the coefficients from the negative binomial regression results in Table 19. Instead, MassDOT should assign binary risk factor scores if a characteristic is present on a focus segment (i.e., a 0 if it is not present and a 1 if it is present). Table 20 summarizes the proposed town-level risk factors for Occupant Protection. MassDOT can then calculate the risk score for each town and, for visualization purposes, apply that same score to each road segment in the town. MassDOT can then apply the segment-level risk factor scoring summarized in Table 21 to the roadway segments for additional risk scoring derived from the overrepresented crash-level linked roadway data characteristics. This will result in a two-tiered scoring scheme – segments will have a baseline level of risk which comes from the risk of the town – then risk variance is added due to the segment-level characteristics.

Table 20. Town-level risk factors for unbelted crashes.

Town Risk Factors for Unbelted Crashes	Scoring
Number of EJ Indicators for City/Town	1.0 if three; 0 otherwise
Proportion of Licensed Drivers 29 or Younger	0 if less than 0.08; 0.25 if 0.08 to 0.14; 0.50 if 0.14 to 0.20; 0.75 if 0.20 to .26, 1.0 if greater than 0.26
Proportion of Centerline Mileage which is Interstate	0 if less than 0.06; 0.5 if 0.06 to 0.07; 0.625 if 0.07 to 0.08; 0.75 if 0.08 to 0.09; 0.875 if 0.09 to 0.10; 1.0 if greater than 0.10
Proportion of Centerline Mileage which is Rural or Urban Principal Arterial	0 if less than 0.05; 0.5 if 0.05 to 0.08; 0.6 if 0.08 to 0.11; 0.7 if 0.11 to 0.14; 0.8 if 0.14 to 0.17; 0.9 if 0.17 to 0.20; 1 if greater than 0.20
Population Density (persons per square mile)	0 if less than 500; 0.33 if greater than 3,500; 0.67 if between 500 and 2,000; 1.0 if between 2,000 and 3,500
Proportion of City/Town Citations for Unbelted Violations	1.0 if greater than 0.025; 0 otherwise
Weighted Average Posted Speed Limit in Town	1.0 if greater than 35; 0 otherwise
Seat Belt Usage	1.0 if Worcester County; 0.5 if Berkshire, Franklin, Hampshire, Hampden, or Bristol Counties; 0 otherwise

Table 21. Segment-level risk factors for unbelted crashes.

Segment Risk Factors for Unbelted Crashes	Scoring
Functional Class	0.5 if rural or urban principal arterial; 1 if interstate, 0 otherwise
AADT	0.5 if 100,000 or greater; 0.75 if 40,000 to 59,999; 1 if 60,000 to 99,999; 0 otherwise
Posted Speed Limit	0.5 if 40 to 55 MPH; 1 if 60 to 70 MPH; 0 otherwise
Curbing	0.5 if right side only; 1 if none; 0 otherwise
Right Shoulder Width	0.5 if three feet to eight feet; 1 if wider than eight feet; 0 otherwise
Median Type	1 if barrier is present; 0 otherwise

Table 22 provides an example application of the risk factors on a hypothetical segment. To provide context for these risk factor scores in relation to other emphasis areas as part of the SDI grant analysis, MassDOT can normalize the cumulative score of the risk factors by divided by the total possible score, which in this case is 14. This would generate a risk score of 100 percent if all risk factors for the facility type are present. Under this approach, the risk score for the example segment in Table 22 is 0.257, or 25.7 percent.

Since the crash type assessment underscored the prevalence of lane departure crash characteristics, VHB recommends that MassDOT only use these results for targeted education and enforcement campaigns and point local agencies interested in engineering solutions towards the lane departure emphasis area risk sites.

Table 22. Example risk score calculations for unbelted crashes.

Variable	Segment Characteristic	Risk Factor	Risk Score
Number of EJ Indicators for City/Town	2	1.0 of three; 0 otherwise	0
Proportion of Licensed Drivers 29 or Younger	0.16	0 if less than 0.08; 0.25 if 0.08 to 0.14; 0.50 if 0.14 to 0.20; 0.75 if 0.20 to .26, 1.0 if greater than 0.26	0.50
Proportion of Centerline Mileage which is Interstate	0.05	0 if less than 0.06; 0.5 if 0.06 to 0.07; 0.625 if 0.07 to 0.08; 0.75 if 0.08 to 0.09; 0.875 if 0.09 to 0.10; 1.0 if greater than 0.10	0
Proportion of Centerline Mileage which is Rural or Urban Principal Arterial	0.11	0 if less than 0.05; 0.5 if 0.05 to 0.08; 0.6 if 0.08 to 0.11; 0.7 if 0.11 to 0.14; 0.8 if 0.14 to 0.17; 0.9 if 0.17 to 0.20; 1 if greater than 0.20	0.60
Population Density (persons per square mile)	231	0 if less than 500; 0.33 if greater than 3,500; 0.67 if between 500 and 2,000; 1.0 if between 2,000 and 3,500	0
Proportion of City/Town Citations for Unbelted Violations	0.03	1.0 if greater than 0.025; 0 otherwise	1.0
Weighted Average Posted Speed Limit in Town	37	1.0 if greater than 35; 0 otherwise	1.0
County	Suffolk	1.0 if Worcester County; 0.5 if Berkshire, Franklin, Hampshire, Hampden, or Bristol Counties; 0 otherwise	0
Functional Class	Urban Minor Arterial	0.5 if rural or urban principal arterial; 1 if interstate, 0 otherwise	0
AADT	32,000	0.5 if 100,000 or greater; 0.75 if 40,000 to 59,999; 1 if 60,000 to 99,999; 0 otherwise	0
Posted Speed Limit	45 MPH	0.5 if 40 to 55 MPH; 1 if 60 to 70 MPH; 0 otherwise	0.5
Curbing	Both Sides of Road	0.5 if right side only; 1 if none; 0 otherwise	0
Right Shoulder Width	2 feet	0.5 if three feet to eight feet; 1 if wider than eight feet; 0 otherwise	0
Median Type	Unprotected	1 if barrier is present; 0 otherwise	0
		Total Risk Score:	3.6
		Normalized Risk Score:	0.257

In order to finalize the data, MassDOT dissolved the road inventory based on the risk factor inputs to generate uniform corridors. These corridors can be used to identify targeted safety improvement projects. Additionally, MassDOT identified the closest address geospatially to the beginning and end of each corridor as reference points. The addresses include the street number, street name, and town of the address. Note these are the closest addresses geospatially, so the reference address may not be on the same street as the corridor itself, and the beginning and end reference address may be the same. MassDOT continues to provide mileposts for MassDOT routes and encourages users to use both mileposts and address points as references.

The segments are then ranked at both the Statewide and MPO levels using the normalized risk score and the percentile of score 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%. The risk categories were then determined using the computed ranks. For example, segments ranked in the top 5 percentile (95 through 100) were categorized as "Primary Risk Site," segments ranked in the next 10 percentile (85 through 95) were categorized as "Secondary Risk Site," and the remaining sites 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% or next 10% may not be equal to 5 or 10%. This is a byproduct of the weak ranking approach used. Table 23 and Table 24 show the distribution of segments with the normalized risk score (presented as percentages) across these categories for Statewide and MPO rankings, respectively.

VHB also scored and ranked towns to display as a secondary map for this emphasis area in IMPACT. The scoring was done using the town-level risk factors in Table 17 and ranked using the methodology described in the previous section.

Table 23. Statewide risk categories.

State	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored State Segments
MA	Primary Risk Site	37.5%	78.57%	17,245	5.3%
	Secondary Risk Site	32.14%	37.14%	38,355	11.7%

Table 24. Distribution of risk sites by MPO.

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored MPO Segments
Berkshire Regional Planning Commission	Primary Risk Site	35.71%	56.96%	771	5.68%
	Secondary Risk Site	31.21%	35.54%	1,613	11.89%
Boston Region MPO	Primary Risk Site	33.93%	74.43%	6,005	5.44%
	Secondary Risk Site	29.79%	33.43%	11,779	10.67%
Cape Cod Commission	Primary Risk Site	31.57%	61.43%	1,508	5.06%
	Secondary Risk Site	28%	31.07%	10,032	33.69%
Central Massachusetts Regional Planning Commission	Primary Risk Site	40.5%	78%	1,849	6.01%
	Secondary Risk Site	36.29%	40%	3,771	12.25%
Franklin Regional Council of Governments	Primary Risk Site	36.93%	64.29%	395	5.08%
	Secondary Risk Site	33.36%	36.43%	854	10.98%
Martha's Vineyard Commission	Primary Risk Site	29.79%	33.36%	176	5.22%
	Secondary Risk Site	22.64%	26.21%	606	17.98%
Merrimack Valley Planning Commission	Primary Risk Site	39.29%	75%	1,226	7.65%
	Secondary Risk Site	32.14%	38.71%	2,130	13.29%
Montachusett Regional Planning Commission	Primary Risk Site	42.29%	73.93%	1,103	6.64%
	Secondary Risk Site	35.71%	41.79%	2,256	13.57%
Nantucket Planning and Economic Development Commission	Primary Risk Site	17.9%	25%	447	18.40%
	Secondary Risk Site	10.71%	14.29%	1,982	81.60%
Northern Middlesex Council of Governments	Primary Risk Site	29.79%	65.5%	1,068	8.21%
	Secondary Risk Site	26.21%	29.14%	1,038	7.98%
Pioneer Valley Planning Commission	Primary Risk Site	39.86%	78%	1,608	5.19%
	Secondary Risk Site	35.14%	39.64%	4,243	13.70%
Old Colony Planning Council	Primary Risk Site	32.71%	67.29%	1,044	5.19%
	Secondary Risk Site	29.14%	32.14%	2,759	13.71%
	Primary Risk Site	42.29%	78.57%	1,663	5.09%

MPO	Risk Category	Minimum Normalized Risk Score Percentage	Maximum Normalized Risk Score Percentage	Number of Segments	Percent of Scored MPO Segments
Southeastern Regional Planning and Economic Development District	Secondary Risk Site	36.93%	41.07%	3,543	10.84%