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

Distracted Driving

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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 distracted driving crashes. 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 relatively high frequency of distracted driving fatalities and serious injuries. MassDOT and its safety partners can use these results to prioritize cities and towns for targeted education campaigns. Further, the analysis identified overrepresented roadway characteristics present among severe distracted driving crashes which will be used to identify segment-level risk factors for further prioritization of segments. Additionally, this report includes specific information about historical distracted driving crashes, which will point safety stakeholders towards other emphasis areas which can be used to install engineering countermeasures for those crashes.

Focus Crash Types

As part of the 2018 SHSP[1], Massachusetts identified Driver Distraction as an emphasis area due to 30 related highway fatalities occurring between 2012 and 2016. Massachusetts has known issues with distracted driving, as the SHSP points out[1]:

- Fatalities from crashes in which at least one driver was distracted account for 8.1 percent of highway fatalities in Massachusetts in 2016.
- The majority of reported driver distractions were inattention and carelessness.

Given that distracted driving in many types of crashes, 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 driver was reported as being distracted. VHB then used the MassDOT IMPACT Crash Data Portal to query for distracted driving crashes using the following steps:

1. Using the Data Query and Visualization Tool, query vehicle-level data to identify when the "Driver Distracted By" field equals one of the following attributes between the years 2015 and 2017[2]:
    a. Manually Operating an Electronic Device.
    b. Talking on Hands-Free Electronic Device.
    c. Talking on Hand-Held Electronic Device.
    d. Other Activity, Electronic Device.
    e. Other Activity (Searching, Eating, Personal Hygiene, etc.).

[1] https://www.mass.gov/doc/massachusetts-shsp-2018/download
[2] The "Driver Distracted By" was determined by MassDOT and VHB to only be reliable from 2015 onward.

f. Passenger.

g. External Distraction (Outside the Vehicle).

2. Export resulting vehicle-level data from IMPACT.

   a. IMPACT exports vehicle-level data with the crash data tied to each vehicle in a crash, so if there are 2 vehicles in a crash, each vehicle has the same crash-level data attributes but their vehicle-level data attributes differ. To condense the vehicle-level data export to crash-level, VHB used Microsoft Excel's "Remove Duplicates" function to remove duplicate crash entries with the "Crash Number" field.

This query resulted in a total of 31,522 crashes with a reportedly distracted driver, of which 41 were fatal crashes and 605 were incapacitating injury crashes between 2015 and 2017. VHB compared the distribution of distracted driving fatal and incapacitating injury (KA) crashes to the distribution of all distracted driving crashes (KABCO) across a series of crash-level characteristics. 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 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. Attributes identified as being overrepresented are bolded in the tables. The goal of these sections is to summarize the typical characteristics of severe distracted driving crashes. 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 distracted driving crashes to target education and enforcement campaigns.

Manner of Collision and First Harmful Event

Table 1 shows the comparison of distracted driving KA crashes and distracted driving KABCO crashes distributed by manner of collision. While rear-end crashes account for the plurality of all distracted driving crashes (42.7 percent of KABCO crashes), single-vehicle crashes account for the plurality of KA crashes (36.4 percent), and are notably overrepresented, considering single-vehicle crashes only account for 24.4

percent of all distracted driving crashes. The other notably overrepresented manner of collision is head-on, which accounts for 14.4 percent of KA distracted driving crashes, compared to only 3.5 percent of all distracted driving crashes. Both of these results point towards correlation with lane and roadway departure crashes.

To further investigate this relationship, Table 2 compares the distribution of some notable first harmful event categories for distracted driving KA and KABCO crashes. While the plurality of KA crashes involve a collision with a motor vehicle in traffic, there is overrepresentation for fixed object crashes, including collisions with trees and utility poles. This further supports the conclusion from Table 1 that there is a correlation between severe lane departure and distracted driving crashes. As such, stakeholders interested in engineering countermeasures which could reduce severe distracted driving crash frequency and severity should consider developing projects using the Lane Departure emphasis area risk factor map. There is also notable overrepresentation among pedestrian and pedalcycle collisions, which towns can target specifically using the risk factor results for the Bicycle and Pedestrian emphasis areas.

Table 1. Summary of distracted driving crashes by manner of collision.

Manner of Collision	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Single vehicle crash	**235**	**36.4%**	**1.89%**	**7,694**	**24.4%**	**0.24%**
Rear-end	159	24.6%	1.69%	13,455	42.7%	0.28%
Angle	106	16.4%	1.46%	5,730	18.2%	0.22%
Head-on	**93**	**14.4%**	**1.38%**	**1,108**	**3.5%**	**0.10%**
Sideswipe, same direction	28	4.3%	0.80%	2,152	6.8%	0.14%
Sideswipe, opposite direction	15	2.3%	0.59%	945	3.0%	0.10%
Not reported	6	0.9%	0.38%	87	0.3%	0.03%
Other/Unknown/Reported but Invalid	3	0.5%	0.27%	137	0.4%	0.04%
Rear-to-rear	1	0.2%	0.15%	190	0.6%	0.04%
Front to Front	0	0.0%	0.00%	10	0.0%	0.01%
Front to Rear	0	0.0%	0.00%	14	0.0%	0.01%

Table 2. Notable first harmful events for distracted driving crashes.

Notable First Harmful Events[3]	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Collision with motor vehicle in traffic	334	51.7%	1.97%	20,263	64.3%	0.27%
Collision with pedestrian	**72**	**11.1%**	**1.24%**	**429**	**1.4%**	**0.07%**
Collision with tree	**58**	**9.0%**	**1.12%**	**1,080**	**3.4%**	**0.10%**
Collision with parked motor vehicle	44	6.8%	0.99%	3,130	9.9%	0.17%
Collision with utility pole	38	5.9%	0.93%	2,268	7.2%	0.15%
Collision with guardrail	13	2.0%	0.55%	575	1.8%	0.08%
Collision with pedalcycle (bicycle, tricycle, unicycle, pedal car)	**12**	**1.9%**	**0.53%**	**118**	**0.4%**	**0.03%**
Collision with curb	11	1.7%	0.51%	589	1.9%	0.08%
Collision with other	10	1.5%	0.49%	314	1.0%	0.06%
Collision with unknown fixed object	10	1.5%	0.49%	779	2.5%	0.09%

Intersection Related and Junction Type

Table 3 details the relationship of KA crashes to specific intersection types. Table 3 indicates that distracted driving 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 distracted driving crashes tend to be related to lane departure, and potentially at higher speeds between intersections.

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

Table 3. Summary of distracted driving crashes by junction type.

Junction Type	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Not at junction	396	61.3%	1.92%	18,597	59.0%	0.28%
T-intersection	110	17.0%	1.48%	5,071	16.1%	0.21%
Four-way intersection	92	14.2%	1.37%	4,906	15.6%	0.20%
Y-intersection	15	2.3%	0.59%	751	2.4%	0.09%
Driveway	11	1.7%	0.51%	754	2.4%	0.09%
On-ramp	6	0.9%	0.38%	372	1.2%	0.06%
Not reported	5	0.8%	0.34%	144	0.5%	0.04%
Off-ramp	3	0.5%	0.27%	417	1.3%	0.06%
Five-point or more	3	0.5%	0.27%	108	0.3%	0.03%
Traffic circle	3	0.5%	0.27%	284	0.9%	0.05%
Unknown/Other	2	0.3%	0.22%	101	0.3%	0.03%
Railway grade crossing	0	0.0%	0.00%	17	0.1%	0.01%
Reported but invalid	0	0.0%	0.00%	0	0.0%	0.00%

Lighting Condition and Time of Day

Table 4 underscores that distracted driving KA crashes are much more likely to occur during dark conditions than KABCO crashes, no matter if lighting is present or not. 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 distracted driving 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 distracted driving crashes occur between 8 pm and 6 am, as opposed to 26.5 percent of KABCO distracted driving crashes.

Table 4. Summary of distracted driving crashes by lighting condition.

Lighting Condition	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Daylight	388	60.1%	1.93%	22,061	70.0%	0.26%
Dark - lighted roadway	**172**	**26.6%**	**1.74%**	**6,378**	**20.2%**	**0.23%**
Dark - roadway not lighted	**54**	**8.4%**	**1.09%**	**1,520**	**4.8%**	**0.12%**
Dusk	12	1.9%	0.53%	853	2.7%	0.09%
Dawn	11	1.7%	0.51%	379	1.2%	0.06%
Dark - unknown roadway lighting	5	0.8%	0.34%	210	0.7%	0.05%
Not reported	3	0.5%	0.27%	56	0.2%	0.02%
Other	1	0.2%	0.15%	30	0.1%	0.02%
Unknown	0	0.0%	0.00%	35	0.1%	0.02%

Table 5. Summary of distracted driving crashes by hour of day.

Hour of Day	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
12 AM - Midnight	18	2.8%	0.65%	578	1.8%	0.08%
1 AM	18	2.8%	0.65%	604	1.9%	0.08%
2 AM	14	2.2%	0.57%	507	1.6%	0.07%
3 AM	7	1.1%	0.41%	321	1.0%	0.06%
4 AM	8	1.2%	0.44%	210	0.7%	0.05%
5 AM	11	1.7%	0.51%	294	0.9%	0.05%
6 AM	15	2.3%	0.59%	666	2.1%	0.08%
7 AM	28	4.3%	0.80%	1,527	4.8%	0.12%
8 AM	28	4.3%	0.80%	1,703	5.4%	0.13%
9 AM	30	4.6%	0.83%	1,475	4.7%	0.12%
10 AM	26	4.0%	0.77%	1,464	4.6%	0.12%
11 AM	19	2.9%	0.66%	1,769	5.6%	0.13%
12 PM - Noon	35	5.4%	0.89%	1,991	6.3%	0.14%
1 PM	33	5.1%	0.87%	1,977	6.3%	0.14%
2 PM	52	8.0%	1.07%	2,337	7.4%	0.15%
3 PM	42	6.5%	0.97%	2,453	7.8%	0.15%
4 PM	50	7.7%	1.05%	2,522	8.0%	0.15%
5 PM	42	6.5%	0.97%	2,558	8.1%	0.15%
6 PM	37	5.7%	0.91%	1,838	5.8%	0.13%
7 PM	29	4.5%	0.81%	1,236	3.9%	0.11%
8 PM	22	3.4%	0.71%	1,016	3.2%	0.10%
9 PM	**32**	**5.0%**	**0.85%**	**953**	**3.0%**	**0.10%**
10 PM	26	4.0%	0.77%	850	2.7%	0.09%
11 PM	23	3.6%	0.73%	667	2.1%	0.08%
Unknown	1	0.2%	0.15%	6	0.0%	0.01%

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 for distracted driving crashes.

Roadway Classification Characteristics

Table 6 summarizes the distribution of distracted driving crashes by functional class. The plurality of crashes were on “urban minor arterial or rural major collector” roads (29.6 percent), with crashes on “rural minor arterial or urban principal arterial” a close second (26.0 percent). However, crashes on “urban collector or rural minor collector” were found to be statistically overrepresented for KA distracted driving crashes compared to distracted driving crashes of all severities.

Table 6. Summary of distracted driving crashes by functional class.

MassDOT Functional Class	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Urban minor arterial or rural major collector	191	29.6%	1.80%	9,952	31.6%	0.26%
Rural minor arterial or urban principal arterial	168	26.0%	1.73%	8,048	25.5%	0.25%
Urban collector or rural minor collector	**86**	**13.3%**	**1.34%**	**3,205**	**10.2%**	**0.17%**
Local	73	11.3%	1.25%	4,417	14.0%	0.20%
Rural or urban principal arterial	58	9.0%	1.12%	2,683	8.5%	0.16%
Blank	41	6.3%	0.96%	2,038	6.5%	0.14%
Interstate	29	4.5%	0.81%	1,179	3.7%	0.11%

Table 7 summarizes the distribution of distracted driving crashes by annual average daily traffic (AADT). While none of these categories were found to be statistically overrepresented, note that the AADT range from 15,000 vehicles per day to 59,999 vehicles per day accounted for 20.7 percent of KA crashes, a larger proportion than the 18.5 percent of distracted driver crashes of all severities.

Table 7. Summary of distracted driving crashes by AADT.

AADT	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	166	25.7%	1.72%	9,013	28.6%	0.25%
1-499	5	0.8%	0.34%	192	0.6%	0.04%
500-1999	29	4.5%	0.81%	1,189	3.8%	0.11%
2000-4999	104	16.1%	1.45%	4,693	14.9%	0.20%
5000-9999	118	18.3%	1.52%	5,683	18.0%	0.22%
10000-14999	69	10.7%	1.22%	3,688	11.7%	0.18%
15000-19999	56	8.7%	1.11%	2,617	8.3%	0.16%
20000-29999	42	6.5%	0.97%	1,889	6.0%	0.13%
30000-39999	13	2.0%	0.55%	645	2.0%	0.08%
40000-59999	23	3.6%	0.73%	685	2.2%	0.08%
60000-99999	10	1.5%	0.49%	521	1.7%	0.07%
100,000 or Greater	11	1.7%	0.51%	707	2.2%	0.08%

Table 8 summarizes the distribution of distracted driving crashes by roadway jurisdiction. The majority of distracted driving crashes (both KA and all severities) occurred on "city or town accepted roads". None of these attributes were found to be statistically overrepresented for KA distracted driver crashes.

Table 8. Summary of distracted driving crashes by roadway jurisdiction.

Jurisdiction	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
City or Town accepted road	428	66.3%	1.86%	20,762	65.9%	0.27%
Massachusetts Department of Transportation	168	26.0%	1.73%	8,087	25.7%	0.25%
Blank	41	6.3%	0.96%	2,040	6.5%	0.14%
Department of Conservation and Recreation	4	0.6%	0.31%	278	0.9%	0.05%
Unaccepted by city or town	4	0.6%	0.31%	324	1.0%	0.06%
Private	1	0.2%	0.15%	8	0.0%	0.01%
Federal Park or Forest	0	0.0%	0.00%	1	<0.1%	0.00%
Massachusetts Port Authority	0	0.0%	0.00%	8	0.0%	0.01%
Other Federal	0	0.0%	0.00%	1	<0.1%	0.00%
State college or university	0	0.0%	0.00%	8	0.0%	0.01%
State Institutional	0	0.0%	0.00%	2	<0.1%	0.00%
State Park or Forest	0	0.0%	0.00%	3	<0.1%	0.01%

Table 9 summarizes distracted driving crashes by access control on the roadway. Most crashes occurred on roadways with no access control. There is slight overrepresentation for crashes on fully access controlled roadways, but the overrepresentation was not statistically significant.

Table 9. Summary of distracted driving crashes by access control.

Access Control	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	41	6.3%	0.96%	2,037	6.5%	0.14%
Full Access Control	54	8.4%	1.09%	2,001	6.3%	0.14%
No Access Control	538	83.3%	1.47%	26,540	84.2%	0.21%
Partial Access Control	13	2.0%	0.55%	944	3.0%	0.10%

Table 10 shows the distribution of distracted driving crashes by posted speed limit. While no individual posted speed limits were found to be statistically overrepresented, it is notable that crashes on roads with a posted speed limit from 40 to 65 MPH accounted for 24.6 percent of distracted driver KA crashes, compared to just 19.4 percent of distracted driver crashes of all severities.

Table 10. Summary of distracted driving crashes by posted speed limit.

Posted Speed Limit	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	313	48.5%	1.97%	15,964	50.6%	0.28%
0 MPH	2	0.3%	0.22%	128	0.4%	0.04%
10 MPH	0	0.0%	0.00%	2	0.0%	0.00%
15 MPH	0	0.0%	0.00%	7	0.0%	0.01%
20 MPH	4	0.6%	0.31%	294	0.9%	0.05%
25 MPH	26	4.0%	0.77%	1,576	5.0%	0.12%
30 MPH	84	13.0%	1.32%	4,167	13.2%	0.19%
35 MPH	58	9.0%	1.12%	3,270	10.4%	0.17%
40 MPH	63	9.8%	1.17%	2,465	7.8%	0.15%
45 MPH	37	5.7%	0.91%	1,456	4.6%	0.12%
50 MPH	19	2.9%	0.66%	720	2.3%	0.08%
55 MPH	14	2.2%	0.57%	662	2.1%	0.08%
60 MPH	1	0.2%	0.15%	49	0.2%	0.02%
65 MPH	25	3.9%	0.76%	758	2.4%	0.09%
99 MPH	0	0.0%	0.00%	4	0.0%	0.01%

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 11 summarizes the distribution of distracted driving 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 distracted driving crashes of all severities (21.7 percent of KA distracted driver crashes compared to 18.3 percent of all distracted driver crashes).

Table 11. Summary of distracted driving crashes by right shoulder width.

Right Shoulder Width	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Blank	43	6.7%	0.98%	2,107	6.7%	0.14%
0'	300	46.4%	1.96%	15,751	50.0%	0.28%
1'-2'	163	25.2%	1.71%	7,911	25.1%	0.24%
3'-4'	41	6.3%	0.96%	1,686	5.3%	0.13%
5'-6'	29	4.5%	0.81%	1,027	3.3%	0.10%
7'-8'	24	3.7%	0.74%	990	3.1%	0.10%
Wider than 8'	46	7.1%	1.01%	2,050	6.5%	0.14%

Table 12 shows the breakdown of crashes by the presence of curbing along the roadway. KA distracted driving crashes on roads with no curbing were found to be nearly statistically overrepresented compared to distracted driving crashes of all severities.

Table 12. Summary of distracted driving KA Crashes by curbing on the roadside.

Curbing Type	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	269	41.6%	1.94%	11,758	37.3%	0.27%
Both Sides	255	39.5%	1.92%	14,208	45.1%	0.28%
Blank	52	8.0%	1.07%	2,420	7.7%	0.15%
Right Side Only	36	5.6%	0.90%	1,715	5.4%	0.13%
Left Side Only	33	5.1%	0.87%	1,335	4.2%	0.11%
All Curbs (Divided Highway)	1	0.2%	0.15%	85	0.3%	0.03%
Along Median Only	0	0.0%	0.00%	1	0.0%	0.00%

Table 13 shows the distribution of crashes by median type. While most distracted driving crashes (both KA and all severity) occurred on roads with no median, crashes on roads with median barrier present were found to be slightly overrepresented for KA distracted driving crashes (9.6 percent) compared to all severity distracted driving crashes (8.4 percent).

Table 13. Summary of distracted driving crashes by median type.

Median Type	Distracted Driving KA Crashes			Distracted Driving KABCO Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	524	81.1%	1.54%	25,360	80.5%	0.22%
Blank	41	6.3%	0.96%	2,080	6.6%	0.14%
Positive Barrier - Unspecified	30	4.6%	0.83%	1,067	3.4%	0.10%
Positive Barrier - Semi-Rigid	26	4.0%	0.77%	945	3.0%	0.10%
Curbed	15	2.3%	0.59%	1,307	4.1%	0.11%
Positive Barrier - Rigid	6	0.9%	0.38%	615	2.0%	0.08%
Unprotected	4	0.6%	0.31%	136	0.4%	0.04%
Positive Barrier - Flexible	0	0.0%	0.00%	10	0.0%	0.01%
Raised Median	0	0.0%	0.00%	2	0.0%	0.00%

Distracted Drivers

This section attempts to describe who engages in distracted driving behavior. The descriptions come from two sources – an annual survey of seat belt and cell phone usage by the University of Massachusetts, and a review of drivers and persons involved in distracted driving crashes.

Cell Phone Usage Survey

The University of Massachusetts Traffic Safety Research Program publishes an annual summary of observed driver cell phone usage, which is collected as part of the team's annual seat belt usage survey[4]. Education and public messaging campaigns should review the findings of that study for additional

[4] University of Massachusetts Traffic Safety Research Program. (2019). 2019 Massachusetts Driver Cell Phone Use Observation Findings. University of Massachusetts, Amherst, MA.

information about who the campaign should target to reduce distracted driving behaviors. The findings of the 2019 survey include:

- Male and female drivers had a similar level of cell-phone use, with female drivers slightly more likely to be observed using a phone, at 5.0 percent compared to 4.6 percent of male drivers.
- Compared to 2018, the percent of teen drivers observed using a cell phone increased from 5.0 percent to 7.1 percent, adult drivers observed using a cell phone increased from 4.3 percent to 5.1 percent, and observed use by elder drivers slightly decreased.
- Usage in sport-utility vehicles (SUVs) increased from 3.7 percent in 2018 to 5.1 percent in 2019. The vehicle categories with the highest observed usage rates were pickup trucks (5.3 percent) and passenger style commercial vehicles (6.2 percent).
- 5.3 percent of drivers without a passenger were observed using a cell phone, compared to only 1.7 percent of drivers with a passenger.
- Statewide, there was little variance in observed usage, as the lowest observed rate was 3.5 percent in Worcester County and the highest observed rate was 5.7 percent in Middlesex County.

Distracted Drivers in Crashes

VHB reviewed vehicle- and person-level crash data from IMPACT for crashes involving distracted drivers to summarize the characteristics of drivers involved in distracted driving crashes. Between 2015 and 2017, there were 33,027 drivers reported to be distracted at the time of the crash. Table 14 shows that the plurality of distracted drivers (30.4 percent of KABCO crashes and KA crashes) are aged 20-29. Distracted drivers aged 30-49 are overrepresented among KA crashes, accounting for 37.7 percent of KA crashes compared to 31.0 percent of KABCO crashes.

Table 14. Summary of distracted drivers by age.

Driver Age	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes		All Drivers in KABCO Crashes
	Total	Percentage	Total	Percentage	Percentage
Blank/Unknown/Other	6	0.9%	491	1.5%	9.8%
14-19	57	8.5%	3,897	11.8%	7.0%
20-24	120	17.9%	5,574	16.9%	12.0%
25-29	84	12.5%	4,445	13.5%	11.0%
30-39	135	20.1%	5,732	17.4%	16.7%
40-49	118	17.6%	4,507	13.6%	14.6%
50-59	73	10.9%	4,073	12.3%	14.2%
60-69	44	6.5%	2,515	7.6%	8.7%
70-79	24	3.6%	1,214	3.7%	4.1%
80-89	9	1.3%	522	1.6%	1.7%
90-Plus	2	0.3%	57	0.2%	0.2%

Table 15 summarizes the types of distractions engaging the driver at the time of the crash. The most common type of distraction for both KA and KABCO crashes was “other” activities, such as searching, eating, or engaging in personal hygiene. This activity is also slightly overrepresented for KA crashes.

Table 15. Summary of driver distractions.

Driver Distracted By	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes	
	Total	Percentage	Total	Percentage
External Distraction (Outside the Vehicle)	136	20.2%	7,971	24.1%
Manually Operating an Electronic Device	128	19.0%	6,633	20.1%
Other Activity (Searching, Eating, Personal Hygiene, etc.)	293	43.6%	13,049	39.5%
Other Activity, Electronic Device	43	6.4%	2,605	7.9%
Passenger	48	7.1%	1,784	5.4%
Talking on Hand-Held Electronic Device	18	2.7%	759	2.3%
Talking on Hands-Free Electronic Device	6	0.9%	226	0.7%

Table 16 summarizes the distracted drivers by the States they are licensed in. By far, the majority of drivers are from Massachusetts, and these drivers are slightly overrepresented in KA crashes compared to KABCO crashes (91.5 percent to 89.6 percent, respectively).

Table 16. Summary of distracted drivers by state of license.

Driver License State	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes	
	Total	Percentage	Total	Percentage
Massachusetts	615	91.5%	29,595	89.6%
New Hampshire	8	1.2%	749	2.3%
Rhode Island	7	1.0%	587	1.8%
Connecticut	9	1.3%	415	1.3%
Blank/Unknown	13	1.9%	599	1.8%
Other States	20	3.1%	1,082	3.2%

Table 17 summarizes distracted drivers by the number of occupants in the vehicle. While the majority of drivers in KA and KABCO crashes were the sole occupant of the vehicle, distracted drivers with passengers were overrepresented in KA crashes. This is likely related to the presence of multiple people being in the vehicle increasing the likelihood that someone in the vehicle gets seriously injured in a crash.

Table 17. Summary of distracted drivers by vehicle occupants.

Number of Vehicle Occupants	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes	
	Total	Percentage	Total	Percentage
Not Reported	24	3.6%	1,670	5.1%
1 Occupant (Driver)	474	70.5%	25,797	78.1%
2 Occupants (Driver and One Passenger)	104	15.5%	3,987	12.1%
3 or More Occupants	70	10.4%	1,573	4.8%

Per Table 18, the majority of distracted drivers in crashes were operating passenger cars in both KA (75.7 percent) and KABCO (78.8 percent) crashes. There is notable overrepresentation for motorcycle drivers (4.2 percent of KA drivers compared to 0.5 percent of KABCO drivers), but this is expected given the common overrepresentation of motorcycle drivers in KA crashes.

Table 18. Summary of distracted drivers by vehicle type.

Vehicle Type	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes		All Drivers in KABCO Crashes
	Total	Percentage	Total	Percentage	Percentage
Blank/Unknown	0	0%	33	0.1%	0.2%
All-Terrain Vehicle	1	0.1%	6	<0.1%	<0.1%
Bus (Seats 16 or more, including driver)	0	0%	71	0.2%	0.4%
Bus (seats 9-15, including driver)	3	0.4%	52	0.2%	0.2%
Light Truck (van, mini-van, pickup, sport utility)	113	16.8%	5,798	17.6%	21.4%
Low Speed Vehicle	0	0%	4	<0.1%	<0.1%
Moped	2	0.3%	35	0.1%	0.1%
Motor Home/Recreational Vehicle	1	0.1%	5	<0.1%	<0.1%
Motorcycle	28	4.2%	165	0.5%	0.8%
Not Reported	0	0%	64	0.2%	1.2%
Other, e.g. Farm Equipment	4	0.6%	88	0.3%	0.4%
Passenger Car	509	75.7%	26,023	78.8%	71.6%
Reported but Invalid	0	0%	14	<0.1%	<0.1%
Single-Unit Truck (2-axle, 6-tires)	6	0.9%	225	0.7%	1.0%
Single-Unit Truck (3-or-more axles)	1	0.1%	45	0.1%	0.3%
Snowmobile	0	0%	0	0%	<0.1%
Tractor/Doubles	0	0%	5	<0.1%	<0.1%
Tractor/Semi-Trailer	2	0.3%	129	0.4%	0.9%
Tractor/Triples	0	0%	4	<0.1%	<0.1%
Truck Tractor (bobtail)	0	0%	5	<0.1%	<0.1%
Truck/Trailer	2	0.3%	139	0.4%	0.8%
Unknown Heavy Truck, Cannot Classify	0	0%	117	0.4%	0.5%

Finally, Table 19 summarizes the distribution of distracted drivers by reported gender. Comparing distracted drivers to all drivers, it appears male drivers are overrepresented in distracted driving crashes. Further, male drivers are also overrepresented in distracted driving KA crashes, accounting for 61.5 percent of distracted drivers in KA crashes compared to just 56.4 percent of distracted drivers in all severity crashes.

Table 19. Summary of distracted drivers by reported gender.

Reported Gender	Distracted Drivers in KA Crashes		Distracted Drivers in KABCO Crashes		All Drivers in KABCO Crashes
	Total	Percentage	Total	Percentage	Percentage
Blank/Not Reported	17	2.5%	945	2.9%	11.0%
Female	241	35.9%	13,455	40.7%	38.3%
Male	413	61.5%	18,611	56.4%	50.6%
Unknown	1	0.1%	16	<0.1%	0.1%

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 distracted driving (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 before segment-based risk factors are applied.

Risk Factor Analysis

This section describes the methodology, data, and results of the risk factor analysis for distracted driving 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 distracted driving-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 distracted driving 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.

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 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 noted this could lead to misunderstanding or outright disregard for potentially noteworthy results.[6]

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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.

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://geo-massdot.opendata.arcgis.com/datasets/town-boundaries). 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 distracted driving crashes from MassDOT's IMPACT Crash Data Portal as described previously in this report. VHB then joined total distracted driving KA crashes for the years 2015 through 2017 to the town data using the city/town name field in the crash data. VHB was limited to those years as they were the years for which distracted driving crashes were available.

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.

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/data). 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.

Citation Data

MassDOT provided statewide traffic citation data by town for the years 2017 through 2020. These data also included the number of citations which were related to speeding, unbelted, distracted, and impaired driving. VHB used the average number of citations per year for these categories by town to capture some measure of risk-taking driving behavior, typically associated with a propensity to drive while distracted.

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.

Results

This section describes the results of the negative binomial regression modeling effort. Table 20 documents the results of the final model. VHB reviewed the correlation between independent variables – the maximum correlation between any two variables was 0.67. Additionally, for indicator variables, the minimum number of observations for which a given indicator variable was true was 21 observations. The model predicts the total number of KA distracted driving crashes over the five-year study period from 2015 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 (3) for each town.

Table 20. 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
Town Population is between 35,000 and 74,999	0.226	0.168	1.35	0.178	-0.103	0.555
Town Population is 75,000 or Higher	0.952	0.246	3.87	<0.001	0.471	1.43
Town is true for Environmental Justice – Income indicator	0.254	0.133	1.91	0.056	-0.007	0.515
Fewer than 0.1 Colleges or Universities per Square Mile in the Town	0.663	0.228	2.91	0.004	0.217	1.109
Proportion of Functional Class 2[7] Mileage is 0.05 or greater	0.257	0.150	1.71	0.086	-0.037	0.551
Proportion of Functional Class 5[8] Mileage is 0.20 or greater	0.280	0.169	1.65	0.099	-0.052	0.612
Annual Number of Impaired Driving Citations per Centerline Mile in the Town is between 0.25 and 0.75	0.354	0.157	2.26	0.024	0.047	0.662
Annual Number of Impaired Driving Citations per Centerline Mile in the Town is greater than 0.75	0.870	0.243	3.58	<0.001	0.393	1.347
Annual Traffic Citations per Centerline Mile is greater than 10	0.241	0.166	1.45	0.146	-0.084	0.566
Annual Distracted Driving Citations per Centerline Mile is greater than 0.25	0.398	0.164	2.44	0.015	0.078	0.719
Constant	-6.876	0.266	-25.89	<0.001	-7.396	-6.355
Alpha	0.283	0.070	N/A	N/A	0.174	0.459

Note: Number of observations = 350; Log likelihood = -496.01362; Pseudo R2 = 0.0970; LR chi2(10) = 106.54; Prob > chi2 = <0.0001.

The negative binomial regression model described in Table 20 predicts the number of KA distracted driving 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 the income EJ indicator in a town suggests that severe distracted driving crashes are more prevalent in low-income communities, so these areas should be targeted for anti-distracted driving campaigns. Town population provides some

[7] Urban or rural principal arterial

[8] Urban minor arterial or rural major collector

overall level of exposure for the town – towns with high relative populations experience a higher frequency of severe distracted driving crashes. A low density of colleges and universities in a town is correlated with increased severe distracted driving crash frequency. The high proportion of freeway and expressway mileage suggests a correlation between high-speed and more severe likely outcomes for distracted driving crashes, while the high proportion of lower classification roads suggests the lower level of design, increased required stops, and increased conflicts on those roads present more opportunities for distracted drivers to enter into a severe crash. The distracted driving citation metric provides some direct measure of the level of distracted driving in the town, while the impaired and total traffic citation metrics provide an additional surrogate level of exposure for hazardous driving behaviors.

Conclusions and Recommendations

The purpose of this analysis is to identify town-level risk factors for fatal and serious injury distracted driving crashes in Massachusetts, as well as segment level risk factors for further prioritization for education, enforcement, and other strategies. VHB recommends that MassDOT disregard the coefficients from the negative binomial regression results in Table 20. 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 21 summarizes the proposed town-level risk factors for distracted driving. 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 22 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 21. Town-level risk factors for distracted driving crashes.

Town Risk Factors for Distracted Driving Crashes	Scoring
Town Population	0 if population less than 35,001; 0.5 if population between 35,001 and 75,000; 1.0 if population is greater than 75,000
Environmental Justice – Income	1 if town is an Environmental Justice – Income town; 0 otherwise
College and University Density	Risk Score = 1-5*(Colleges & Universities per Square Mile) if Colleges and Universities per Square Miles less than or equal to 0.1; 0 otherwise
Proportion of Town's Centerline Mileage that is Urban or Rural Principal Arterial (Functional Class = 2)	Risk Score = 2.692*Proportion + 0.3654 if proportion is greater than or equal to 0.05; 0 otherwise
Proportion of Town's Centerline Mileage that is Urban Minor Arterial or Rural Major Collector (Functional Class = 5)	Risk Score = 2.027*Proportion + 0.0946 if proportion is greater than or equal to 0.20; 0 otherwise
Annual Impaired Driving Citations per Centerline Mile in the Town	0 if less than 0.25 citations per mile; 0.5 if ratio is between 0.25 and 0.75 citations per mile; 1 if ratio is greater than 0.75 citations per mile
Annual Total Traffic Citations per Centerline Mile in the Town	1.0 if greater than 10 citations per mile; 0 otherwise
Annual Distracted Driving Citations per Mile	1.0 if greater than 0.25 citations per mile; 0 otherwise

Table 22. Segment-level risk factors for distracted driving crashes.

Segment Risk Factors for Distracted Driving Crashes	Scoring
Functional Class	1.0 if the segment's functional class is urban collector or rural minor collector (Functional Class = 6); 0 otherwise
AADT	Risk Score = 0.00002*AADT + 0.2 if AADT is between 15,000 and 40,000 vehicles per day; 1.0 if AADT is between 40,000 and 60,000; 0 otherwise
No Curbing Present	1 if true; 0 otherwise
Right Shoulder Width	1 if 3 feet or wider; 0 otherwise
Median Type	1 if barrier is present; 0 otherwise
Posted Speed Limit	Risk Score = 0.02*Posted Speed Limit – 0.30 if posted speed limit is between 40 and 65 miles per hour; 0 otherwise

Town-level risks should be used primarily for developing education campaigns for distracted driving. Education campaigns can include multimedia messaging including television, radio, social media, signage, public engagement, etc. Segment-level risk factors should be used to further target education campaigns. Towns and other local agencies can target high-risk corridors with variable message signs or other forms to deliver anti-distracted driving messages to drivers. Additionally, given the high prevalence of lane departure crashes for severe distracted driving crashes, towns can look for overlap between distracted driving and lane departure risk corridors to implement engineering lane departure countermeasures. A combined education and engineering approach can reduce both distracted driving behaviors and the potential frequency and severity of lane departure crashes resulting from distracted driving. A common, severe outcome of distracted driving is a severe lane departure crash, so the goal should be to prevent distracted driving in the first place. Given it cannot be 100 percent prevented, agencies should build a safe system which provides forgiveness for errant distracted drivers.

Table 23 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 23 is 7.08, associated with a normalized risk score of 0.51 for the segment.

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 23. Example risk score calculation for distracted driving.

Variable	Segment Characteristic	Risk Factor	Risk Score
Town Population	2,500	0 if population less than 35,001; 0.5 if population between 35,001 and 75,000; 1.0 if population is greater than 75,000	0
Environmental Justice Indicators Present	None	1 if town is an Environmental Justice – Income town; 0 otherwise	0
Colleges and Universities per Square mile	2.5	Risk Score = 1-5*(Colleges & Universities per Square Mile) if Colleges and Universities per Square Miles less than or equal to 0.1; 0 otherwise	0
Proportion of Functional Class 2 Mileage	0.11	Risk Score = 2.692*Proportion + 0.3654 if proportion is greater than or equal to 0.05; 0 otherwise	0.66
Proportion of Functional Class 5 Mileage	0.26	Risk Score = 2.027*Proportion + 0.0946 if proportion is greater than or equal to 0.20; 0 otherwise	0.62
Impaired Driving Citations per Year per Mile	0.10	0 if less than 0.25 citations per mile; 0.5 if ratio is between 0.25 and 0.75 citations per mile; 1 if ratio is greater than 0.75 citations per mile	0
Total Traffic Citations per Year per Mile	12	1.0 if greater than 10 citations per mile; 0 otherwise	1
Distracted Driving Citations per Year per Mile	0.5	1.0 if greater than 0.25 citations per mile; 0 otherwise	1
Functional Class	Interstate	1.0 if the segment's functional class is urban collector or rural minor collector (Functional Class = 6); 0 otherwise	0
AADT	55,000	Risk Score = 0.00002*AADT + 0.2 if AADT is between 15,000 and 40,000 vehicles per day; 1.0 if AADT is between 40,000 and 60,000; 0 otherwise	1
No Curbing Present	True	1 if true; 0 otherwise	1
Shoulder Width	6 feet	1 if 3 feet or wider; 0 otherwise	1
Median Type	Depressed	1 if barrier is present; 0 otherwise	0
Posted Speed Limit	55 mph	Risk Score = 0.02*Posted Speed Limit – 0.30 if posted speed limit is between 40 and 65 miles per hour; 0 otherwise	0.8
		Total Risk Score:	7.08
		Normalized Risk Score:	0.51

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 24 and Table 25 show the distribution of segments with the normalized risk score (presented as percentages) across these categories for Statewide and MPO rankings, respectively.

Table 24. 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	43.99%	78.57%	15,797	5.1%
	Secondary Risk Site	39.29%	43.99%	36,185	11.7%

Table 25. MPO risk categories.

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	44.93%	65%	1,073	8.33%
	Secondary Risk Site	37.79%	44.79%	1,723	13.38%
Boston Region MPO	Primary Risk Site	44.77%	78.18%	5,231	5.00%
	Secondary Risk Site	39.29%	44.76%	13,440	12.85%
Cape Cod Commission	Primary Risk Site	39.29%	63.58%	1,645	5.88%
	Secondary Risk Site	35.14%	39.13%	3,742	13.36%
Central Massachusetts Regional Planning Commission	Primary Risk Site	42.86%	71.05%	1,761	5.96%
	Secondary Risk Site	39.29%	42.83%	3,170	10.72%
Franklin Regional Council of Governments	Primary Risk Site	37.65%	64.88%	706	9.56%
	Secondary Risk Site	32.14%	37.38%	596	8.07%
Martha's Vineyard Commission	Primary Risk Site	42.86%	61.47%	196	6.24%
	Secondary Risk Site	40.04%	40.04%	366	11.66%
Merrimack Valley Planning Commission	Primary Risk Site	45.88%	70%	759	5.00%
	Secondary Risk Site	40.83%	45.84%	1,976	13.03%
Montachusett Regional Planning Commission	Primary Risk Site	43.99%	71.43%	1,283	8.09%
	Secondary Risk Site	71.80%	43.64%	1,241	7.83%
Nantucket Planning and Economic Development Commission	Primary Risk Site	32.14%	46.43%	420	18.56%
	Secondary Risk Site	N/A	N/A	0	0%
Northern Middlesex Council of Governments	Primary Risk Site	43.97%	71.11%	1,058	8.58%
	Secondary Risk Site	36.83%	43.70%	2,359	19.12%
Pioneer Valley Planning Commission	Primary Risk Site	42.86%	70.67%	1,479	5.07%
	Secondary Risk Site	39.29%	42.27%	4,041	13.86%
Old Colony Planning Council	Primary Risk Site	43.57%	67.86%	953	5.03%
	Secondary Risk Site	40%	43.55%	1,898	10.01%
	Primary Risk Site	46.43%	78.57%	1,902	6.19%

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	42.86%	46.21%	3,158	10.28%