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

Impaired Driving

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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 impaired 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 impaired 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 impaired 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 impaired driving crashes, which will point safety stakeholders towards other emphasis areas and opportunities to install engineering countermeasures to address or mitigate those crashes.

Focus Crash Types

As part of the 2018 SHSP[1], Massachusetts identified Impaired Driving as an emphasis area due to 124 related highway fatalities occurring between 2012 and 2016, the second highest total for emphasis areas within the SHSP. Massachusetts has known issues with impaired driving[1]:

- Almost one-third of Massachusetts's traffic fatalities are associated with alcohol-impaired driving crashes.
- Roughly one quarter of deceased drivers who were tested were found to have THC from marijuana in their system.

Given that impaired driving can be a factor in many types of crashes, MassDOT and VHB opted to not further refine the focus crash type, thus defining a focus crash type as any severe crash in which a driver was reported as being suspected of impairment. VHB and MassDOT divided crashes into two classes – suspected alcohol use and suspected drug use. VHB then used the MassDOT IMPACT Crash Data Portal to query for alcohol and drug impaired driving crashes using the following steps:

1. Using the Data Query and Visualization Tool, query vehicle-level data to identify when the "Alcohol Suspected" field or "Drug Suspected" field is "Yes" for the years 2016 and 2019[2].
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

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

[2] There are new fields which MassDOT determined was only consistent for the years 2016 onward. Additionally, as of writing, 2019 was not a closed year of crash data so the crash totals are subject to change.

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 15,766 crashes with a driver suspected of alcohol impairment, of which 96 were fatal crashes and 695 were incapacitating injury (or suspected serious injury) crashes between 2016 and 2019. For suspected drug use, the query returned a total of 4,657 crashes with a driver suspected of drug impairment, of which 25 were fatal crashes and 270 were incapacitating injury crashes. VHB reviewed the crashes by town and found possible underreporting for multiple communities. MassDOT reached out to these communities, and though they were not able to confirm the level of underreporting, the analysis proceeded with the knowledge that there are likely some severe impaired driver crashes not accounted for in this sample given underreporting.

VHB compared separately the distribution of alcohol and drug impaired driving fatal and incapacitating injury (KA) crashes to the distribution of all KA crashes across a series of crash-level and linked roadway-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 impaired 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 bolded in the tables were found to be statistically overrepresented. The goal of these sections is to summarize the typical characteristics of severe impaired 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 impaired driving crashes to target education and enforcement campaigns.

Suspected Alcohol Impaired Driving

The following sections summarize the characteristics of KA crashes with reported suspected alcohol impairment.

Manner of Collision and First Harmful Event

Table 1 shows the comparison of alcohol impaired driving KA crashes and all KA crashes distributed by manner of collision. The majority of these crashes are single vehicle crashes (54.6 percent), and that manner of collision is also overrepresented. While rear end crashes account for the second highest proportion, they are not overrepresented. Head-on crashes are the third highest proportion of KA crashes (14.5 percent) compared to 11.0% of all KA crashes; these crashes are statistically overrepresented.

To further investigate this relationship, Table 2 compares the distribution of some notable first harmful event categories for alcohol impaired driving KA crashes and all KA crashes crashes. While the plurality of alcohol-impaired KA crashes included a first harmful event of 'collision with motor vehicle in traffic' (38.7 percent), this is not statistically overrepresented compared to all KA crashes. Three other first harmful events are overrepresented among alcohol-impaired KA crashes compared to all KA crashes:

- Collision with tree (12.9 percent of alcohol KA compared to 7.4 percent of all KA).
- Collision with utility pole (10.7 percent of alcohol KA compared to 5.1 percent of all KA).
- Collision with guardrail (6.6 percent of alcohol KA compared to 3.7 percent of all KA).

The collision with tree, utility pole, and guardrail results correlate with the single vehicle overrepresentation identified in Table 1. Based on these results, agencies looking to target impaired driving crashes with engineering countermeasures should review the lane departure emphasis area and pedestrian emphasis area maps.

Table 1. Summary of suspected alcohol impaired driving crashes by manner of collision.

Manner of Collision	Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Single vehicle crash	**432**	**54.6%**	**1.8%**	**4431**	**41.6%**	**0.5%**
Rear-end	121	15.3%	1.3%	1589	14.9%	0.3%
Head-on	**115**	**14.5%**	**1.3%**	**1176**	**11.0%**	**0.3%**
Angle	70	8.8%	1.0%	2502	23.5%	0.4%
Sideswipe, same direction	24	3.0%	0.6%	441	4.1%	0.2%
Sideswipe, opposite direction	14	1.8%	0.5%	199	1.9%	0.1%
Other/Unknown/Reported but Invalid	6	0.8%	0.3%	100	0.9%	0.1%
Not Reported	4	0.5%	0.3%	131	1.2%	0.1%
Front to Rear	4	0.5%	0.3%	29	0.3%	0.1%
Front to Front	1	0.1%	0.1%	31	0.3%	0.1%
Rear-to-rear	0	0%	0%	17	0.2%	<0.1%

Table 2. Notable first harmful events for suspected alcohol impaired driving crashes.

Notable First Harmful Events[3]	Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Collision with motor vehicle in traffic	306	38.7%	1.7%	5063	47.6%	0.5%
Collision with tree	**102**	**12.9%**	**1.2%**	**790**	**7.4%**	**0.3%**
Collision with utility pole	**85**	**10.7%**	**1.1%**	**539**	**5.1%**	**0.2%**
Collision with guardrail	**52**	**6.6%**	**0.9%**	**396**	**3.7%**	**0.2%**
Collision with pedestrian	41	5.2%	0.8%	1498	14.1%	0.3%
Collision with parked motor vehicle	34	4.3%	0.7%	359	3.4%	0.2%
Collision with unknown fixed object	**30**	**3.8%**	**0.7%**	**166**	**1.6%**	**0.1%**
Collision with curb	29	3.7%	0.7%	257	2.4%	0.1%
Overturn/rollover	27	3.4%	0.6%	223	2.1%	0.1%

Intersection Related and Junction Type

Table 3 details the relationship of KA crashes to specific intersection types. Table 3 indicates that suspected alcohol impaired driving KA crashes tend to be not at junctions (i.e., on segments). Crashes coded as "Not at junction" are also overrepresented for alcohol-impaired KA crashes (74.8 percent) compared to all KA crashes (58.4 percent).

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

Table 3. Summary of suspected alcohol impaired driving crashes by junction type.

Junction Type	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Not at junction	**592**	**74.8%**	**1.5%**	**6217**	**58.4%**	**0.5%**
T-intersection	74	9.4%	1.0%	1696	15.9%	0.4%
Four-way intersection	56	7.1%	0.9%	1708	16.0%	0.4%
Off-ramp	24	3.0%	0.6%	194	1.8%	0.1%
Y-intersection	24	3.0%	0.6%	239	2.2%	0.1%
Driveway	5	0.6%	0.3%	207	1.9%	0.1%
On-ramp	5	0.6%	0.3%	121	1.1%	0.1%
Traffic circle	5	0.6%	0.3%	50	0.5%	0.1%
Not Reported	3	0.4%	0.2%	122	1.1%	0.1%
Unknown/Other	3	0.4%	0.2%	38	0.4%	0.1%
Five-point or more	0	0.0%	0.0%	48	0.5%	0.1%
Railway grade crossing	0	0.0%	0.0%	6	0.1%	<0.1%

Lighting Condition and Time of Day

Table 4 underscores that suspected alcohol impaired driving KA crashes occur primarily during darkness, as compared to all KA crashes, of which the majority occurred during daylight. This is likely due to correlation with when people consume alcohol. This correlates with the high number of severe crashes occurring during evening into the early morning hours, particularly from 9 PM to 3 AM. The individual crash hours from 9 PM to 5 AM were found to be statistically overrepresented for alcohol impaired KA crashes compared to all KA crashes.

Table 4. Summary of suspected alcohol impaired driving crashes by lighting condition.

Lighting Condition	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Dark - lighted roadway	**375**	**47.4%**	**1.8%**	**2719**	**25.5%**	**0.4%**
Dark - roadway not lighted	**182**	**23.0%**	**1.5%**	**1043**	**9.8%**	**0.3%**
Daylight	178	22.5%	1.5%	6255	58.8%	0.5%
Dusk	30	3.8%	0.7%	308	2.9%	0.2%
Dark - unknown roadway lighting	13	1.6%	0.5%	78	0.7%	0.1%
Dawn	9	1.1%	0.4%	175	1.6%	0.1%
Not reported	2	0.3%	0.2%	54	0.5%	0.1%
Unknown	2	0.3%	0.2%	6	0.1%	<0.1%
Other	0	0.0%	0.0%	8	0.1%	<0.1%

Table 5. Summary of suspected alcohol impaired driving crashes by hour of day.

Hour of Day	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
12 AM - Midnight	**75**	**9.5%**	**1.0%**	**304**	**2.9%**	**0.2%**
1 AM	**82**	**10.4%**	**1.1%**	**315**	**3.0%**	**0.2%**
2 AM	**65**	**8.2%**	**1.0%**	**254**	**2.4%**	**0.1%**
3 AM	**29**	**3.7%**	**0.7%**	**153**	**1.4%**	**0.1%**
4 AM	**23**	**2.9%**	**0.6%**	**129**	**1.2%**	**0.1%**
5 AM	14	1.8%	0.5%	180	1.7%	0.1%
6 AM	7	0.9%	0.3%	277	2.6%	0.2%
7 AM	4	0.5%	0.3%	398	3.7%	0.2%
8 AM	4	0.5%	0.3%	435	4.1%	0.2%
9 AM	3	0.4%	0.2%	366	3.4%	0.2%
10 AM	4	0.5%	0.3%	429	4.0%	0.2%
11 AM	8	1.0%	0.4%	519	4.9%	0.2%
12 PM - Noon	8	1.0%	0.4%	553	5.2%	0.2%
1 PM	13	1.6%	0.5%	587	5.5%	0.2%
2 PM	26	3.3%	0.6%	673	6.3%	0.2%
3 PM	18	2.3%	0.5%	684	6.4%	0.2%
4 PM	36	4.6%	0.7%	707	6.6%	0.2%
5 PM	47	5.9%	0.8%	748	7.0%	0.2%
6 PM	48	6.1%	0.8%	682	6.4%	0.2%
7 PM	49	6.2%	0.9%	545	5.1%	0.2%
8 PM	46	5.8%	0.8%	514	4.8%	0.2%
9 PM	**62**	**7.8%**	**1.0%**	**504**	**4.7%**	**0.2%**
10 PM	**52**	**6.6%**	**0.9%**	**386**	**3.6%**	**0.2%**
11 PM	**68**	**8.6%**	**1.0%**	**303**	**2.8%**	**0.2%**
Unknown	0	0.0%	0.0%	1	<0.1%	<0.1%

Roadway Classification Characteristics

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 suspected alcohol impaired driving crashes. Note that these characteristics only describe where impaired driving crashes occur – not necessarily where impaired drivers are traveling. As such, these road-based risk factors should be used to prioritize countermeasure installations. Additionally, this section disregards non-geolocated crashes. To identify risk factors, MassDOT compared the proportion of KA impaired driving crashes to all KA crashes.

Table 6 summarizes the distribution of suspected alcohol impaired driving crashes by functional class. The plurality of crashes were on "urban minor arterial or rural major collector" roads (29.0 percent) followed by "rural minor arterial or urban principal arterial" (20.2 percent). No functional classes were statistically overrepresented for KA suspected alcohol impaired driving crashes.

Table 6. Summary of suspected alcohol impaired driving crashes by functional class.

MassDOT Functional Class	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Urban minor arterial or rural major collector	216	29.0%	1.66%	3,226	31.6%	0.30%
Rural minor arterial or urban principal arterial	150	20.2%	1.47%	2,525	24.7%	0.32%
Local	112	15.1%	1.31%	1,218	11.9%	0.43%
Rural or urban principal arterial	93	12.5%	1.21%	1,124	11.0%	0.31%
Urban collector or rural minor collector	88	11.8%	1.18%	1,064	10.4%	0.30%
Interstate	85	11.4%	1.17%	1,048	10.3%	0.46%

Table 7 summarizes the distribution of suspected alcohol impaired driving crashes by annual average daily traffic (AADT). The AADT range from 500 to 14,999 vehicles per day accounted for 60.9 percent of KA impaired driving crashes. Meanwhile, the AADT range from 500 to 1,999 vehicles per day is overrepresented, accounting for 10.2 percent of impaired driving KA crashes compared to just 6.7 percent of all severity KA crashes. Given low-volume roads are typically lower speed, the overrepresentation of impaired driving KA crashes suggests impaired drivers may be traveling at higher speeds on these facilities.

Table 7. Summary of suspected alcohol impaired driving crashes by AADT.

AADT	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
1-499	10	1.6%	0.52%	85	1.0%	0.11%
500-1999	**62**	**10.2%**	**1.23%**	**562**	**6.7%**	**0.27%**
2000-4999	104	17.1%	1.53%	1,330	15.9%	0.40%
5000-9999	124	20.4%	1.63%	1,768	21.1%	0.45%
10000-14999	80	13.2%	1.37%	1,334	15.9%	0.40%
15000-19999	40	6.6%	1.01%	804	9.6%	0.32%
20000-29999	42	6.9%	1.03%	776	9.3%	0.32%
30000-39999	29	4.8%	0.86%	349	4.2%	0.22%
40000-59999	32	5.3%	0.91%	403	4.8%	0.23%
60000-99999	39	6.4%	0.99%	516	6.2%	0.26%
100,000 or Greater	46	7.6%	1.07%	458	5.5%	0.25%

Table 8 summarizes the distribution of suspected alcohol impaired driving crashes by roadway jurisdiction. The majority of suspected alcohol impaired driving KA crashes occurred on "city or town accepted roads". However, crashes on MassDOT roads were found to be overrepresented, accounting for 38.9 percent of impaired driving KA crashes compared to 33.9 percent of all KA crashes.

Table 8. Summary of suspected alcohol impaired driving crashes by roadway jurisdiction.

Jurisdiction	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
City or Town accepted road	430	58.3%	1.82%	6,393	62.9%	0.48%
Massachusetts Department of Transportation	**287**	**38.9%**	**1.79%**	**3,445**	**33.9%**	**0.47%**
Department of Conservation and Recreation	14	1.9%	0.50%	175	1.7%	0.13%
Unaccepted by city or town	7	0.9%	0.36%	131	1.3%	0.11%
Federal Park or Forest	0	0.0%	0.00%	1	<0.1%	0.01%
Massachusetts Port Authority	0	0.0%	0.00%	6	0.1%	0.02%
Private	0	0.0%	0.00%	3	<0.1%	0.02%
State college or university	0	0.0%	0.00%	1	<0.1%	0.01%
State Institutional	0	0.0%	0.00%	1	<0.1%	0.01%
State Park or Forest	0	0.0%	0.00%	5	<0.1%	0.02%

Table 9 summarizes suspected alcohol impaired driving crashes by access control on the roadway. While most crashes occurred on roadways with no access control, there is statistical overrepresentation for full access control roadways, which account for 20.0 percent of impaired driving KA crashes compared to just 16.0 percent of all KA crashes.

Table 9. Summary of suspected alcohol impaired driving crashes by access control.

Access Control	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
No Control	571	77.1%	1.54%	8,287	81.3%	0.39%
Full Control	**148**	**20.0%**	**1.47%**	**1,632**	**16.0%**	**0.36%**
Partial Control	22	3.0%	0.62%	270	2.6%	0.16%

Table 10 shows the distribution of suspected alcohol impaired driving crashes by posted speed limit. The highest proportion of alcohol impaired KA crashes occurred on roads with a posted speed limit of 30 MPH (17.5 percent), with 40 MPH (15.2 percent), 65 MPH (15.2 percent), and 35 MPH (14.4 percent) having similar proportions. No speed limit categories were overrepresented compared to all KA crashes.

Table 10. Summary of suspected alcohol impaired driving crashes by posted speed limit.

Posted Speed Limit	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
15 MPH	0	0.0%	0.00%	3	<0.1%	0.03%
20 MPH	9	1.9%	0.63%	125	1.9%	0.17%
25 MPH	37	7.8%	1.23%	439	6.8%	0.31%
30 MPH	83	17.5%	1.75%	1,512	23.5%	0.53%
35 MPH	68	14.4%	1.61%	1,034	16.1%	0.46%
40 MPH	72	15.2%	1.65%	815	12.7%	0.41%
45 MPH	42	8.9%	1.31%	512	8.0%	0.34%
50 MPH	18	3.8%	0.88%	292	4.5%	0.26%
55 MPH	38	8.0%	1.25%	458	7.1%	0.32%
60 MPH	5	1.1%	0.47%	59	0.9%	0.12%
65 MPH	72	15.2%	1.65%	821	12.8%	0.42%
99 MPH	29	6.1%	1.10%	369	5.7%	0.29%

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 suspected alcohol impaired driving crashes by right shoulder width. The majority of impaired driving KA crashes occur on roadways with a shoulder width between 0 and 2 feet, with the total between 1 and 2 feet being overrepresented compared to all KA crashes (31.5 percent of impaired driving KA crashes compared to just 22.9 percent of all KA crashes).

Table 11. Summary of suspected alcohol impaired driving crashes by right shoulder width.

Right Shoulder Width	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
0'	282	38.7%	1.81%	5,141	50.8%	0.50%
1'-2'	**229**	**31.5%**	**1.72%**	**2,319**	**22.9%**	**0.42%**
3'-4'	48	6.6%	0.92%	532	5.3%	0.22%
5'-6'	28	3.8%	0.71%	338	3.3%	0.18%
7'-8'	25	3.4%	0.67%	361	3.6%	0.18%
Wider than 8'	116	15.9%	1.36%	1,433	14.2%	0.35%

Table 12 shows the breakdown of crashes by the presence of curbing along the roadway. The majority of KA impaired driving crashes occurred on roads with no curbing. These were also statistically overrepresented when compared to all KA crashes in Massachusetts during the same time period.

Table 12. Summary of suspected alcohol impaired driving KA crashes by curbing on the roadside.

Curbing Type	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	**420**	**58.6%**	**1.84%**	**4,384**	**43.9%**	**0.50%**
Both Sides	232	32.4%	1.75%	4,592	46.0%	0.50%
Right Side Only	42	5.9%	0.88%	565	5.7%	0.23%
Left Side Only	22	3.1%	0.64%	410	4.1%	0.20%
All Curbs (Divided Highway)	1	0.1%	0.14%	28	0.3%	0.05%
Along Median Only	0	0%	0%	1	<0.1%	0.01%

Table 13 shows the distribution of crashes by median type. Most KA impaired driving crashes occurred on roads with no median, and at a similar proportion as all KA crashes. While there are no individual statistical overrepresentations, it is notable there is slight overrepresentation for each form of positive barrier when comparing impaired KA crashes to all KA crashes.

Table 13. Summary of suspected alcohol impaired driving crashes by median type.

Median Type	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	562	76.7%	1.56%	7,958	78.5%	0.41%
Positive Barrier - Unspecified	64	8.7%	1.04%	763	7.5%	0.26%
Positive Barrier - Semi-Rigid	44	6.0%	0.88%	533	5.3%	0.22%
Positive Barrier - Rigid	33	4.5%	0.77%	342	3.4%	0.18%
Curbed	18	2.5%	0.57%	326	3.2%	0.18%
Raised Median	6	0.8%	0.33%	110	1.1%	0.10%
Depressed Median	4	0.5%	0.27%	46	0.5%	0.07%
Unprotected	1	0.1%	0.14%	52	0.5%	0.07%
Positive Barrier - Flexible	1	0.1%	0.14%	4	<0.1%	0.02%

Suspected Alcohol Impaired Drivers in Crashes

VHB reviewed vehicle- and person-level crash data from IMPACT for crashes involving suspected alcohol impaired drivers to summarize the characteristics of drivers involved in suspected alcohol impaired driving crashes. Between 2016 and 2019, there were 15,939 drivers reported to be suspected alcohol impaired at the time of the crash, 795 of which were in KA crashes. Table 14 shows that the plurality of suspected alcohol impaired drivers (37.2 percent of KA crashes and 35.0 percent of KABCO crashes) are aged 20-29, compared to just 23 percent of all drivers in all crashes.

Table 14. Summary of suspected alcohol impaired drivers by age.

Driver Age	Suspected Alcohol Impaired Drivers in KA Crashes			Suspected Alcohol Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Blank, Unknown, Other	1	0.1%	0.11%	153	1.0%	0.08%	9.8%
14-19	27	3.4%	0.64%	447	2.8%	0.13%	7.0%
20-24	153	19.2%	1.40%	2,758	17.3%	0.30%	12.0%
25-29	143	18.0%	1.36%	2,823	17.7%	0.30%	11.0%
30-39	202	25.4%	1.54%	3,730	23.4%	0.34%	16.7%
40-49	115	14.5%	1.25%	2,455	15.4%	0.29%	14.6%
50-59	102	12.8%	1.18%	2,236	14.0%	0.28%	14.2%
60-69	41	5.2%	0.79%	1,049	6.6%	0.20%	8.7%
70-79	9	1.1%	0.37%	215	1.3%	0.09%	4.1%
80-89	2	0.3%	0.19%	36	0.2%	0.04%	1.7%
90-Plus	0	0.0%	0%	1	<0.1%	0.01%	0.2%

Table 15 summarizes the suspected alcohol impaired drivers by the States they are licensed in. The majority of drivers are from Massachusetts, and these drivers are slightly overrepresented in KA crashes compared to KABCO crashes (93.1 percent to 90.9 percent, respectively).

Table 15. Summary of suspected alcohol impaired drivers by state of license.

Driver License State	Suspected Alcohol Impaired Drivers in KA Crashes			Suspected Alcohol Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Massachusetts	740	93.1%	0.90%	14,492	90.9%	0.23%	80.5%
New Hampshire	12	1.5%	0.43%	291	1.8%	0.11%	2.1%
Rhode Island	13	1.6%	0.45%	249	1.6%	0.10%	2.1%
Connecticut	6	0.8%	0.32%	187	1.2%	0.09%	1.2%
Blank or Unknown	5	0.6%	0.27%	270	1.7%	0.10%	10.4%
Other States	19	2.4%	0.54%	450	2.8%	0.13%	3.7%

Table 16 summarizes suspected alcohol impaired 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, suspected alcohol impaired 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 16. Summary of suspected alcohol impaired drivers by vehicle occupants.

Number of Vehicle Occupants	Suspected Alcohol Impaired Drivers in KA Crashes			Suspected Alcohol Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Not Reported	17	2.1%	0.51%	458	2.9%	0.13%	10.7%
1 Occupant (Driver)	578	72.7%	1.58%	13,196	82.8%	0.30%	72.2%
2 Occupants (Driver and One Passenger)	**139**	**17.5%**	**1.35%**	**1,748**	**11.0%**	**0.25%**	**12.0%**
3 or More Occupants	**61**	**7.7%**	**0.95%**	**537**	**3.4%**	**0.14%**	**5.1%**

Per Table 17, the majority of suspected alcohol impaired drivers in crashes were operating passenger cars in both KA (71.8 percent) and KABCO (78.0 percent) crashes. There is notable overrepresentation for motorcycle drivers (7.5 percent of KA drivers compared to 1.0 percent of KABCO drivers), but this is expected given the common overrepresentation of motorcycle drivers in KA crashes. The motorcycle proportion does not stand out when comparing all drivers in KA crashes, but the passenger car proportion is notably higher, suggesting that crashes involving passenger cars are more likely to be severe when the driver is impaired.

Table 17. Summary of suspected alcohol impaired drivers by vehicle type.

Vehicle Type	Suspected Alcohol Impaired Drivers in KA Crashes		Suspected Alcohol Impaired Drivers in KABCO Crashes		All Drivers in KA Crashes	All Drivers in KABCO Crashes
	Total	Percentage	Total	Percentage	Percentage	Percentage
Blank, Unknown	1	0.1%	7	<0.1%	0.3%	0.2%
All-Terrain Vehicle	2	0.3%	2	<0.1%	0.1%	<0.1%
Bus (Seats 16 or more, including driver)	0	0%	6	<0.1%	0.3%	0.4%
Bus (seats 9-15, including driver)	0	0%	1	<0.1%	0.2%	0.2%
Light Truck (van, mini-van, pickup, sport utility)	152	19.1%	3,146	19.7%	22.0%	21.4%
Low Speed Vehicle	1	0.1%	1	<0.1%	<0.1%	<0.1%
Moped	6	0.8%	31	0.2%	0.8%	0.1%
Motor Home/Recreational Vehicle	1	0.1%	2	<0.1%	<0.1%	<0.1%
Motorcycle	60	7.5%	154	1.0%	7.5%	0.8%
Not Reported	0	0%	16	0.1%	0.6%	1.2%
Other, e.g. Farm Equipment	0	0%	16	0.1%	0.4%	0.4%
Passenger Car	571	71.8%	12,434	78.0%	63.9%	71.6%
Reported but Invalid	0	0%	5	<0.1%	<0.1%	<0.1%
Single-Unit Truck (2-axle, 6-tires)	1	0.1%	48	0.3%	1.2%	1.0%
Single-Unit Truck (3-or-more axles)	0	0%	4	<0.1%	0.6%	0.3%
Snowmobile	0	0%	1	<0.1%	0%	<0.1%
Tractor - Doubles	0	0%	0	0%	<0.1%	<0.1%
Tractor - Semi-Trailer	0	0%	17	0.1%	1.2%	0.9%
Tractor - Triples	0	0%	0	0%	<0.1%	<0.1%
Truck Tractor (bobtail)	0	0%	1	<0.1%	0.1%	<0.1%
Truck - Trailer	0	0%	27	0.2%	0.6%	0.8%
Unknown Heavy Truck, Cannot Classify	0	0%	20	0.1%	0.2%	0.5%

Finally, Table 18 summarizes the distribution of suspected alcohol impaired drivers by reported gender. Comparing suspected alcohol impaired drivers to all drivers, it appears male drivers are overrepresented in suspected alcohol impaired driving crashes. Further, male drivers are also overrepresented in suspected alcohol impaired driving KA crashes, accounting for 77.1 percent of suspected alcohol impaired drivers in KA crashes compared to 68.3 percent of suspected alcohol impaired drivers in all severity crashes.

Table 18. Summary of suspected alcohol impaired drivers by reported gender.

Reported Gender	Suspected Alcohol Impaired Drivers in KA Crashes			Suspected Alcohol Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Blank, Not Reported	13	1.6%	0.45%	439	2.8%	0.13%	11.0%
Female	169	21.3%	1.45%	4,564	28.6%	0.36%	38.3%
Male	**613**	**77.1%**	**1.49%**	**10,883**	**68.3%**	**0.37%**	**50.6%**
Unknown	0	0%	0%	53	0.3%	0.04%	0.1%

Suspected Drug Impaired Driving

The following sections summarize the characteristics of KA crashes with reported suspected drug impairment.

Manner of Collision and First Harmful Event

Table 19 shows the comparison of drug impaired driving KA crashes and drug impaired driving KABCO crashes distributed by manner of collision. The plurality of these crashes are single vehicle crashes (48.0 percent of drug-impaired KA crashes), though this is not statistically overrepresented compared to all KA crashes. While rear end crashes account for the second highest proportion, they also are not overrepresented. Head-on crashes are the third highest proportion of drug-impaired KA crashes (16.0 percent) and are statistically overrepresented compared to all KA crashes.

To further investigate this relationship, Table 20 compares the distribution of some notable first harmful event categories for drug impaired driving KA crashes and all KA crashes. While the plurality of KA crashes included a first harmful event of 'collision with motor vehicle in traffic' (42.2 percent), these crashes are not overrepresented. Two other first harmful events are overrepresented among drug-impaired KA crashes compared to all KA crashes:

- Collision with tree (15.0 percent of drug-impaired KA compared to 7.4 percent of all KA crashes).
- Collision with guardrail (7.5 percent of drug-impaired KA compared to 3.7 percent of all KA crashes).

The collision with tree and collision with guardrail results correlate with the single vehicle overrepresentation identified in Table 19. Based on these results, agencies looking to target impaired driving crashes with engineering countermeasures should review the lane departure emphasis area maps.

Table 19. Summary of suspected drug impaired driving crashes by manner of collision.

Manner of Collision	Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Single vehicle crash	141	48.0%	2.9%	4431	41.6%	0.5%
Rear-end	52	17.7%	2.2%	1589	14.9%	0.3%
Head-on	**47**	**16.0%**	**2.1%**	**1176**	**11.0%**	**0.3%**
Angle	31	10.5%	1.8%	2502	23.5%	0.4%
Sideswipe, same direction	15	5.1%	1.3%	441	4.1%	0.2%
Sideswipe, opposite direction	5	1.7%	0.8%	199	1.9%	0.1%
Other/Unknown/Reported but Invalid	1	0.3%	0.3%	100	0.9%	0.1%
Not Reported	2	0.7%	0.5%	131	1.2%	0.1%
Front to Rear	0	0.0%	0.0%	29	0.3%	0.1%
Front to Front	0	0.0%	0.0%	31	0.3%	0.1%
Rear-to-rear	0	0.0%	0.0%	17	0.2%	<0.1%

Table 20. Summary of suspected drug impaired driving crashes by notable first harmful events.

Notable First Harmful Events[4]	Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Collision with motor vehicle in traffic	124	42.2%	2.9%	5063	47.6%	0.5%
Collision with tree	**44**	**15.0%**	**2.1%**	**790**	**7.4%**	**0.3%**
Collision with utility pole	26	8.8%	1.7%	539	5.1%	0.2%
Collision with guardrail	**22**	**7.5%**	**1.5%**	**396**	**3.7%**	**0.2%**
Collision with pedestrian	10	3.4%	1.1%	1498	14.1%	0.3%
Collision with parked motor vehicle	16	5.4%	1.3%	359	3.4%	0.2%
Collision with unknown fixed object	11	3.7%	1.1%	166	1.6%	0.1%
Collision with curb	6	2.0%	0.8%	257	2.4%	0.1%
Overturn/rollover	6	2.0%	0.8%	223	2.1%	0.1%

Intersection Related and Junction Type

Table 21 details the relationship of KA crashes to specific intersection types. Table 21 indicates that suspected drug impaired driving KA crashes tend to be not at junctions (i.e., on segments). Crashes coded

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

as "Not at junction" are overrepresented for drug-impaired KA crashes (76.5 percent) compared to all KA crashes (58.4 percent).

Table 21. Summary of suspected drug impaired driving crashes by junction type.

Junction Type	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Not at junction	**225**	**76.5%**	**2.5%**	**6217**	**58.4%**	**0.5%**
T-intersection	28	9.5%	1.7%	1696	15.9%	0.4%
Four-way intersection	19	6.5%	1.4%	1708	16.0%	0.4%
Off-ramp	6	2.0%	0.8%	194	1.8%	0.1%
Driveway	4	1.4%	0.7%	207	1.9%	0.1%
On-ramp	4	1.4%	0.7%	121	1.1%	0.1%
Y-intersection	3	1.0%	0.6%	239	2.2%	0.1%
Not reported	2	0.7%	0.5%	122	1.1%	0.1%
Traffic circle	1	0.3%	0.3%	50	0.5%	0.1%
Unknown/Other	1	0.3%	0.3%	38	0.4%	0.1%
Five-point or more	1	0.3%	0.3%	48	0.5%	0.1%
Railway grade crossing	0	0.0%	0.0%	6	0.1%	<0.1%

Lighting Condition and Time of Day

Table 22 underscores that the majority of suspected drug impaired driving KA crashes occur under daylight conditions. Further, though not statistically overrepresented, the proportions of KA crashes under dark – no lighting and dark- lighting conditions were higher than the proportion of all KA crashes under those same conditions. Table 23 shows the distribution of suspected drug impaired driving crashes by time of day. No hours were found to be statistically overrepresented.

Table 22. Summary of suspected drug impaired driving crashes by lighting condition.

Lighting Condition	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Daylight	159	54.1%	2.9%	6255	58.8%	0.5%
Dark - lighted roadway	84	28.6%	2.6%	2719	25.5%	0.4%
Dark - roadway not lighted	40	13.6%	2.0%	1043	9.8%	0.3%
Dawn	5	1.7%	0.8%	175	1.6%	0.1%
Dusk	4	1.4%	0.7%	308	2.9%	0.2%
Dark - unknown roadway lighting	2	0.7%	0.5%	78	0.7%	0.1%
Not reported	0	0.0%	0.0%	54	0.5%	0.1%
Unknown	0	0.0%	0.0%	6	0.1%	<0.1%
Other	0	0.0%	0.0%	8	0.1%	<0.1%

Table 23. Summary of suspected drug impaired driving crashes by hour of day.

Hour of Day	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
12 AM - Midnight	15	5.1%	1.3%	304	2.9%	0.2%
1 AM	10	3.4%	1.1%	315	3.0%	0.2%
2 AM	7	2.4%	0.9%	254	2.4%	0.1%
3 AM	7	2.4%	0.9%	153	1.4%	0.1%
4 AM	5	1.7%	0.8%	129	1.2%	0.1%
5 AM	1	0.3%	0.3%	180	1.7%	0.1%
6 AM	6	2.0%	0.8%	277	2.6%	0.2%
7 AM	9	3.1%	1.0%	398	3.7%	0.2%
8 AM	14	4.8%	1.2%	435	4.1%	0.2%
9 AM	7	2.4%	0.9%	366	3.4%	0.2%
10 AM	10	3.4%	1.1%	429	4.0%	0.2%
11 AM	13	4.4%	1.2%	519	4.9%	0.2%
12 PM - Noon	18	6.1%	1.4%	553	5.2%	0.2%
1 PM	13	4.4%	1.2%	587	5.5%	0.2%
2 PM	15	5.1%	1.3%	673	6.3%	0.2%
3 PM	15	5.1%	1.3%	684	6.4%	0.2%
4 PM	22	7.5%	1.5%	707	6.6%	0.2%
5 PM	16	5.4%	1.3%	748	7.0%	0.2%
6 PM	16	5.4%	1.3%	682	6.4%	0.2%
7 PM	18	6.1%	1.4%	545	5.1%	0.2%
8 PM	14	4.8%	1.2%	514	4.8%	0.2%
9 PM	14	4.8%	1.2%	504	4.7%	0.2%
10 PM	18	6.1%	1.4%	386	3.6%	0.2%
11 PM	11	3.7%	1.1%	303	2.8%	0.2%
Unknown	0	0.0%	0.0%	1	<0.1%	<0.1%

Roadway Classification Characteristics

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 suspected drug impaired driving crashes.

Table 24 summarizes the distribution of suspected drug impaired driving crashes by functional class. The plurality of crashes were on "urban minor arterial or rural major collector" roads (31.3 percent of drug-impaired driving KA crashes) followed by "rural minor arterial or urban principal arterial" (21.6 percent of drug-impaired KA crashes). The "interstate" functional class was found to be statistically overrepresented for KA drug-impaired crashes compared to all KA crashes.

Table 24. Summary of suspected drug impaired driving crashes by functional class.

MassDOT Functional Class	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
Urban minor arterial or rural major collector	84	31.3%	2.83%	3,226	31.6%	0.46%
Rural minor arterial or urban principal arterial	58	21.6%	2.52%	2,525	24.7%	0.43%
Interstate	**43**	**16.0%**	**2.24%**	**1,048**	**10.3%**	**0.30%**
Rural or urban principal arterial	33	12.3%	2.01%	1,124	11.0%	0.31%
Urban collector or rural minor collector	28	10.4%	1.87%	1,064	10.4%	0.30%
Local	22	8.2%	1.68%	1,218	11.9%	0.32%

Table 25 summarizes the distribution of suspected drug impaired driving crashes by AADT. While none of these categories were found to be statistically overrepresented, note that the AADT range of 30,000 vehicles per day or greater accounted for 27.6 percent of drug impaired KA crashes, a larger proportion than the 20.7 percent of suspected drug impaired driver crashes of all KA crashes. When combined, this range is statistically overrepresented compared to all KA crashes.

Table 25. Summary of suspected drug impaired driving crashes by AADT.

AADT	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
1-499	2	0.9%	0.61%	85	1.0%	0.11%
500-1999	13	5.6%	1.51%	562	6.7%	0.27%
2000-4999	38	16.4%	2.43%	1,330	15.9%	0.40%
5000-9999	50	21.6%	2.70%	1,768	21.1%	0.45%
10000-14999	34	14.7%	2.32%	1,334	15.9%	0.40%
15000-19999	13	5.6%	1.51%	804	9.6%	0.32%
20000-29999	18	7.8%	1.76%	776	9.3%	0.32%
30000-39999	11	4.7%	1.40%	349	4.2%	0.22%
40000-59999	12	5.2%	1.45%	403	4.8%	0.23%
60000-99999	19	8.2%	1.80%	516	6.2%	0.26%
100,000 or Greater	22	9.5%	1.92%	458	5.5%	0.25%

Table 26 summarizes the distribution of suspected drug impaired driving crashes by roadway jurisdiction. The majority of suspected drug impaired driving KA crashes occurred on "city or town accepted roads". Though not statistically overrepresented, MassDOT roads account for a 5.3 percent higher proportion of KA drug impaired crashes compared to all KA crashes.

Table 26. Summary of suspected drug impaired driving crashes by roadway jurisdiction.

Jurisdiction	Suspected Alcohol Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
City or Town accepted road	154	58.1%	3.03%	6,393	62.9%	0.48%
Massachusetts Department of Transportation	104	39.2%	3.00%	3,445	33.9%	0.47%
Department of Conservation and Recreation	4	1.5%	0.75%	175	1.7%	0.13%
Unaccepted by city or town	3	1.1%	0.65%	131	1.3%	0.11%
Federal Park or Forest	0	0%	0%	1	<0.1%	0.01%
Massachusetts Port Authority	0	0%	0%	6	0.1%	0.02%
Private	0	0%	0%	3	<0.1%	0.02%
State college or university	0	0%	0%	1	<0.1%	0.01%
State Institutional	0	0%	0%	1	<0.1%	0.01%
State Park or Forest	0	0%	0%	5	<0.1%	0.02%

Table 27 summarizes suspected drug impaired driving crashes by access control on the roadway. While most KA drug impaired crashes occurred on roadways with no access control, there is statistical overrepresentation for full access control roadways, which accounted for 25.0 percent of KA drug impaired crashes compared to just 16.0 percent of all KA crashes.

Table 27. Summary of suspected drug impaired driving crashes by access control.

Access Control	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
No Control	196	73.1%	2.71%	8,287	81.3%	0.39%
Full Control	**67**	**25.0%**	**2.65%**	**1,632**	**16.0%**	**0.36%**
Partial Control	5	1.9%	0.83%	270	2.6%	0.16%

Table 28 shows the distribution of suspected drug impaired driving KA crashes by posted speed limit. Three posted speed limits were tied with the highest proportion of KA drug impaired crashes (30 MPH, 35 MPH, and 40 MPH), each accounting for 15.3 percent of crashes – a sum total of 45.9 percent of crashes; however, those speed limits account for 52.3 percent of all KA crashes. The posted speed limit of 55 MPH is statistically overrepresented compared to all KA crashes – with 13.2 percent of drug impaired KA crashes compared to 7.1 percent of all KA crashes.

Table 28. Summary of suspected drug impaired driving crashes by posted speed limit.

Posted Speed Limit	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
15 MPH	0	0%	0%	3	<0.1%	0.03%
20 MPH	4	2.1%	1.04%	125	1.9%	0.17%
25 MPH	14	7.4%	1.90%	439	6.8%	0.31%
30 MPH	29	15.3%	2.61%	1,512	23.5%	0.53%
35 MPH	29	15.3%	2.61%	1,034	16.1%	0.46%
40 MPH	29	15.3%	2.61%	815	12.7%	0.41%
45 MPH	9	4.7%	1.54%	512	8.0%	0.34%
50 MPH	12	6.3%	1.76%	292	4.5%	0.26%
55 MPH	**25**	**13.2%**	**2.45%**	**458**	**7.1%**	**0.32%**
60 MPH	4	2.1%	1.04%	59	0.9%	0.12%
65 MPH	23	12.1%	2.37%	821	12.8%	0.42%
99 MPH	12	6.3%	1.76%	369	5.7%	0.29%

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 29 summarizes the distribution of suspected drug impaired driving KA crashes by right shoulder width. While the majority of crashes occurred on roadway segments with shoulders 0 to 2 feet, there is overrepresentation for KA crashes when the shoulder width is 8 feet or wider compared to all KA crashes (21.1 percent of KA suspected drug impaired driver crashes compared to 14.2 percent of all KA crashes).

Table 29. Summary of suspected drug impaired driving crashes by right shoulder width.

Right Shoulder Width	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
0'	102	38.3%	2.98%	5,141	50.8%	0.50%
1'-2'	72	27.1%	2.72%	2,319	22.9%	0.42%
3'-4'	14	5.3%	1.37%	532	5.3%	0.22%
5'-6'	12	4.5%	1.27%	338	3.3%	0.18%
7'-8'	10	3.8%	1.17%	361	3.6%	0.18%
Wider than 8'	**56**	**21.1%**	**2.50%**	**1,433**	**14.2%**	**0.35%**

Table 30 shows the breakdown of crashes by the presence of curbing along the roadway. The majority of drug impaired driving KA crashes occurred on roads with no curbing, and this is statistically overrepresented compared to the proportion of all KA crashes (55.6 percent of drug impaired KA crashes compared to 43.9 percent of all KA crashes).

Table 30. Summary of suspected drug impaired driving KA crashes by curbing on the roadside.

Curbing Type	Suspected Drug Impaired Driving KA Crashes			KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	**148**	**55.6%**	**3.05%**	**4,384**	**43.9%**	**0.50%**
Both Sides	92	34.6%	2.92%	4.592	46.0%	0.50%
Right Side Only	17	6.4%	1.50%	565	5.7%	0.23%
Left Side Only	8	3.0%	1.05%	410	4.1%	0.20%
All Curbs (Divided Highway)	1	0.4%	0.38%	28	0.3%	0.05%
Along Median Only	0	0.%	0.00%	1	<0.1%	0.01%

Table 31 shows the distribution of crashes by median type. The majority of drug impaired KA crashes occurred on roads with no median (73.1 percent). There were no statistically significant overrepresentations when compared to all KA crashes.

Table 31. Summary of suspected drug impaired driving crashes by median type.

Median Type	Suspected Drug Impaired Driving KA Crashes			All KA Crashes		
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error
None	193	73.1%	2.73%	7,958	78.5%	0.41%
Positive Barrier - Unspecified	25	9.5%	1.80%	763	7.5%	0.26%
Positive Barrier - Semi-Rigid	18	6.8%	1.55%	533	5.3%	0.22%
Positive Barrier - Rigid	13	4.9%	1.33%	342	3.4%	0.18%
Curbed	8	3.0%	1.06%	326	3.2%	0.18%
Raised Median	4	1.5%	0.75%	110	1.1%	0.10%
Depressed Median	3	1.1%	0.65%	46	0.5%	0.07%
Unprotected	0	0%	0%	52	0.5%	0.07%
Positive Barrier - Flexible	0	0%	0%	4	<0.1%	0.02%

Suspected Drug Impaired Drivers in Crashes

VHB reviewed vehicle- and person-level crash data from IMPACT for crashes involving suspected drug impaired drivers to summarize the characteristics of drivers involved in suspected drug impaired driving crashes. Between 2016 and 2019, there were 4,663 drivers reported to be suspected drug impaired at the time of the crash, 295 of which were in KA crashes. Table 32 shows that the plurality of suspected drug impaired drivers (33.6 percent of KA crashes and 26.0 percent of KABCO crashes) are aged 30-39, compared to just 16.7 percent of all drivers in all crashes. The proportion of drug impaired drivers in KA crashes aged 30-39 was statistically overrepresented to the proportion of drug impaired drivers in all severity crashes.

Table 32. Summary of suspected drug impaired drivers by age.

Driver Age	Suspected Drug Impaired Drivers in KA Crashes			Suspected Drug Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Blank, Unknown, Other	3	1.0%	0.58%	95	2.0%	0.21%	9.8%
14-19	18	6.1%	1.39%	269	5.8%	0.34%	7.0%
20-24	42	14.2%	2.03%	708	15.2%	0.53%	12.0%
25-29	45	15.3%	2.10%	806	17.3%	0.55%	11.0%
30-39	**99**	**33.6%**	**2.75%**	**1212**	**26.0%**	**0.64%**	**16.7%**
40-49	44	14.9%	2.07%	690	14.8%	0.52%	14.6%
50-59	32	10.9%	1.81%	557	12.0%	0.48%	14.2%
60-69	10	3.4%	1.06%	235	5.0%	0.32%	8.7%
70-79	1	0.3%	0.32%	68	1.5%	0.18%	4.1%
80-89	1	0.3%	0.32%	21	0.5%	0.10%	1.7%
90-Plus	0	0%	0%	2	<0.1%	0.03%	0.2%

Table 33 summarizes the suspected drug impaired drivers by the States they are licensed in. By far, the majority of drivers are from Massachusetts. There are no statistically significant overrepresentations when comparing drug impaired drivers in KA crashes to drug impaired drivers in all severity crashes.

Table 33. Summary of suspected drug impaired drivers by state of license.

Driver License State	Suspected Drug Impaired Drivers in KA Crashes			Suspected Drug Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Massachusetts	266	90.2%	1.73%	4,173	89.5%	0.45%	80.5%
New Hampshire	13	4.4%	1.19%	126	2.7%	0.24%	2.1%
Rhode Island	3	1.0%	0.58%	82	1.8%	0.19%	2.1%
Connecticut	3	1.0%	0.58%	51	1.1%	0.15%	1.2%
Blank or Unknown	3	1.0%	0.58%	111	2.4%	0.22%	10.4%
Other States	7	2.4%	0.89%	120	2.5%	0.23%	3.7%

Table 34 summarizes suspected drug impaired 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, suspected drug impaired 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 34. Summary of suspected drug impaired drivers by vehicle occupants.

Number of Vehicle Occupants	Suspected Drug Impaired Drivers in KA Crashes			Suspected Drug Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Not Reported	10	3.4%	1.06%	308	6.6%	0.36%	10.7%
1 Occupant (Driver)	210	71.2%	2.64%	3,618	77.6%	0.61%	72.2%
2 Occupants (Driver and One Passenger)	**58**	**19.7%**	**2.32%**	**537**	**11.5%**	**0.47%**	**12.0%**
3 or More Occupants	17	5.8%	1.36%	200	4.3%	0.30%	5.1%

Per Table 35, the majority of suspected drug impaired drivers in crashes were operating passenger cars in both KA (76.3 percent) and KABCO (77.6 percent) crashes. Passenger car drivers are also overrepresented in drug impaired KA crashes when compared to drivers in all KA crashes – 76.3 percent of drug impaired drivers in KA crashes compared to just 63.9 percent of drivers in all crashes.

Table 35. Summary of suspected drug impaired drivers by vehicle type.

Vehicle Type	Suspected Drug Impaired Drivers in KA Crashes		Suspected Drug Impaired Drivers in KABCO Crashes		All Drivers in KA Crashes	All Drivers in KABCO Crashes
	Total	Percentage	Total	Percentage	Percentage	Percentage
Blank, Unknown	0	0%	2	<0.1%	0.3%	0.2%
All-Terrain Vehicle	1	0.3%	1	<0.1%	0.1%	<0.1%
Bus (Seats 16 or more, including driver)	0	0%	4	0.1%	0.3%	0.4%
Bus (seats 9-15, including driver)	0	0%	0	0%	0.2%	0.2%
Light Truck (van, mini-van, pickup, sport utility)	56	19.0%	939	20.1%	22.0%	21.4%
Low Speed Vehicle	0	0%	0	0%	<0.1%	<0.1%
Moped	1	0.3%	4	0.1%	0.8%	0.1%
Motor Home/Recreational Vehicle	0	0%	0	0%	<0.1%	<0.1%
Motorcycle	10	3.4%	23	0.5%	7.5%	0.8%
Not Reported	1	0.3%	10	0.2%	0.6%	1.2%
Other, e.g. Farm Equipment	0	0%	4	0.1%	0.4%	0.4%
Passenger Car	**225**	**76.3%**	**3,619**	**77.6%**	**63.9%**	**71.6%**
Reported but Invalid	0	0%	2	<0.1%	<0.1%	<0.1%
Single-Unit Truck (2-axle, 6-tires)	1	0.3%	19	0.4%	1.2%	1.0%
Single-Unit Truck (3-or-more axles)	0	0%	2	<0.1%	0.6%	0.3%
Snowmobile	0	0%	0	0%	0%	<0.1%
Tractor/Doubles	0	0%	1	<0.1%	<0.1%	<0.1%
Tractor/Semi-Trailer	0	0%	12	0.3%	1.2%	0.9%
Tractor/Triples	0	0%	0	0%	<0.1%	<0.1%
Truck Tractor (bobtail)	0	0%	0	0%	0.1%	<0.1%
Truck/Trailer	0	0%	13	0.3%	0.6%	0.8%
Unknown Heavy Truck, Cannot Classify	0	0%	8	0.2%	0.2%	0.5%

Finally, Table 36 summarizes the distribution of suspected drug impaired drivers by reported gender. Comparing suspected drug impaired drivers to all drivers, it appears male drivers are overrepresented in suspected drug impaired driving crashes. Further, male drivers are also overrepresented in suspected drug impaired driving KA crashes, accounting for 72.2 percent of suspected drug impaired drivers in KA crashes compared to just 65.8 percent of suspected drug impaired drivers in all severity crashes.

Table 36. Summary of suspected drug impaired drivers by reported gender.

Reported Gender	Suspected Drug Impaired Drivers in KA Crashes			Suspected Drug Impaired Drivers in KABCO Crashes			All Drivers in KABCO Crashes
	Total	Percentage	Sampling Error	Total	Percentage	Sampling Error	Percentage
Blank, Not Reported	5	1.7%	0.75%	175	3.8%	0.28%	11.0%
Female	77	26.1%	2.56%	1,412	30.3%	0.67%	38.3%
Male	**213**	**72.2%**	**2.61%**	**3,066**	**65.8%**	**0.69%**	**50.6%**
Unknown	0	0%	0%	10	0.1%	0.05%	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 impaired driving (targeted education, messaging campaigns, 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 impaired driving crashes in Massachusetts. The methodology and data sources apply to both the suspected alcohol and suspected drug impaired driving models.

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 impaired 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 count data). The dependent variable in the model is the number of alcohol- or drug-impaired driving KA crashes between 2016 and 2019, 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 impaired driving-related KA crashes at location i.

β = vector of estimated parameters.

X_i = vector of independent variables that characterize location i and influence impaired 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]

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 basis 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 impaired driving crashes from MassDOT's IMPACT Crash Data Portal as described previously in this report. VHB then joined total suspected alcohol impaired and suspected drug impaired driving KA crashes for the years 2016 through 2019 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 impaired driving crashes appeared consistently reported with the new crash data field.

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, the three years closest to the years of data used 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 to determine the number of ABCC licenses present in each city or town.

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 exposure of impaired driving as well as general risk-taking behaviors by drivers in the town.

Additionally, the Massachusetts Department of Public Health provided the number of admissions into first and second offense operating under the influence (OUI) programs by city and town for the years 2016 through 2019. Similar to the citation data, this served as an additional measure of surrogate exposure for the level of impaired driving in the area.

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 for alcohol-impaired driving crashes. Given the suspected underreporting of drug-impaired driving crashes, MassDOT and VHB elected not to develop a model for those crashes, though MassDOT plans to develop a model in the future as more reliable data are reported.

Table 37 documents the results of the final suspected alcohol impaired driving model. VHB reviewed the correlation between independent variables – the maximum correlation between any two variables was 0.36. Additionally, for indicator variables, the minimum number of observations for which a given indicator variable was true was 57 observations. The model predicts the total number of KA alcohol impaired driving crashes over the four-year study period from 2016 to 2019. 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 (4) for each town.

Table 37. Negative binomial count regression model results for suspected alcohol impaired driving.

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
More than 1,500 residents per square mile in the city or town	0.378	0.097	3.92	<0.001	0.189	0.568
4 or fewer ABCC licenses per 1,000 residents in the city or town	0.644	0.222	2.91	0.004	0.210	1.079
More than 1 person enrolled in an OUI offense program per year per 1,000 residents in the city or town	0.480	0.090	5.33	<0.001	0.304	0.657
More than 4 OUI citations per 1,000 residents per year in the city or town	0.275	0.126	2.18	0.029	0.027	0.522
More than 50 total traffic citations per 1,000 residents per year in the city or town	0.379	0.108	3.50	<0.001	0.167	0.590
Constant	-6.614	0.240	-27.57	<0.001	-7.084	-6.144
Alpha	0.107	0.043			0.048	0.235

Note: Number of observations = 350; Log likelihood = -560.72558; Pseudo R2 = 0.0652; LR chi2(5) = 78.26; Prob > chi2 = <0.0001.

The negative binomial regression model described in Table 37 predicts the number of KA suspected alcohol impaired driving crashes expected in a town. The independent variables are primarily citation and population based. A relatively high-level of population density is correlated with an increased number of

impaired driving crashes – likely as a measure of exposure. Interestingly, towns and cities with a low density of ABCC licenses (less than 4 per 1,000 residents) are also correlated with increased alcohol impaired driving crash frequency – likely a sign that residents in those communities have to travel further to purchase and/or consume alcohol, increasing potential drunk driving exposure. Both OUI citations and OUI offender program enrollments provide some base measure of impaired driving for communities—for a high number of impaired drivers to be arrested, there must be a high number of people engaging in that behavior. Finally, a relatively high number of total traffic citations captures some additional measure of risk-taking behavior in the community that is correlated with a high frequency of KA suspected alcohol impaired driving crashes.

Conclusions and Recommendations

The purpose of this analysis is to identify town-level risk factors for fatal and serious injury suspected alcohol impaired and suspected drug impaired driving crashes in Massachusetts, as well as segment level risk factors for further prioritization for education, enforcement, and other strategies. Unfortunately, the team was only able to develop a strong model for suspected alcohol impaired driving. In the future, as more reliable drug-impaired crash data arise, MassDOT will be able to develop strong models to identify correlations and eventually create risk factor maps for drug impaired driving.

VHB recommends that MassDOT disregard the coefficients from the negative binomial regression results in Table 37. 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 38 summarizes the proposed town-level risk factors for suspected alcohol impaired 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 39 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 38. Town-level risk factors for suspected alcohol impaired driving crashes.

Town Risk Factors for Impaired Driving Crashes	Scoring
Population Density (Residents per Square Mile)	Linear from 0.5 at 1,500 to 1.0 at max (19,586.9); 0 if less than 1,500
ABCC Licenses per 1,000 Residents	1.0 if 4 or less; 0 if greater than 4
Annual OUI Offender Program Enrollments per 1,000 Residents	1.0 if greater than 1; 0 if 1 or fewer
Annual OUI Citations per 1,000 Residents	Linear from 0.5 at 4 to 1.0 at 10 and greater; 0 if less than 4
Annual Traffic Citations per 1,000 Residents	Linear from 0.5 at 50 to 1.0 at 500 and greater; 0 if less than 50

Table 39. Segment-level risk factors for suspected alcohol impaired driving crashes.

Segment Risk Factors for Impaired Driving Crashes	Scoring
Normalized Lane Departure Risk Score	Range from 0 to 1
Normalized Pedestrian Risk Score	Range from 0 to 1
AADT [vehicles per day]	Linear from 0.5 at 1,999 to 1.0 at 500; 0 otherwise
Roadway Jurisdiction	1.0 if MassDOT; 0 otherwise
Access Control	1.0 if full control; 0.5 if partial control; 0 if no control
Right Shoulder Width	1.0 if 1 to 2 feet; 0 otherwise
Presence of Curbing	1.0 if no curbing present; 0 otherwise

Town-level risks should be used primarily for developing education and enforcement campaigns for suspected alcohol impaired driving. Education campaigns can include multimedia messaging including television, radio, social media, signage, public engagement, etc. Segment-level risk factors should be used to target messaging, enforcement checkpoints, and engineering countermeasures for lane departure and pedestrian crashes which will have some secondary reduction on severe impaired driving crashes. Towns and other local agencies can target high-risk corridors with variable message signs or other forms to deliver anti-impaired driving messages to drivers. A combined education, enforcement, and engineering approach can reduce both alcohol impaired driving behaviors and the potential frequency and severity of lane departure crashes and pedestrian crashes resulting from alcohol impaired driving. A common, severe outcome of alcohol impaired driving is a severe lane departure crash or pedestrian crash. Given it cannot be 100 percent prevented, agencies should build a safe system which provides forgiveness for errant impaired drivers.

Table 40 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 dividing by the total possible score, which in this case is 12. 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 40 is 5.83, associated with a normalized risk score of 0.49 (5.83/12) for the segment.

Since the crash type assessment underscored the prevalence of lane departure and pedestrian 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 and pedestrian emphasis area risk sites.

Table 40. Example risk score calculation for suspected alcohol impaired driving.

Variable	Town or Segment Characteristic	Risk Factor	Risk Score
Population Density	1,250	Linear from 0.5 at 1,500 to 1.0 at max (19,586.9); 0 if less than 1,500	0
ABCC Licenses per 1,000 Residents	2.1	1.0 if 4 or less; 0 if greater than 4	1
Annual OUI Offender Program Enrollments per 1,000 Residents	3	1.0 if greater than 1; 0 if 1 or fewer	1
Annual OUI Citations per 1,000 Residents	2	Linear from 0.5 at 4 to 1.0 at 10 and greater; 0 if less than 4	0
Annual Traffic Citations per 1,000 Residents	23	Linear from 0.5 at 50 to 1.0 at 500 and greater; 0 if less than 50	0
Normalized Lane Departure Risk Score	0.7	Range from 0 to 1	0.7
Normalized Pedestrian Risk Score	0.3	Range from 0 to 1	0.3
AADT [vehicles per day]	1,000	Linear from 0.5 at 1,999 to 1.0 at 500; 0 otherwise	0.83
Roadway Jurisdiction	City or town road	1.0 if MassDOT; 0 otherwise	0
Access Control	No control	1.0 if full control; 0.5 if partial control; 0 if no control	0
Right Shoulder Width	2 feet	1.0 if 1 to 2 feet; 0 otherwise	1
Presence of Curbing	None	1.0 if no curbing present; 0 otherwise	1
		Total Risk Score:	5.83
		Normalized Risk Score:	0.36

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 41 and Table 42 show the distribution of segments with the normalized risk score (presented as percentages) across these categories for statewide and MPO rankings, respectively.

Table 41. 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	46.78%	67.12%	16,153	5.00%
	Secondary Risk Site	40.40%	46.78%	32,345	10.02%

Table 42. 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	41.55%	54.97%	646	5.00%
	Secondary Risk Site	34.39%	41.54%	1,294	10.02%
Boston Region MPO	Primary Risk Site	44.92%	67.12%	5,701	5.06%
	Secondary Risk Site	39.85%	44.91%	11,532	10.23%
Cape Cod Commission	Primary Risk Site	49.16%	65.15%	1,448	5.11%
	Secondary Risk Site	40.82%	49.15%	3,038	10.72%
Central Massachusetts Regional Planning Commission	Primary Risk Site	45.63%	61.73%	1,543	5.04%
	Secondary Risk Site	40.20%	45.61%	3,048	9.96%
Franklin Regional Council of Governments	Primary Risk Site	41.71%	63.74%	380	5.05%
	Secondary Risk Site	34.56%	41.65%	758	10.08%
Martha's Vineyard Commission	Primary Risk Site	40.79%	52.48%	162	5.01%
	Secondary Risk Site	29.81%	40.76%	325	10.05%
Merrimack Valley Planning Commission	Primary Risk Site	48.36%	60.57%	1,036	6.71%
	Secondary Risk Site	42.02%	48.35%	1,325	8.59%
Montachusett Regional Planning Commission	Primary Risk Site	45.82%	58.81%	828	5.16%
	Secondary Risk Site	43.19%	45.77%	1,589	9.91%
Nantucket Planning and Economic Development Commission	Primary Risk Site	32.95%	42.91%	259	11.06%
	Secondary Risk Site	28.09%	31.87%	100	4.27%
Northern Middlesex Council of Governments	Primary Risk Site	49.34%	58.69%	650	5.02%
	Secondary Risk Site	41.49%	49.26%	1,294	10.00%
Pioneer Valley Planning Commission	Primary Risk Site	48.96%	58.56%	1,138	5.89%
	Secondary Risk Site	44.17%	48.93%	1,767	9.15%
Old Colony Planning Council	Primary Risk Site	46.85%	59.70%	1,505	5.00%
	Secondary Risk Site	40.82%	46.82%	3,023	10.05%
Southeastern Regional Planning and Economic Development District	Primary Risk Site	49.20%	66.39%	1,653	5.25%
	Secondary Risk Site	44.10%	49.18%	3,072	9.75%