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

## Older Drivers (65+)

PREPARED FOR

Massachusetts Department of Transportation

PREPARED BY

vhb

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 older driver-related (i.e., involving a driver aged 65 or older) 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.

## Focus Crash Types

Over 14,000 fatal (K) and suspected serious injury (A) crashes (1,693 K and 12,528 A crashes, respectively) occurred in Massachusetts between 2013 and 2017. This analysis excluded incomplete crash data from the City of Boston, leaving 1,576 K and 11,997 A crashes during the 5-year study period. Based on discussions with MassDOT, VHB established that any crash that involved a driver over the age of 64 is defined as an older driver-related crash (regardless of the party at-fault). Of the 13,573 KA crashes that occurred during the study period, 2,466 involved an older driver (309 K and 2,157 A crashes).

A preliminary comparison of KA older driver crashes and less severe older driver crashes did not reveal many significant differences in crash characteristic distributions. However, there were substantial differences between older driver crashes and crashes of all types in Massachusetts. Therefore, VHB compared the distribution of older driver KA crashes to the distribution of remaining KA crashes (i.e., those that did not involve an older driver) 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 older driver KA crashes is larger than the upper bound of the comparison group, the attribute was considered "overrepresented" for the data.

$$95\%\ Confidence\ Interval, Lower\ Bound\ =\ p - 1.96 * \sqrt{\frac{p(1-p)}{N}}$$

***Figure 1. Calculation of the lower bound of the 95 percent confidence interval for the proportion of crashes with an attribute***

$$95\%\ Confidence\ Interval, Upper\ Bound\ =\ p + 1.96 * \sqrt{\frac{p(1-p)}{N}}$$

***Figure 2. Calculation of the upper bound of the 95 percent confidence interval for the proportion of crashes with an attribute.***

The following sections document these comparisons and highlight the key takeaways for systemic risk factor analysis.

## Manner of Collision and First Harmful Event

Tables 1 and 2 illustrate that older-driver related KA crashes are much more likely to be the result of multi-vehicle crashes than other KA crashes. Only 27 percent of older driver-related KA crashes involved a single vehicle, while 44 percent of non-older driver KA crashes involved a single vehicle. Within all multi-vehicle crash types, angle, rear-end, and head on crashes are overrepresented in older driver crashes. This conclusion is reflected in the first harmful event field, as 62 percent of older driver-related crashes involved another motor vehicle, while less than half (46 percent) of non-older driver KA crashes involved another motor vehicle.

***Table 1. Summary of KA crashes by manner of collision.***

| Manner of Collision | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| **Angle** | **799** | **32.4%** | **0.9%** | **2,653** | **23.9%** | **0.4%** |
| Single Vehicle Crash | 673 | 27.3% | 0.9% | 4,867 | 43.8% | 0.4% |
| **Rear-End** | **435** | **17.6%** | **0.8%** | **1,652** | **14.9%** | **0.3%** |
| **Head-On** | **341** | **13.8%** | **0.7%** | **1,096** | **9.9%** | **0.3%** |
| Sideswipe, Same Direction | 90 | 3.6% | 0.4% | 412 | 3.7% | 0.2% |
| **Sideswipe, Opposite Direction** | **72** | **2.9%** | **0.3%** | **187** | **1.7%** | **0.1%** |
| Unknown | 27 | 1.1% | 0.2% | 101 | 0.9% | 0.1% |
| Not Reported | 20 | 0.8% | 0.2% | 116 | 1.0% | 0.1% |
| Rear-to-Rear | 7 | 0.3% | 0.1% | 17 | 0.2% | 0.0% |
| Front to Front | 1 | 0.0% | 0.0% | 2 | 0.0% | 0.0% |
| Other | 1 | 0.0% | 0.0% | 2 | 0.0% | 0.0% |
| Front to Rear | 0 | 0.0% | 0.0% | 2 | 0.0% | 0.0% |

***Table 2. Summary of KA crashes by first harmful event.***

| First Harmful Event | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| **Collision with motor vehicle in traffic** | **1,530** | **62.0%** | **1.0%** | **5,104** | **46.0%** | **0.4%** |
| Collision with pedestrian | 305 | 12.4% | 0.7% | 1,482 | 13.3% | 0.3% |
| Collision with tree | 130 | 5.3% | 0.5% | 896 | 8.1% | 0.2% |
| Collision with pedalcycle | 78 | 3.2% | 0.4% | 411 | 3.7% | 0.2% |
| Collision with utility pole | 75 | 3.0% | 0.3% | 644 | 5.8% | 0.2% |
| Collision with parked motor vehicle | 68 | 2.8% | 0.3% | 334 | 3.0% | 0.1% |
| Other First Harmful Event | 280 | 10.2% | -- | 2,236 | 16.8% | -- |

## Intersection Related and Junction Type

Table 3 details the relationship of KA crashes to specific intersection types. Table 3 demonstrates that older driver-related KA crashes are related to an intersection more frequently than other KA crashes. This supports the results in Tables 1 and 2 and suggests that older driver crashes tend to be multi-vehicle collisions, particularly angle, head on, and rear-end crashes. Older driver-related KA crashes tend to be overrepresented at four-leg intersections, but only 21 percent of crashes were related to four-leg intersections. However, Tables 4 and 5 do not indicate a significant difference in the distribution of older driver-related and non-older driver KA crashes with respect to traffic control devices and vehicle maneuvers at intersections; only stop signs and the "entering traffic lane" action showed a significant overrepresentation of older-driver KA crashes.

***Table 3. Summary of KA crashes by junction type.***

| Junction Type | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| Not at junction | 1,669 | 50.5% | 0.9% | 6,155 | 59.9% | 0.4% |
| **Four-way intersection** | **707** | **21.4%** | **0.7%** | **1,463** | **14.2%** | **0.3%** |
| T-intersection | 600 | 18.2% | 0.7% | 1,662 | 16.2% | 0.3% |
| **Driveway** | **112** | **3.4%** | **0.3%** | **198** | **1.9%** | **0.1%** |
| Y-intersection | 75 | 2.3% | 0.3% | 234 | 2.3% | 0.1% |
| Not reported | 35 | 1.1% | 0.2% | 103 | 1.0% | 0.1% |
| Off-ramp | 34 | 1.0% | 0.2% | 185 | 1.8% | 0.1% |
| On-ramp | 34 | 1.0% | 0.2% | 115 | 1.1% | 0.1% |
| Traffic circle | 16 | 0.5% | 0.1% | 56 | 0.5% | 0.1% |
| Five-point or more | 15 | 0.5% | 0.1% | 58 | 0.6% | 0.1% |
| Unknown | 6 | 0.2% | 0.1% | 36 | 0.4% | 0.1% |
| Railway grade crossing | 1 | 0.0% | 0.0% | 4 | 0.0% | 0.0% |

***Table 4. Summary of KA intersection-related crashes by traffic control device.[1]***

| Traffic Control Type | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| No controls | 433 | 37.1% | 1.4% | 1,766 | 40.1% | 0.7% |
| **Stop signs** | **347** | **29.8%** | **1.3%** | **1,123** | **25.5%** | **0.7%** |
| Traffic control signal | 324 | 27.8% | 1.3% | 1,245 | 28.3% | 0.7% |
| Flashing traffic control signal | 24 | 2.1% | 0.4% | 84 | 1.9% | 0.2% |
| Yield signs | 16 | 1.4% | 0.3% | 93 | 2.1% | 0.2% |
| Warning signs | 11 | 0.9% | 0.3% | 42 | 1.0% | 0.1% |
| Not reported | 8 | 0.7% | 0.2% | 35 | 0.8% | 0.1% |
| Unknown | 2 | 0.2% | 0.1% | 8 | 0.2% | 0.1% |
| School zone signs | 1 | 0.1% | 0.1% | 1 | 0.0% | 0.0% |
| Railway crossing device | 0 | 0.0% | 0.0% | 6 | 0.1% | 0.1% |

[1] Excludes Not at junction, Not reported, and Unknown codes in the "rdwy_jnct_type_descr" field.

***Table 5. Summary of KA intersection-related crashes by vehicle maneuver.*** [2,3]

| Junction Type | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | **Total** | **Percentage** | **Sampling Error** | **Total** | **Percentage** | **Sampling Error** |
| Travelling straight ahead | 1,299 | 57.8% | 1.0% | 4,437 | 57.9% | 0.6% |
| Turning left | 364 | 16.2% | 0.8% | 1,222 | 15.9% | 0.4% |
| Slowing or stopped in traffic | 270 | 12.0% | 0.7% | 805 | 10.5% | 0.4% |
| **Entering traffic lane** | **120** | **5.3%** | **0.5%** | **294** | **3.8%** | **0.2%** |
| Turning right | 51 | 2.3% | 0.3% | 293 | 3.8% | 0.2% |
| Parked | 49 | 2.2% | 0.3% | 155 | 2.0% | 0.2% |
| **Backing** | **27** | **1.2%** | **0.2%** | **42** | **0.5%** | **0.1%** |
| Changing lanes | 15 | 0.7% | 0.2% | 57 | 0.7% | 0.1% |
| Not reported | 14 | 0.6% | 0.2% | 82 | 1.1% | 0.1% |
| Other | 9 | 0.4% | 0.1% | 40 | 0.5% | 0.1% |
| Leaving traffic lane | 7 | 0.3% | 0.1% | 57 | 0.7% | 0.1% |
| Overtaking | 7 | 0.3% | 0.1% | 71 | 0.9% | 0.1% |
| Passing | 7 | 0.3% | 0.1% | 71 | 0.9% | 0.1% |
| Unknown | 4 | 0.2% | 0.1% | 18 | 0.2% | 0.1% |
| Making U-turn | 3 | 0.1% | 0.1% | 20 | 0.3% | 0.1% |

Table 6 provides a more detailed summary of intersection-related crashes by comparing older driver-related KA crashes with older driver intersection-related crashes of all severities and all intersection-related crashes. This table is significant because it not only highlights the differences within the pool of older driver crashes, but also demonstrates differences between older driver and all intersection-related crashes. For instance, although more severe older driver intersection-related crashes tend to happen later in the evening and during dark lighting conditions, older driver crashes, regardless of severity, tend to happen during daylight hours.

[2] Excludes Not at junction, Not reported, and Unknown codes in the “rdwy_jnct_type_descr” field.
[3] Only includes V1, V2, and V3 maneuvers.

***Table 6. Comparison of older driver KA intersection-related crashes with all intersection-related crash types.[4]***

| Crash Data Field | Crash Data Attribute | Percentage of Older Driver KA Intersection Crashes | Percentage of All Older Driver Intersection Crashes | Percentage of KA Intersection Crashes | Percentage of All Intersection Crashes | Over-represented Relative to All Older Driver Crashes | Over-represented Relative to KA Intersection Crashes |
|---|---|---|---|---|---|---|---|
| Crash Hour | 11:00 AM to 11:59 AM | 8.5% | 8.5% | 5.2% | 5.8% | No | Yes |
| Crash Hour | 12:00 PM to 12:59 PM | 10.2% | 8.9% | 5.8% | 6.6% | No | Yes |
| Crash Hour | 7:00 PM to 7:59 PM | 4.6% | 2.8% | 5.3% | 4.1% | Yes | No |
| Driver Contributing Circumstance - 1 | Failed to yield right of way | 16.6% | 14.3% | 11.9% | 9.3% | No | No |
| Driver Contributing Circumstance - 1 | Illness | 1.2% | 0.3% | 0.9% | 0.2% | Yes | No |
| Driver Contributing Circumstance - 1 | Operating vehicle in erratic, reckless, careless, negligent, or aggressive manner | 2.1% | 0.7% | 6.1% | 1.8% | Yes | No |
| Driver Contributing Circumstance - 2 | Failed to yield right of way | 3.4% | 1.7% | 1.9% | 8.5% | Yes | No |
| Manner of Collision | Angle | 52.9% | 52.4% | 46.8% | 43.9% | No | Yes |
| Manner of Collision | Head-on | 10.1% | 3.2% | 9.9% | 3.4% | Yes | No |
| Manner of Collision | Single vehicle crash | 16.1% | 5.5% | 25.0% | 10.3% | Yes | No |
| First Harmful Event | Collision with pedestrian | 12.6% | 1.7% | 14.4% | 2.3% | Yes | No |
| First Harmful Event | Collision with pedalcycle (bicycle, tricycle, unicycle, pedal car) | 3.7% | 1.2% | 5.6% | 1.6% | Yes | No |
| Lighting Conditions | Dark - lighted roadway | 16.5% | 11.9% | 26.9% | 22.0% | Yes | No |
| Lighting Conditions | Daylight | 78.7% | 83.8% | 66.3% | 72.4% | No | Yes |
| Traffic Control Type | No controls | 30.3% | 26.0% | 33.6% | 27.6% | Yes | No |
| Traffic Control Type | Stop signs | 29.1% | 29.3% | 28.5% | 24.5% | No | No |

[4] Includes Five-point or more, Four-way intersection, T-intersection, Traffic circle, and Y-intersection codes in the “rdwy_jnct_type_descr” field.

## Weather and Road Surface Condition

There were no substantial differences between older driver-related KA crashes and other crash types with respect to weather and road surface conditions.

## Lighting Condition and Time of Day

Table 7 underscores that older driver-related KA crashes are much more likely to occur during daylight conditions than other crash types. This is likely a result of preferred travel patterns for individuals over the age of 64. Table 8 reflects this trend, as nearly 75 percent of all older driver-related KA crashes occurred between 9:00 am and 6:00 pm (compared to less than half of all other KA crash types).

***Table 7. Summary of KA crashes by lighting condition.***

| Lighting Condition | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| **Daylight** | **1,964** | **79.6%** | **0.8%** | **6,293** | **56.7%** | **0.4%** |
| Dark - lighted roadway | 324 | 13.1% | 0.7% | 3,010 | 27.1% | 0.4% |
| Dark - roadway not lighted | 97 | 3.9% | 0.4% | 1,187 | 10.7% | 0.3% |
| Dusk | 47 | 1.9% | 0.3% | 298 | 2.7% | 0.1% |
| Dawn | 21 | 0.9% | 0.2% | 173 | 1.6% | 0.1% |
| Dark - unknown roadway lighting | 6 | 0.2% | 0.1% | 91 | 0.8% | 0.1% |
| Not reported | 6 | 0.2% | 0.1% | 39 | 0.4% | 0.1% |
| Other | 1 | 0.0% | 0.0% | 8 | 0.1% | 0.0% |
| Unknown | 0 | 0.0% | 0.0% | 8 | 0.1% | 0.0% |

***Table 8. Summary of KA crashes by hour of day.***

| Hour of Day | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| 12 AM - Midnight | 10 | 0.4% | 0.1% | 374 | 3.4% | 0.2% |
| 1 AM | 8 | 0.3% | 0.1% | 397 | 3.6% | 0.2% |
| 2 AM | 6 | 0.2% | 0.1% | 269 | 2.4% | 0.1% |
| 3 AM | 1 | 0.0% | 0.0% | 181 | 1.6% | 0.1% |
| 4 AM | 14 | 0.6% | 0.2% | 139 | 1.3% | 0.1% |
| 5 AM | 13 | 0.5% | 0.1% | 183 | 1.6% | 0.1% |
| 6 AM | 38 | 1.5% | 0.2% | 251 | 2.3% | 0.1% |
| 7 AM | 70 | 2.8% | 0.3% | 438 | 3.9% | 0.2% |
| 8 AM | 106 | 4.3% | 0.4% | 461 | 4.2% | 0.2% |
| **9 AM** | **118** | **4.8%** | **0.4%** | **355** | **3.2%** | **0.2%** |
| **10 AM** | **156** | **6.3%** | **0.5%** | **406** | **3.7%** | **0.2%** |
| **11 AM** | **209** | **8.5%** | **0.6%** | **445** | **4.0%** | **0.2%** |
| **12 PM - Noon** | **234** | **9.5%** | **0.6%** | **495** | **4.5%** | **0.2%** |
| **1 PM** | **238** | **9.7%** | **0.6%** | **555** | **5.0%** | **0.2%** |
| **2 PM** | **232** | **9.4%** | **0.6%** | **669** | **6.0%** | **0.2%** |
| **3 PM** | **218** | **8.8%** | **0.6%** | **748** | **6.7%** | **0.2%** |
| 4 PM | 191 | 7.7% | 0.5% | 762 | 6.9% | 0.2% |
| 5 PM | 204 | 8.3% | 0.6% | 796 | 7.2% | 0.2% |
| 6 PM | 129 | 5.2% | 0.4% | 696 | 6.3% | 0.2% |
| 7 PM | 94 | 3.8% | 0.4% | 567 | 5.1% | 0.2% |
| 8 PM | 67 | 2.7% | 0.3% | 543 | 4.9% | 0.2% |
| 9 PM | 52 | 2.1% | 0.3% | 538 | 4.8% | 0.2% |
| 10 PM | 33 | 1.3% | 0.2% | 438 | 3.9% | 0.2% |
| 11 PM | 24 | 1.0% | 0.2% | 398 | 3.6% | 0.2% |

## Focus Facility Types

Table 3 demonstrates that intersections are a focus facility type for older driver-related crashes (primary four-leg intersections); however, the IMPACT Safety Analysis Module will only screen the network at the segment level due to data constraints at the time of module development. Future iterations of the analysis and tool will use intersections as the focus facility type. To supplement the findings in previous sections and identify segment-level risk factors, VHB compared the distribution of older driver KA crashes to the distribution of non-older driver KA crashes (i.e., those that did not involve an older driver) across a series of facility-level characteristics. Table 9 and 10 document the key takeaways from this comparison.

Older driver-related crashes were more likely to occur on non-access-controlled arterials (e.g., other principal arterials and minor arterials) than other crash types. Older drivers were less likely to be involved in crashes on both the highest speed and traffic volume facilities (e.g., interstates and freeways) and the lowest speed and traffic volume facilities (e.g., local roads and collectors). This is reflected in the facility types in Table 10. Interstates and freeways are more likely to be median divided, and older driver-related KA crashes occurred more frequently on two-way, undivided roads.

***Table 9. Summary of KA crashes by federal functional classification.***

| Federal Functional Classification | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| **Minor Arterial** | **851** | **34.5%** | **1.0%** | **3,285** | **29.6%** | **0.4%** |
| **Principal Arterial - Other** | **843** | **34.2%** | **1.0%** | **3,169** | **28.5%** | **0.4%** |
| Major Collector | 244 | 9.9% | 0.6% | 1,274 | 11.5% | 0.3% |
| Local | 187 | 7.6% | 0.5% | 1,254 | 11.3% | 0.3% |
| Interstate | 145 | 5.9% | 0.5% | 986 | 8.9% | 0.2% |
| Blank | 109 | 4.4% | 0.4% | 564 | 5.1% | 0.2% |
| Principal Arterial - Other Freeways and Expressways | 76 | 3.1% | 0.3% | 527 | 4.7% | 0.2% |
| Minor Collector | 11 | 0.4% | 0.1% | 48 | 0.4% | 0.1% |

***Table 10. Summary of KA crashes by facility type.***

| Facility Type | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| **Two-way, not divided** | **1,653** | **67.0%** | **0.9%** | **6,852** | **61.7%** | **0.5%** |
| Two-way, divided, unprotected median | 381 | 15.5% | 0.7% | 1,778 | 16.0% | 0.3% |
| Two-way, divided, positive median barrier | 282 | 11.4% | 0.6% | 1,749 | 15.7% | 0.3% |
| One-way, not divided | 87 | 3.5% | 0.4% | 496 | 4.5% | 0.2% |
| Not reported | 36 | 1.5% | 0.2% | 147 | 1.3% | 0.1% |
| Unknown | 27 | 1.1% | 0.2% | 85 | 0.8% | 0.1% |

Figure 3 further underscores that fatal and serious injury older driver crashes are overrepresented on arterial roads, as the proportion of these crashes exceed the statewide proportion of centerline mileage and vehicle miles traveled (VMT) on these facilities. The emphasis on middle-tier arterial roads is also reflected in the distribution of older driver-related KA crashes across posted speed limits. Table 11 shows that there is a higher proportion of older driver KA crashes on roadways with more moderate posted speed limits (35-45 mph) compared to roadways with the higher posted speeds for other KA crash types; however, this is likely highly correlated with the functional classification findings in Table 9.

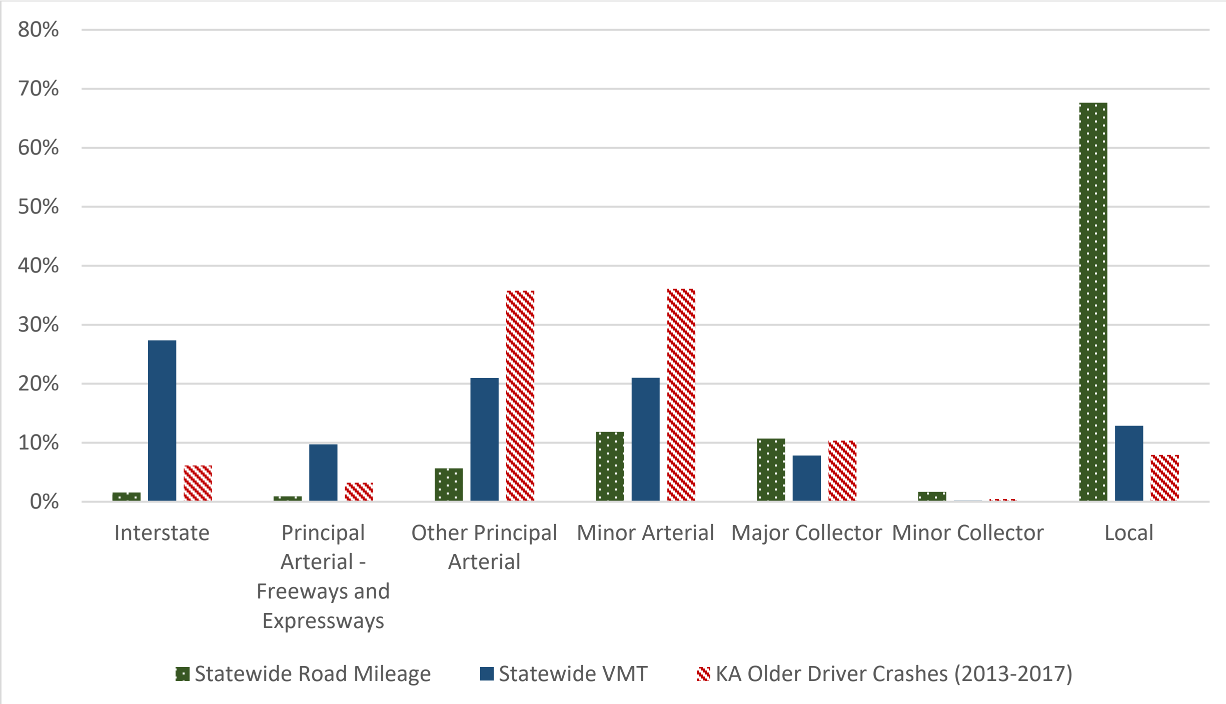


***Figure 3. Distribution of road mileage[5], VMT[6], and older driver KA crashes across all functional classifications.***

***Table 11. Summary of KA crashes by posted speed limit.[7]***

| Posted Speed Limit | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | Total | Percentage | Sampling Error | Total | Percentage | Sampling Error |
| 15 | 0 | 0.0% | 0.0% | 2 | 0.0% | 0.0% |
| 20 | 25 | 2.0% | 0.4% | 101 | 1.9% | 0.1% |
| 25 | 74 | 5.9% | 0.7% | 331 | 6.1% | 0.2% |
| 30 | 278 | 22.3% | 1.2% | 1,235 | 22.7% | 0.4% |
| **35** | **273** | **21.9%** | **1.2%** | **941** | **17.3%** | **0.4%** |
| **40** | **206** | **16.5%** | **1.1%** | **715** | **13.1%** | **0.3%** |
| 45 | 138 | 11.0% | 0.9% | 469 | 8.6% | 0.3% |
| 50 | 56 | 4.5% | 0.6% | 282 | 5.2% | 0.2% |
| 55 | 83 | 6.6% | 0.7% | 425 | 7.8% | 0.3% |
| 60 | 10 | 0.8% | 0.3% | 69 | 1.3% | 0.1% |
| 65 | 106 | 8.5% | 0.8% | 870 | 16.0% | 0.3% |

Table 12 Compares KA crashes by annual average daily traffic (AADT) volume; older driver crashes are not substantially different than non-older driver-related KA crashes; however, there is a slight increase in the proportion of older driver KA crashes between 5,000 and 20,000 AADT (51.4%) relative to other KA crashes (43.3%)

[5] FHWA 2018 Highway Statistics; HM-20 Tables. https://www.fhwa.dot.gov/policyinformation/statistics/2018/
[6] FHWA 2018 Highway Statistics; VM-2 Table. https://www.fhwa.dot.gov/policyinformation/statistics/2018/
[7] Only includes crashes with known posted speed limits.

***Table 12. Summary of KA crashes by AADT category.***[8]

| AADT Category | Older Driver KA Crashes | | | Non-Older Driver KA Crashes | | |
|---|---|---|---|---|---|---|
| | **Total** | **Percentage** | **Sampling Error** | **Total** | **Percentage** | **Sampling Error** |
| Less than 5,000 | 596 | 29.0% | 1.0% | 2,778 | 30.9% | 1.0% |
| **5,000-10,000** | **493** | **24.0%** | **0.9%** | **1,862** | **20.7%** | **0.9%** |
| **10,000-15,000** | **363** | **17.7%** | **0.8%** | **1,351** | **15.0%** | **0.8%** |
| **15,000-20,000** | **201** | **9.8%** | **0.7%** | **684** | **7.6%** | **0.6%** |
| 20,000-25,000 | 113 | 5.5% | 0.5% | 443 | 4.9% | 0.5% |
| 25,000-30,000 | 47 | 2.3% | 0.3% | 224 | 2.5% | 0.3% |
| 30,000-35,000 | 38 | 1.8% | 0.3% | 148 | 1.6% | 0.3% |
| 35,000-40,000 | 19 | 0.9% | 0.2% | 142 | 1.6% | 0.3% |
| 40,000-45,000 | 16 | 0.8% | 0.2% | 106 | 1.2% | 0.2% |
| 45,000-50,000 | 16 | 0.8% | 0.2% | 163 | 1.8% | 0.3% |
| Over 50,000 | 154 | 7.5% | 0.6% | 1,103 | 12.3% | 0.7% |

# Risk Factor Analysis

After identifying focus crash type and focus facility types, VHB proceeded with the risk factor analysis. The following sections describe the methodology, data, and results of this analysis.

## 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 older driver-related KA crashes. Negative binomial regression is a commonly used method in transportation safety as it applies to over-dispersed count data (i.e., the variance exceeds the mean of the observed data). The dependent variable in the model is the number of older driver-related KA crashes, making a count model appropriate for the data. The functional form of the negative binomial regression model is shown in Figure 4.[9]

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

***Figure 4. 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 $\alpha$.

$\lambda i$ = expected number of older driver-related KA crashes at location i.

$\beta$ = vector of estimated parameters.

[8] Only includes crashes with known AADT values.
[9] 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

> Xi = vector of independent variables that characterize location i and influence older driver-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.[10]

## Data

VHB used ArcGIS to manage and integrate data for this analysis. VHB aggregated data at the city and town level. In Massachusetts, all roads and geographic area are covered by town jurisdictions. Due to limitations with crash data acquisition, VHB excluded the City of Boston from the analysis. MassDOT provided VHB with various sources of data, as described in the following sections.

### Crash Data

MassDOT provide statewide geolocated older driver-related crash data for the years 2013 through 2017.

### 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.

### Intersection Data

MassDOT provided a snapshot of the State's intersection location inventory as of January 2021. Intersections are represented as a single point in the transportation network.

### Driver License Data

MassDOT provided driver's license data by age and town for the years 2011 through 2015. Due to a substantial jump in the number of registered drivers in the dataset between 2011 and 2012 (28%), VHB excluded 2011 and used an average number of drivers in each age group for the years 2012 through 2015. VHB then calculated the total, proportion, and density of older drivers (i.e., drivers aged 65 and older) for each city, town, metropolitan planning organization (MPO), and regional planning agency (RPA).

### Emergency Medical Services (EMS) and Hospital Location Data

In addition to the data provided by MassDOT, VHB accessed EMS 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/362c9480f12e4587b6a502f9ceedccde_0). The agency's data description notes:

> "The EMS stations dataset consists of any location where emergency medical service (EMS) personnel are stationed or based out of, or where equipment that such personnel use in carrying

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

out their jobs is stored for ready use. Ambulance services are included even if they only provide transportation services, but not if they are located at, and operated by, a hospital. If an independent ambulance service or EMS provider happens to be collocated with a hospital, it will be included in this dataset. The dataset includes both private and governmental entities. A concerted effort was made to include all emergency medical service locations in the United States and its territories."

Hospital location data were also obtained from the HIFLD repository (https://hifld-geoplatform.opendata.arcgis.com/datasets/6ac5e325468c4cb9b905f1728d6fbf0f_0). This dataset includes locations for all hospital types, including psychiatric and long-term care. For the purposes of this analysis, VHB only included the "Critical Access" and "General Acute Care" hospital subtypes.

### Healthy Aging Data Reports

The Gerontology Institute of the John W. McCormack Graduate School of Policy and Global Studies at the University of Massachusetts Boston produces a suite of town-level socio-demographic data and indicators that reflect the health and quality of life of the elderly in Massachusetts, Rhode Island, New Hampshire. These data represent population characteristics, community engagement, access to care and amenities, wellness, mental and physical health, and disability prevalence.[11] While this program produces over 100 potential metrics for elderly quality of life, VHB limited the analysis to only consider 10 core inputs[12]:

- Number of nursing homes (within 5 miles of a town center).
- Number of assisted living sites.
- Number of home health agencies.
- Number of nonmedical (quality of life) senior transportation services.
- Number of senior transportation providers.
- Percentage of adults 65+ with self-reported ambulatory difficulty.
- Percentage of adults 65+ with self-reported cognition difficulty.
- Percentage of adults 65+ with self-reported independent living difficulty.
- Summary transportation performance score.

## Results

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

### Variables of Interest

To account for unobserved influences due to road facilities and traffic exposure, VHB established a base model that included the natural log of total centerline mileage and the proportion of centerline mileage classified as arterials (i.e., other principal arterials and minor arterials) by town. Before including additional variables in the negative binomial, VHB developed a correlation matrix of input variables. Highly correlated variables are indicators of potential complications in the model development process. Although VHB considered all potential variables in this matrix, Table 13 shows the correlation matrix for the following variables included in the final older driver model.

1. Natural log of total length of all centerlines in the town (miles).
2. Proportion of total centerline length that are arterials in the town (miles).

[11] https://healthyagingdatareports.org/about/
[12] http://mahealthyagingcollaborative.org/wp-content/uploads/2018/12/2018_MA_HealthyAgingReport_Technical_Documentation.pdf

3. Indicator that town has more older drivers per square mile than the governing MPO/RPA as a whole.
4. Ratio of total centerline length to total number of intersections (Average block length).
5. Number of senior transportation providers.
6. Percentage of adults 65+ with self-reported independent living difficulty.

***Table 13. Correlation matrix of input variables.***

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **1** | **1.00** | | | | | |
| **2** | **0.14** | **1.00** | | | | |
| **3** | **0.27** | **0.20** | **1.00** | | | |
| **4** | **-0.39** | **-0.50** | **-0.47** | **1.00** | | |
| **5** | **0.44** | **0.20** | **0.22** | **-0.29** | **1.00** | |
| **6** | **0.29** | **0.19** | **0.34** | **-0.41** | **0.13** | **1.00** |

### Model Results

Table 13 documents the results of the final model. Total centerline length and the proportion of length on arterials are both positively correlated with an increase in older driver-related KA crashes. This likely reflects overall exposure, and the correlation with arterial centerlines supports the results detailed in the *Focus Facility Types* section. An indicator variable associated with the density of licensed older drivers relative to the density within the MPO/RPA as a whole was also positively associated with an increase in KA crash frequency. This demonstrates that a relative increase in older drivers in a town compared to the neighboring municipalities can indicate a high-risk community in the State (i.e., even if that town is below the statewide average in density of older drivers).

The correlation between a lower average block length, defined as the ratio of total centerline length in a town divided by the total number of intersections, and fewer numbers of KA older driver-related crashes is reflected in the preliminary crash analysis as well. A lower value for this metric indicates a greater density of intersections relative to the overall road network (i.e., shorter blocks); towns with more intersections relative to the overall road network would expect to be higher risk for older driver crashes given the overrepresentation of this crash type at intersections. While the complete intersection inventory was not available at the time of this analysis, future iterations will consider mapping risk factors at intersections as a focus crash type.

The number of senior transportation providers and percentage of adults 65+ with self-reported independent living difficulty are positively correlated with older driver-related KA crashes. While there are several potential reasons for these correlations, the project team identified some likely contributing factors:

- Senior-related transportation services not only indicate a higher density of seniors, it may also indicate a density of potentially desirable destinations for seniors; in other words, a high density of origins and destinations would make multiple services necessary and viable.
- The percentage of adults 65+ with self-reported independent living difficulty was highly correlated with the percentage of adults 65+ with self-reported ambulatory difficulty or cognition difficulty (although cognitive difficulty was negatively correlated with KA crashes). VHB selected independent living difficulty as the preferred variable as this may indicate older drivers in need of extra accommodation in the transportation system relative to the rest of the driving population.

***Table 14. Negative binomial count regression model results.***

| Variable (Number) | Coefficient | Standard Error | z-value | P>\|z\| | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| Natural log of total length of all centerlines in the town (miles) | 1.14 | 0.07 | 17.45 | <0.001 | 1.01 | 1.27 |
| Proportion of total centerline length that are arterials in the town (miles)[13] | 1.72 | 0.62 | 2.77 | 0.006 | 0.50 | 2.94 |
| Indicator that town has more older drivers per square mile than the governing MPO/RPA as a whole | 0.16 | 0.08 | 1.98 | 0.047 | 0.00 | 0.31 |
| Ratio of total centerline length to total number of intersections (Average block length) | -0.72 | 0.10 | -6.96 | <0.001 | -0.92 | -0.52 |
| Number of senior transportation providers | 0.02 | 0.00 | 5.44 | <0.001 | 0.01 | 0.03 |
| Percentage of adults 65+ with self-reported independent living difficulty | 0.97 | 0.83 | 1.16 | 0.245 | -0.66 | 2.61 |
| Constant | -3.69 | 0.39 | -9.35 | <0.001 | -4.46 | -2.92 |
| Alpha | 0.13 | 0.02 | - | - | 0.09 | 0.19 |

Note: Number of observations = 348; Log likelihood = -792.271; Pseudo R2 = 0.2363; LR chi2(6) = 490.32; Prob > chi2 = 0.0000.

Generally, EMS location metrics were not statistically significant compared to the impact of older driver populations and density. At the crash location-level, more severe older driver-related crashes tend to occur further away from EMS locations and hospitals compared to less severe older driver-related crashes (Figure 5). This is a risk factor associated with more severe older driver crashes; however, VHB notes that this trend is consistent with other KA crash types and not unique to older driver-related crashes specifically (Figure 6).

[13] Other principal arterials and minor arterials.

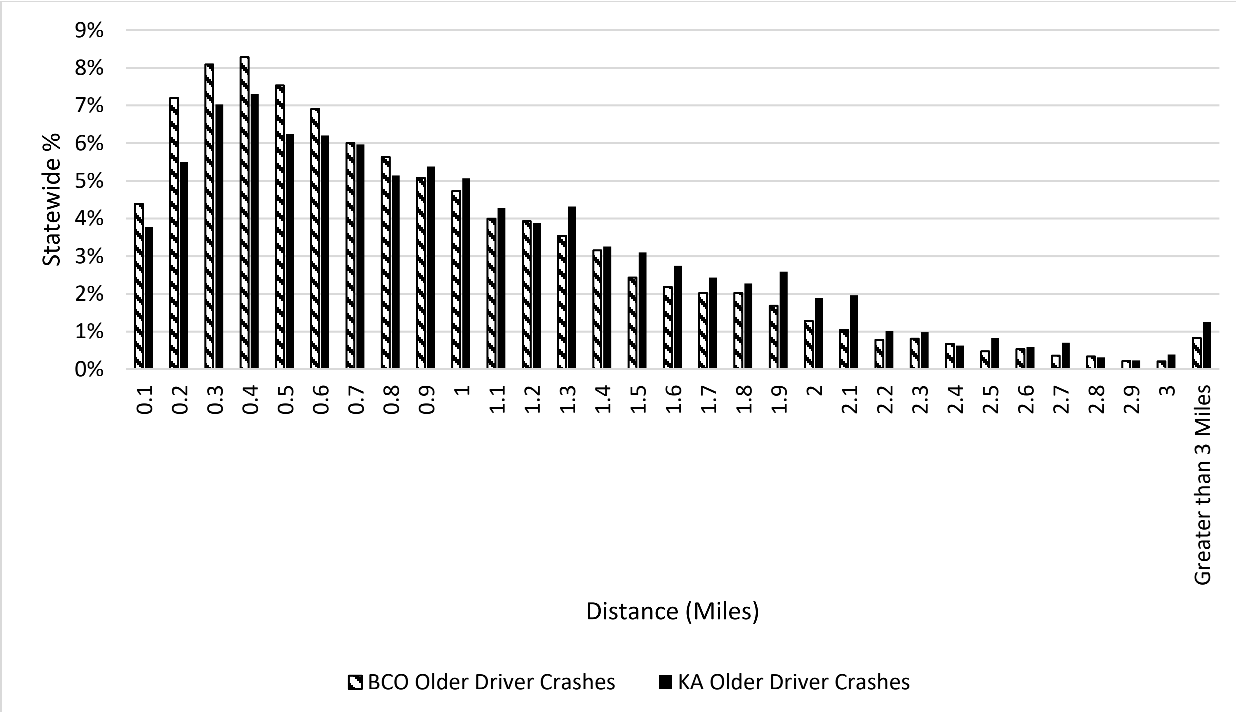


***Figure 5. Distance of older driver-related crashes to the nearest EMS location or hospital.[14]***

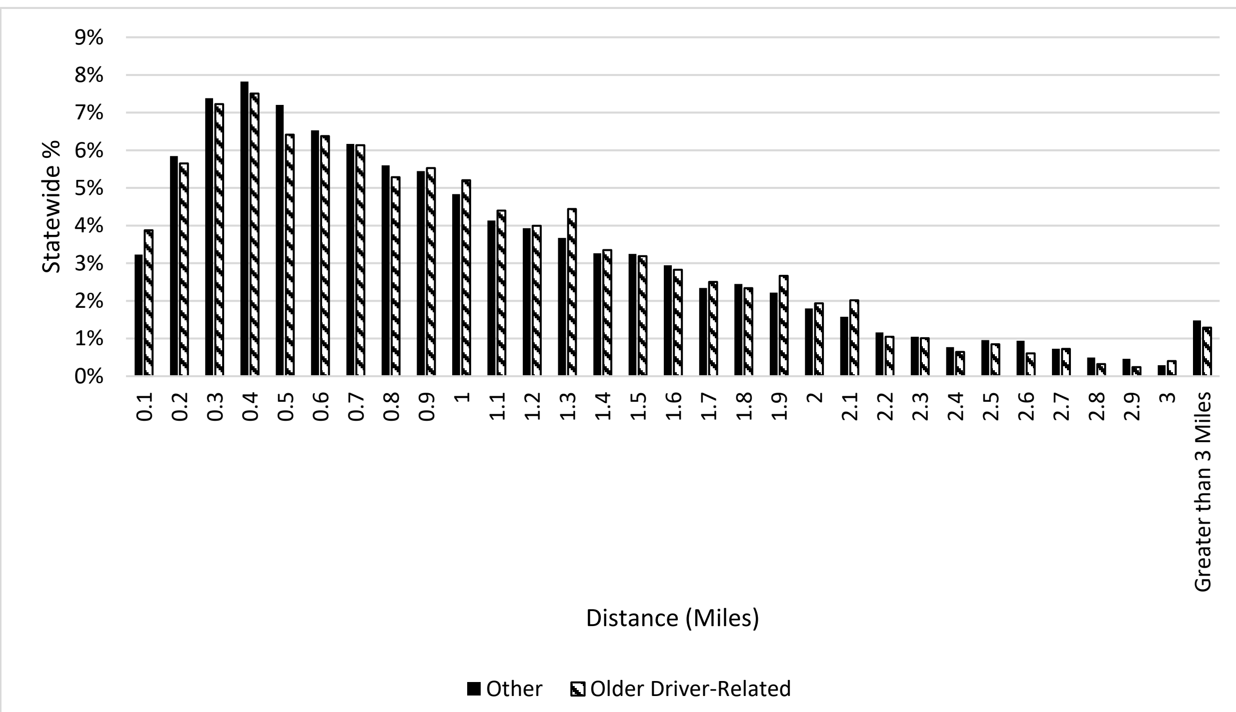


***Figure 6. Distance of all KA crashes to the nearest EMS location or hospital.[15]***

[14] Straight-line, non-network distance; Excludes City of Boston.
[15] Straight-line, non-network distance; Excludes City of Boston.

## Conclusions and Recommendations

The purpose of this analysis is to identify segment-level risk factors for fatal and serious injury risk factors. Although intersections represent a significant focus facility type for older drivers, MassDOT's IMPACT Safety Analysis Module only includes road centerline segments; future enhancements could map risk factors at intersections for older driver crashes. VHB recommends that MassDOT disregard the coefficients in the negative binomial regression results in Table 14. 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). For the three continuous variables in Table 15, VHB recommends that MassDOT normalize the values for this variable and assign a percentile rank to each town in Massachusetts and assign a percentile rank with the highest value being 1. For instance, if a town had a ratio of centerline length to intersections greater than 87 percent of all towns in the State, it would be assigned a risk score of 0.13 (due to the negative correlation).

Table 15 summarizes the risk factors identified in this analysis.

***Table 15. Summary of risk factors for older driver KA crashes.***

| Segment Risk Factors for Older Drivers | Type |
|---|---|
| Segment functional class is Principal Arterial – Other or Minor Arterial | Binary |
| Segment is more than 0.8 miles from an EMS location or hospital | Binary |
| Segment is undivided | Binary |
| AADT is between 5,000 and 20,000 vpd | Binary |
| Indicator that town has more older drivers per square mile than the governing MPO/RPA as a whole | Binary |
| Ratio of total centerline length to total number of intersections (Average block length) | Continuous |
| Number of senior transportation providers. | Continuous |
| Percentage of adults 65+ with self-reported independent living difficulty | Continuous |

Table 16 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 binary risk factors plus the value of the one continuous risk factor. 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 16 is 59.9 percent. Table 17 and Table 18 show the distribution of segments by risk category Statewide and by MPO, respectively. Risk categories are based on the proposed risk scoring scheme in Table 15 and exemplified in Table 16.

***Table 16. Example risk score calculations for older driver-related crashes.***

| Variable | Segment Characteristic | Risk Factor | Risk Score |
|---|---|---|---|
| Functional Classification | Minor Arterial | Segment functional class is Principal Arterial – Other or Minor Arterial | 1 |
| Distance to EMS Location or Hospital | 1.2 miles from nearest EMS location or hospital | Segment is more than 0.8 miles from an EMS location or hospital | 1 |
| Median Presence | Positive median barrier | Segment is undivided | 0 |
| AADT | 16,000 vpd | AADT is between 5,000 and 20,000 | 1 |
| Density of Older (65+) Driving Residents | 105 licensed older drivers per sq. mi. | Segment is in a town that has more older drivers per square mile than the governing MPO/RPA as a whole (74 licensed older drivers per sq. mi) | 1 |
| Ratio of total centerline length to total number of intersections | 1.11 centerline miles/ intersection | Greater than 70% of towns in the State | 0.3 |
| Number of senior transportation providers. | 2 | Greater than 19.4% of towns in the State | 0.19 |
| Percentage of adults 65+ with self-reported independent living difficulty | 10% | Greater than 30% of towns in the State | 0.3 |
| | | **Total Risk Score:** | 4.79 |
| | | **Risk Percent Score:** | 59.9% |

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 were 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, sites ranked in the top 5 percentile (95 through 100) were categorized as “Primary Risk Site,” sites 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 17 and 18 show the distribution of focus facility type segments with the normalized risk score (presented as percentages) across these categories for Statewide and MPO rankings, respectively.

***Table 17. 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 | 72.51% | 89.98% | 14772 | 5.0% |
| | Secondary Risk Site | 62.34% | 72.49% | 29527 | 10.0% |

***Table 18. 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 | 72.8% | 89.84% | 824 | 6.81% |
| | Secondary Risk Site | 63.2% | 71.66% | 1021 | 8.44% |
| Boston Region MPO | Primary Risk Site | 68.53% | 87.34% | 5018 | 5.04% |
| | Secondary Risk Site | 59.53% | 58.49% | 9968 | 10.01% |
| Cape Cod Commission | Primary Risk Site | 66.95% | 85.64% | 1403 | 5.17% |
| | Secondary Risk Site | 55.88% | 66.88% | 3102 | 11.43% |
| Central Massachusetts Regional Planning Commission | Primary Risk Site | 76.1% | 88.6% | 1994 | 7.23% |
| | Secondary Risk Site | 63.6% | 75.2% | 5728 | 20.76% |
| Franklin Regional Council of Governments | Primary Risk Site | 65.95% | 86.68% | 342 | 5.02% |
| | Secondary Risk Site | 58.49% | 64.53% | 684 | 10.04% |
| Martha's Vineyard Commission | Primary Risk Site | 61.03% | 86.03% | 396 | 12.65% |
| | Secondary Risk Site | 48.53% | 60.7% | 344 | 10.99% |
| Merrimack Valley Planning Commission | Primary Risk Site | 68.16% | 84.45% | 975 | 6.70% |
| | Secondary Risk Site | 59.45% | 67.34% | 1543 | 10.60% |
| Montachusett Regional Planning Commission | Primary Risk Site | 73.26% | 85.76% | 829 | 5.66% |
| | Secondary Risk Site | 60.76% | 73.06% | 2094 | 14.30% |
| Nantucket Planning and Economic Development Commission | Primary Risk Site | 34.81% | 59.81% | 1569 | 70.36% |
| | Secondary Risk Site | N/A | N/A | 0 | 0% |
| Northern Middlesex Council of Governments | Primary Risk Site | 69.45% | 84.45% | 661 | 5.57% |
| | Secondary Risk Site | 59.45% | 66.8% | 1907 | 16.07% |
| Pioneer Valley Planning Commission | Primary Risk Site | 75.05% | 84.91% | 1384 | 5.04% |
| | Secondary Risk Site | 59.91% | 74.2% | 3272 | 11.91% |
| Old Colony Planning Council | Primary Risk Site | 75.34% | 89.45% | 1318 | 7.26% |
| | Secondary Risk Site | 62.84% | 74.78% | 2879 | 15.87% |
| Southeastern Regional Planning and Economic Development District | Primary Risk Site | 77.23% | 89.98% | 1518 | 5.13% |
| | Secondary Risk Site | 64.8% | 77.16% | 4138 | 13.99% |