Massachusetts Department of Transportation

Safety Data Visualization

MassDOT's IMPACT Tool and Promoting Safety Planning in Massachusetts

SAFETY DATA CASE STUDY

FHWA-SA-21-078

Federal Highway Administration Office of Safety

Roadway Safety Data Program

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16. Abstract The Strategic Highway Safety Plan (SHSP) is a critical part of the Federal Highway Safety Improvement Program (HSIP). As part of the SHSP process, States are encouraged to take a broad view of safety needs and identify over-arching emphasis areas (EAs). This case study presents a safety analysis and technology improvement project conducted by the Massachusetts Department of Transportation (MassDOT) to increase access to roadway safety-related data for multi-disciplinary and multi-jurisdictional stakeholders in the State. In 2020, MassDOT received a grant from the United States Department of Transportation (USDOT) as part of the USDOT's competitive Safety Data Initiative (SDI) process. This grant allowed MassDOT to develop a series of tools and analyses to upgrade the State's web-based safety data portal, IMPACT, and provide MassDOT's safety partners across the State with greater access to data, capacity, and insights to encourage traffic safety initiatives and awareness. MassDOT's innovative use of traditional and non-traditional data sources allowed the agency to analyze many of the State's core safety priorities and EAs. The improvements to the IMPACT platform were the result of a collaborative process between MassDOT and the agency's institutional and jurisdictional partners, and it will support and promote safety initiatives throughout Massachusetts.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

Acronyms

Acronym	Description
A	Suspected Serious Injury
AADT	Annual Average Daily Traffic
B	Suspected Minor Injury
DOT	Department of Transportation
EA	emphasis area
FHWA	Federal Highway Administration
HSIP	Highway Safety Improvement Program
K	Fatal Injury
MassDOT	Massachusetts Department of Transportation
mph	miles per hour
RPA	Regional Planning Agency
RwD	roadway departure
SDI	Safety Data Initiative
SHSP	Strategic Highway Safety Plan
USDOT	United States Department of Transportation

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Executive Summary

The Strategic Highway Safety Plan (SHSP) is a critical part of the Federal Highway Safety Improvement Program (HSIP). As part of the SHSP process, States are encouraged to take a broad view of safety needs and identify over-arching emphasis areas (EAs). This case study presents a safety analysis and technology improvement project conducted by the Massachusetts Department of Transportation (MassDOT) to increase access to roadway safety-related data for multi-disciplinary and multi-jurisdictional stakeholders in the State. In 2020, MassDOT received a grant from the United States Department of Transportation (USDOT) as part of the USDOT's competitive Safety Data Initiative (SDI) process. This grant allowed MassDOT to develop a series of tools and analyses to upgrade the State's web-based safety data portal, IMPACT, and provide MassDOT's safety partners across the State with greater access to data, capacity, and insights to encourage traffic safety initiatives and awareness. MassDOT's innovative use of traditional and non-traditional data sources allowed the agency to analyze many of the State's core safety priorities and EAs. The improvements to the IMPACT platform were the result of a collaborative process between MassDOT and the agency's institutional and jurisdictional partners, and it will support and promote safety initiatives throughout Massachusetts.

Introduction

The Strategic Highway Safety Plan (SHSP) is a critical part of the Federal Highway Safety Improvement Program (HSIP). As part of the SHSP process, States are encouraged to take a broad view of safety needs and identify over-arching emphasis areas (EAs; e.g., lane departure, intersection safety, or age-related issues) for attention over a multi-year period. These plans not only inform the priorities of a State department of transportation (DOT), but they also provide an avenue for multi-disciplinary and multi-jurisdictional collaboration. An SHSP can help align the activities of engineers, law enforcement, emergency services, and educators, as well as provide a means for a State DOT to communicate with its regional and local stakeholders.

Purpose and Need

This case study presents a safety analysis and technology improvement project conducted by Massachusetts Department of Transportation (MassDOT) to increase access to roadway safety-related data for multi-disciplinary and multi-jurisdictional stakeholders in the State. In 2020, MassDOT received a grant from the United States Department of Transportation (USDOT) as part of the USDOT's competitive Safety Data Initiative (SDI) process. This grant allowed MassDOT to develop a series of tools and analyses to upgrade the State's web-based safety data portal, IMPACT, and provide MassDOT's safety partners across the State with greater access to the agency's data, capacity, and insights to encourage traffic safety initiatives and awareness.

Target Audience:

- Executive leadership.
- Information technology staff.
- Data managers, analysts, and stewards.
- Stakeholders involved in the SHSP process, including planning, engineering, education, law enforcement, emergency response staff.
- Local technical assistance program managers and staff.

Background

IMPACT originally went live in 2018. Initial functionality included dashboards for high-level data review, the ability to query and download crash data, automatic report generation, and the ability to develop cross-tabulations of crash data. Although access to data was helpful for its partners, MassDOT soon identified the need to provide safety analysis and results in the tool. With USDOT's SDI grant, MassDOT developed a *Safety Analysis Tools* module for IMPACT that includes crash-based network screening maps, risk-based network screening maps, a crash tree maker, and a test of proportions tool. Figure 1 is a screenshot of IMPACT's *Safety Analysis Tools* module.

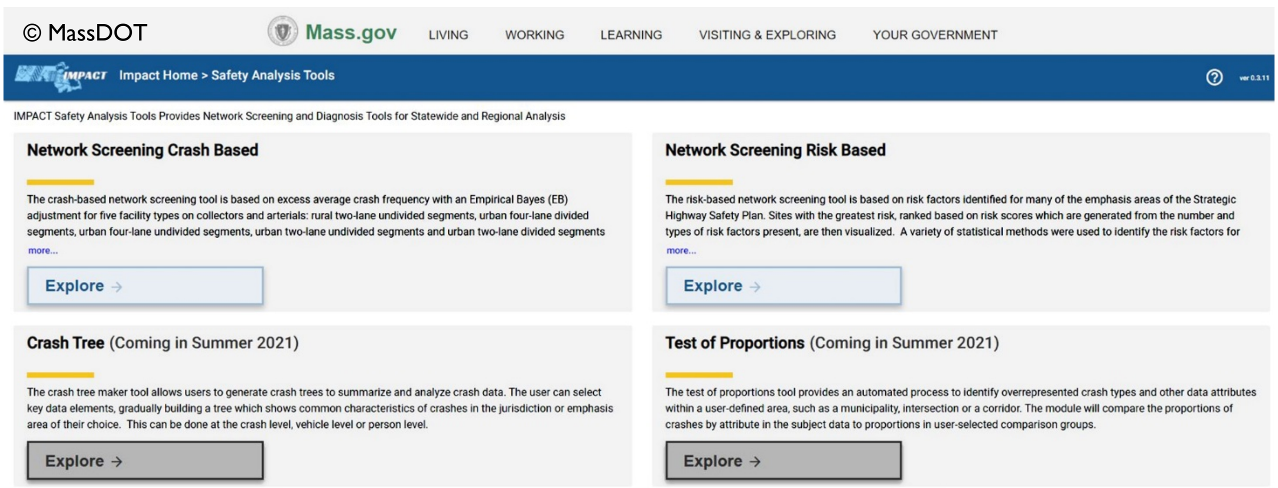


Figure 1. Graphic. Screenshot of the IMPACT Safety Analysis Tools module.

These tools and visualizations fill a critical need for MassDOT; they provide data-driven outputs to support project selection for MassDOT's HSIP and SHSP programs. They also make these outputs accessible to the State's stakeholders and the general public. MassDOT's risk-based network screening results follow the EAs outlined in the State's SHSP. The accompanying risk maps allow MassDOT to inform safety stakeholders about locations of greatest safety risk and proactively plan projects with the greatest need. Prior to this project, MassDOT's safety program was primarily based on a hot spot approach; this hot spot analysis process identified intersections for safety projects based on crash history.

While this addressed locations that experienced a high frequency of crashes, a hot spot approach does not account for the infrequency of severe crashes; these are susceptible to regression to the mean and tend not to cluster year after year. A network screening approach based on risk rather than crash history alone identifies and proactively addresses risk factors that could contribute to severe crashes before they occur. This case study focuses on the process MassDOT employed to identify risk factors for most EAs in the State's SHSP and visualize the results to encourage data-driven decision-making across the State.

IMPACT Enhancements and Development Process

USDOT's SDI grant process required MassDOT to conduct analysis on a condensed 12-month timeline. This required parallel efforts that simultaneously conducted systemic analyses and developed a custom visualization module in the State's IMPACT tool. This section documents how MassDOT incorporated relevant stakeholder feedback to develop a series of systemic analyses and maps. These maps visualize the highest priority locations for potential safety improvements across the State and for each Regional Planning Agency (RPA).

Stakeholder Engagement

MassDOT actively engaged potential users throughout the project to solicit input, including a kickoff meeting during the scoping stage and mid-way through the project. MassDOT held webinar-style meetings and invited potential users at Federal, State, regional, and local agencies, as well as consultants and representatives from public health, law enforcement, and public advocacy groups. MassDOT used these meetings to gather input on the usability of the tools, as well as preferred data formats produced by the application. MassDOT also held a recorded webinar at the conclusion of the SDI grant process to update stakeholders on project progress and functionality.

Systemic Analysis Process

Based on stakeholder input and the project scoping process, MassDOT prepared a series of customized systemic analyses to address many of the State's most important safety needs. This process included data collection, focus crash and facility type development, and risk scoring methodology formulation.

Data Approach

MassDOT performed systemic safety analyses to develop risk-based network screening maps for 12 EAs in the State's 2018 SHSP. These EAs are loosely divided into two categories: EAs where the targeted countermeasure approach is typically engineering-focused (e.g., rumble strips for roadway departure), and EAs where countermeasures may be more behaviorally-focused (e.g., targeted education and enforcement for occupant protection).

The complete list of EAs considered in MassDOT's analysis include the following:

- Bicycles.
- Distracted driving.
- Impaired driving.
- Intersections.
- Large vehicles or trucks.
- Motorcycles.
- Occupant protection (or unbelted vehicle occupants).
- Older drivers (65 and older).
- Pedestrians.
- Roadway departures (RwD) - urban and rural.
- Speeding and aggressive driving.
- Young drivers (24 and younger).

Individual systemic analysis identified potential risk factors associated with each EA. MassDOT used the following steps, based on the Federal Highway Administration's (FHWA's) *Systemic Safety Project Selection Tool*:

1. Identify the focus crash types.
2. Identify the focus facility types.
3. Perform the risk factor analysis.
4. Develop a risk factor scoring approach.
5. Rank results based on risk category.

MassDOT used statewide crash and road inventory data for all EAs. Depending on the nature of each EA (either engineering or behavioral), MassDOT applied other supporting geospatial datasets (e.g., horizontal curves and Census data), reports, and tabular files. Examples of these supplementary datasets include:

- Aging-related health and access data from the University of Massachusetts-Boston.
- Census estimates.
- Citation records.
- Driver's license records.
- Environmental justice metrics (e.g., proportion of non-white population, limited English proficiency households, and median household income).
- Freight corridors.
- Hospital and emergency services locations.
- Intersections.
- Motorcycle ownership.
- School locations.

Identify Focus Crash Types

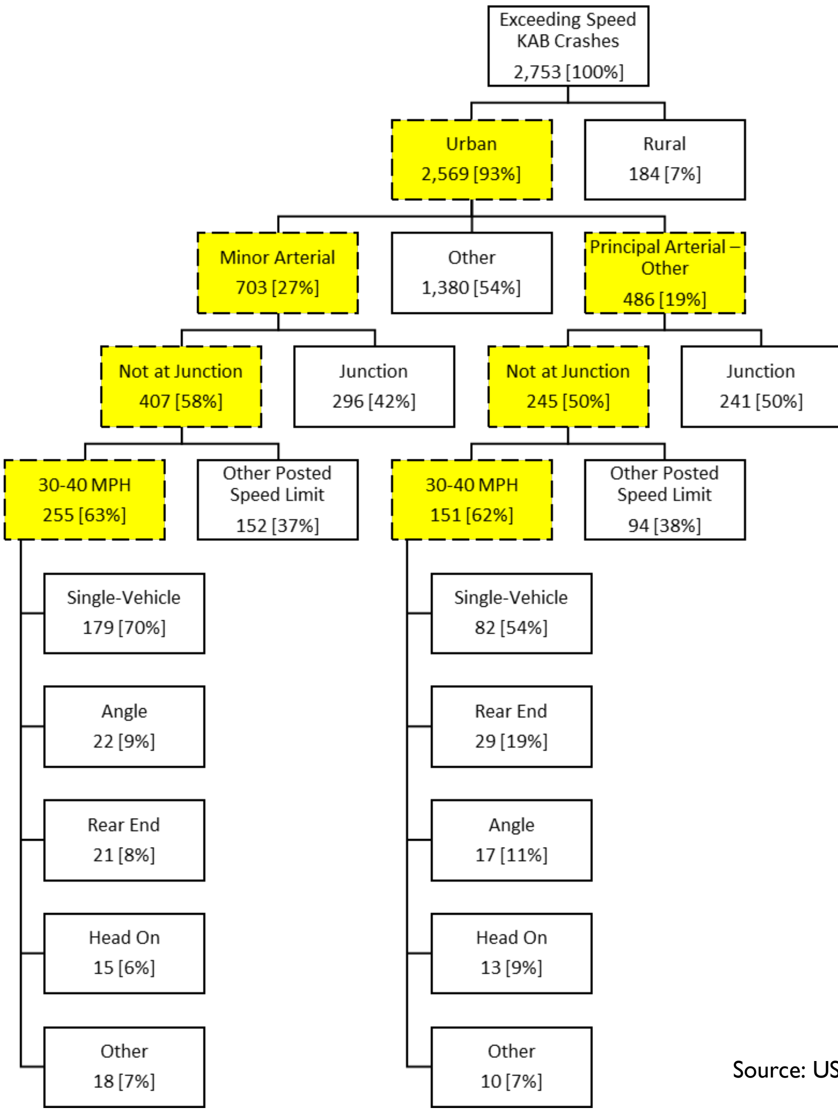
MassDOT identified focus crash types using a 5-year crash dataset from 2013 to 2017, using the most recent year of closed crash data at the time of the analysis. The approach to identify the focus crash type was tailored for different EAs. Engineering EAs used a crash tree analysis, guided by engineering judgment. For instance, MassDOT identified angle crashes at intersections to further define the focus crash type. MassDOT focused solely on overrepresentation of severe crashes for behavioral EAs. The project team used crash severity as a filter on the focus crash type, and the target severity levels varied by sample size. While most of the systemic analysis focused on fatal injury (K) and suspected serious injury (A) crashes, suspected minor injury (B) crashes were included for some EAs to address low sample size concerns.

MassDOT used crash-level, vehicle-level, and person-level data as needed to query the relevant crashes for each EA. An example focus crash type identified by MassDOT for the Large Vehicle EA (engineering) is rear-end, non-intersection crashes involving heavy trucks. Meanwhile, focus crash types for the Occupant Protection EA (behavioral) is any severe crash involving an unbelted vehicle occupant.

Identify Focus Facilities

MassDOT did not identify focus facility types for behavioral EAs because the common countermeasures—education and enforcement—are community-level countermeasures that do not necessarily apply to a specific class of road. Additionally, behavioral crashes, such as impaired driving or unbelted driving, occur on all roadway types. The *Perform Risk Factor Analysis* section contains more information on how MassDOT applied community-level data to road segments.

For engineering EAs, MassDOT used crash trees to identify the focus facility type (figure 2). The crash trees typically used a focus crash type (where applicable), area type, functional classification, and posted speed limit. MassDOT identified the combinations that accounted for the largest proportions of focus crash types and focus facility types. For example, focus facility types for the Large Vehicle EA were Interstates and Principal Arterial Freeways and Expressways for a focus crash type of rear-end, non-intersection large vehicle crashes.



Source: USDOT

Figure 2. Graphic. Crash tree example for KAB speeding-related crashes.

Perform Risk Factor Analysis

MassDOT used three methods to identify the potential risk factors: binary logistic regression, mileage exposure analysis, and negative binomial regression (table 1). These methods varied depending on the EA and the underlying data. For the roadway departure EA, mileage exposure analysis compared the portion of KA (or KAB) crashes against the portion of segment length (in miles) for the roadway characteristic of interest. Although MassDOT explored using vehicle miles traveled as the primary exposure metric, the agency decided that road mileage was a more reliable indicator across the State. MassDOT then selected risk factors by selecting roadway characteristics that were "overrepresented" for a combination of KA or KAB crashes compared to the mileage.

Table 1. Summary of risk factor methods used by emphasis area.

Emphasis Area	Method Approach
Intersections	Binary Logistic Regression
Large Vehicles or Trucks	Binary Logistic Regression
Speeding and Aggressive Driving	Binary Logistic Regression
Motorcycles	Binary Logistic Regression
Bicycles	Binary Logistic Regression
Pedestrians	Binary Logistic Regression
RwD - Urban and Rural	Mileage Exposure Analysis
Impaired Driving	Negative Binomial Regression
Distracted Driving	Negative Binomial Regression
Older Drivers	Negative Binomial Regression
Occupant Protection	Negative Binomial Regression
Young Drivers	Negative Binomial Regression

For the remaining engineering EAs, MassDOT used binary logistic regression to identify risk factors. This probabilistic modeling technique assesses the probability that an event has occurred (i.e., a KA motorcycle crash) at a given segment based on the model inputs. Agresti (2007) provides more background information on this method. The odds ratio metric helped identify final risk factors, where a value greater than one represents an independent increase in the probability of a KA crash occurring on that segment for a given input variable. These models typically included standard road segment factors, such as number of lanes, posted speed limit, shoulder width, and others. MassDOT used segment length as an offset and treated the rest of the variables as binary inputs, including developing binned binary variables for continuous variables.

For behavioral EAs, MassDOT used negative binomial regression to identify community-level characteristics that are associated with higher frequencies of focus KA crashes. Negative binomial regression is a commonly used analysis method for over-dispersed count data (i.e., the variance exceeds the mean of the observed data). The dependent variable in the model is the total KA crashes for the EA of interest, making a count model appropriate for the data. Example independent variables included an offset of mile-years for the town as well as proportions of mileage by facility type, population density, citation history, alcohol sales establishments, and proportion of young-licensed drivers (age 15-24) in a town.

After identifying community-level risk factors for the behavioral EAs, MassDOT further identified segment-level risk factors by reviewing the roadway characteristic data linked to the crash data. This methodology conformed to a similar approach in FHWA's Crash Data Summary Template. MassDOT identified any roadway characteristics which were statistically overrepresented for KA focus crashes compared to focus crashes of all severities as risk factors. This resulted in a two-tier series of risk factors for behavioral EAs, with segments receiving a town-level risk score and a supplemental segment-level risk score.

Develop Risk Factor Scoring Approach

The number and the nature of identified risk factors varied for each EA; MassDOT developed unique scoring schemes for each risk factor and for each EA. Typically, a risk factor was scored between 0 and 1 depending on the risk factor characteristics, professional judgement, and the regression model results. For example, in the motorcycle crash analysis, the project team identified three RPAs as high-risk areas based on the logistic regression. Once MassDOT identified the most appropriate form for each risk factor score, the total risk score for a segment or town is the sum of the individual risk factor scores normalized by the number of risk factors (which ranged between 0 and 100 percent). Table 2 provides an example of this scoring method with respect to the speeding EA.

Table 2. Sample table of speeding risk factors and associated scores.

Variable	Risk Factor Criteria	Example Segment Characteristic	Risk Score
Annual average daily traffic (AADT)	AADT between 20,000 and 40,000 vehicles per day	25,000	0.875
Proportion of younger drivers in census tract	Proportion of younger drivers in census tract between 0.15 and 0.21	0.12	0
Divided or undivided	Undivided segment	Undivided	1
Weighted average degree of curvature (degrees per 100 ft)	Weighted average degree of curvature 10 or more degrees per 100 ft	11	0.6
Posted speed limit in miles per hour (mph)	Posted speed limit of 30 mph	30	1
Sidewalk (left, right, or both)	No sidewalk present on the segment	None	1
Right Shoulder Type	Right shoulder is stable	Stable	1
RPA	Segment is in the Pioneer Valley Planning Commission or Southeastern Regional Planning and Economic Development District	Southeastern Regional Planning and Economic Development District	1
		Total Risk Score:	6.475
		Normalized Risk Score:	81%

Rank Results Based on Risk Category

MassDOT ranked the total risk factor results for each EA to identify locations for targeted countermeasures. MassDOT used a percentile rank approach to sort the normalized risk scores. Sites ranked in the top 5 percentile were categorized as "Primary Risk Sites," and sites ranked in the next 10 percentiles (85th to 95th percentiles) were categorized as "Secondary Risk

Sites." MassDOT excluded all other sites from the IMPACT visualization. MassDOT applied the percentile rankings at the statewide- and RPA-levels, producing two maps for each EA.

Visualization

After assigning normalized risk scores to the relevant segments, MassDOT visualized the results in the IMPACT Risk-Based Network Screening tool. This tool provides a statewide map of segments that users can query against using different levels of interest, such as town, RPA, MassDOT engineering district, and route. For these maps, "primary risk sites" are colored red and "secondary risk sites" are colored blue; all other segments are gray. The only segments shown in the maps are focus facility type segments. The visualization also includes a data grid which provides attribute details for the segments, as well as dashboards that summarize segment characteristics by category.

Training

Although MassDOT does not plan any formal trainings for its statewide stakeholders specific to the latest enhancements, MassDOT recorded a webinar in fall 2021 to demonstrate the tool. This recording provides an initial tutorial for new users and could form the foundation of future training efforts across the State. Existing IMPACT modules (i.e., prior to the enhancements) have guided tutorials and recorded trainings to support the tool's use.

Challenges

MassDOT encountered a few challenges during the development of the risk-based network screening maps. The following sections briefly describe some of the noteworthy challenges for agencies considering a similar data sharing, analysis, and visualization approach.

Data Quality

MassDOT accomplished the series of analyses and completed the tool despite occasional challenges with data quality or missing data. MassDOT assessed these data on a case by case basis and made tradeoffs when necessary. To overcome missing datasets that might directly link to key safety indicators (e.g., bicycle and pedestrian counts), MassDOT applied known surrogates (e.g., population and employment density and access to a motor vehicle) to narrow the focus on locations of highest risk for certain EAs. MassDOT plans to refine the analyses as future data become available (e.g., probe data for speed and exposure).

Crash Data

The process of finalizing a year of crash data in Massachusetts can be a time-consuming process. Even though the analyses were performed between 2020 to 2021, MassDOT used their last 5 years of "closed" crash data, 2013 through 2017. Users of the tool expressed concern when informed of this, and MassDOT intends to regularly update the results with more recent crash data when possible.

Road Inventory

MassDOT's road inventory data has several very short segments due to the segmentation process applied by the agency's geographic information system service. When modeling, MassDOT excluded short segments from their analysis to remove potential bias arising from these otherwise uninformative locations for roadway safety analysis and project development. However, these short segments present an issue for visualization. As a result, MassDOT aggregated these short segments to more practical lengths by dissolving the road inventory segments using the risk factor characteristics.

Visualization

MassDOT made minor compromises in the map visualizations given the differences in data between EAs. Performance could be significantly reduced for the tool to be completely dynamic and produce customized statistics on the fly. As a result, MassDOT had to assess tradeoffs between the data to be visualized, the visualization methodology, and ensuring a quality user experience for users of all capabilities.

Conclusions and Lessons Learned

Accessibility to data is a critical part of managing a statewide safety program. This not only includes the data required to conduct safety analysis, but it also means delivering the results of these analyses and insights to all decision makers across the community. Through a USDOT SDI grant, MassDOT was able to perform an extensive systemic analysis of nearly all of their SHSP EAs and introduce a proactive component to the agency's entire safety program.

MassDOT's innovative use of traditional and non-traditional data sources allowed the agency to analyze many of the State's core safety priorities and EAs; while behavioral EAs are typically excluded from systemic analysis approaches, community-level data allowed MassDOT to identify priority road segments for more multi-disciplinary interventions. For future improvements, MassDOT noted that the tool could potentially include the ability to overlay and combine results across EAs. This would allow stakeholders to efficiently track and address segments that meet several risk criteria across SHSP EAs.

The improvements to the IMPACT platform were the result of a collaborative process between MassDOT and the agency's institutional and jurisdictional partners, and it will support and promote safety initiatives throughout the State. IMPACT's visualization capabilities will engage stakeholders across Massachusetts, many of which may have had limited information in the past, and allow safety stakeholders from all backgrounds to contribute to safety efforts in their communities.

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