Assessment of Transportation Systems Management and Operations (TSMO) for the Michigan Department of Transportation

FINAL REPORT

Authors

Jonathan Kay, Timothy Gates, and Andrew Ceifetz

Sponsoring Organization

Michigan Department of Transportation

Performing Organization

Michigan State University
Department of Civil and Environmental Engineering
428 South Shaw Lane
East Lansing, MI 48824

and

WSP USA
500 Griswold Street
Suite 2600
Detroit, MI 48226

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16. Abstract Transportation System Management and Operations (TSMO) is an emerging concept being adopted by highway agencies across the United States. While the concept is currently defined very broadly depending on the objectives of the agency, TSMO essentially is an integrated set of strategies which may enable transportation agencies to stretch their funding to benefit more areas and customers. The Michigan Department of Transportation (MDOT) is one agency which has embraced the potential of TSMO, recently developing a TSMO Implementation and Strategic Plan. In order to make progress towards its TSMO mission, MDOT sponsored this assessment into the feasibility and traffic safety impacts associated with further implementing TSMO across the department. The intent of this study is to provide important guidance to allow MDOT to make informed decisions as to potential changes to the internal management structure of the systems and operations divisions. A comprehensive review of the existing guidance, tools and literature specific to TSMO was conducted as well as interviews with other states' TSMO staff. An evaluation was conducted to determine the potential relationship between a state's safety funding levels and relative safety performance. Estimates were also developed to determine by how much current funding levels would need to increase to reach the short-term goals identified in Michigan's Strategic Highway Safety Plan. Ultimately, a variety of recommendations are provided towards the further implementation of TSMO within MDOT based upon best practices and other findings identified as a part of this assessment.			
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Principal Investigator
Timothy J. Gates, Ph.D., P.E., P.T.O.E.
Associate Professor
Michigan State University

Co-Principal Investigator
Andrew Ceifetz, P.E., R.S.P.
Lead Transportation Engineer
WSP USA

Authors
Jonathan Kay, Timothy Gates, and Andrew Ceifetz

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A report from
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EXECUTIVE SUMMARY

Transportation System Management and Operations (TSMO) is an emerging concept being adopted by state departments of transportation across the United States. While the concept is currently defined very broadly depending on the objectives of the agency, TSMO represents one of the front-lines of the transportation system that is most visible and noticeable to the traveling public [*1*]. The intent of TSMO is to encourage the safe, efficient management of integrated and intermodal transportation systems, forming the core of how the traveling public interacts with the travel environment [*1*]. Essentially, TSMO is an integrated set of strategies which may enable transportation agencies to stretch their funding to benefit more areas and customers [*2*].

Given the limited financial resources and increasing demands for transportation improvements, TSMO integration into the core mission of state departments of transportation (DOTs) can yield significant benefits to both mobility and safety [*3*]. The Michigan Department of Transportation (MDOT) is one such state DOT which has embraced the potential of TSMO, recently developing a *TSMO Implementation and Strategic Plan* [*4*]. Within the strategic plan, MDOT established a TSMO mission statement of operating and managing an optimized, integrated transportation network by delivering high-quality services for the safe and reliable mobility of all users [*4*]. In order to make progress towards this mission, MDOT sponsored research into the feasibility and traffic safety impacts associated with further implementing TSMO across the department. The intent of this study is to provide important guidance to allow MDOT to make informed decisions as to potential changes to the internal management structure of the systems and operations divisions. Within this framework, MDOT identified three specific objectives to be completed as part of the assessment:

1. Perform a comprehensive literature review on TSMO conversions within state DOTs and contact select state DOTs that have converted or are considering TSMO conversion.
2. Research and identify the relationship between safety funding levels and traffic deaths per VMT in peer states.
3. Perform a predictive analysis to determine how much funding levels may need to increase in order to reach safety goals identified in latest Strategic Highway Safety Plan (SHSP), and trunkline and local funding should be included in the analysis.

TSMO in the United States

A comprehensive review of the existing guidance, tools and literature specific to TSMO was conducted by the research team. Additionally, the status of TSMO for each state, including the collection of implementation plans, guidance, and/or case study examples was determined by the research team. Interviews with ten states' TSMO staff were also conducted to gain further insight into TSMO strategies and practices. Ultimately, these findings were aggregated to determine the functions and divisions typically included in a TSMO divisional structure, as well as the benefits and limitations associated with the conversion to TSMO. The key findings include:

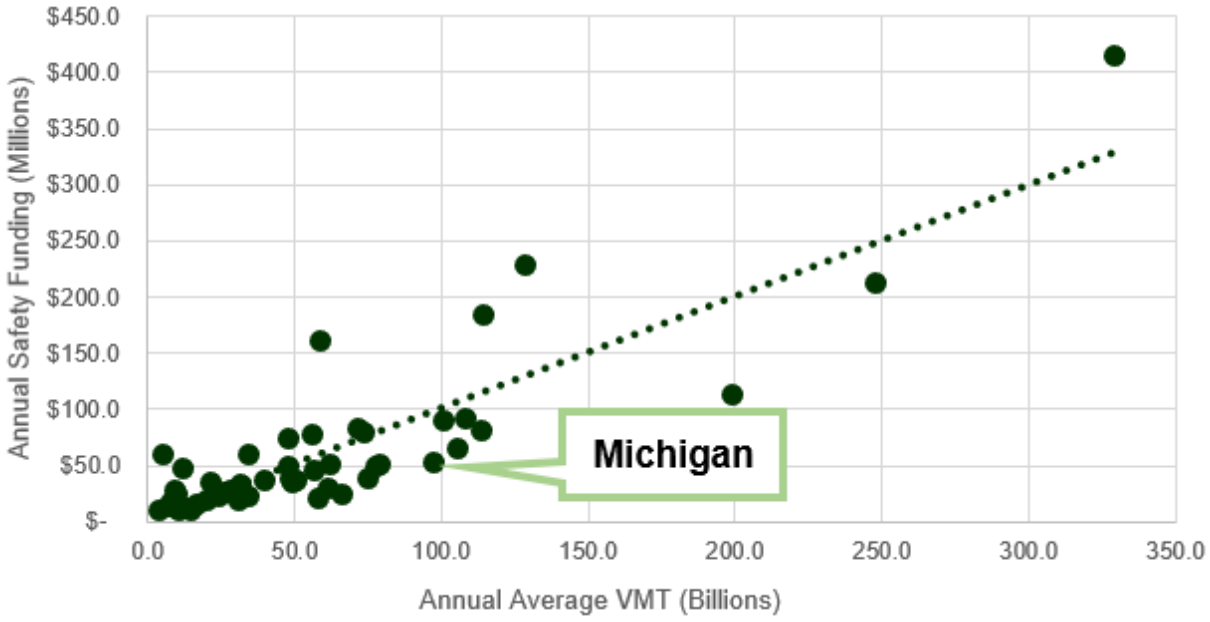
- TSMO has previously been defined in the Moving Ahead for Progress in the 21st Century Act (MAP-21) as "an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services and projects design to preserve capacity and improve security, safety and reliability of the transportation system" [2].
- The Institute of Transportation Engineers (ITE) identified five key components of TSMO – including traffic operations, demand and incident management, multimodal operations, enforcement and safety performance [*1*].
- The Federal Highway Administration (FHWA) notes that TSMO looks at network performance from a systems perspective, as opposed to just one strategy, project or corridor [2]. The intent is to view the transportation network as a unified whole, allowing the individual components of the system work to together for better performance [2].
- While TSMO is a relatively new and emerging concept in the transportation industry, there are a variety of national resources which include tools and guidance for implementing TSMO into highway agency activities.
- MDOT has been advancing TSMO within the agency for several years, beginning with a TSMO workshop sponsored by FHWA in 2013 and culminating with the development of a *TSMO Implementation and Strategic Plan*, currently in its third iteration [*4*].
- In addition to Michigan, at least 24 other state DOTs have implemented some level of TSMO concepts or strategies within agency activities and a variety of best practices can be identified by reviewing key materials from each state's implementation process.
- The research team conducted interviews with 10 of these 24 states, allowing for the identification of additional best practices with a specific focus on safety.

Relationship between State Funding Levels and Safety Performance

The relationship between a state's safety funding levels and relative safety performance may provide important insight into how TSMO implementation at MDOT, specifically changes to safety-related funding templates, may impact fatalities and serious injuries resulting from traffic crashes in Michigan. Consistent with the goal in the *Strategic Highway Safety Plan* (SHSP) to reduce fatalities and serious injuries on Michigan's roadways, an important component of this assessment was to explore this relationship as MDOT continues to implement TSMO.

Data specific to each state (and Washington, D.C.) were collected from two primary resources in order to perform the analysis. Annual obligated safety funding, vehicle miles of travel (VMT) and safety performance data were collected from FHWA's *Highway Safety Improvement Program Reporting* webpage by examining each state's last five annual HSIP reports (2014 to 2018). State population data were also collected from the United States Census Bureau.

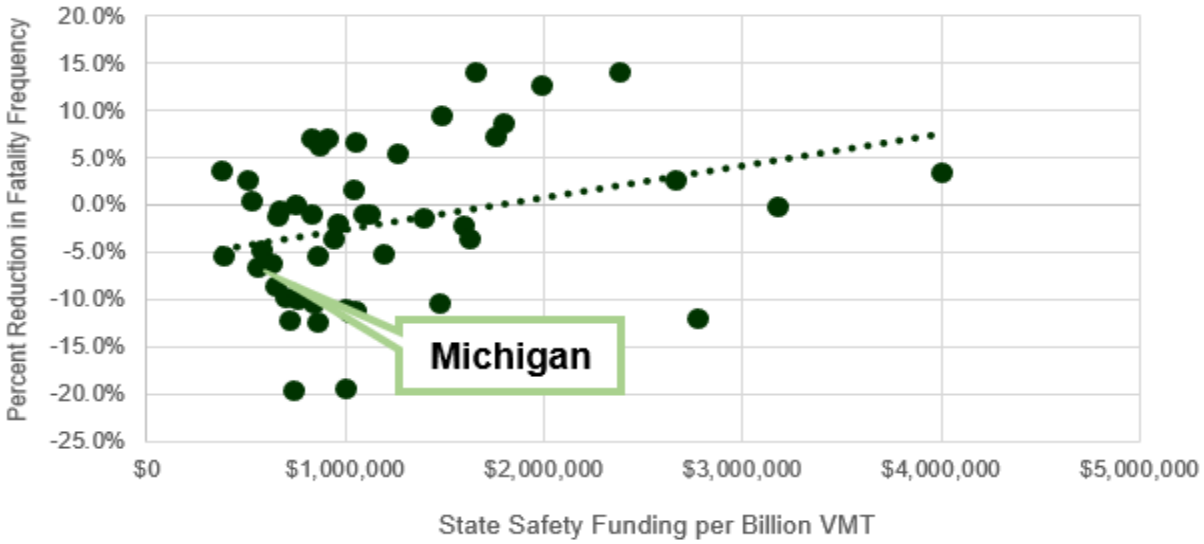
Intuitively, annual average safety funds were heavily correlated with the annual average of VMT from each state. The annual average obligated safety funding across all states (and Washington, D.C.) ranged from $10,900,406 (Maine) to $415,068,169 (California). Michigan obligated an annual average of $54,126,469 over the last five years, just less than the national mean of $61,372,061 but considerably greater than the national median of $38,135,558.



Annual Average Safety Funding (Millions) vs. State VMT (Billions)

In order to estimate recent progress in reducing fatalities, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in fatality frequency. The fatality reductions ranged from -19.6 percent (Colorado – representing an increase in fatality frequency) to 14.2 percent (Rhode Island). Michigan experienced a -6.2 percent reduction in fatality frequency, representing a modest increase over the study period.

The potential relationship between the percent reduction in fatality frequency and safety funding per VMT, excluding the unique cases of Alaska, Hawaii and Washington, D.C (which have extremely limited travel and/or highway networks that are not representative of the 48 contiguous states), was explored by the research team. While there is not a statistically significant relationship between the two, it is worth noting that the top-performing states tended to be on the higher end of safety funding per VMT and the states which experienced fatality frequency increases were on the lower end of funding per VMT. Michigan was ranked 47th with $556,998 per billion VMT.

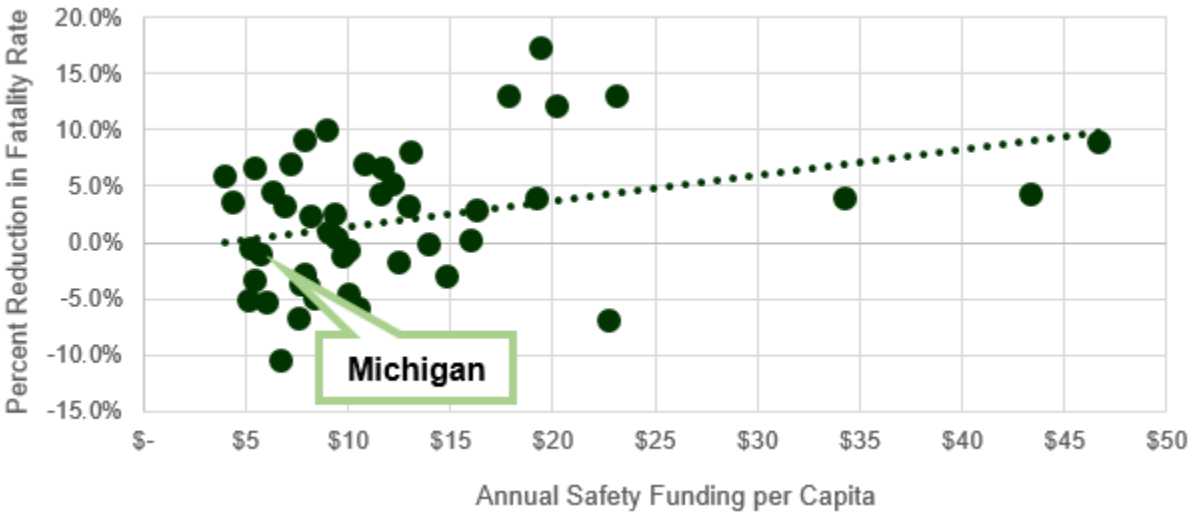


Percent Reduction in Fatalities (2009-2013 to 2013-2017) vs. Safety Funding per VMT

While the overall frequency of fatalities is an important consideration, especially in support of the state's long-term goal of zero deaths on Michigan's roadways, it is also important to recognize the potential impact of changes in traffic volume on fatality frequency. In order to estimate recent progress in reducing fatality rates per 100M VMT, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an

estimate of relative improvement in fatality rate. The fatality rate reductions ranged from -10.5 percent (Colorado – representing an increase in fatality rate) to 13.0 percent (Rhode Island). Michigan experienced a -3.3 percent reduction in fatality rate, representing a modest increase over the study period.

The potential relationship between the percent reduction in fatality rates and safety funding per capita, excluding the unique cases of Alaska, Hawaii and Washington, D.C (which have extremely limited travel and/or highway networks that are not representative of the 48 contiguous states), was also evaluated by the research team. It is worth noting that there was a modest statistically significant relationship between the two, suggesting that states which have invested more funding per capita have experienced greater reductions in fatality rate during the study period. Michigan was ranked 46th with $5.50 in annual average safety funding per capita.

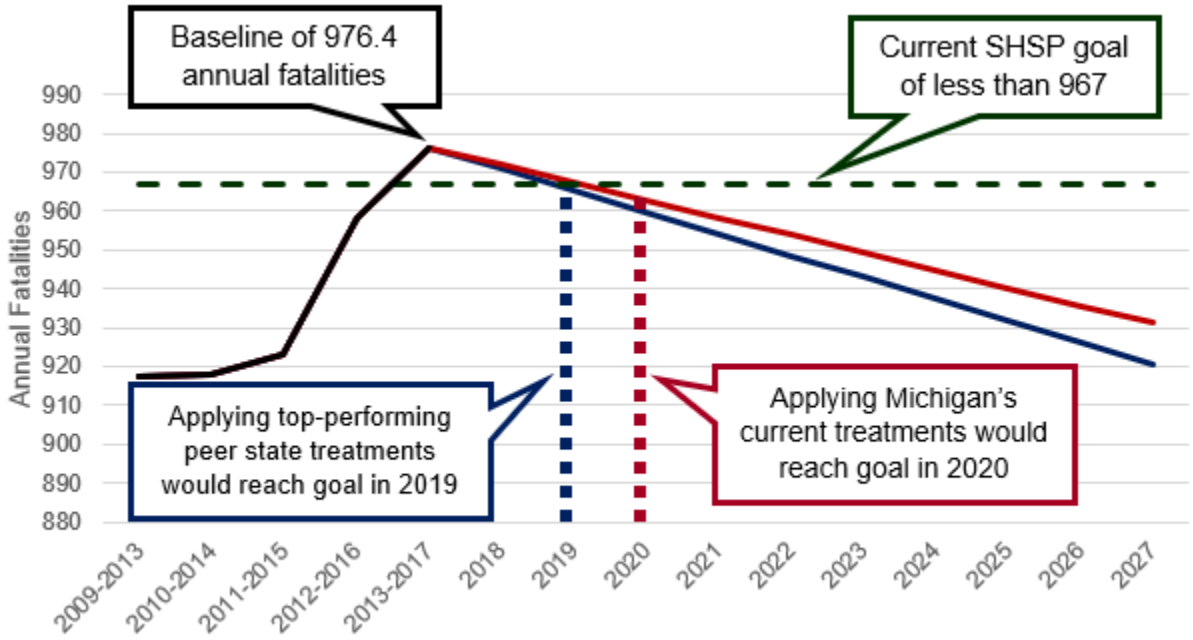


Percent Reduction in Fatality Rate (2009-2013 to 2013-2017) vs. Safety Funding per Capita

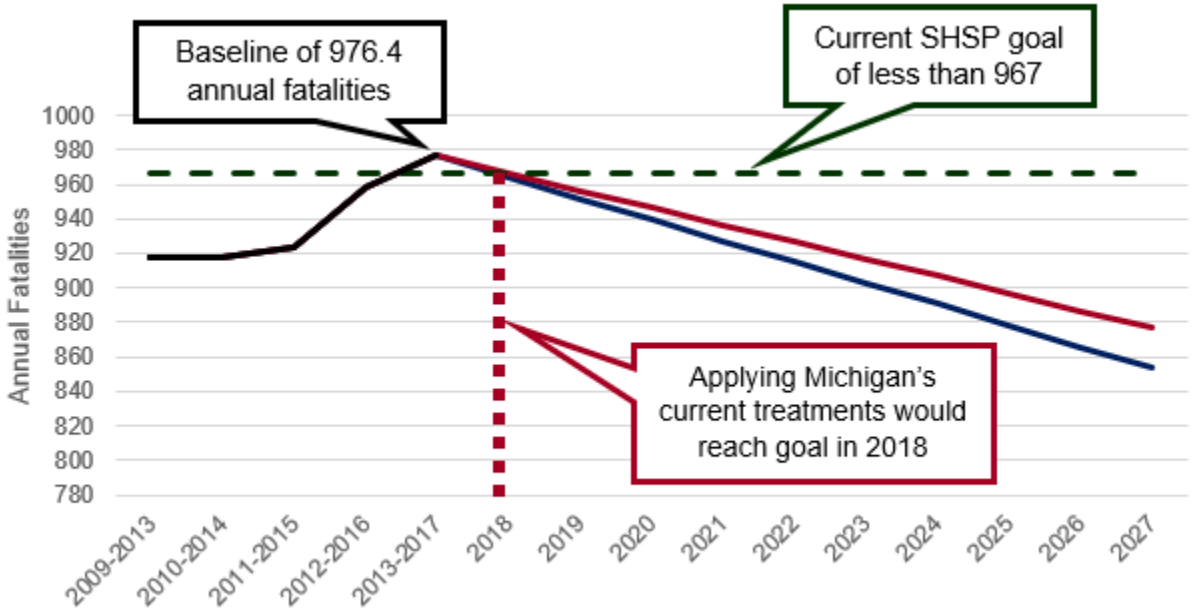
Estimate Funding Levels to Reach Statewide Safety Goals

The current SHSP identifies short-term safety goals for 2018 of less than 967 fatalities and less than 4,600 serious injuries for Michigan's roadways. Given the potential relationship between safety funding levels and fatalities, an important consideration as the department continues to evaluate changes to safety funding templates as a part of TSMO implementation is the level of safety funding required to reach these short-term safety goals. In order to develop an estimate of funding levels necessary to reduce fatalities and serious injuries to meet the short-term goals, a broad range of data was collected and combined. Given the existing funding levels, it is predicted that the application of Michigan's current treatment strategy (in red) would reach the fatality goal

in 2020, while using top-performing peer states (Pennsylvania, Minnesota and Wisconsin) treatment strategy (in blue) which achieves slightly larger annual reductions in fatalities would reach the goal in 2019. However, increasing funding levels to 120-percent of their current value, it is expected that the 2018 fatality goal would be met using either Michigan's current treatment strategy or that of the top-performing peer states. Results were less favorable for serious injuries due to the more aggressive nature of the short-term goal.



Annual Predicted Fatalities with Existing Funding Levels



Annual Predicted Fatalities with 120-Percent Increase in Funding Levels

Recommendations

Recommendations were developed by the research team, aggregating key findings from the review of TSMO in the United States, the evaluation of the relationship between funding levels and safety performance, and finally the estimate of funding levels required to reach the state's current safety goals. A brief description of each recommendation is provided along with the location of where more detail can be obtained in the full report.

Summary of TSMO Related Recommendations for MDOT to Consider

TSMO Recommendation	Description	Report Section
Continue development and further updates to MDOT's *TSMO Implementation and Strategic Plan*	Currently in its third iteration, MDOT's plan represents the departments formal effort to document TSMO implementation efforts. Future iterations of the plan should include recommendations developed by each of the business areas and commonality area groups which were not ready for inclusion as a part of the third version. Additionally, as stated in Section 7 of the plan, maintenance of the plan and action items should be continued as these were intended to be "living documents". Findings from this report, specifically best practices identified from other States identified in **Section 2.0** of this report, should be considered when developing future iterations of MDOT's TSMO plan.	2.3.1
Continue application of the Capability Maturity Model (CMM)	MDOT's TSMO plan is founded upon the CMM, beginning with the 2013 CMM workshop and continuing with MDOT's 2018 CMM reassessment. This process represents a core component of the TSMO effort and is based upon the national guidance developed for TSMO integration. Similar efforts should continue as the department further implements TSMO concepts into agency activities.	2.2.1
Consider regional meetings or workshops similar to the regional operations forums conducted by the California Department of Transportation (Caltrans)	Caltrans conducted regional operations forums (ROFs) to provide an opportunity for staff and local partners to share TSMO experiences and strategies – as well as conducting CMM self-assessments – which were specific to each district. Similar meetings or workshops at the region-level within MDOT may be beneficial.	2.3.3 (California)

TSMO Recommendation	Description	Report Section
Consider the implementation of TSMO evaluations for projects similar to the process developed by the Colorado Department of Transportation (CDOT)	An important component of CDOT's TMSO program are the TSMO evaluations conducted as a part of all new projects. The evaluation consists of a safety assessment, an operations assessment and an ITS assessment which are ultimately aggregated to make recommendations to the project team to improve safety and mobility. A similar process could be developed by MDOT as a part of TSMO implementation.	2.3.3 (Colorado)
Fund additional TSMO research related to specific aspects of the TSMO program similar to projects funded by the Florida Department of Transportation (FDOT)	While this report represents an investment by MDOT in developing research specific to its TSMO program, FDOT has recently funded research related to specific aspects of the its TSMO program. As MDOT continues to develop its TSMO plan and integrate functions into agency activities, specific elements may be identified which could benefit from additional research. Sponsoring such projects may identify opportunities not well addressed by existing literature or best practice examples.	2.3.3 (Florida)
Consider the development of "Service Layer" plans such as those developed by the Iowa Department of Transportation (Iowa DOT)	Several state DOTs, including the work notably conducted by Iowa DOT, have developed separate service layer plans which provide additional detailed recommendations and actions specific to distinct service areas of TSMO. MDOT could consider the development of such service layer plans as a part of future iterations of its TSMO plan.	2.3.3 (Iowa)
Ensure that MDOT's TSMO plan provides a framework to implement TSMO functions identified in this report	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 52 categories of potential TSMO functions. It is important that the framework for TSMO developed by MDOT allows for the implementation of as many of these functions as possible given the potential benefits.	2.5.1
Consider the TSMO divisional structures and funding mechanisms implemented by other agencies	A variety of divisional structures and funding mechanisms have been implemented with success by state DOTs which have allowed for the integration of TSMO functions within agency activities. These best practices should be considered as MDOT is evaluating changes to its division structure and funding templates as a part of TSMO integration.	2.5.2

TSMO Recommendation	Description	Report Section
Ensure that MDOT's TSMO plan provides a framework to maximize the potential benefits of TSMO	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 31 categories of potential TSMO benefits. It is important that the framework for TSMO developed by MDOT allows for the maximization of the potential benefits which can be derived from TSMO implementation.	2.5.3
Ensure that MDOT's TSMO plan provides a framework to address the potential limitations of TSMO	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 34 categories of potential limitations for TSMO. It is important that the framework for TSMO developed by MDOT attempts to address as many of these potential limitations as possible.	2.5.4
Seek opportunities to increase the level of safety funding and/or consider shifting safety funding priorities to align with top performing peer states.	Given the potential relationship between historical safety funding and recent progress in safety performance, an important consideration as MDOT evaluates changes to funding templates is to seek additional funding sources for safety-related engineering improvements for highway infrastructure. The TSMO implementation process represents a key opening to address this consideration as projects developed via non-safety related funding templates may offer opportunities to implement engineering countermeasures to improve highway safety performance.	3.0 – 4.0

1.0 INTRODUCTION

Transportation System Management and Operations (TSMO) is an emerging concept being adopted by state departments of transportation across the United States. While the concept is currently defined very broadly depending on the objectives of the agency, TSMO represents one of the front-lines of the transportation system that is most visible and noticeable to the traveling public [*1*]. The intent of TSMO is to encourage the safe, efficient management of integrated and intermodal transportation systems, forming the core of how the traveling public interacts with the travel environment [*1*]. Essentially, TSMO is an integrated set of strategies which may enable transportation agencies to stretch their funding to benefit more areas and customers [*2*].

Given the limited financial resources and increasing demands for transportation improvements, TSMO integration into the core mission of state departments of transportation can yield significant benefits to both mobility and safety [*3*]. The Michigan Department of Transportation (MDOT) is one such state DOT which has embraced the potential of TSMO, recently developing a *TSMO Implementation and Strategic Plan* [*4*]. Within the strategic plan, MDOT established a TSMO mission statement of operating and managing an optimized, integrated transportation network by delivering high-quality services for the safe and reliable mobility of all users [*4*]. In order to make progress towards this mission, MDOT sponsored research into the feasibility and traffic safety impacts associated with further implementing TSMO across the department. This report provides details on the methods, findings, conclusions, and recommendations associated with this research.

1.1 Objectives of the Assessment

The intent of this study is to provide important guidance to allow MDOT to make informed decisions as to potential changes to the internal management structure of the systems and operations divisions. Within this framework, MDOT identified three specific objectives to be completed as part of the assessment:

1. Perform a comprehensive literature review on TSMO conversions within state DOTs and contact select state DOTs that have converted or are considering TSMO conversion.
2. Research and identify the relationship between safety funding levels and traffic deaths per VMT in peer states.
3. Perform a predictive analysis to determine how much funding levels may need to increase in order to reach safety goals identified in latest Strategic Highway Safety Plan (SHSP), and trunkline and local funding should be included in the analysis.

1.2 Structure of the Report

In order to accomplish the stated study objectives, the report is structured into the sections described in **Table 1**. It is important to note that while a detailed background of overall TSMO concepts and state integration is covered within this report, a considerable focus is placed on the potential traffic safety impacts of further implementing TSMO within MDOT.

Table 1. Structure of the TSMO Assessment

Section		Description
2.0	TSMO in the United States	• Overview of available guidance, tools and other literature related to TSMO • Identification of states that have implemented TSMO • Interviews with state DOT TSMO staff • TSMO functions and divisional structures • Benefits and limitations of TSMO
3.0	Relationship between State Funding Levels and Safety Performance	• Historical safety funding data, safety performance data and exposure data (including travel and population data) for each state were collected and analyzed in order to evaluate the relationship between the level of safety funding and changes in safety performance
4.0	Estimate Funding Levels to Reach Statewide Goals in SHSP	• An estimation of funding levels needed to reach the safety performance goals identified in Michigan's current SHSP for both trunkline and locally-owned highways
5.0	TSMO Recommendations	• Recommendations for further implementation of TSMO and related matters (such as potential changes to safety funding) were aggregated based upon the findings of **Sections 2.0 - 4.0**

2.0 TSMO IN THE UNITED STATES

A comprehensive review of the existing guidance, tools and literature specific to TSMO was conducted by the research team. Additionally, the status of TSMO for each state, including the collection of implementation plans, guidance, and/or case study examples was determined by the research team. Interviews with ten states' TSMO staff were also conducted to gain further insight into TSMO strategies and practices. Ultimately, these findings were aggregated to determine the functions and divisions typically included in a TSMO divisional structure, as well as the benefits and limitations associated with the conversion to TSMO.

2.1 What is TSMO?

TSMO is an emerging concept which is broadly defined depending on the goals of the agency. It has previously been defined in the Moving Ahead for Progress in the 21st Century Act (MAP-21) as "an integrated set of strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services and projects design to preserve capacity and improve security, safety and reliability of the transportation system" [*2*].

Within MDOT's *TSMO Implementation and Strategic Plan*, TSMO was defined as "an integrated program to optimize the performance of existing multimodal infrastructure by implementing systems, services and projects to maximize capacity and improve the security, safety and reliability of the transportation system" [*4*]. The MDOT definition also states that MDOT "employs TSMO strategies and solutions to provide more efficient use of existing transportation resources by implementing strategies, deploying technologies, and integrating system to address freeway and arterial congestion, improve safety and mobility, and encourage sustainability" [*4*].

The Institute of Transportation Engineers (ITE) breaks down TSMO into five key components [*1*]:

- Traffic operations
- Demand and incident management
- Multimodal operations
- Enforcement
- Safety performance

The Federal Highway Administration (FHWA) notes that TSMO looks at network performance from a systems perspective, as opposed to just one strategy, project or corridor [*2*]. The intent is to view the transportation network as a unified whole, allowing the individual components of the system work to together for better performance [*2*]. This involves an integrated set of strategies which are coordinated across multiple jurisdictions, agencies and modes [*2*]. Ultimately, these integrated strategies span multiple levels of a typical highway agency (**Table 2**).

Table 2. Levels of TSMO Integration across a Typical Highway Agency [*2*]

Level	Description
System	Implementing and combining strategies as a corridor or region matures
Technical	Developing a framework used to support information sharing between technology deployed on the system
Cultural	Developing a workforce that values and prioritizes TSMO
Operational	Coordinating operational strategies to achieve corridor, region or system-wide objectives
Institutional	Incorporating TSMO policies and procedures into all agency activities

There are a variety of potential strategies which could be considered as a part of TSMO integration, including (but not limited to) [*2*]:

- Work zone management
- Traffic incident management
- Special event management
- Road weather management
- Transit management
- Freight management
- Traffic signal coordination
- Traveler information
- Ramp management
- Congestion pricing
- Active transportation and demand management
- Integrated corridor management
- Access management
- Improve bicycle and pedestrian crossings
- Connected and automated vehicle deployment

2.2 Existing National TSMO Tools and Guidance

While TSMO is a relatively new and emerging concept in the transportation industry, there are a variety of national resources which include tools and guidance for implementing TSMO into highway agency activities. These resources are summarized in **Table 3** and will be referred to in subsequent subsections.

Table 3. Summary of National TSMO Resources and References

Reference	Summary
National Operations Center of Excellence (NOCoE)	The NOCoE is designed to offer resources for the TSMO community, including peer exchange workshops, webinars, best practices and on-call assistance [*5*]. The center is a partnership between the American Association of State Highway and Transportation Officials (AASHTO), ITE, the Intelligent Transportation Society of America (ITSA) and FHWA [*5*].
AASHTO *TSMO Guidance*	Web-based self-assessment guide designed for transportation agency managers responsible for operations and management of the roadway system [*6*]. Based upon the capability maturity model (CMM), the guidance was developed as a part of the second Strategic Highway Research Program (SHRP2) [*6*].
FHWA *The Planning for TSMO Guidebook: A Comprehensive Planning Methodology for TSMO*	National guidance document intended to provide a comprehensive descriptive of the programmatic approach to TSMO from planning to construction [*7*]. The guidebook includes methodology for transportation professionals to effectively implement improvements and strategies to develop a long-term program [*7*].
FHWA *Creating an Effective Program to Advance TSMO Primer*	Primer which provides high-level guidance focused on key program, process and organizational capabilities to develop TSMO strategies [*8*]. The primer is designed for program and activity-level managers responsible for TSMO activities at state, regional and local transportation agencies [*8*].

Reference	Summary
ITE *TSMO Mega Issue White Paper*	White paper developed by ITE which covers the history of TSMO, the current status of TSMO, and ITE's role in developing the future of TSMO [*9*].
FHWA *Developing and Sustaining a TSMO Mission for Your Organization: A Primer for Program Planning*	A primer which discusses the key elements of successful TSMO program planning, designed to be a practical resource for state and local agencies to implement TSMO within their organizations [*10*]. The primer identifies ten guiding principles to advance TSMO program planning within roadway agencies [*10*]
FHWA *TSMO in Action*	The document highlights a series of TSMO case studies implemented throughout the United States [*11*]. The intent is to provide state and local agencies with examples and advice for planning and implementing TSMO strategies within their jurisdictions [*11*].
FHWA *Planning for TSMO within Subareas: A Desk Reference*	Desk reference designed to assist state and local agencies with planning and implementing TSMO within a subarea context [*12*]. The document defines subareas as a specific portion of a region (such as a city, county or central business district) which typically involve plans with a greater level of detail [*12*].
FHWA *Planning for TSMO within Corridors: A Desk Reference*	Desk reference designed to assist state and local agencies with planning and implementing TSMO within a corridor context [*13*]. The document considers TSMO with an integrated corridor management (ICM) approach, as opposed to a single facility [*13*].
FHWA Role of *TSMO in Supporting Livability and Sustainability Primer*	The document describes the role of TSMO in advancing livability and sustainability [*14*]. Nine key elements of TSMO are identified to support livability and sustainability, in addition to the inclusion of case study examples and implementation guidance [*14*].

Reference	Summary
Guide to Improving Capability for Systems Operations and Management	Guidance document designed to support transportation agencies in developing institutional arrangements suitable to the demands of congestion management [*15*]. The guide focuses on a change tool referred to as the Institutional Capability Maturity Model [*15*].
FHWA *TSMO Benefit-Cost Analysis Compendium*	The compendium is a collection of case study examples from across the county where a benefit-cost analysis has been applied to a specific TSMO technology or strategy [*16*]. The document also includes hypothetical examples to demonstrate how the analysis can be used for a specific technology or strategy [16].
FHWA *Advancing TSMO: Making the Business Case for Institutional, Organizational, and Procedural Changes*	The guidance document provides details on how transportation agencies can establish institutional, organizational and procedural "ways of doing business" to reduce barriers and increase capacity for implementing TSMO [*17*].
FHWA TSMO Fact Sheets	Given that TSMO often supports, impacts or relates to other transportation agency functions and offices, it is important to strengthen the connection between each discipline [*18*]. The FHWA developed nine fact sheets to detail how TSMO relates to asset management, construction, design, environment, human resources, maintenance, performance management, planning and safety [*18*]

2.2.1 Capability Maturity Model (CMM)

It is important to note that much of the guidance developed for TSMO, particularly the guidance provided by AASHTO, is based upon the CMM [*6, 8*]. This concept, initially developed within the IT industry, was adapted as a part of the SHRP2 research to fit the needs of the transportation community [*6, 8*]. The CMM identifies six key dimensions of process and institutional capability that directly relate to improving TSMO program effectiveness [*8*], summarized in **Table 4**.

Table 4. Six Key Dimensions associated with TSMO Activities [*6, 8*]

Dimension	Description
Business process	Includes formal scoping, planning, programming and budgeting activities
Systems and technology	Includes systems engineering, systems architecture standards, interoperability and standardization
Performance measurement	Includes measures, definition, data acquisition, analysis and utilization
Culture	Includes technical understanding, leadership, policy commitment, outreach and program legal authority
Organization and workforce	Includes programmatic status, organizational structure, staff development, capability, recruitment and retention
Collaboration	Includes relationships with public safety agencies, local governments, MPOs and the private sector

The CMM approach assesses the strengths and weaknesses of an agency's current capabilities within the key dimensions by assigning one of four distinct capability levels, shown in **Figure 1** [*8*]. Each level reflects the current or potential level of capability within that dimension to support an effective TSMO program [*8*]. The capability levels are defined using specific criteria that is easy to interpret [*8*]. With each successive level, there is an emphasis on establishing a program with documented practices, measures of effectiveness, clear lines of authority, defined accountability, and formal relationships [*8*].

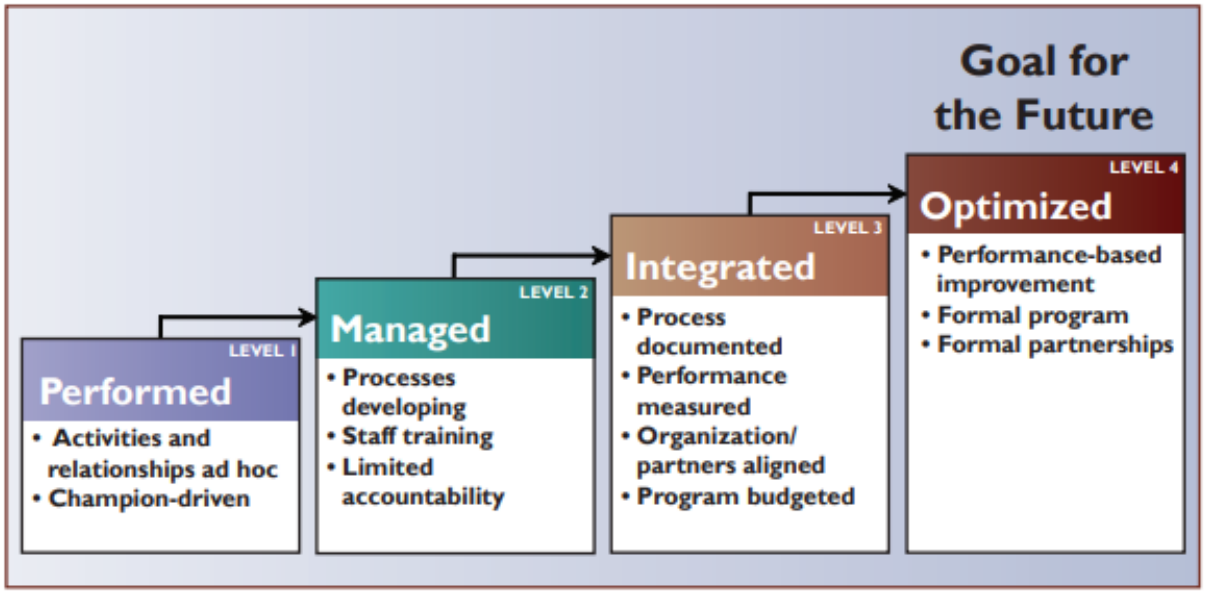


Figure 1. Levels of Agency Capability Maturity [*8*]

Level 1, or performed activities and relationships, are largely conducted ad hoc, are informal and often champion-driven [*6*]. Level 1 activities are generally substantially outside the mainstream of other DOT activities [*6*]. Level 2, or managed activities and relationships, are basic strategy applications with staff capacity under development but limited accountability, collaboration and sustainable resources [*6*]. Level 3, or integrated activities, are standardized strategies with a TSMO technical process that has been developed, documented and integrated into agency activities [*6*]. Level 4, or optimized activities, include full, sustainability core DOT program priorities established with continued improvement and formal partnerships. [*6*].

The key dimension with the lowest level of capability is often the principal constraint to improvement and therefore represents the highest priority to be addressed [*6*]. While it may be difficult to improve capability across each dimension due to competing interests between each dimension, lack of control over specific activities, or other limitations, it is essential to improve each dimension in order to make continued progress [*6*]. It is also important to note that for any element, levels cannot be skipped [*6,8*]. Given that each level builds on the prior technical and/or organizational readiness of the previous level, steps taken for a specific dimension need to be in place for a period (such as one year) to become embedded as the basis for the next level of improvement [*6, 8*].

2.3 TSMO Integration into State DOTs

The research team investigated the current status of TSMO integration for each DOT across the United States. This included the review of any implementation plans, guidance, case study examples or other materials developed by each DOT. This process initiated with a review of MDOT's current TSMO plan to provide context during the review of other state's materials.

2.3.1 Michigan TSMO Implementation and Strategic Plan

MDOT has been advancing TSMO within the agency for several years, beginning in 2013 when the department hosted a TSMO CMM workshop sponsored by the FHWA [*4*]. This was followed by several additional efforts over the next few years, including a meeting with the Michigan Transportation Planning Association (MTPA) and holding a second Detroit, Metro-region focused CMM workshop at the Southeast Michigan Transportation Operations Center (SEMTOC) [*4*]. Further, it is important to note that the department has a long history of integrated transportation activities and processes which were conducted before the TSMO concept was popularized [*4*]. MDOT has also developed five business cases tailored to five key stakeholder groups, including:

- The general public;
- Legislators;
- MDOT decision-makers and senior staff;
- MDOT operations staff; and
- Transportation partners and MDOT non-operations staff [*4*].

Recently, the department has developed a *TSMO Implementation and Strategic Plan*, currently in its third iteration [*4*]. This process began with a workshop conducted in September of 2016 where MDOT staff reached consensus on TSMO mission and vision statements [*4*]. The MDOT TSMO vision includes [*4*]:

- Integrate operations as a core MDOT program united with the execution of MDOT's overall mission
- Inspire public confidence as a progressive and innovative national leader in the management and operations of our transportation system
- Collaborate across program areas, leveraging technology and resources to achieve the best possible results
- Maintain a sustainable and engaged operations workforce with exceptional knowledge, skills and abilities

Three to four priority actions were identified across ten MDOT TSMO business areas, resulting in 34 total prior actions identified as a part of the workshop. The ten business areas included [4]:

- Traffic incident management
- Work zone management
- Congestion (recurring) management
- Safety
- Modal interaction and integration
- Road weather management
- Field equipment, asset and functionality management (ITS, Signals)
- Transportation operations centers (TOC) and traveler information systems
- Connected and automated vehicle (CAV) systems
- Data collection, storage, utilization, analytics and decision-support systems

The workshop also included identification of seven strategic areas of focus which summarize themes from the workshop discussion and relate to each priority action [*4*]:

1. Evaluate and streamline information and technology processes
2. Integrate operations across all business areas
3. Integrate the operations of intelligent transportation systems (ITS) and signals
4. Adapt processes, products and training to advances in technology
5. Enhance communications and outreach to external and internal stakeholders
6. Prioritize resources to meet critical emerging needs
7. Drive progress with meaningful performance measures

In order to avoid redundancies, during the review of priority action items it was determined that there were several overlapping business areas [*4*]. These five categories were eventually identified as commonality areas, including [*4*]:

- Improve IT processes and MDOT-Department of Technology, Management and Budget (DTMB) interactions
- Data
- TSMO functional integration
- TSMO funding integration template
- Outreach and business cases

A one-day work session was also held in 2017 with key MDOT TSMO staff to discuss funding templates which served as critical funding sources for TSMO but had inadvertently posed barriers to certain TSMO activities [*4*]. Each of the TSMO-related funding templates are summarized in **Table 5**. Ultimately, the work session resulted in priority action items related to the funding integration template commonality area [*4*].

Table 5. Existing MDOT TSMO-Related Funding Templates as of 2017 [*4*]

Template Designation	Approximate Annual Funding Level	Funding Source Distribution	Requirements and Goals
ITS	$12-$16M	80% Federal / 20% Michigan	ITS Infrastructure
Signals	$18M	100% Federal	Signal projects to advance mobility and safety
Safety	$60-63M	90% Federal/ 10% Michigan or 100% Federal	Reducing fatalities and injuries
Congestion Mitigation and Air Quality (CMAQ)	$34-36M + CMAQ Set-Aside $9-10M	81.85% Federal/ 18.15% Michigan (note some projects eligible for 100% federal)	Air quality Environmental Protection Agency (EPA) requirement for projects to be in or near nonattainment/maintenance areas or counties
Operations	$6M	100% Michigan	Contract Service, Support and Maintenance
For Comparison Only:			
Pavement Rehab and Rehabilitation	$350M-590M	Approx. 80% Federal/ 20% Michigan	Pavement condition state

Both the TSMO business areas and commonality areas continue progress towards advancing the priority action items as a part of the TSMO development process. Priority recommendations specific to each TSMO business and commonality area are being developed and will subsequently be included in future iterations of MDOT's *TSMO Implementation and Strategic Plan*.

2.3.2 New TSMO Unit with MDOT

As a part of the TSMO conversion process, MDOT has also implemented organizational structure changes within the Bureau of Field Services. Specifically, a new TSMO unit was created which oversees three additional units, including Maintenance/System Operations, Traffic & Safety, and ITS Program Administration. An excerpt from the updated Bureau of Field Services organizational chart (current as of May 2019) is provided in **Figure 2**.

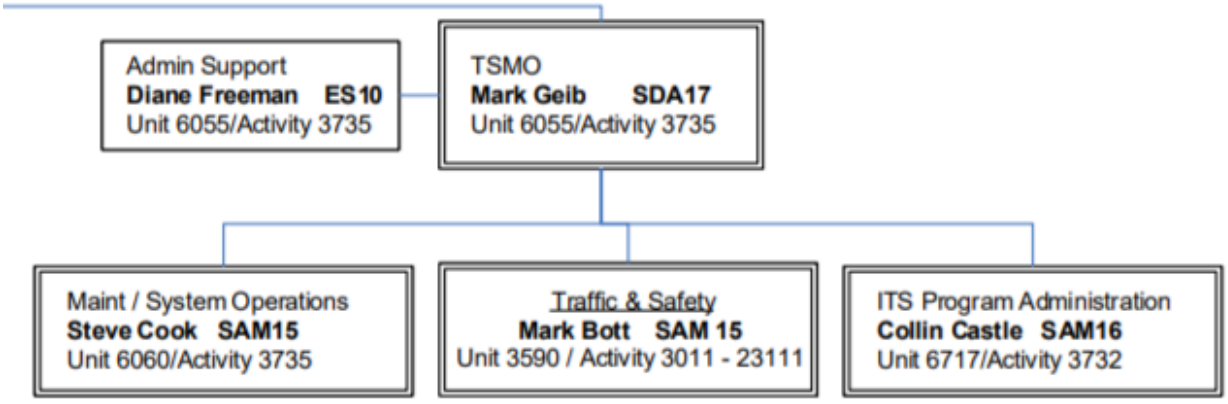


Figure 2. Excerpt from Bureau of Field Services Organizational Chart

2.3.3 States with TSMO Integration

In addition to Michigan, as of May 2019, at least 24 other state DOTs have implemented some level of TSMO concepts or strategies within agency activities (**Figure 3**). Note that the map presented in **Figure 3** does not include regional MPOs or local governments which have implemented TSMO within their jurisdictions. TSMO integration in state DOTs ranges from agencies which have developed an entire TSMO division to those which have incorporated TSMO concepts only on specific projects. This section summarizes the best practice examples from states around the county to provide further guidance for Michigan's TSMO implementation process.

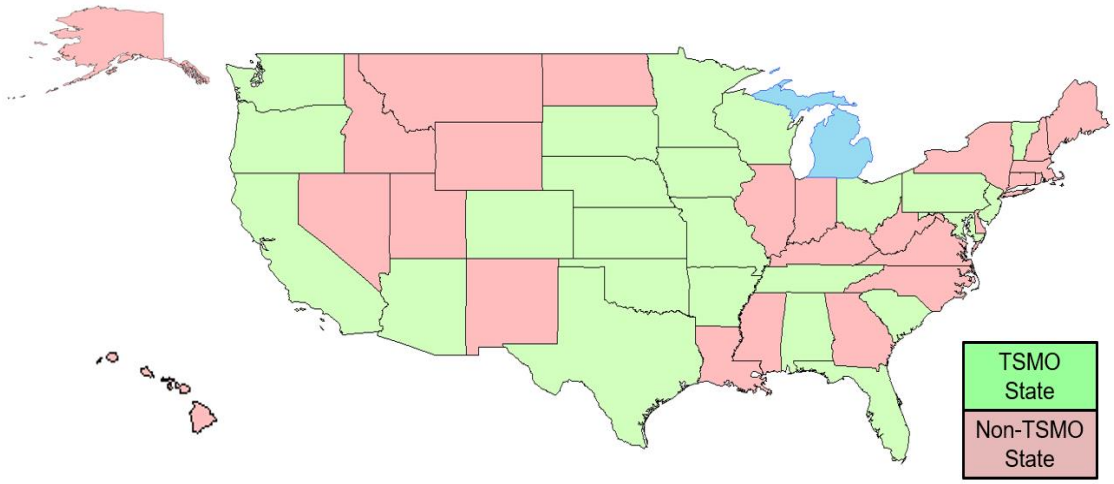


Figure 3. Map of State DOTs that have Implemented TSMO

Arizona

The Arizona DOT has recently converted to a new TSMO structure after undergoing a CMM self-assessment conducted in 2014 [*19*]. With support from both the governor and DOT director, Arizona restructured its DOT to better align with present and future operations, improve system preservation and operations, and increase synergies through improved interagency coordination [*19*]. The restructuring included shifting the following seven groups under a new TSMO division:

- Systems Technology
- System Maintenance
- Operations and Traffic and Safety
- Traffic Maintenance
- Traffic Management
- Systems Management
- Business Administration

TSMO functions conducted at the department include [*19*]:

- Integrated corridor management
- Management of the traffic operations center (TOC)
- Signal systems coordination
- Work zone traffic management
- Travel weather management
- Advanced traffic demand management (such as managed lanes and variable speed limits)
- Traffic incident management (TIM)
- Special event and emergency management
- Revolutionary and rapid technologies (including connected and automated vehicles)
- Statewide permitting
- Freight management (including the I-10 connected freight corridor)

It is also worth noting that the AZDOT recently won the 2018 Best TSMO Project (Creative Solution) from NOCoE for the US-60 restriping project [*20*]. The project involved implementation of a sign redesign and lane restriping of westbound I-60 in advance of the interchange with I-10 in the Phoenix metropolitan area [*20*]. A comprehensive safety review was performed by several groups within the agency as well as an independent RSA [*20*]. Operational concerns were found to contribute to the crash history experienced along the segment and ultimately redesigned striping and signage resulted in a reduction of both crashes and congestion (**Figure 4**) [*20*].

Figure 4. Improved US-60 and I-10 Interchange in Tempe, Arizona [*20*]

California

The California Department of Transportation (Caltrans) has a long history of implementing strategies similar to TSMO, beginning with a mobility model developed in the early 2000's which established a foundation for maintenance and management of the Caltrans system [*21*]. Caltrans efforts have continued to evolve, including conducting a CMM self-assessment in 2013, but have been built upon the Caltrans System Management Pyramid, shown in **Figure 5** [*21*].

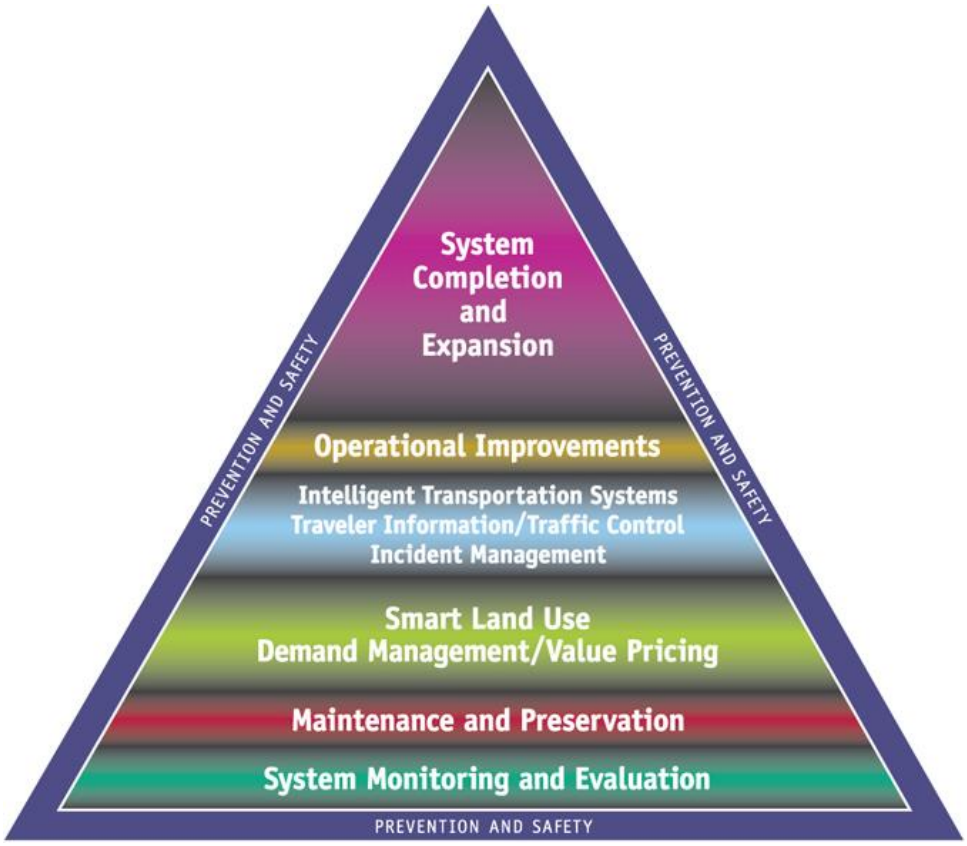


Figure 5. Caltrans System Management Pyramid [*21*]

Caltrans also conducts regional operations forums (ROFs) to provide an opportunity to agency staff and local partners to share the latest TSMO experiences and strategies [*22*]. These ROFs have often represented an opportunity to focus on strategic corridors where partnering agencies can work together to improve corridor system performance [*22*]. Additionally, the ROFs also included CMM self-assessments to determine the combined ability of stakeholders in the district to implement and sustain TSMO [*22*]. Caltrans has conducted ROFs in each of its 12 districts (except District 7 which conducted a more comprehensive assessment) as of November 2017 [*22*].

Colorado

The Colorado Department of Transportation (CDOT) has been recognized by several state agencies as a model for their own TSMO implementation process, with CDOT's Division of TSMO becoming FHWA's national model for organizing for Operations in 2013 [*23*]. The division was initially formed in 2013 with 87 employees and four branches after an extensive process (**Figure 6**) which culminated in CDOT's *TSMO Reorganization Report* [*23, 24*].

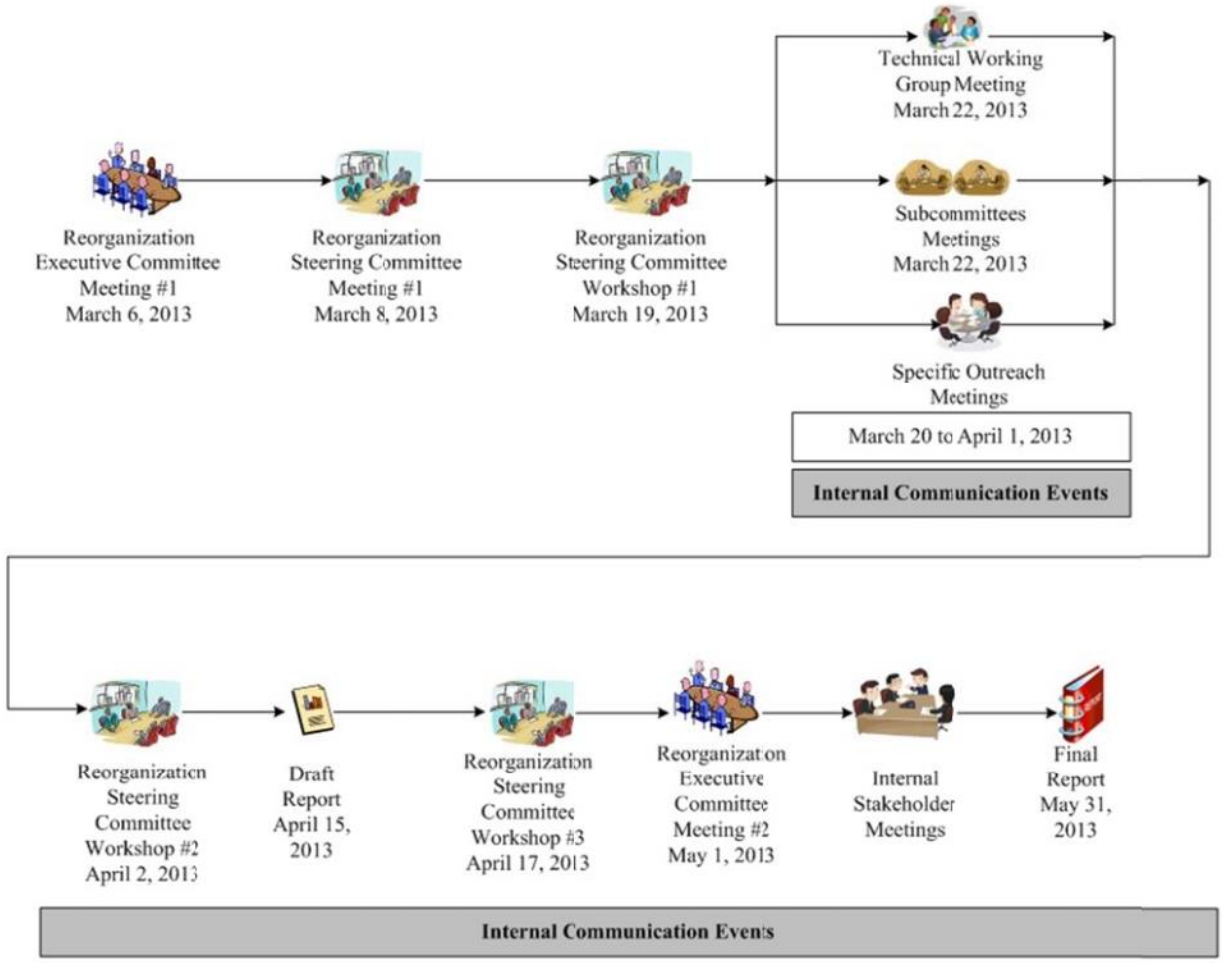


Figure 6. CDOT TSMO Plan Process [*24*]

The mission of the new division was to synthesize technology, engineering and operations to save lives and reduce congestion [*23*]. Additionally, seeking innovative solutions as opposed to expensive capacity expansion projects was a goal of TSMO [*23*]. Ultimately, the purpose of the new division was to enable the department to maximize transportation funding and obtain a higher return on investment [*23*]. The division of TSMO at CDOT oversees the ITS branch, the safety and traffic engineering branch and the operations management branch [*23*].

As a result of the TSMO conversion, ten new programs were developed that previously did not exist at CDOT, including [*23*]:

- Statewide traffic signal and ramp meter program
- Traffic incident management
- Operations policy and support
- Planning, performance and travel demand management
- I-70 corridor operations
- I-25 corridor operations
- Statewide traffic management centers program
- TSMO evaluations
- Corridor operations and bottleneck reduction assistance (COBRA) program
- Connected and autonomous technologies program

An important component of CDOT's TMSO program are the TSMO evaluations conducted as a part of all new projects. The evaluation consists of a safety assessment, an operations assessment and an ITS assessment which are ultimately aggregated to make recommendations to the project team to improve safety and mobility [*25*]. The purpose of the evaluation is to ensure a consistent and inter-disciplinary approach including maintenance, access, regions, operations, safety, ITS and FHWA [*25*]. The TSMO evaluation allows for enhanced opportunities to provide safety improves, accountability to stakeholders, increased ability to note lessons learned, streamlines business processes and provides increased system reliability [*25*].

Florida

TSMO at the Florida Department of Transportation (FDOT) is a program which is integrated at both the central office traffic engineering level and within each district at the traffic operations level. The intent of the TSMO program at FDOT is to deliver positive and safety mobility outcomes for the traveling public in Florida [*26*]. This includes a variety of functions within the department which fall under TSMO, shown in **Figure 7**. In 2017, the department completed a TSMO strategic plan which presents the mission, goals, objectives and priority focus areas of the departments TSMO program [*27*]. It is also important to note that FDOT has funded recent research projects to contribute to the program [*28, 29*].

Figure 7. TSMO Functions at FDOT [*26*]

Iowa

Iowa developed a TSMO program in 2016, aligning with the overall goals and core values of the Iowa Department of Transportation [*30*]. As a part of developing the program Iowa DOT identified six strategic goals which set the overall direction for TSMO and frame the priorities for developing and integrating TSMO in Iowa (**Figure 8**) [*30*]. The TSMO program was ultimately composed of a *Strategic Plan*, a *Program Plan* and eight *Service Layer Plans* [*30*]. The relationship between each document is shown in **Figure 9**.

Strategic Goal	Strategic Objective
1. Safety	Reduce crash frequency and severity
2. Reliability	Improve transportation system reliability, increase system resiliency, and add highway capacity in critical corridors
3. Efficiency	Minimize traffic delay and maximize transportation system efficiency to keep traffic moving
4. Convenience	Provide ease of access and mobility choices to customers
5. Coordination	Engage all DOT disciplines, and external agencies and jurisdictions to proactively manage and operate the transportation system
6. Integration	Incorporate TSMO strategies throughout DOT's transportation planning, design, construction, maintenance, and operations activities

Figure 8. Iowa DOT TSMO Strategic Goals and Objectives [*30*]

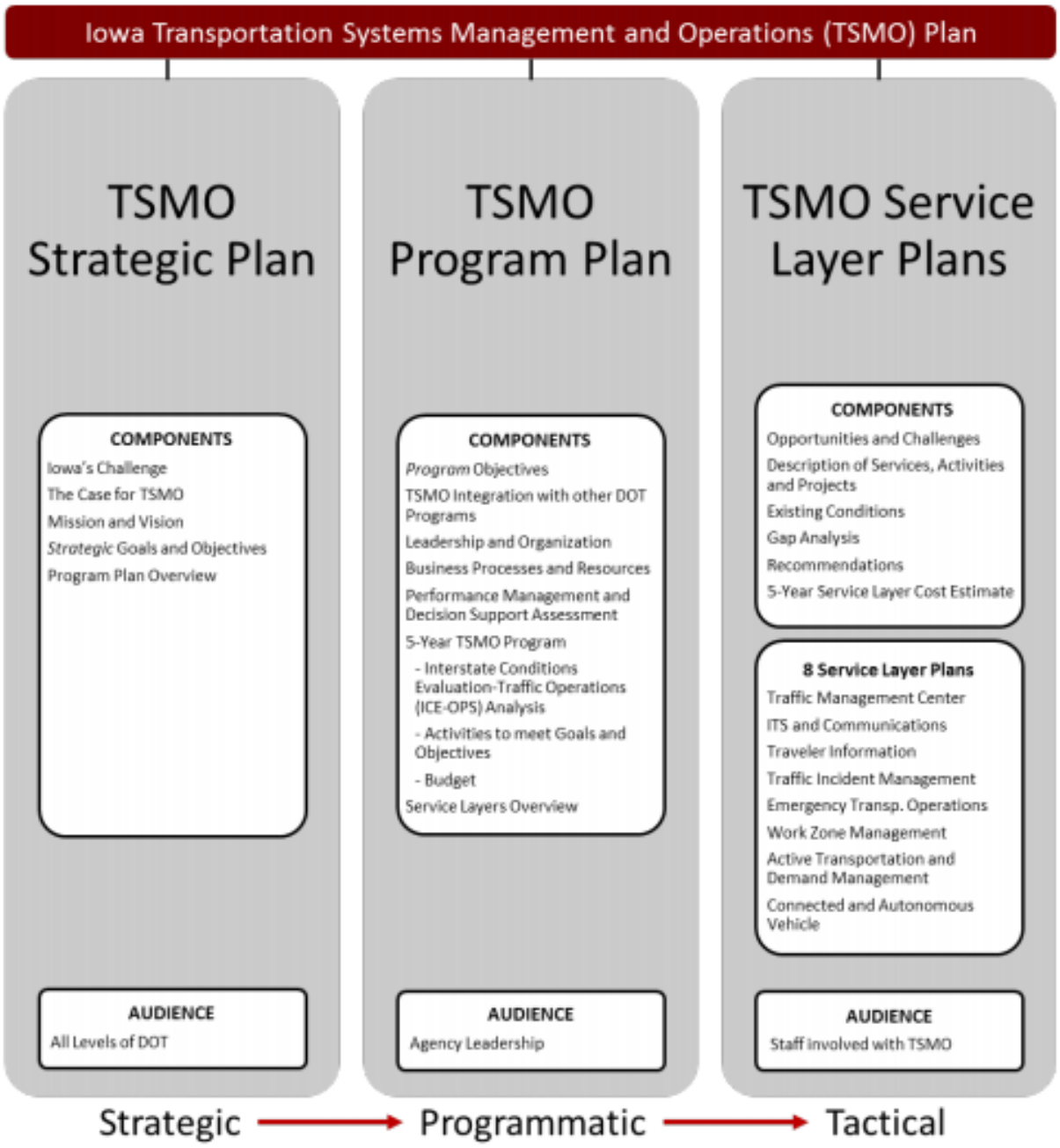


Figure 9. Iowa DOT TSMO Document Relationships [*30*]

The *Strategic Plan* provides overall direction for the TSMO plan, highlights Iowa's challenges, makes the case for TSMO and outlines the departments TSMO vision, mission, goals and strategic objectives [*30*]. The *Program Plan* is a companion to the Strategic Plan and provides the structure for the comprehensive TSMO program [*31*]. The program plan provides the key details of the TSMO program, including the objectives, strategies, processes, procedures and resources needed

to implement TSMO in Iowa [*31*]. Each of the eight Service Layer Plans provide additional detailed recommendations and actions specific distinct service areas, shown in **Figure 10 [***30*].

Service Layer	Definition
Traffic Management Center	The around-the-clock hub of DOT traffic coordination activities throughout the state. The Traffic Management Center recently relocated from Ames to a newly remodeled facility in the Iowa Motor Vehicle Division Building in Ankeny.
ITS and Communications	Fixed and mobile traffic detectors, non-enforcement traffic cameras, dynamic message signs, highway advisory radio, and supporting communications infrastructure.
Traveler Information	Traveler Information tools that help publicly broadcast planned and prevailing traffic conditions, such as Iowa 511 and various social media.
Traffic Incident Management	The coordination of how Iowa DOT and its partners respond to routine highway traffic incidents.
Emergency Transportation Operations	The coordination of how Iowa DOT and its partners respond to large scale incidents (not necessarily highway related), such as flooding, tornado, epidemics, etc.
Work Zone Management	The planning and deployment of various strategies to maintain traffic flow and safety through highway work zones.
Active Transportation and Demand Management	Innovative strategies to maximize available capacity of roadways, such as ramp metering, variable speed limits, lane control signing, and time-of-day shoulder use.
Connected and Autonomous Vehicle	An emerging technology that considers the challenges and opportunities of vehicle-to-vehicle, vehicle-to-infrastructure, and autonomous vehicles to improve vehicle safety and efficiency. Iowa DOT's primary role is an information service provider.

Figure 10. Iowa DOT TSMO Service Layer Plan Definitions [*30*]

The intent of TSMO in Iowa is not to replace any of the current responsibilities but to build upon the people, processes and systems already in place [*31*]. TSMO offers resources and strategies to realize the full capacity of the existing system, including the basic and cross-cutting functions performed by Iowa DOT, shown in **Figure 11** [*31*]. The *Program Plan* identifies specific system-level objectives (or those which relate to the overall transportation system) and program-level objectives (or those which related to the department's TSMO program efforts) which provide a foundation for TSMO [*31*].

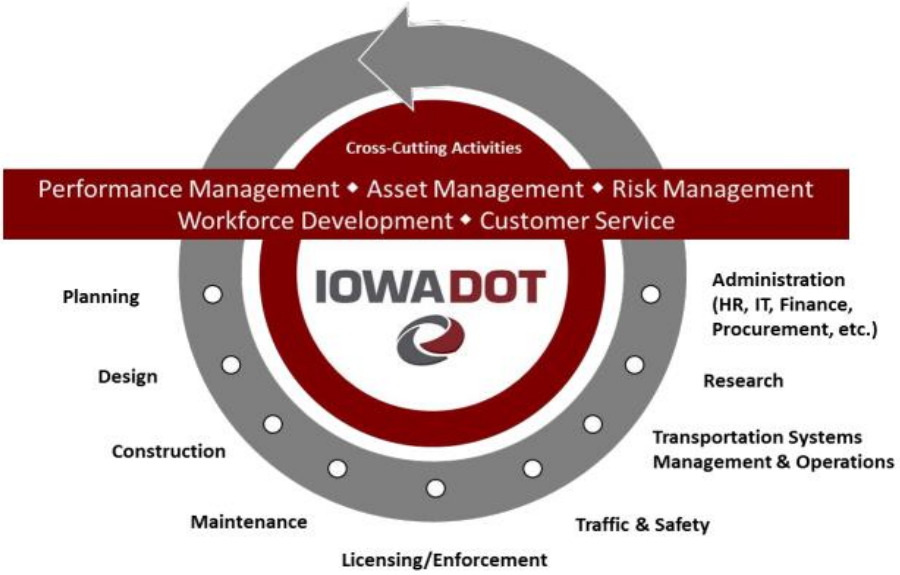


Figure 11. Iowa DOT TSMO Basic and Cross-Cutting Functions [*31*]

Instead of restructuring the agency, Iowa DOT opted to integrate TSMO functions as a part of the traffic operations office. **Figure 12** provides a flowchart of the systems planning process in Iowa which includes TSMO activities [*31*].

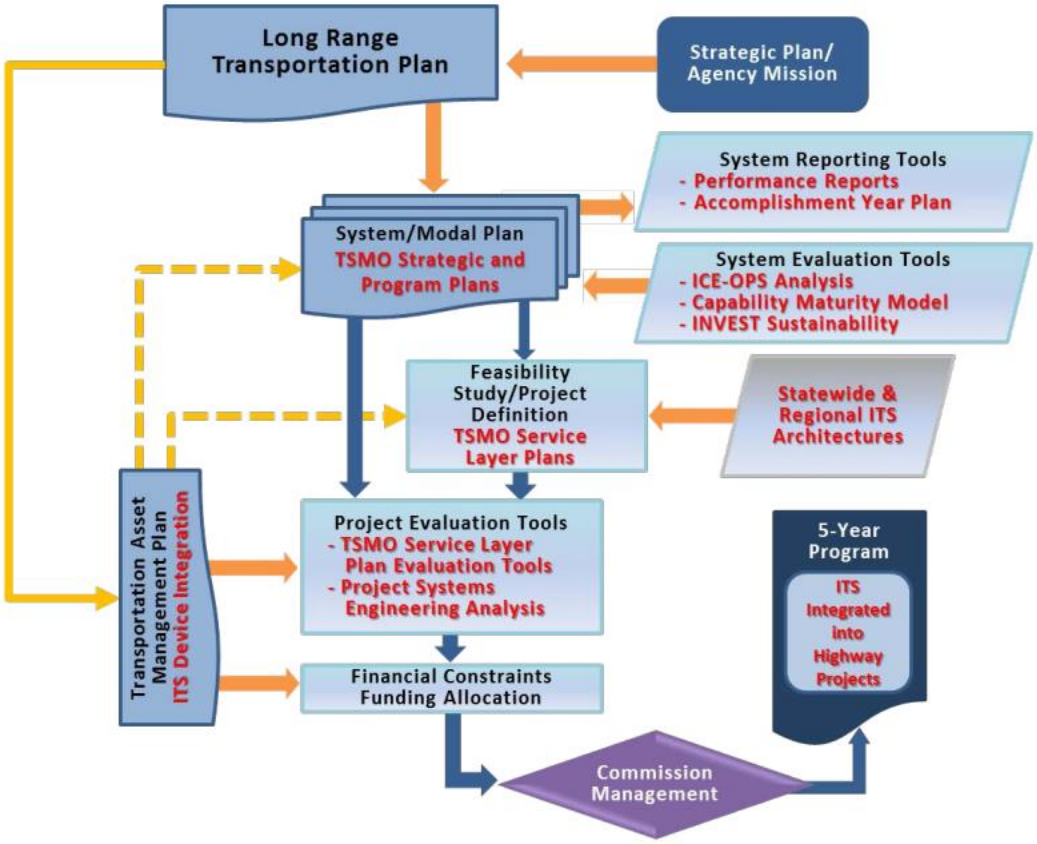


Figure 12. Iowa DOT TSMO Program Plan and Systems Planning Process [*31*]

Maryland

Beginning in 2014 with a CMM workshop, the Maryland DOT recently developed a *TSMO Strategic Implementation Plan* published in 2016 (**Figure 13**) [*32*]. The Strategic Implementation Plan included TSMO vision and mission statements as well as goals, objectives and strategies for implementing TSMO [*32*]. Ultimately, action items and deliverables were identified that outline how TSMO will be integrated in Maryland with key internal and external stakeholders [*32*].

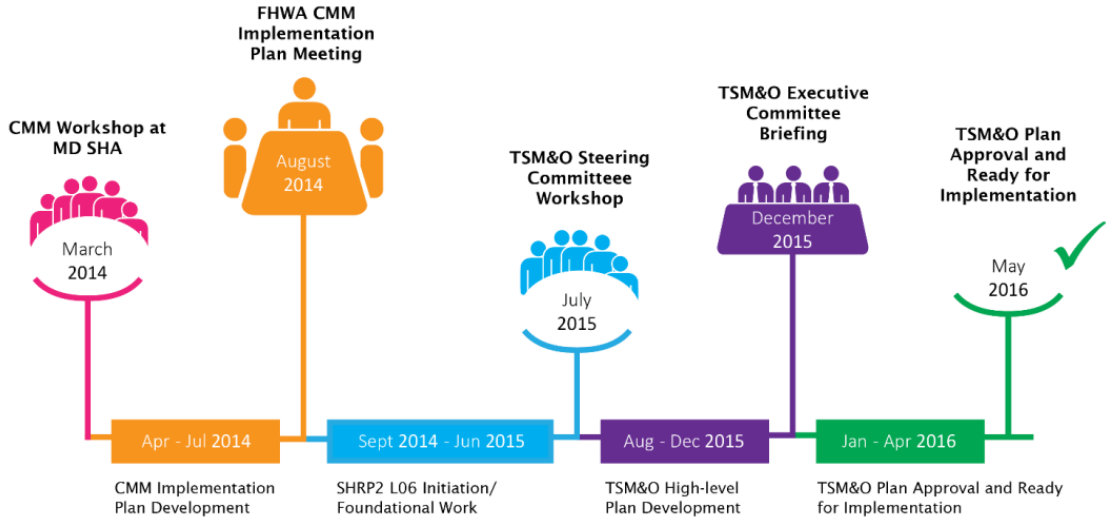


Figure 13. Maryland TSMO Plan Adoption Timeline [*32*]

The plan proposed the creation of a TSMO Executive Committee (**Figure 14**) responsible for overall oversight and guidance of the TSMO program but did not include a new TSMO office [*32*]. Instead, a TSMO Program Manager would facilitate TSMO within existing offices [*32*].

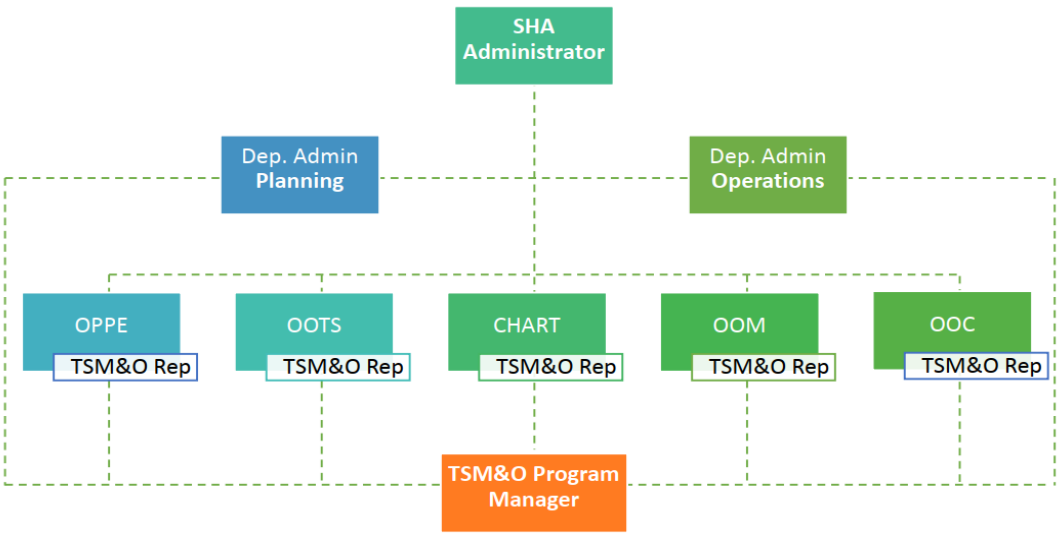


Figure 14. Maryland TSMO Proposed Organizational Structure [*32*]

Minnesota

The Minnesota Department of Transportation (MnDOT) has recently undertaken several steps towards developing a comprehensive TSMO plan, including the development of a TSMO Strategic Plan published in 2018 [*33*]. Additionally, a TSMO Implementation Plan and a TSMO Business Plan are also being developed to form MnDOT's overall TSMO plan (**Figure 15**).

Figure 15. Relationship between MnDOT TSMO Plans [*33*]

While MnDOT has performed activities similar to TSMO for some time, the *Strategic Plan* provides a high-level overview of how MnDOT will further TSMO in the state [*33*]. The *Strategic Plan* identifies three specific goals to support MnDOT's TSMO vision and mission (**Figure 16**) and objectives to complete the stated goals [*33*].

Figure 16. MnDOT's TSMO Goals [*33*]

Missouri

Similar to other states, the Missouri Department of Transportation (MoDOT) performed a variety of functions which were analogous to TSMO for some time (**Figure 17**). However, the department has placed a greater emphasis on TSMO efforts, leading to the publication of a TSMO *Program and Action Plan* in 2017 [*34*]. The *Program and Action Plan* is intended to help MoDOT achieve the following:

- Establish the mission, goals, objectives and strategic direction for TSMO;
- Define the framework for organizational procedures, resources, activities, services and projects;
- Outline specific steps and action items to institutionalize TSMO; and
- Provide guidance to MoDOT and other stakeholders related to the management and operations of the transportation system [*34*].

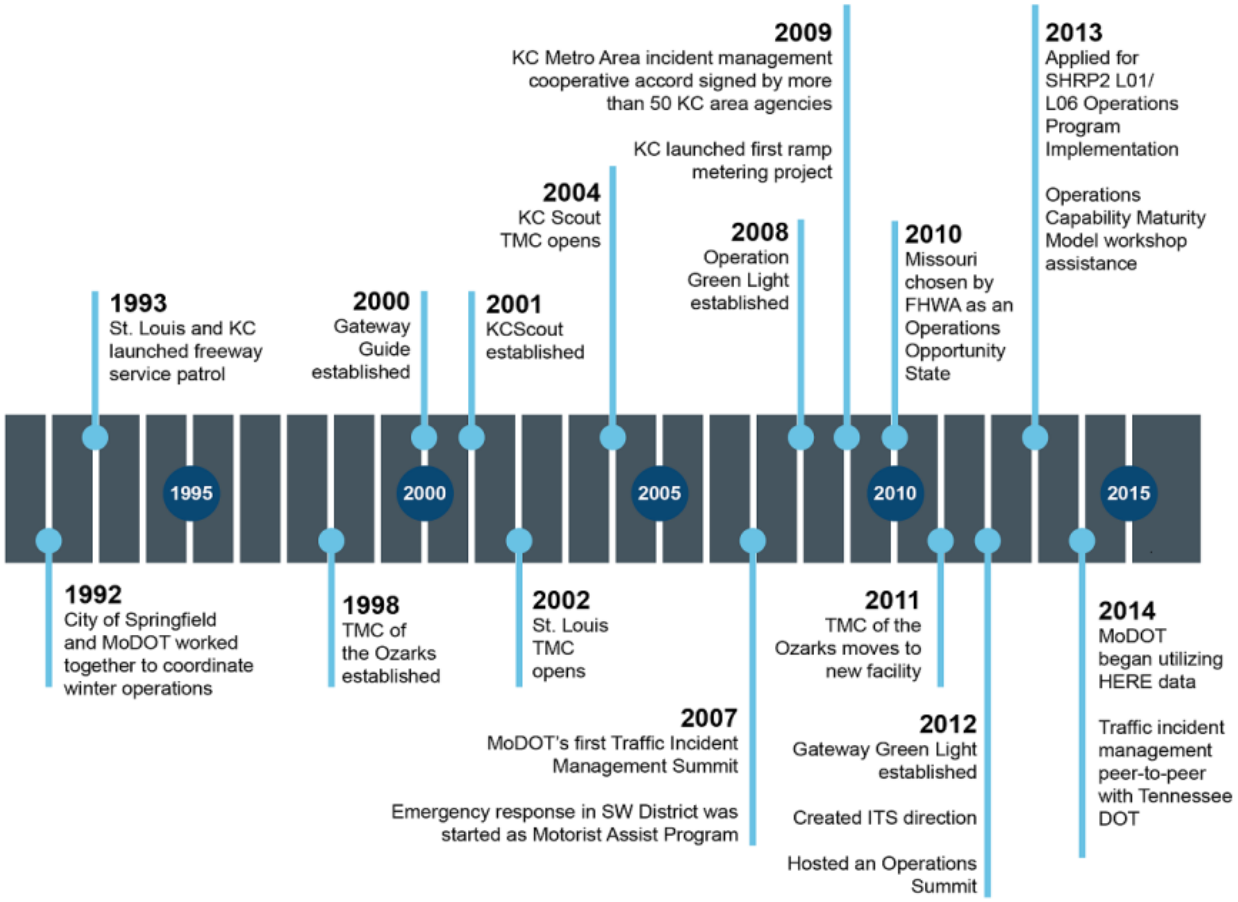


Figure 17. MoDOT's Timeline of TSMO-Related Efforts [*34*]

MoDOT's TSMO goals and objectives are summarized in **Figure 18**:

Goals	Objectives
Operate MoDOT's existing system efficiently, reliably, and effectively through the application of TSM&O strategies and programs	Provide for TSM&O deployments statewide
Consider TSM&O solutions and strategies in every MoDOT project	Include TSM&O proactively rather than opportunistically/reactively
Include TSM&O in the planning stages of projects and programs	Include planning for operations principles in MoDOT planning process documents
Strengthen TSM&O related education and workforce development	Provide new and supplement existing TSM&O outreach, training, and recruitment resources for MoDOT staff and partners
Document progress toward meeting each goal and MoDOT's stated tangible results	Quantify and document TSM&O performance measures

Figure 18. MoDOT's TSMO Goals and Objectives [*34*]

As a part of the *Program and Action Plan*, MoDOT identified several teams and working groups at various levels within the agency to advance TSMO [*34*]. MoDOT's TSMO organizational support structure is shown in **Figure 19**.

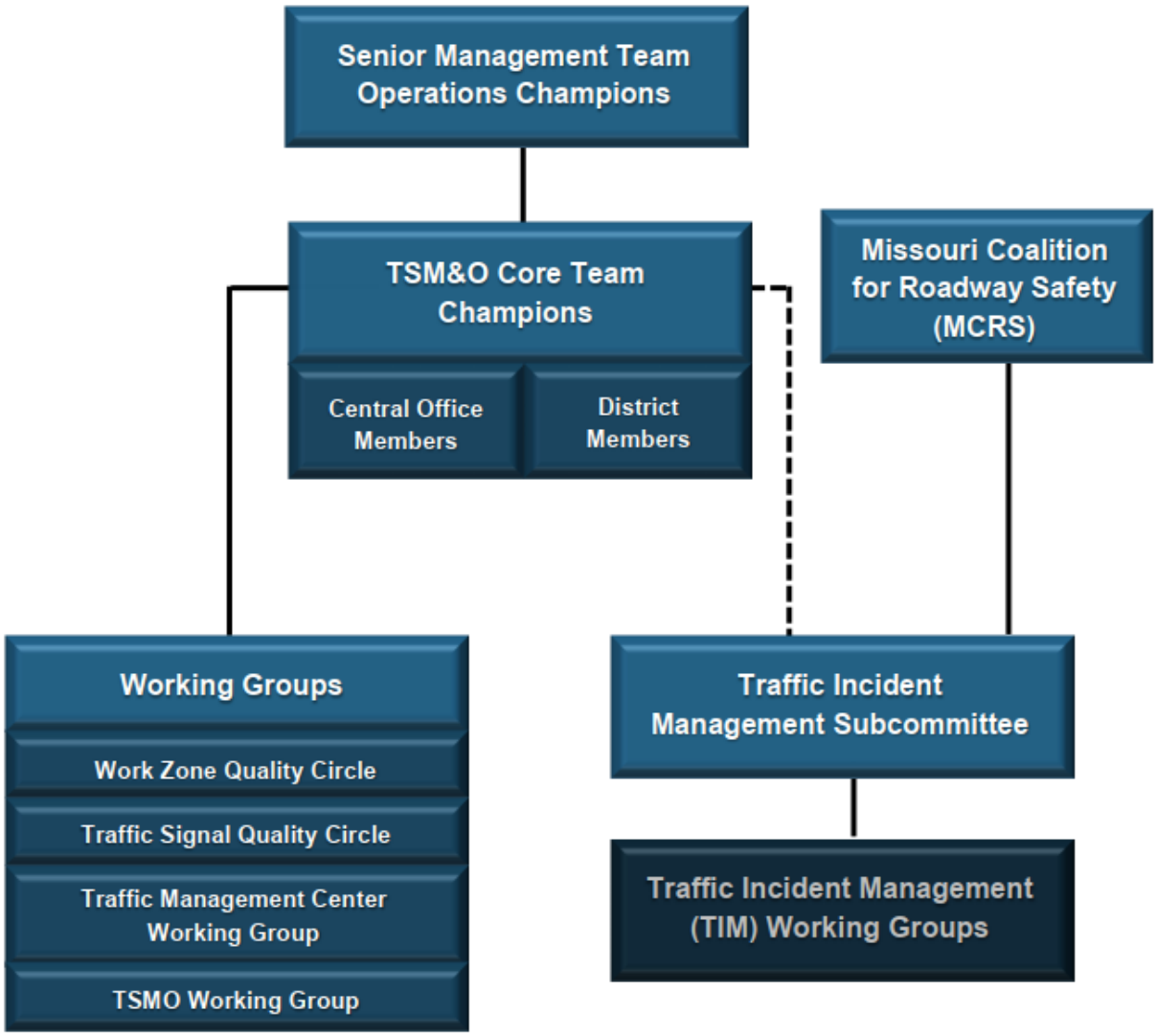


Figure 19. MoDOT's TSMO Organizational Support Structure [*34*]

North Carolina

The North Carolina Department of Transportation (NCDOT) recently won a 2018 award from NOCoE for its preparation and response to Hurricane Florence which included TSMO concepts [*35*]. As a result of the storm, more than 2,400 roadways were closed due to widespread flooding (**Figure 20**) [*35*]. NCDOT's Statewide Traffic Operations Center (STOC) and regional TMCs coordinated resources around the clock in order to prepare for and respond to the storm [*35*].

Figure 20. Roadway in North Carolina Flooded by Hurricane Florence [*35*]

As evacuation orders went into effect, NCDOT implemented plans to support additional traffic demands, quick clearance and immediate tow programs as well as the Voice Interoperability Plan for Emergency Responders (VIPER) radio programming [*35*]. NCDOT also developed a strategy for hard shoulder running (HSR) and implemented elongated merge areas at key interchanges to improve capacity [*35*]. During the storm, STOC staff established a routing room for monitoring real-time traffic conditions and determining passable routes for emergency responders [*35*]. Given the historic flooding which occurred in the aftermath of the storm, a coordinated effort was undertaken to maintain accurate road conditions and relay this information to the traveling public via DriveNC.gov [*35*]. NCDOT staff also conducted an After-Action Review following the hurricane to determine where improvements could be made [*35*].

Ohio

The Ohio Department of Transportation (ODOT) has developed a comprehensive TSMO plan, beginning with a CMM workshop in 2013 and culminating with the publication of a formal plan in 2017 [*36*]. The intent of the TSMO plan is to provide a basis for statewide policy and process changes to increase the focus and execution of traffic operations to meet future system needs [*36*]. The ODOT TSMO plan is comprised of several technical documents and supporting reports, shown in **Figure 21** [*36*].

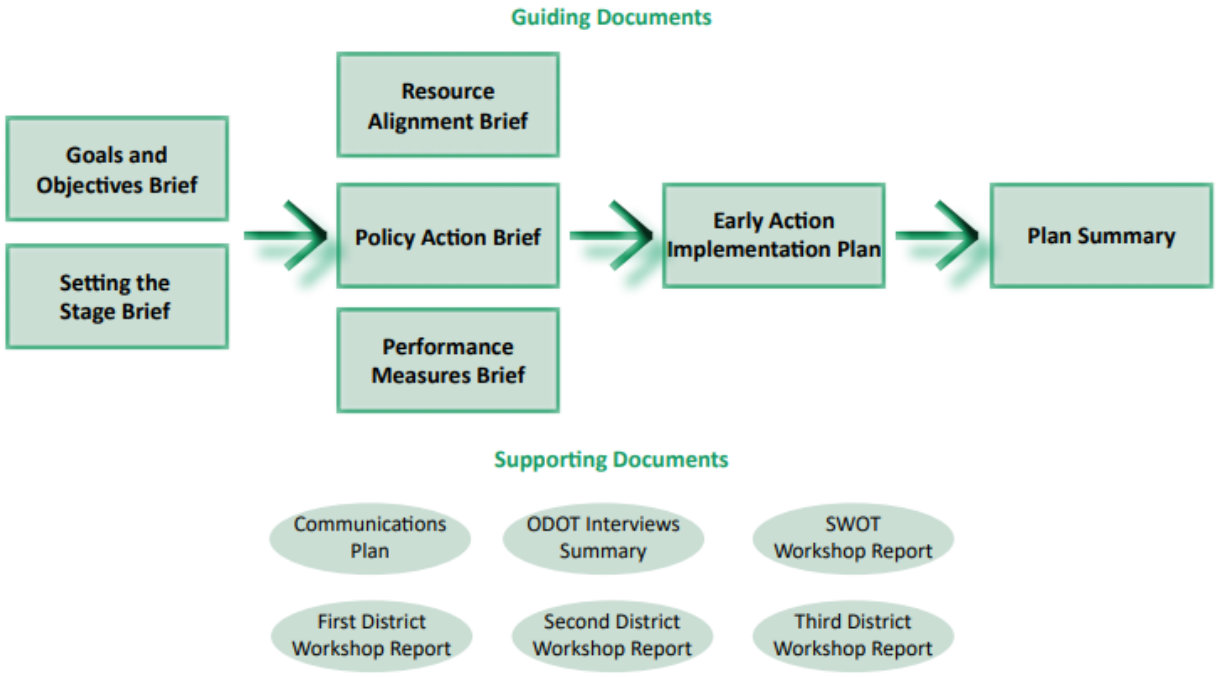


Figure 21. ODOT TSMO Plan Flowchart [*36*]

The *Goals and Objectives Brief* sets the overall direction for the TSMO program, while the *Setting the State Brief* summarizes ODOT's current functions, national best practices and a catalogue of TSMO resources [*36*]. The *Resource Alignment Brief* provides recommendations for aligning ODOT resources in support of TSMO [*36*]. The *Policy Action Brief* includes recommendations for policy actions to establish, develop and maintain the TSMO program [*36*]. Performance measures and targets for assessing the effectiveness of the TSMO program are included in the *Performance Measures Brief* [*36*]. The *Early Action Implementation Plan* includes immediate actions to implement TSMO in Ohio [*36*]. The *Communications Plan* provides information to create awareness of TSMO benefits while the *Workshop and Interview Reports* summarizes the discussions with ODOT staff. [*36*].

Oregon

The Oregon Department of Transportation, which has implemented TSMO in its System Operations and ITS Division, recently won a 2018 award from NOCoE for its use of social media to engage first responders and promote safety laws [*37*]. In order to more effectively engage first responders, Oregon DOT developed a strategic communications plan to increase interaction, outreach and awareness of TIM elements and activities [*37*]. While the department previously had

a newsletter to connect first responders, part of the communications plan included the development of a Facebook webpage to promote TIM trainings and share information (**Figure 22**) [*37*].

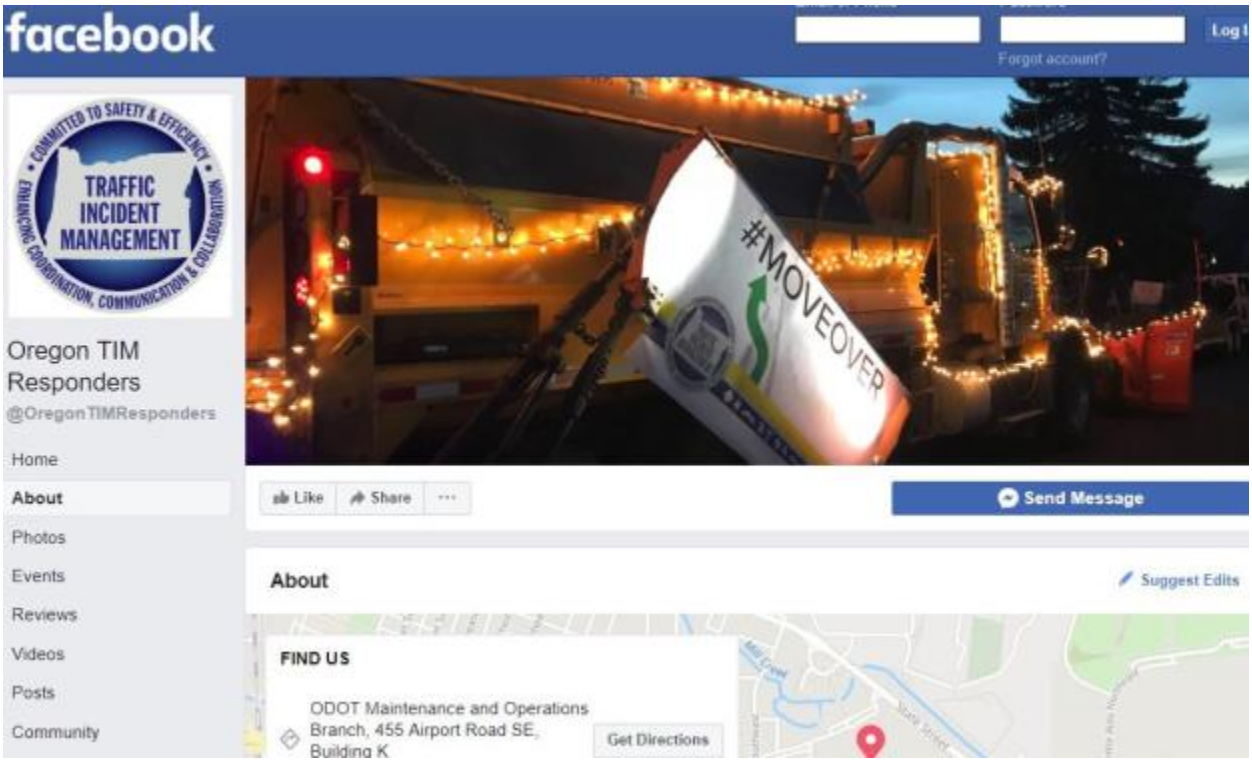


Figure 22. Oregon DOT TIM Responders Facebook Page [*37*]

The social media page has provided a platform for Oregon DOT to share messages, graphics, videos and other content which responders and other agencies can further distribute within their networks [*37*]. For example, the 2017 National Move Over Day activity on the Facebook page allowed Oregon DOT to reach approximately 47,900 people in the state [*37*]. Ultimately, the TIM Responders page has allowed Oregon DOT to build inclusivity within TIM partnerships, increase the efficiency and effectiveness of engaging stakeholders and fill an existing knowledge gap with the general public [*37*].

Pennsylvania

The Pennsylvania Department of Transportation (PennDOT) has recently developed a comprehensive TSMO program, beginning with a CMM workshop and assessment [*38*]. The TSMO program in Pennsylvania is comprised of three major elements (**Figure 23**): a *Strategic Framework*, a *Program Plan* and a *TSMO Guidebook* [*38*]. The Strategic Plan is intended to make the case for TSMO in Pennsylvania and increase awareness of the benefits of TSMO [*38*].

Figure 23. Structure of PennDOT's TSMO Program [*38*]

The *Program Plan* builds upon the *Strategic Framework* and presents a CMM-based approach to reach Pennsylvania's TSMO vision [*38*]. The *Guidebook* provides details for partners to develop regional operations plans and congestion-related business are plans [*38*]. As a part of the *Program Plan*, nine specific TSMO needs were identified (**Figure 24**). Strategies were identified in order to address each need and are categorized according to standard CMM key dimensions presented in **Table 4** in **Section 2.2.1**.

Need A – Consider Operations Throughout Project Life Cycle
Need B – Provide Adequate Funding and Guidance
Need C – Establish Performance Measures
Need D – Foster Knowledge and Provide Training
Need E – Improve Intra-Agency Coordination
Need F – Improve Interagency Coordination
Need G – Provide Appropriate Staffing and Organizational Structure
Need H – Provide Proper Documentation and Tools
Need I – Document Operations Policies and Procedures.

Figure 24. PennDOT's Nine TSMO Program Plan Needs [*38*]

Consistent with identified *Need A – Considering Operations Throughout Project Life Cycle*, PennDOT has placed a focus on considerating TSMO in the planning, design, construction, maintenance and opererations stages of the project life cycle (**Figure 25**) [*38*].

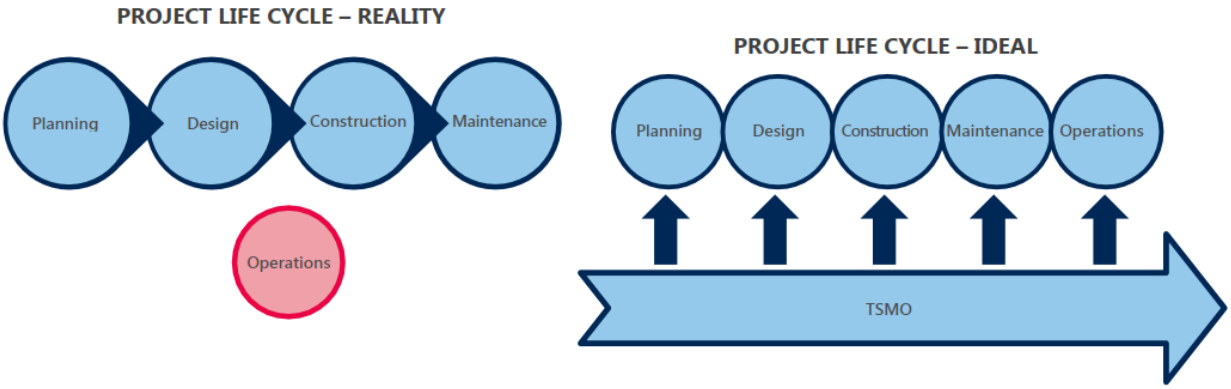


Figure 25. Current Project Life Cycle vs. Ideal TSMO Project Life Cycle [*38*]

Instead of developing a new organizational structure, PennDOT integrated TSMO activities and functions identified in the program plan into several key business areas, including [*39*]:

- Inclement weather
- ITS and Traffic Signals
- Work Zones
- Traffic Incidents
- Special Events
- Bottlenecks
- Traffic Management Centers
- Traveler Information
- Connected/Autonomous Vehicles

South Dakota

The South Dakota Department of Transportation (SDDOT) recently commissioned a study to develop a TSMO *Program Plan* [*40*]. While SDDOT has conducted a variety of TMSO activities on an informal, as-needed basis (**Figure 26**), the *Program Plan* was intended to specify a set of goals, actions and priorities to establish TSMO as a formal, critical activity in the state [*40*]. The *Program Plan* was intended to be used by SDDOT as a business plan for near-term decision making, initiate planning and prioritization, a strategic plan for long-term decisions, guidance for target setting and as a stepwise implementation manual for TSMO [*40*]. While SDDOT performed an initial CMM-workshop in 2013, the CMM approach was used in the development of the Program Plan [*40*].

	Traveler Information Services	Traffic Incident Management	Road Weather Mgt. / Winter Operations[c]	Special Event Management	Work Zone Management	Com. Vehicle Ops. / CVISN	Urban Traffic Control[d]	Agricultural Vehicle Mgt.[e]
Statewide	X	X	X		X	X		
I-90 Corridor	X	X	X		X	X		
I-29 Corridor	X	X	X		X	X		
Sioux Falls Region	X	X	X	X	X		X	
Rapid City Region	X	X	X	X	X			
Rural[a]	X	X	X		X			X
Multistate[b]			X			X		

[a] Generally off the I-90 and I-29 corridors and outside the Sioux Falls, Rapid City, and other urban regions
[b] Incorporates collaboration with neighboring states
[c] Includes all severe weather events and disaster response
[d] Includes application of adaptive signal controllers, traffic signal timing plans, and surveillance and detection
[e] Agricultural Vehicle Mgt. refers to operational strategies and treatments to safely manage the movement of agricultural vehicles and equipment on high-speed, two-lane roadways

Figure 26. Existing South Dakota DOT TSMO Activities [*40*]

The SDDOT TSMO *Program Plan* ultimately includes a series of recommendations in the form of actions, task and implementation steps to implement TSMO formally in South Dakota [*40*]. Instead of specifying specific projects, the plan identifies key processes and institutional capabilities that have been shown to be critical to TSMO [*40*].

Tennessee

The Tennessee Department of Transportation (TDOT) also has integrated TSMO into its activities via the TDOT Traffic Operations Program Plan [*41*]. The plan was developed to advance TSMO strategies in support of TDOT's operational goals for system operation and preservation [*41*]. In Tennessee, the Traffic Operations Division (which is a headquarters level division) is responsible for TSMO implementation [*41*]. The Traffic Operations Division is comprised of a Transportation Management Office, a Traffic Engineering Office and an Intelligent Transportation Systems Office (**Figure 27**). The headquarters level Traffic Operations Division interfaces with regional staff in support of TSMO (**Figure 28**). As a part of its TSMO efforts, TDOT also maintains a TSMO Coordinating Committee consisting of four working groups which include both headquarters and regional staff [*41*]. The committee is comprised of an ITS working group, a systems performance measures working group, a collaboration working group and a traffic working group (**Figure 29**).

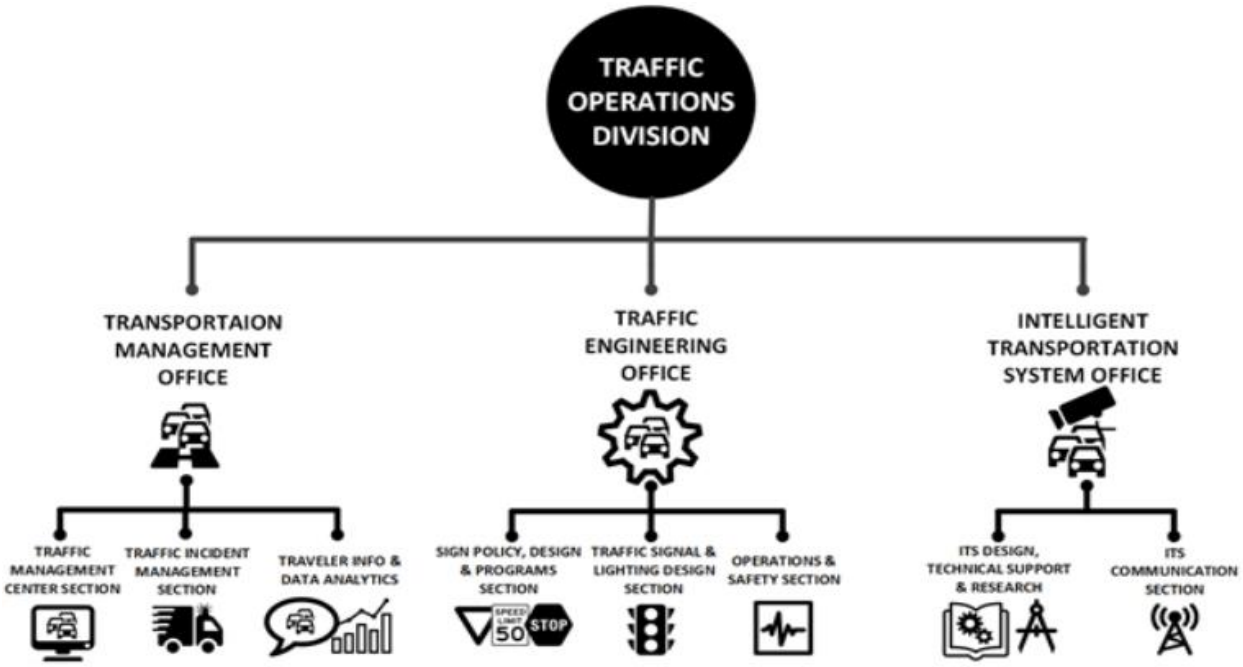


Figure 27. Traffic Operations Division Headquarters Organizational Chart [*41*]

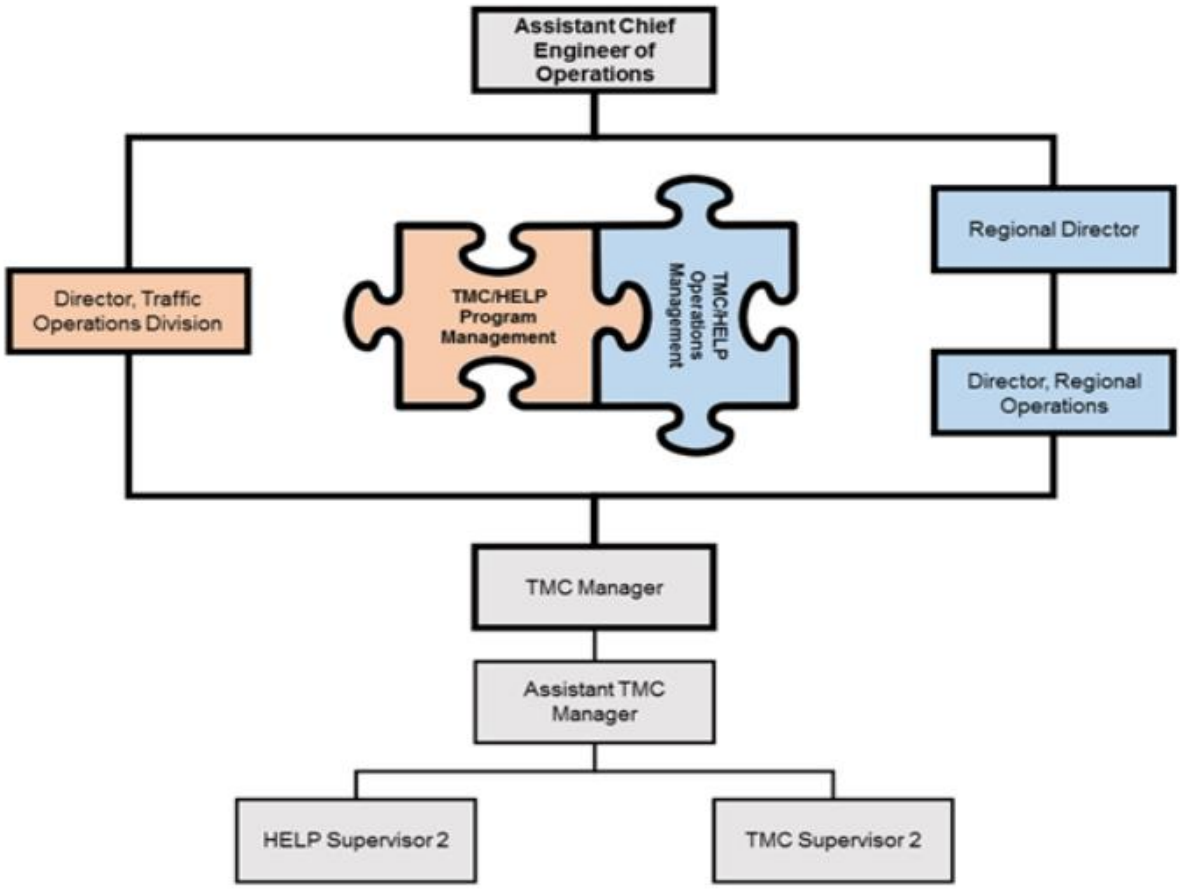


Figure 28. Headquarters and Region Working Relationship in Tennessee [*41*]

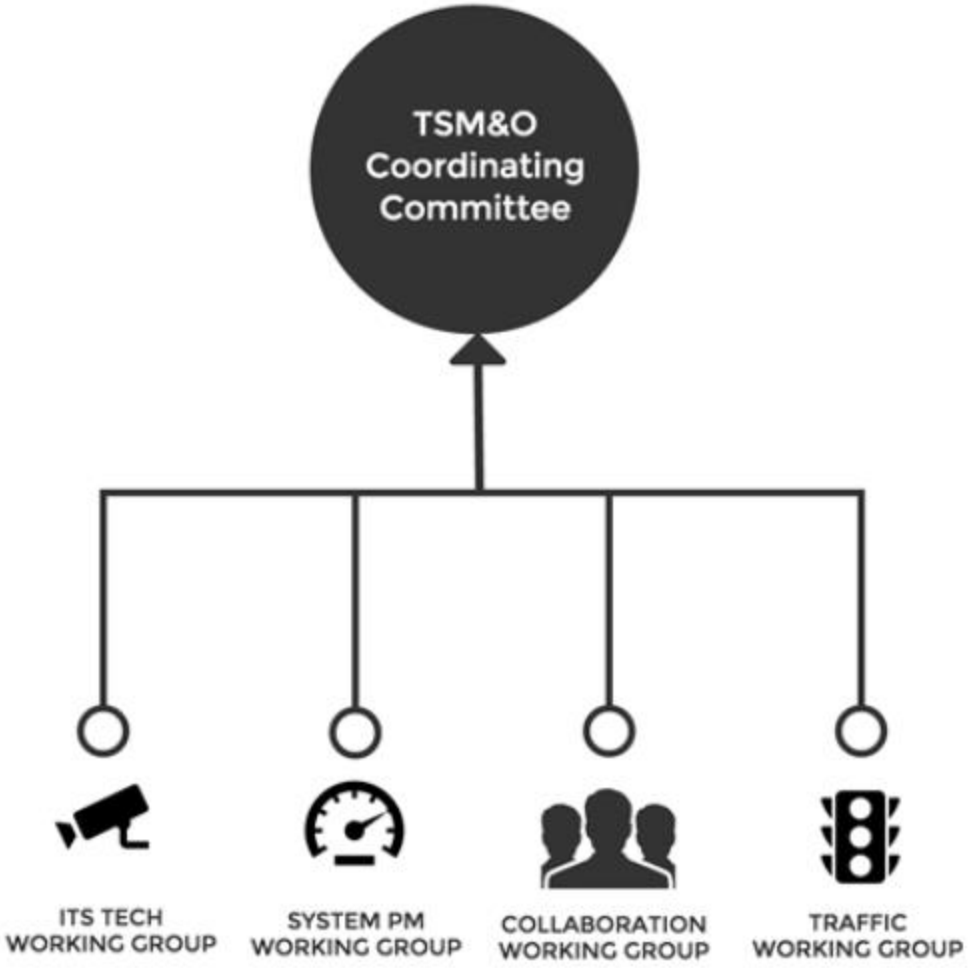


Figure 29. TSMO Coordinating Committee Working Group in Tennessee [*41*]

Texas

The Texas Department of Transportation (TxDOT) has recently developed a TSMO *Statewide Strategic Plan*, published in 2017 [*42*]. Due to the size of the Texas transportation network and TxDOT's structure, the plan was developed with a three-pronged approach, including (1) the statewide strategic plan, (2) district-level program plans and (3) district-level service layer plans (**Figure 30**) [*42*]. The statewide plan provides overall guidance for TSMO in Texas and districts will use this framework to develop program plans for their jurisdiction [*42*]. Additionally, each district will develop service player plans depending on their specific needs [*42*]. The statewide plan also provides overall goals and objectives towards the implementation of TSMO in Texas (**Figure 31**). It is important to note that TxDOT does not have formal TSMO structure, instead TSMO concepts (including statewide guidance, standards and policy) are carried out by the recently renamed Traffic Safety Division.

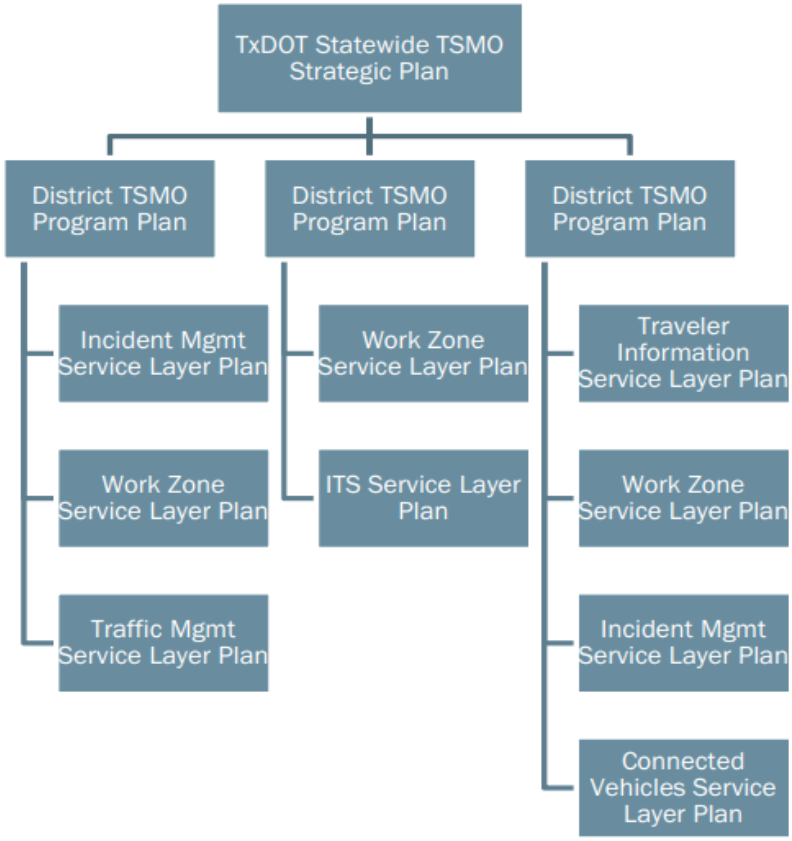


Figure 30. TxDOT TSMO Program Components [*42*]

Goal	Objective
Safety	Reduce crashes and fatalities through continuous improvement of traffic management systems and procedures.
Reliability	Maintain consistent travel times on transportation systems in critical corridors to ensure travelers are reaching their destinations in the amount of time they expected for the journey.
Efficiency	Implement projects that optimize existing transportation system capacity and alleviate congestion.
Customer Service	Provide timely and accurate travel information to customers so they can make informed mobility decisions.
Collaboration	Proactively manage and operate an integrated transportation system through multi-jurisdictional coordination, and cooperation between various transportation disciplines and partner agencies.
Integration	Prioritize TSMO as a core objective in the agency's planning, design, construction, operations, and maintenance activities.

Figure 31. TxDOT TSMO Goals and Objectives [*42*]

Vermont

The State of Vermont Agency of Transportation (VTrans) incorporates five units which work together to execute and implement TSMO strategies (**Figure 32**) [*43*]. The Traffic Operations, Traffic Research, ITS, Traffic Mobility and Traffic Signals units all report to a single TSMO section to ensure TSMO concepts and strategies are integrated into the daily work and culture of the agency [*43*].

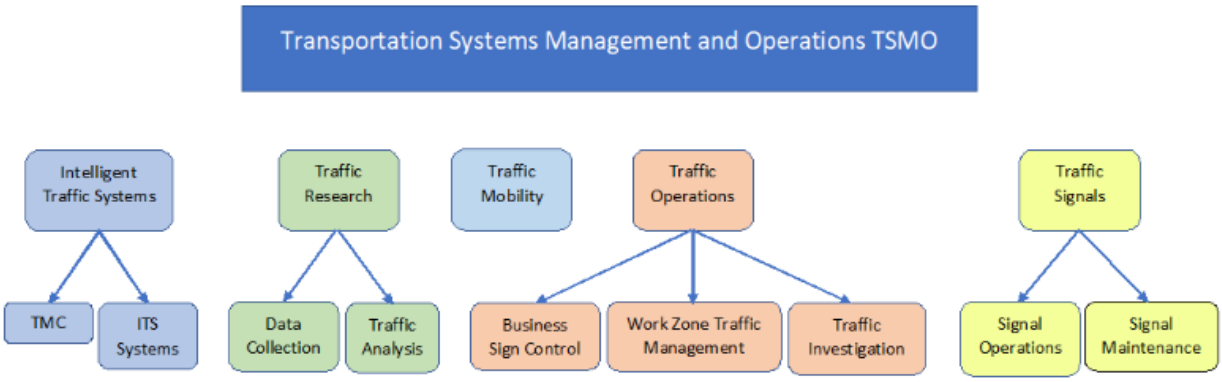


Figure 32. TSMO at VTrans [*43*]

ITS Heartland TSMO University Educational Program

An additional initiative which is important to note is the ITS Heartland TSMO University Educational Program which recently won an award from NOCoE for improving an agency's TSMO capabilities [*44*]. The program was intended to increase the capacity for TSMO in Iowa, Kansas, Missouri, Nebraska and Oklahoma (in addition to other national participants) [*44*]. A series of webinars, live training and train-the trainer sessions (**Figure 33**) were conducted in order to disseminate the latest technologies and trends [*44*].

Figure 33. ITS Heartland TSMO University Train-the-Trainer Session [*44*]

2.4 Interviews with State DOT TMSO Staff

The research team contacted and conducted interviews with 10 of the 24 states which have implemented TSMO within agency activities (**Figure 34**). A copy of the interview questionnaire distributed to each DOT interviewed as a part of this process is included in **Appendix A**. The central theme of the interview questionnaire, consistent with the intent of this assessment, is how TSMO has impacted traffic safety within the DOT. While the full responses to the interview questionnaire for each DOT can be found in **Appendix B**, a summary of the key findings from each interview is provided in **Table 6**.

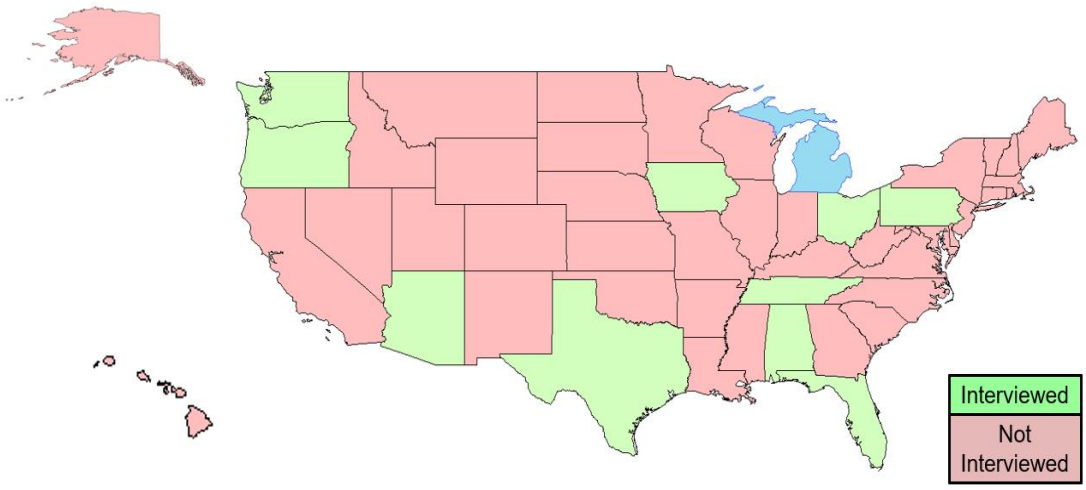


Figure 34. Map of State DOTs Interviewed by Research Team

Table 6. Key Findings from Interviews with State DOT TSMO Personnel

State DOT	Key Findings
Alabama	• Congestion management, traffic incident management and smart work zones were functions included in TSMO structure • Challenges to TSMO implementation included buy-in with staff, such as applying TSMO strategies to reduce congestion as opposed to adding lanes • TSMO was implemented one region at a time and transportation management centers (TMCs) went into 24-7 operation • Suggestions included effective collaboration with key stakeholders (such as MPOs), educating upper management on the benefits of TSMO and focus training/recruiting effective TSMO staff • Cultural shift within organization and understanding of benefits of effective congestion management has made it easier to receive funding

State DOT	Key Findings

Arizona	• Agency restructured with seven groups underneath one TSMO division:
	  ○ Systems Technology (emerging tech, system performance, ITS ops)
	  ○ System Maintenance (Signal ops, ITS maintenance, lighting)
	  ○ Operations and Traffic and Safety (regional traffic engineers, RSA, SHSP, HSIP, data)
	  ○ Traffic Maintenance (statewide signing and striping)
	  ○ Traffic Management (TOCs, TIM, emergency management)
	  ○ Systems Management
	  ○ Business Administration
	• The TSMO division includes $32M in annual funding and was developed from the prior intermodal transportation division which was disassembled
	• TSMO divisional structure allows for TSMO director to advocate for projects and funding with DOT director which fit TSMO theme
	• SafetyAnalyst is used to evaluate safety performance on all TSMO projects
	• Buy-in from director and state engineer made transition easier
	• Two positions were added, including TSMO director

Florida	• Both central office traffic engineering and traffic operations at the district level fall under TSMO
	• Separate state safety office which does not fall under traffic engineering
	• Arterial management was moved to the ITS division, which now includes management of both freeways and arterials
	  ○ Arterial management has improved with additional input from DOT as opposed to just local agency management
	  ○ Additional funding for arterial management/signal improvements
	• ITS, operations and signals are all included in TSMO
	• Buy-in from the chief engineer and secretary made transition easier
	• Recommend monthly meetings with districts to review program progress

State DOT	Key Findings
Iowa	• State did not implement structural changes, instead TSMO group was created as a part of the traffic operations office • A TSMO office director position was created and one of six district offices created a TSMO coordinator position ○ The other districts are looking into adding a TSMO officer • TSMO functions include the statewide TMCs, service patrol, incident management, emergency management, smart work zones, and ITS • Traffic safety funding is not currently included as a part of TSMO, but is being discussed for the future • Changing culture related to TSMO has been a challenge, getting out of the it's an "operations program" mindset, specifically among mid-level staff • Implementing TSMO operational strategies early in the project development process has also been a challenge • Work force development an additional challenge, ensuring that operations division staff has the skillset to implement TSMO • Statewide TSMO steering committee has helped to ensure broad understanding and coordinate training • Buy-in from high-level executives has made transition easier • Recommend not changing structure until agency has a plan and has ironed out issues related to implementation • TSMO has helped focus and reinvigorate staff

Ohio	• Don't have a stand-alone TSMO division, operations division functions as TSMO division but without being renamed
	  ○ Includes traffic management, traffic operations, aviation and permits
	• TMCs are centralized at ODOT – statewide TMC as well as a TSMO coordinator for each of the 12 districts
	• Implementing new funding arm for congestion and bottlenecks which would function similar to the HSIP model
	  ○ Have discussed combing this with HSIP funding
	• ODOT has passed along CMAQ to MPOs, but also have discussed including under TSMO
	• TSMO implementation has resulted in culture shift within the department with an increased focus on integrating safety and communications between various divisions
	• Lack of funding and staff buy-in has been primary challenges
	• Buy-in from executive management and chief engineer made implementation process easier
	• Buy-in with new technologies vs. old technologies has been a struggle

State DOT	Key Findings

Oregon	• TMSO is represented in Operations and ITS division, which includes:
	  ○ Systems ITS, travel information, incident management, dispatch operations and collaborates with signals and ramp metering
	  ○ New positions were added, such as a traffic incident management coordinator
	• Traffic safety is currently not included in Operations and ITS division
	  ○ However, TSMO has improved awareness of safety-related programs
	• Support from upper management has made transition easier
	• Cultural mindset remains the primary obstacle to implementation

Pennsylvania	• Traffic operations, emerging technology, arterial management, temporary traffic control, incident and emergency management all included in TSMO • Combined funding from grant and planning division ($10M total) allowed for implementation of fiber/conduit throughout the state to reduce congestion, made possible by TSMO collaboration • TSMO has resulted in change where safety benefits are considered • Marketing has made TSMO implementation easier • Including MPOs/RPCs in the process helps to get planning stakeholders involved in the process • Currently preparing a TSMO guidebook series

Tennessee	• Traffic operations division represents TSMO efforts in the agency, including transportation management office, ITS office and traffic engineering office
	  ○ Traffic operations is headquarters level division, each region has an operations director who oversees incident management and TMCs
	  ○ Central office more involved with policy and guideline development
	  ○ CMAQ is included under operations division
	• HSIP activities fall outside of the traffic operations division
	  ○ However, HSIP funds have been used to support operational endeavors such as a traffic incident management training center
	  ○ Wrong-way treatment pilot projects have been implemented
	• Change to regional TMCs reporting to central operations division has been a challenge as regions previously had autonomy
	• Buy-in from chief engineer provided support for implementation
	• TSMO has resulted in increased collaboration with stakeholders, institutionalized operations-related performance measures, and expansion of service patrol
	• Uncertainty from staff related to new technology has made it difficult to break out of "build it first" mentality

State DOT	Key Findings

Texas	• TxDOT does not have formal TSMO structure, instead TSMO concepts (including statewide guidance, standards and policy) are carried out by the recently renamed Traffic Safety Division
	• Decentralized agency with 25 districts which have independent budgets and organizational structures
	• Much of the funding related to TSMO is obtained from maintenance funds
	• CMAQ is also considered a funding source for ITS/TSMO
	  o No direct funding source for ITS
	• While TMSO has not specifically increased focus on safety, department has had recent awareness of safety with recent renaming of Traffic Operations Division to Traffic Safety Division
	• Department has implemented "System Safety" approach of including safety treatments as a part of transportation improvements instead of funding such improvements through the HSIP
	• While the department and staff have long applied concepts and strategies which were similar to TSMO in nature, it has been a challenge to continue to change the culture to implement more of a strategic approach to TMSO
	• Buy-in from administration to support TSMO as an elevated priority has made implementation process easier
	• Recommend to begin the implementation process with executive-level buy-in, perform outreach and training with personnel most integral to TSMO, and develop broad strategy with regard to TSMO
	  o Further expand outreach and training to other units and refine the strategy as needed
	• Current challenge is to gain additional buy-in from other units
	• Each district is also developing TSMO program plans

State DOT	Key Findings
Washington	• Agency does not currently have a TSMO division and no realignment was performed as a part of TSMO implementation • TSMO is defined within functional areas and includes multimodal planning, connected vehicles, ITS, traffic engineering and travel demand management • While signing and marking funding is included in TSMO activities, HSIP-related activities are not included in TSMO • Safety performance has been positively impacted indirectly through TSMO projects, including ramp closures, ramp metering, and work zone policy which includes ITS technology • The broad and ambiguous definition of TSMO has represented a challenge to implementation, especially relating to obtaining buy-in from staff • A TSMO manager position has been created and certain regions have also created TSMO-specific positions • Recommend that TSMO should not be considered as competing interests but instead viewed as streamlining and integrating funding ○ Local agency buy-in is also considerably important for TSMO • After TSMO implementation, roadway widening is no longer the first solution to congestion concerns • Buy-in from middle management has remained an issue for TSMO implementation, as well as funding levels

2.5 Summary of TSMO Functions, Structures, Benefits and Limitations

Given the review of national and state TSMO resources, a summary of the potential aspects of a TSMO program was developed. The following subsection aggregates the potential TSMO functions, divisional structures, benefits and limitations identified during the review of existing TSMO literature and interviews conducted with state personnel. For each aspect, a brief summary of the potential function, divisional structure, benefit or limitation is provided as well as the source(s) where each was identified.

2.5.1 TSMO Functions

Potential TSMO functions which have been identified from national and state resources are identified in **Table 7.**

Table 7. Summary of Potential TSMO Functions

Potential TSMO Function	Source(s)
Implementing geometric improvements – such as road diets, exclusive turn lanes or changes in curvature/superelevation	ITE [*1*], FHWA [*7*]
Improvements or modifications to signing, pavement markings or other traffic control	ITE [*1*], Arizona [*20*]
Travel demand management or other similar strategies such as HOV lanes, toll lanes, ramp metering, reversible lanes, variable speed limits, bus shoulders, hard shoulder running, variable message signs, congestion pricing or dynamic lane assignment	ITE [*1, 9*], AASHTO [*6*], FHWA [*2, 7, 11, 12, 13, 14, 16, 17*], Alabama [*Appendix B*], Arizona [*19*], Colorado [*23*], Florida [*26*], Iowa [*31*], Maryland [*32*], Minnesota [*33*], South Dakota [*40*], Tennessee [*41*]
Minimizing conflicts between modes of transportation	ITE [*1*], South Dakota [*40*]
Setting appropriate speed limits	ITE [*1*]
Construction of pull out areas for enforcement activities	ITE [*1*]

Potential TSMO Function	Source(s)
Implementation of data-driven safety analysis (DDSA) and appropriate safety project prioritization	ITE [*1*], FHWA [*7, 14*]
Work zone management techniques and initiatives	FHWA [*2, 7, 11, 12, 13, 14, 16, 17*], AASHTO [*6*], ITE [*9*], Arizona [*19*], Florida [*26*], Iowa [*31*], Maryland [*32*], Minnesota [*33*], Missouri [*34*], South Dakota [*40*]
Traffic incident management techniques and initiatives	FHWA [*2, 7, 8, 11, 12, 13, 14, 17*], AASHTO [*6*], ITE [*9*], Arizona [*19*], Colorado [*23*], Florida [*26*], Iowa [*31*], Maryland [*32*], Minnesota [*33*], Missouri [*34*], Oregon [*37*], South Dakota [*40*]
Road weather management techniques and initiatives	FHWA [*2, 11, 12, 13, 14, 16, 17*], AASHTO [*6*], ITE [*9*], Arizona [*19*], Florida [*26*], Maryland [*32*], Minnesota [*33*], North Carolina [*35*]
Transit management techniques and initiatives	FHWA [*2, 7, 11, 12, 13, 14, 16*], Florida [*26*]
Freight management techniques and initiatives	FHWA [*2, 7, 12, 13, 14, 16*], Arizona [*19*], Florida [*26*], Maryland [*32*], South Dakota [*40*]
Traffic signal coordination or other signal-related treatments	FHWA [*2,7, 11, 12, 13, 14, 16, 17*], AASHTO [*6*], ITE [*9*], Arizona [*19*], Colorado [*23*], Maryland [*32*], Minnesota [*33*], Tennessee [*41*]
Traveler information techniques and initiatives	FHWA [*2, 7, 12, 13, 14, 16, 17*], AASHTO [*6*], ITE [*9*], Florida [*26*], Iowa [*31*], Maryland [*32*], Minnesota [*33*], South Dakota [*40*]

Potential TSMO Function	Source(s)
Integrated corridor management	FHWA [*2, 7, 12, 13*], AASHTO [*6*], Maryland [*32*], South Dakota [*40*], Tennessee [*41*]
Access management techniques and initiatives	FHWA [*2, 7, 11*]
Improved bicycle/pedestrian crossings and other treatments; complete streets initiatives	FHWA [*2, 7, 11, 12, 13, 14*], ITE [*9*]
Connected and automated vehicle deployment, initiatives and policy-making	FHWA [*2, 11*], Arizona [*19*], Colorado [*23*], Iowa [*31*], Tennessee [*41*]
TMCs with surveillance and detection	AASHTO [*6*], FHWA [*7, 11, 12, 13, 16*], Alabama [*Appendix B*], Arizona [*19*], Colorado [*23*], Iowa [*31*], Missouri [*34*], South Dakota [*40*]
Electronic border crossing systems	AASHTO [*6*]
Bus rapid transit or transit signal priority; queue jumps for buses	AASHTO [*6*], FHWA [*11, 12, 13, 14*]
Park and ride lots; parking management systems	AASHTO [*6*], FHWA [*7, 12, 13, 14*], South Dakota [*40*], Tennessee [*41*]
Bike sharing programs	FHWA [*7, 14*]
Implementation of roundabouts	FHWA [*7, 14*]
Low-cost safety treatments (such as centerline rumble strips or traffic signal backplates)	FHWA [*7*]
Encouraging carpooling, telecommuting or flexible work schedules	FHWA [*7, 12, 13, 14*]
Special event traffic management	FHWA [*7, 12, 13, 14*], Arizona [*19*], Florida [*26*]
Road safety audits	FHWA [*7*]
Staff training in state-of-the-art TSMO strategies, technologies or methods	FHWA [*8, 12, 13*]

Potential TSMO Function	Source(s)
Ensuring funding sources for potential projects or programs; breaking down silos for funding	FHWA [*8*]
Arterial or freeway management	FHWA [*8, 11, 12, 13, 14, 16*], Colorado [*23*], Florida [*26*], South Dakota [*40*]
Warning systems (including queue, curve, intersection, or speed warnings)	FHWA [*11*]
Maintenance and construction activity coordination	FHWA [*11*]
Computer-aided dispatch integration	FHWA [*11*]
Emergency vehicle routing	FHWA [*11*]
Electronic fare collection	FHWA [*11*], Maryland [*32*]
Transit surveillance and security	FHWA [*11*]
High performance transit	FHWA [*11*]
Comprehensive subarea plans	FHWA [*12*]
Comprehensive corridor plans	FHWA [*13*]
Emergency vehicle preemption	FHWA [*13*]
Speed harmonization	FHWA [*13, 16*]
Traffic calming techniques	FHWA [*14*]
Truck over-height or tip-over warning systems	FHWA [*16*]
Statewide permitting activities	Arizona [*19*]
Regional operations forums	California [*22*]
TSMO evaluations	Colorado [*25*]
Corridor operations and bottleneck reduction assistance (COBRA) program	Colorado [*23*]
Safety Service Patrol	Minnesota [*33*]
Automated enforcement	South Dakota [*40*]
Commercial vehicle operation coordination	South Dakota [*40*]
Fog zone detection/warning systems; wrong-way detection systems	Tennessee [*41*]

2.5.2 TSMO Divisional Structures, Funding Mechanisms or Units

Potential TSMO divisional structures, funding mechanisms or units which have been identified from national and state resources are identified in **Table 8.**

Table 8. Summary of Potential TSMO Divisional Structures or Funding Mechanisms

Potential Structure or Funding Mechanism	Source(s)
A funding set-aside developed for specific TSMO projects; some agencies have set aside a portion of available funding which can be spent only on TSMO projects. This approach may include funding for specific programs (such as traffic signal operations) or individual projects (such as a transit signal priority installation). These programs or projects are prioritized on the basis of pre-established selection criteria. Additionally, it should be noted that some agencies have distinct service layer or strategic plans (such as a regional concept for transportation operations or an ITS strategic plan).	FHWA [*12*]
An open competition for both TSMO and non-TSMO projects; some agencies have TSMO-specific projects compete with non-TSMO projects which are evaluated using criteria that address a broad range of transportation needs. In this scenario, the long-range transportation plan (LRTP) should inform the selection of projects that are included in the transportation improvement program. Therefore, selected projects should be prioritized using a performance-based approach which aligns with the agency's LRTP.	FHWA [*12*]
A hybrid of set-aside and open competition funding for TSMO	FHWA [*12*]
Some agencies have restructured around a new TSMO division with the relevant business units (such as operations, ITS, signals, etc.) which report to the TSMO division or director; this has also included distinct funding for the TSMO division	Arizona [*19*], Colorado [*24*], Vermont [*43*]

Potential Structure or Funding Mechanism	Source(s)
Central office traffic engineering and district-level traffic operations units have been placed underneath a new TSMO group which carries out TSMO-related strategies	Florida [*26*]
A new, separate TSMO group was created as a part of the traffic operations office; TSMO coordinators were also added at the district-level	Iowa [*Appendix B*]
A new TSMO program manager position is created to facilitate TSMO within existing offices in addition to a TSMO executive committee which oversees the overall TSMO program	Maryland [*32*]
The creation of a senior management team to serve as TSMO program champions and provide overall program oversight; a TSMO core team comprised of both central office and district-level members which support TSMO activities; several working groups specific to TSMO (including work zones, signals and TMCs)	Missouri [*34*]
Operations division becomes the de facto TSMO division and carries out TSMO strategies; each district has a specific TSMO coordinator	Ohio [*Appendix B*]
The development of a new funding arm for congestion and bottlenecks which functions similar to HSIP for safety improvements	Ohio [*Appendix B*]
TSMO activities and functions identified in the program plan are integrated into several key business areas (inclement weather, ITS and signals, work zones, traffic incidents, special events, bottlenecks, TMCs, traveler information, connected/autonomous vehicles) instead of developing a new organizational structure	Pennsylvania [*39*]

Potential Structure or Funding Mechanism	Source(s)
The traffic operations division represents TSMO efforts in the agency, including the transportation management office, the ITS office and the traffic engineering office. As a part of its TSMO efforts, the agency also maintains a TSMO Coordinating Committee consisting of four working groups which include both headquarters and regional staff. The committee is comprised of an ITS working group, a systems performance measures working group, a collaboration working group and a traffic working group.	Tennessee [*41*]
The traffic operations division is responsible for statewide guidance, standards and policy related to TSMO; each district develops TSMO plan and service layer plans specific to their jurisdiction	Texas [*Appendix B*]
TSMO activities are carried out by each unit without a structural change; a TSMO director hired to support the program and districts hired TSMO coordinators	Washington [*Appendix B*]

2.5.3 Benefits of TSMO

Potential TSMO benefits which have been identified from national and state resources are identified in **Table 9.**

Table 9. Summary of Potential TSMO Benefits

Potential TSMO Benefits	Source(s)
Improved quality of life for road users	FHWA [*2*, *12*, *13*]
Reduced congestion (both recurring and non-recurring) and improved travel time reliability	FHWA [*2*, *7*, *11*, *12*, *13*, *17*], Minnesota [*33*], Missouri [*34*], South Dakota [*40*]
Improved safety performance	FHWA [*2*, *7*, *11*, *12*,*13*, *14*, *17*], Minnesota [*33*], Missouri [*34*], South Dakota [*40*]
Coordination of systems, services and partnerships	FHWA [*17*], Oregon [*37*]
Improved fuel economy; lower vehicle operating costs; reduced vehicle emissions	FHWA [*2*, *11*, *12*, *13*, *14*, *17*]

Potential TSMO Benefits	Source(s)
Increased economic vitality, competitiveness and development	FHWA [*2*, *14*]
More efficient use of facilities, funding and other resources	FHWA [*2*, *17*], Arizona [*19*], Minnesota [*33*], Missouri [*34*], South Dakota [*40*]
Environmental sustainability	FHWA [*7*, *11*, *12*, *13*, *14*]
Reduced delay in project delivery	FHWA [*7*, *17*], Minnesota [*33*]
Pooling funds to avoid duplicate investments or purchases	FHWA [*12*]
Participating in joint training opportunities	FHWA [*12*]
Utilizing special expertise or experience that may reside in a few agencies but not all	FHWA [*12*]
Adopting common standards for technology that can simplify interagency and multijurisdictional interactions	FHWA [*12*]
Acquiring/maintaining more current and effective hardware and software	FHWA [*12*, *17*]
Sharing information between system operators and owners for greater awareness of current and anticipated events	FHWA [*12*], North Carolina [35]
Developing standard protocols and procedures among agencies	FHWA [*12*]
Promote transit ridership and mode shifts	FHWA [*13*]
Protect local arterials from unnecessary diversion	FHWA [*13*]
Reduce sprawl and support land preservation	FHWA [*14*]
Support travel choices and mobility	FHWA [*14*], Minnesota [*33*]
Increase public awareness of suitable travel options	FHWA [*14*], Minnesota [*33*], South Dakota [*40*]
Greater social equity by increasing travel options for disadvantaged populations	FHWA [*14*]
Improved response time and strategy effectiveness	FHWA [*17*]
Improved public accountability	FHWA [*17*]

Potential TSMO Benefits	Source(s)
Reduction in Full Time Equivalents (FTEs)	Arizona [*19*]
Better alignment with present and future operations	Arizona [*19*]
Synergies through improved coordination	Arizona [*19*]
Maximize effectiveness of tools and data	Arizona [*19*]
TSMO Director able to lobby for projects	Arizona [*Appendix B]*
Enhancing freight reliability	Minnesota [*33*]
Monitoring system performance	Minnesota [*33*]

2.5.4 Limitations of TSMO

Potential limitations of implementing TMSO which have been identified from national and state resources are identified in **Table 10.**

Table 10. Summary of Potential TSMO Limitations

Potential TSMO Limitations	Source(s)
Limited research related to specific TSMO strategies	ITE [I]
Conventional wisdom has set low expectations for TSMO due to modest implementation to date	AASHTO [*6*]
Reliability issues not well articulated in policy	AASHTO [*6*]
Policy and cultural differences between transportation and public safety communities	AASHTO [*6*]
Lack of active external stakeholder community with a business/policy understanding of TSMO	AASHTO [*6*]
Overcoming agency-specific cultures and differing priorities	AASHTO [*6*]
Limited leadership for policy change at state level	AASHTO [*6*]
TSMO often not well understood throughout agency culture	AASHTO [*6*]
Well defined and documented processes and recognized performance measures are lacking	AASHTO [*6*]
Consolidated organizational structure and accountability to top management may not be established	AASHTO [*6*]
TSMO frequently lacks sustainable, predictable resources	AASHTO [*6*], Ohio [*Appendix B*], Washington [*Appendix B*]

Potential TSMO Limitations	Source(s)
Essential collaborative relationships are usually informal and often unaligned	AASHTO [*6*]
Idea that TSMO is just another name for ITS	FHWA [*7*]
Idea that TSMO is not ribbon cutting material or is a back-of-the-house concept	FHWA [*7*]
Idea that TSMO benefits are less than capacity building projects	FHWA [*7*]
Limited public and elected-leadership support	TRB [*15*]
Already existing capacity construction program	TRB [*15*]
Limited middle management support	TRB [*15*], Washington [*Appendix B*]
Fuzzy legislative authority	TRB [*15*]
Absence of TSMO manager	TRB [*15*]
Shortfall or turnover in qualified staff/staff level constraints	TRB [*15*], FHWA [*17*], Iowa [*Appendix B*]
State funding ineligible for TSMO	TRB [*15*]
Competition for resources with other programs	TRB [*15*]
No performance outcome measures	TRB [*15*], FHWA [*17*]
Conflicting partner priorities	TRB [*15*]
ITS unit uncoordinated with TMCs	FHWA [*17*]
Buy-in with staff, applying TSMO strategies over adding lanes	Alabama [*Appendix B*], Ohio [*Appendix B*], Tennessee [*Appendix B*]
Idea that TSMO is just operations program	Iowa [*Appendix B*]
Lack of support from mid-level of organization	Iowa [*Appendix B*]
Getting support for new technologies vs. old familiar technologies	Ohio [*Appendix B*], Tennessee [*Appendix B*]
Breaking through regional vs. central office dynamic	Tennessee [*Appendix B*]
Changing culture to see TSMO as a core agency priority	Texas [*Appendix B*]
Obtaining collaboration, cooperation and buy-in from other units and formal processes to support and enable TSMO	Texas [*Appendix B*]
TSMO is nebulous or ambiguous, non-traditional items like permits or land-use planning have been difficult to change existing mentality	Washington [*Appendix B*]

3.0 RELATIONSHIP BETWEEN STATE FUNDING LEVELS AND SAFETY PERFORMANCE

The relationship between a state's safety funding levels and relative safety performance may provide important insight into how TSMO implementation at MDOT, specifically changes to safety-related funding templates, may impact fatalities and serious injuries resulting from traffic crashes. Consistent with the goal in the SHSP to reduce fatalities and serious injuries on Michigan's roadways [*45*], an important component of this assessment was to explore this relationship as MDOT continues to implement TSMO agency-wide.

Data specific to each state (and Washington, D.C.) were collected from two primary resources in order to perform the analysis. Annual safety funding, vehicle miles traveled (VMT) and safety performance data were collected from FHWA's *Highway Safety Improvement Program Reporting* webpage by examining each state's last five annual HSIP reports (2014 to 2018) [*46*]. State population data were also collected from the United States Census Bureau [*47*]. **Table 11** provides further detail of the data used in this assessment.

Table 11. Description of Data used in the Assessment

Data		Description
Exposure Data	Annual Average VMT	An annual average of VMT was derived from each state's HSIP annual reports from 2009 to 2017
	State Population Estimates	An annual average of state population was determined using data from the United States Census Bureau from 2010 to 2018
Safety Data	(1) Annual Fatalities	Consistent with FHWA's state safety targets [*48*], each of the five safety performance metrics were evaluated via five-year rolling averages using data collected from each state's annual HSIP reports from 2009 to 2017; the percent reduction from the first five-year period (2009 to 2013) was compared to the most recent five-year period (2013 to 2017) to assess the relative change in recent safety performance
	(2) Annual Serious Injuries	
	(3) Fatality Rate per 100M VMT	
	(4) Serious Injury Rate per 100M VMT	
	(5) Annual Non-Motorized Fatal and Serious Injuries	

Data		Description
Funding Data	Annual Safety Funding	An average of total annual obligated safety funding was calculated from each state's annual HSIP report from 2014 to 2018, an annual average was used to smooth out variances in annual funding
	Annual Safety Funding per VMT	An estimate of annual safety funding per billion VMT was calculated to provide an estimate of funding relative to exposure
	Annual Safety Funding per Fatality	An estimate of annual safety funding per annual average fatalities (from 2009 to 2017) was calculated to provide an estimate of funding relative to exposure
	Annual Safety Funding per Capita	An estimate of annual safety funding per capita was calculated to provide an estimate of funding relative to exposure

It should be noted that in select cases, safety performance or funding data for certain years was unavailable in the annual HSIP reports. In these instances, the data was excluded from the averaging process. While notable or top performing states are identified in the following subsections for each of the funding and safety data measures, full results for each state can be found in **Appendix C**. Additionally, a comparison of where Michigan currently stands relative to the notable states as well as Midwest peer states (including Illinois, Indiana, Minnesota, Ohio, Pennsylvania and Wisconsin) is also included to provide context as to the current level of funding and safety performance.

3.1 Safety Funding

The annual average obligated safety funding across all states (and Washington, D.C.) ranged from $10,900,406 (Maine) to $415,068,169 (California). However; the majority (88 percent) of states obligated less than $100M in annual safety funding during the study period (**Figure 35**). Michigan obligated an annual average of $54,126,469 over the last five years, just less than the mean of $61,372,061 but considerably greater than the median of $38,135,558.

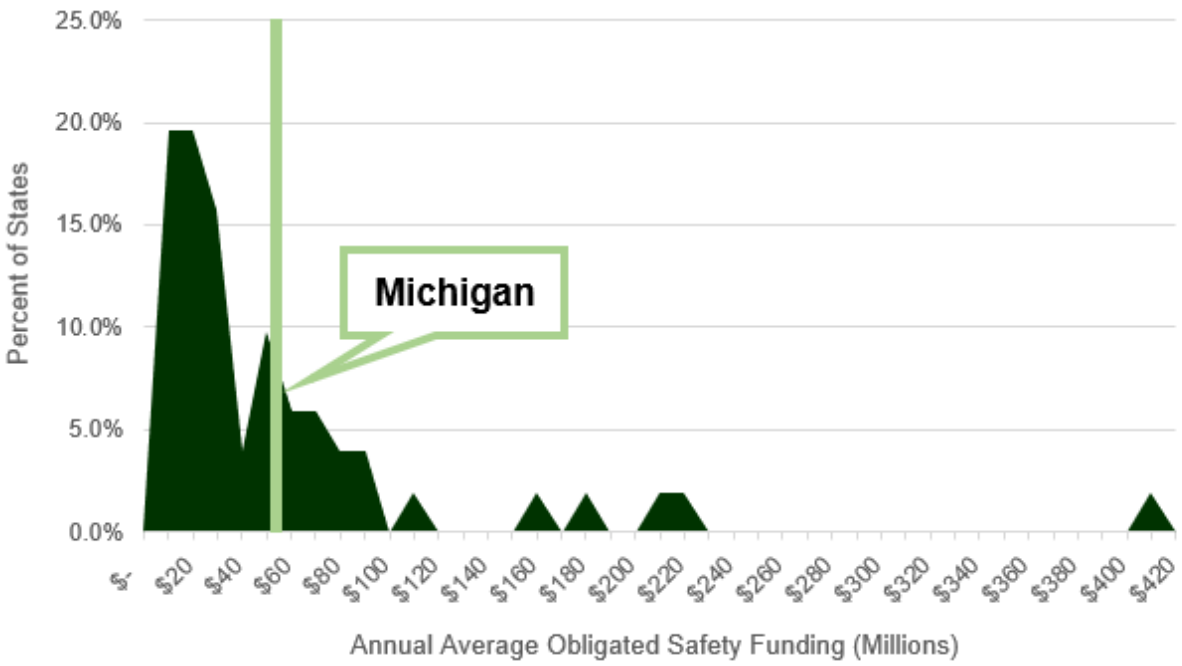


Figure 35. Distribution of Annual Average Safety Funding in Millions (2014-2018)

Intuitively, annual average safety funds were heavily correlated with the annual average of VMT from each state (**Figure 36**).

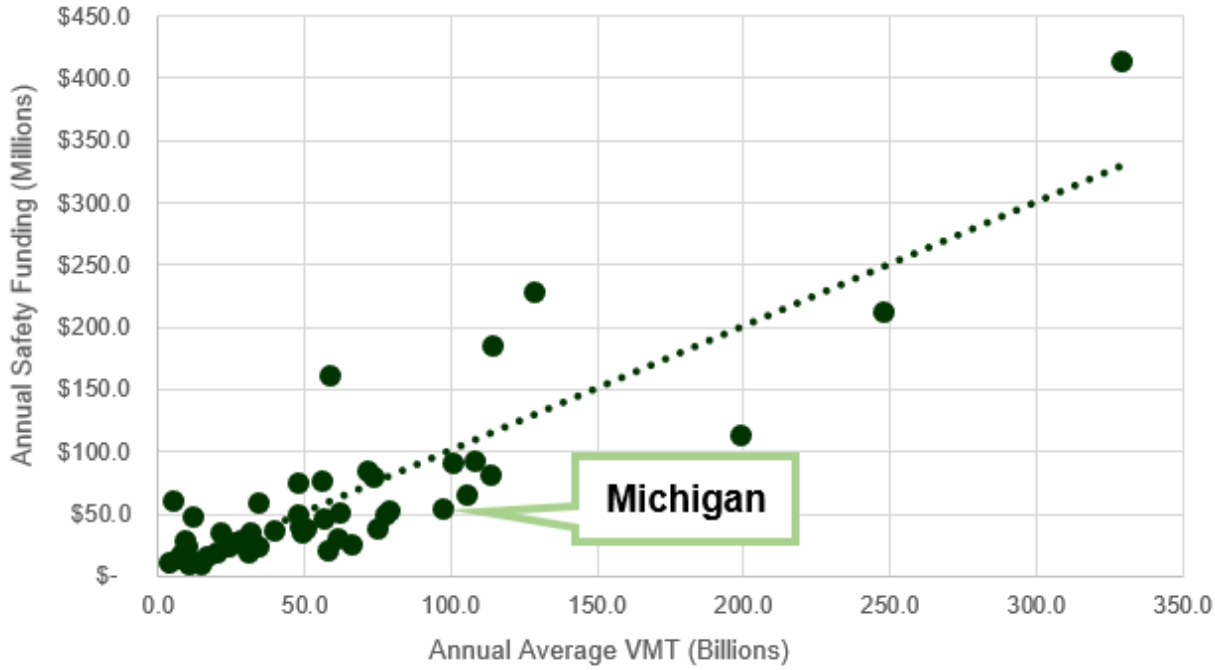


Figure 36. Annual Average Safety Funding (Millions) vs. State VMT (Billions)

Similarly, the top ten states in annual safety funding in general represent the most populous and well-traveled states, with the exceptions of Washington and Missouri which have invested more relative to these normalizing factors (**Table 12**). It is also worth noting that despite the fact Michigan ranks 10th in both population and VMT, the state ranks 17th in annual safety funding. As a result, Michigan is currently ranked 46th in funding per capita and 47th in funding per VMT.

Table 12. Top States in Annual Safety Funding (2014-2018)

State	Safety Funding (Millions)		VMT (Billions)		Population (Millions)		Funding per Billion VMT		Funding per Capita	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
California	$415.1	1	329.1	1	38.55	1	$1,261,278	17	$10.8	22
New York	$229.2	2	128.0	4	19.58	4	$1,791,005	9	$11.7	20
Texas	$213.2	3	247.8	2	26.99	2	$860,597	32	$7.9	35
Ohio	$185.2	4	114.2	5	11.60	7	$1,620,853	12	$16.0	13
Washington	$161.5	5	58.3	19	7.10	13	$2,771,475	5	$22.7	6
Florida	$113.6	6	198.7	3	19.98	3	$571,696	46	$5.7	45
North Carolina	$92.8	7	108.1	7	9.96	9	$858,320	33	$9.3	28
Pennsylvania	$91.6	8	100.7	9	12.77	6	$909,540	30	$7.2	40
Missouri	$84.5	9	71.0	15	6.06	18	$1,189,234	18	$13.9	15
Georgia	$81.8	10	113.3	6	10.10	8	$721,523	40	$8.1	33
Michigan	**$54.1**	**17**	**97.2**	**10**	**9.93**	**10**	**$556,998**	**47**	**$5.5**	**46**

Annual safety funding per billion VMT ranged from $372,531 (Minnesota) to $12,319,992 (Alaska). However; the majority of states (67 percent) obligated less than $1M annually per billion VMT (**Figure 37 – Excludes Alaska**). Michigan was ranked 47th with $556,998 per billion VMT.

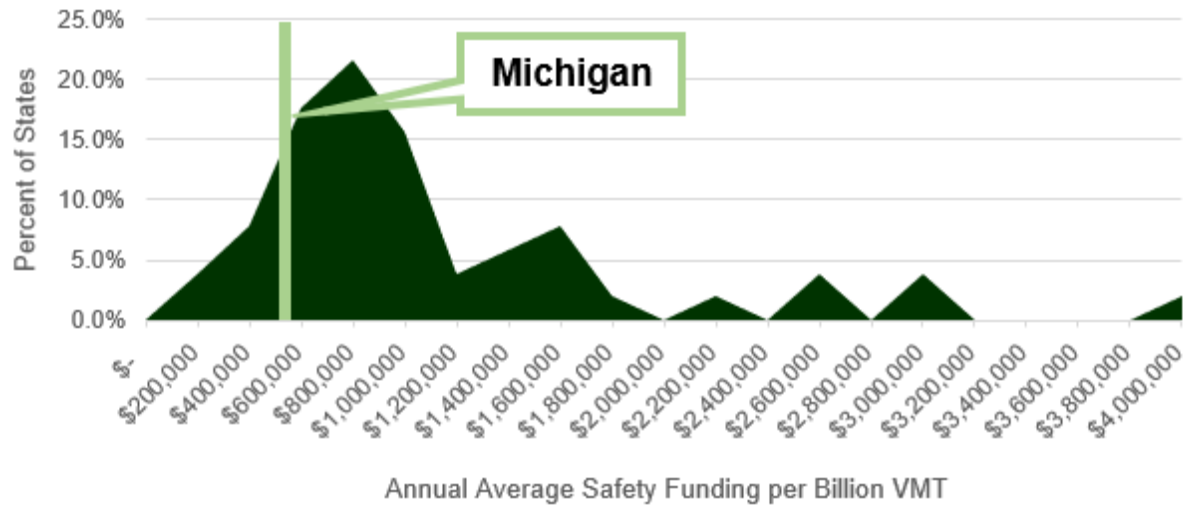


Figure 37. Distribution of Annual Safety Funding per Billion VMT (Excluding Alaska)

The top ten states in safety funding per VMT tend to be the less populous and less well-traveled states, with the major exceptions of Washington and New York which invest more in safety funding relative to VMT (**Table 13**). Alaska represents a notable outlier in the data given that it ranks 15th in annual average safety funding ($61.1M) but 50th in VMT (5.0B).

Table 13. Top States in Annual Safety Funding per VMT (2014-2018)

	Safety Funding (Millions)		VMT (Billions)		Population (Millions)		Funding per Billion VMT		Funding per Capita	
State	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Alaska	$61.1	15	5.0	50	0.73	47	$12,319,992	1	$83.3	1
Montana	$47.8	22	11.9	42	1.02	44	$4,000,874	2	$46.7	2
South Dakota	$29.1	33	9.1	47	0.85	46	$3,178,742	3	$34.3	4
D.C.	$11.2	49	3.6	51	0.66	49	$3,126,079	4	$17.0	11
Washington	$161.5	5	58.3	19	7.10	13	$2,771,475	5	$22.7	6
Wyoming	$25.1	37	9.4	45	0.58	51	$2,657,728	6	$43.4	3
Rhode Island	$18.9	43	7.9	48	1.06	43	$2,373,916	7	$17.9	10
Vermont	$14.5	45	7.3	49	0.63	50	$1,987,604	8	$23.1	5
New York	$229.2	2	128.0	4	19.58	4	$1,791,005	9	$11.7	20
Arkansas	$60.1	16	34.3	29	2.97	32	$1,751,773	10	$20.2	7
Michigan	**$54.1**	**17**	**97.2**	**10**	**9.93**	**10**	**$556,998**	**47**	**$5.5**	**46**

Similar observations can be made from the top ten states in annual safety funding per capita (**Table 14**), with Alaska again representing a major outlier in the data.

Table 14. Top States in Annual Safety Funding per Capita (2014-2018)

	Safety Funding (Millions)		VMT (Billions)		Population (Millions)		Funding per Billion VMT		Funding per Capita	
State	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Alaska	$61.1	15	5.0	50	0.73	47	$12,319,992	1	$83.3	1
Montana	$47.8	22	11.9	42	1.02	44	$4,000,874	2	$46.7	2
Wyoming	$25.1	37	9.4	45	0.58	51	$2,657,728	6	$43.4	3
South Dakota	$29.1	33	9.1	47	0.85	46	$3,178,742	3	$34.3	4
Vermont	$14.5	45	7.3	49	0.63	50	$1,987,604	8	$23.1	5
Washington	$161.5	5	58.3	19	7.10	13	$2,771,475	5	$22.7	6
Arkansas	$60.1	16	34.3	29	2.97	32	$1,751,773	10	$20.2	7
North Dakota	$14.1	46	9.5	44	0.73	48	$1,478,510	14	$19.4	8
West Virginia	$35.3	29	21.3	37	1.84	38	$1,653,668	11	$19.2	9
Rhode Island	$18.9	43	7.9	48	1.06	43	$2,373,916	7	$17.9	10
Michigan	**$54.1**	**17**	**97.2**	**10**	**9.93**	**10**	**$556,998**	**47**	**5.5**	**46**

In comparison to peer states (**Table 15**), Michigan represents the median state in annual average safety funding, population and VMT. It is also worth noting that Michigan and several of its Midwest peer states are near the bottom in both annual funding per VMT and per capita (Illinois, Indiana, Wisconsin and Minnesota). The state of Ohio is notable compared to the peer group in that it ranks 12th in funding per VMT and 13th in funding per capita.

Table 15. Annual Safety Funding - Michigan vs. Peer States (2014-2018)

State	Safety Funding (Millions)		VMT (Billions)		Population (Millions)		Funding per Billion VMT		Funding per Capita	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Ohio	$185.2	4	114.2	5	11.60	7	$1,620,853	12	$16.0	13
Pennsylvania	$91.6	8	100.7	9	12.77	6	$909,540	30	$7.2	40
Illinois	$65.6	14	105.3	8	12.84	5	$622,911	45	$5.1	49
Michigan	**$54.1**	**17**	**97.2**	**10**	**9.93**	**10**	**$556,998**	**47**	**$5.5**	**46**
Indiana	$50.1	21	77.8	12	6.59	16	$643,773	44	$7.6	39
Wisconsin	$31.0	31	61.5	18	5.75	20	$504,420	49	$5.4	47
Minnesota	$21.5	40	57.7	20	5.45	21	$372,532	51	$3.9	51

3.2 Fatalities and Fatality Rate

The annual average for fatalities ranged from 24.6 (Washington, D.C.) to 3,412.7 (Texas), including the entire study period from 2009 to 2017 (**Figure 38**). The state of Michigan experienced 946.3 fatalities on average during this period, considerably greater than the mean of 672.6 and the median of 507.1.

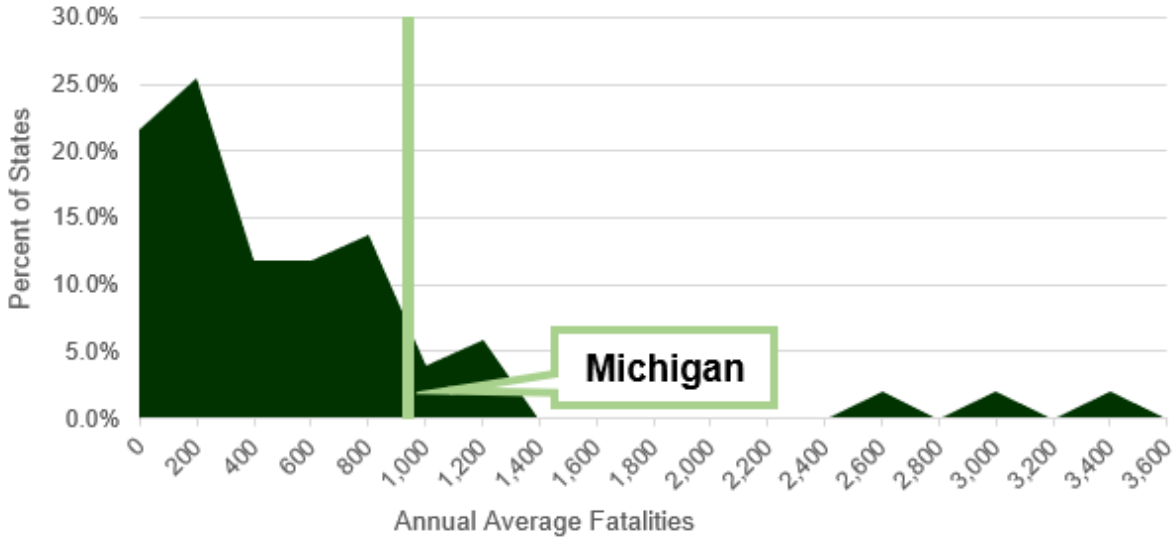


Figure 38. Distribution of Annual Average Fatalities (2009-2017)

In order to estimate recent progress in reducing fatalities, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in fatality frequency. The fatality reductions ranged from -19.6 percent (Colorado – representing an increase in fatality frequency) to 14.2 percent (Rhode Island). Michigan experienced a -6.2 percent reduction in fatality frequency, representing a modest increase over the study period. **Figure 39** shows the distribution of fatality reductions from all 50 states (and Washington, D.C.) which is relatively normally distributed. Michigan's -6.2 percent reduction is slightly lower than both the mean (-2.2 percent) and the median (1.4 percent).

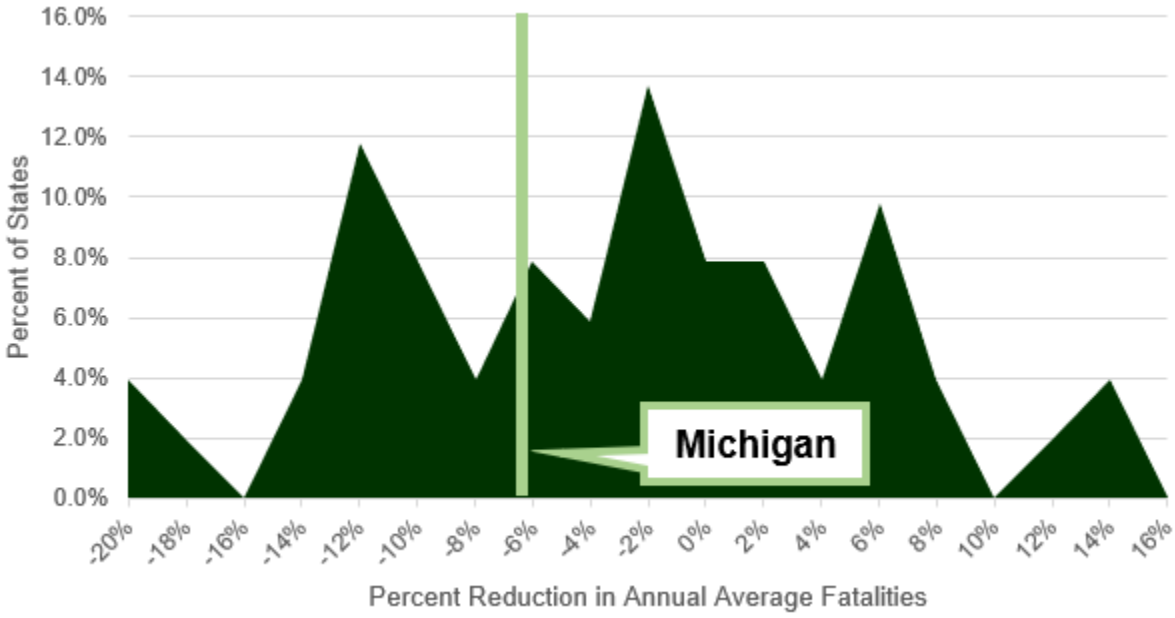


Figure 39. Distribution of Annual Average Fatality Reductions (2009-2013 to 2013-2017)

The top ten states in fatality frequency reduction (**Table 16**) includes several states which are near the top in annual average safety funding (New York, Arkansas and Pennsylvania), annual average safety funding per VMT (Rhode Island, West Virginia, Vermont, North Dakota, New York and Arkansas) and annual average funding per fatality (Rhode Island, West Virginia, Vermont, New York and Arkansas). The state of Michigan ranked 36th in fatality reduction and 44th in annual average funding per fatality.

Table 16. Top States in Fatality Frequency Reductions (2009-2013 to 2013-2017)

State	Fatality Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Fatality	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Rhode Island	69.0	59.2	14.2%	1	$18.9	43	$2,373,916	7	$294,598	4
West Virginia	336.2	288.6	14.2%	2	$35.3	29	$1,653,668	11	$113,795	16
Vermont	69.4	60.6	12.7%	3	$14.5	45	$1,987,604	8	$224,252	7
North Dakota	142.2	128.6	9.6%	4	$14.1	46	$1,478,510	14	$105,090	19
New York	1,182.4	1,079.6	8.7%	5	$229.2	2	$1,791,005	9	$204,097	9
Arkansas	555.2	514.2	7.4%	6	$60.1	16	$1,751,773	10	$111,491	17
Maryland	526.4	488.6	7.2%	7	$47.0	23	$830,972	35	$92,758	23
Pennsylvania	1,276.8	1,185.6	7.1%	8	$91.6	8	$909,540	30	$74,271	31
Oklahoma	692.2	645.4	6.8%	9	$50.4	20	$1,051,782	23	$75,363	30
Iowa	360.6	338.0	6.3%	10	$27.9	34	$865,432	31	$78,962	27
Michigan	**917.2**	**976.4**	**-6.5%**	**36**	**$54.1**	**17**	**$556,998**	**47**	**$57,196**	**44**

It is worth noting that among the list of top ten states in annual funding per VMT (**Table 17**) includes many of the top performing stats in fatality frequency reductions (Montana, Wyoming, Rhode Island, Vermont, New York and Arkansas). This suggests a potential relationship between safety funding levels relative to exposure and reductions in fatality frequency.

Table 17. Fatality Frequency Reduction of Top States in Funding per VMT (2009-2013 to 2013-2017)

State	Fatality Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Fatality	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Alaska	60.4	70.4	-16.6%	49	$61.1	15	$12,319,992	1	$911,515	1
Montana	211.8	204.2	3.6%	14	$47.8	22	$4,000,874	2	$232,217	5
South Dakota	130	130	0.0%	20	$29.1	33	$3,178,742	3	$224,668	6
D.C.	23	25.2	-9.6%	38	$11.2	49	$3,126,079	4	$455,883	2
Washington	456	510	-11.8%	46	$161.5	5	$2,771,475	5	$330,758	3
Wyoming	126.8	123.4	2.7%	15	$25.1	37	$2,657,728	6	$193,757	10
Rhode Island	69	59.2	14.2%	1	$18.9	43	$2,373,916	7	$294,598	4
Vermont	69.4	60.6	12.7%	3	$14.5	45	$1,987,604	8	$224,252	7
New York	1,182.4	1,079.6	8.7%	5	$229.2	2	$1,791,005	9	$204,097	9
Arkansas	555.2	514.2	7.4%	6	$60.1	16	$1,751,773	10	$111,491	17
Michigan	**917.2**	**976.4**	**-6.5%**	**36**	**$54.1**	**17**	**$556,998**	**47**	**$57,196**	**44**

Figure 40 shows the potential relationship between the percent reduction in fatality frequency and safety funding per VMT, excluding the unique cases of Alaska, Hawaii and Washington, D.C. While there is not a statistically significant relationship between the two, it is worth noting that the top-performing states tended to be on the higher end of safety funding per VMT and the states that experienced fatality frequency increases were on the lower end of funding per VMT.

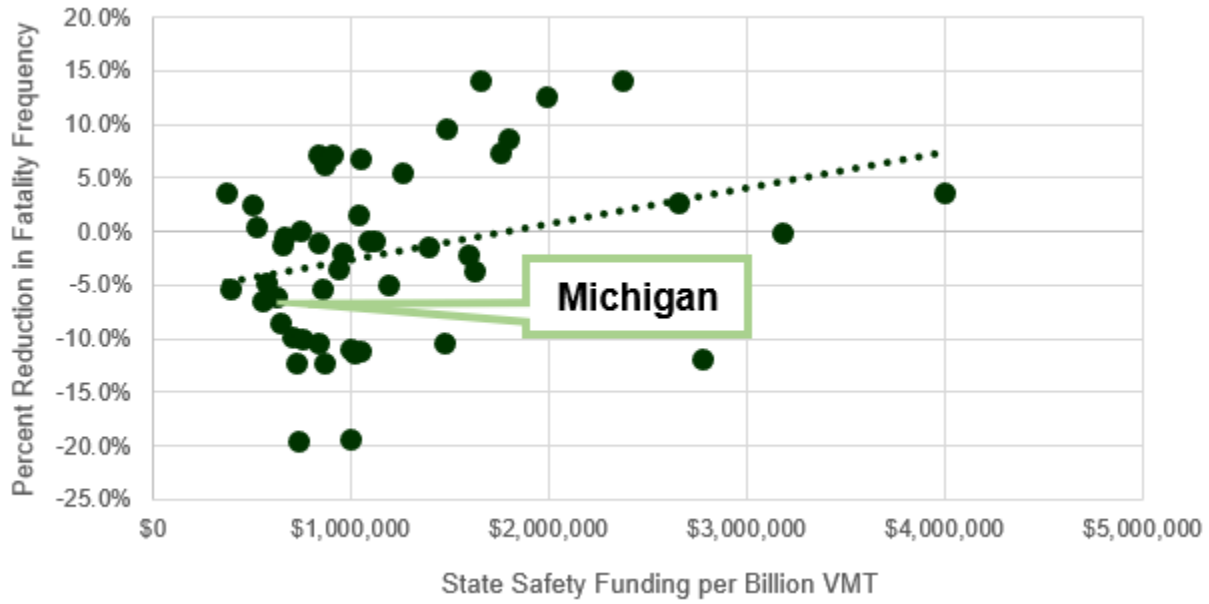


Figure 40. Percent Reduction in Fatalities (2009-2013 to 2013-2017) vs. Safety Funding per VMT

Michigan, ranked 36th overall, was second to last in fatality frequency reduction compared to Midwest peer states during this period (**Table 18**). Pennsylvania, ranked 8th in total funding levels, also ranked 8th in fatality frequency reductions during the study period.

Table 18. Fatality Frequency Reduction – Michigan vs. Peer States (2009-2017)

State	Fatality Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Fatality	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Pennsylvania	1,276.8	1,185.6	7.1%	8	$91.6	8	$909,540	30	$74,271	31
Minnesota	396.4	381.8	3.7%	13	$21.5	40	$372,532	51	$55,203	45
Wisconsin	579	563.8	2.6%	16	$31.0	31	$504,420	49	$54,171	46
Ohio	1,045.8	1,083.4	-3.6%	30	$185.2	4	$1,620,853	12	$172,564	11
Illinois	940.6	997.75	-6.1%	35	$65.6	14	$622,911	45	$68,106	36
Michigan	**917.2**	**976.4**	**-6.5%**	**36**	**$54.1**	**17**	**$556,998**	**47**	**$57,196**	**44**
Indiana	752.6	816.4	-8.5%	37	$50.1	21	$643,773	44	$63,819	38

While the overall frequency of fatalities is an important consideration, especially in support the state's long-term goal of zero deaths on Michigan's roadways [*45*], it is also important to recognize the potential impact of changes in traffic volume on fatality frequency. In order to estimate recent progress in reducing fatality rates per 100M VMT, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in fatality rate. The fatality rate reductions ranged from -10.5 percent (Colorado – representing an increase in fatality rate) to 13.0 percent (Rhode Island). Michigan experienced a -3.3 percent reduction in fatality rate, representing a modest increase over the study period. **Figure 41** shows the distribution of fatality rate reductions from all 50 states (and Washington, D.C.) which is relatively normally distributed. Michigan's -3.3 percent reduction is slightly lower than both the mean (1.7 percent) and the median (2.4 percent).

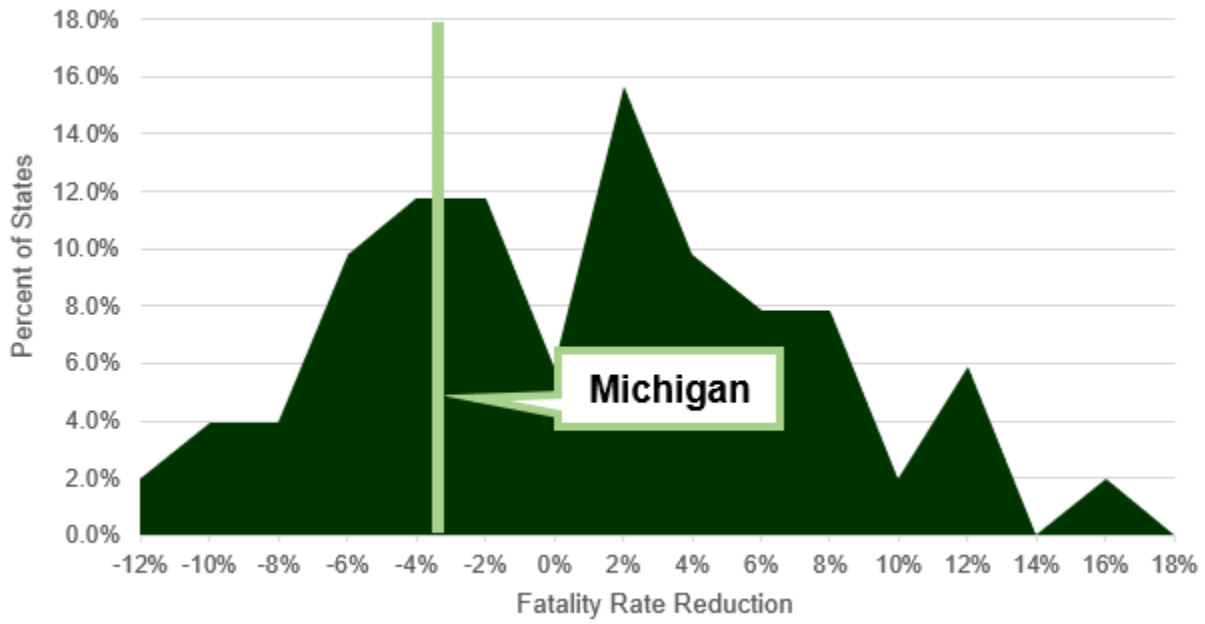


Figure 41. Distribution of Percent Reduction in Fatality Rate (2009-2013 to 2013-2017)

The list of top ten states in fatality rate reductions (**Table 19**) includes many of the top states in safety funding per capita (North Dakota, Rhode Island, Vermont, Arkansas, Montana and Oklahoma) and safety funding per fatality (Rhode Island, Vermont, Montana and California). Michigan ranks 39th in fatality rate reduction and 44th in safety funding per fatality.

Table 19. Top States in Fatality Rate Reduction (2009-2017)

State	Fatality Rate Data				Funding (Millions)		Funding per Capita		Funding per Fatality	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
North Dakota	1.55	1.28	17.3%	1	$14.1	46	$19.4	8	$105,090	19
Rhode Island	0.86	0.75	13.0%	2	$18.9	43	$17.9	10	$294,598	4
Vermont	0.96	0.83	12.9%	3	$14.5	45	$23.1	5	$224,252	7
Arkansas	1.67	1.46	12.1%	4	$60.1	16	$20.2	7	$111,491	17
Iowa	1.15	1.03	10.0%	5	$27.9	34	$9.0	30	$78,962	27
Hawaii	1.10	1.00	9.2%	6	$10.7	51	$7.6	38	$99,844	22
Maryland	0.94	0.85	9.1%	7	$47.0	23	$7.9	34	$92,758	23
Montana	1.83	1.66	9.0%	8	$47.8	22	$46.7	2	$232,217	5
Oklahoma	1.46	1.34	8.0%	9	$50.4	20	$13.0	16	$75,363	30
California	0.98	0.92	7.0%	10	$415.1	1	$10.8	22	$131,508	12
Michigan	**0.96**	**0.99**	**-3.3%**	**39**	**$54.1**	**17**	**$5.5**	**46**	**$57,196**	**44**

Figure 42 shows the potential relationship between the percent reduction in fatality rates and safety funding per capita, excluding the unique cases of Alaska, Hawaii and Washington, D.C. It is worth noting that there was a modest statistically significant relationship between the two, suggesting that states which have invested more funding per capita have experienced greater reductions in fatality rate during the study period.

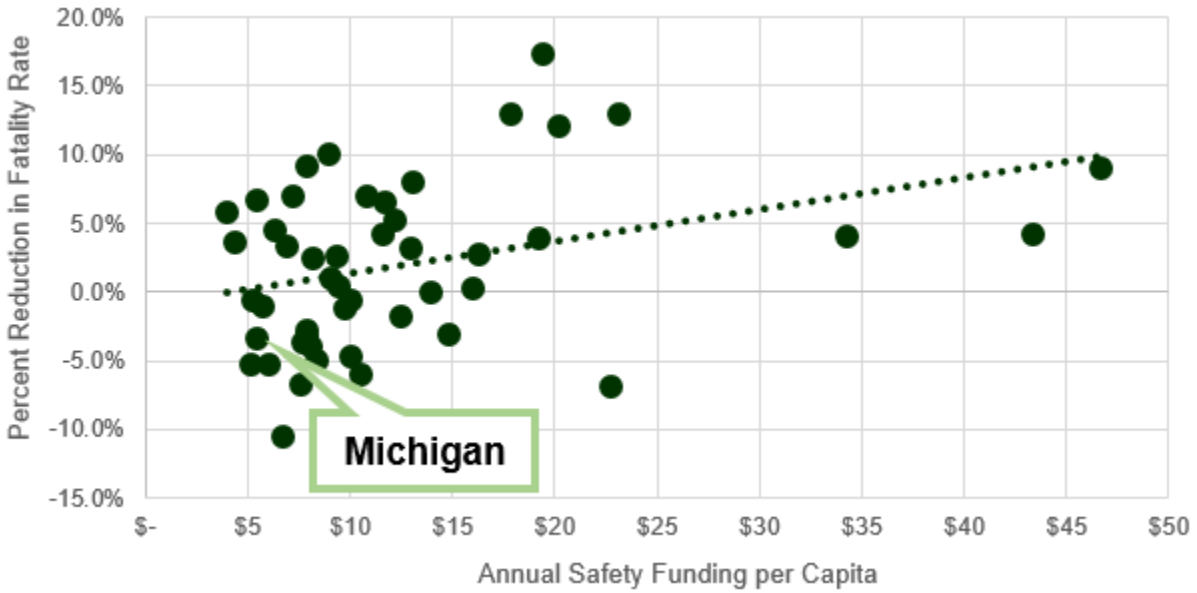


Figure 42. Percent Reduction in Fatality Rate (2009-2013 to 2013-2017) vs. Safety Funding per Capita

Michigan was forth out of seven compared to the peer states in fatality rate reductions during the study period (**Table 20**). It is also worth noting that Pennsylvania, Wisconsin and Minnesota were top performers (11th, 12th and 14th, respectively) in fatality rate reductions, despite ranking near the bottom in safety funding per capita (40th, 47th and 51st, respectively). This suggests that these states have used available safety funds in a particularly efficient manner during the study period.

Table 20. Fatality Rate Reduction – Michigan vs. Peer States (2009-2017)

State	Fatality Rate Data				Funding (Millions)		Funding per Capita		Funding per Fatality	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Pennsylvania	1.27	1.18	7.0%	11	$91.6	8	$7.2	40	$74,271	31
Wisconsin	0.98	0.91	6.7%	12	$31.0	31	$5.4	47	$54,171	46
Minnesota	0.70	0.66	5.8%	14	$21.5	40	$3.9	51	$55,203	45
Ohio	0.93	0.93	0.2%	29	$185.2	4	$16.0	13	$172,564	11
Michigan	**0.96**	**0.99**	**-3.3%**	**39**	**$54.1**	**17**	**$5.5**	**46**	**$57,196**	**44**
Illinois	0.90	0.94	-5.2%	44	$65.6	14	$5.1	49	$68,106	36
Indiana	0.97	1.04	-6.7%	47	$50.1	21	$7.6	39	$63,819	38

3.3 Serious Injuries and Serious Injury Rate

Given that the definition and reporting of serious injuries may vary from state to state, no comparisons were made with respect to total serious injury frequency as a part of this evaluation. Instead, to estimate recent progress in reducing serious injuries, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in serious injury frequency. The serious injury reductions ranged from -34.4 percent (Georgia – representing an increase in serious injury frequency) to 35.4 percent (West Virginia). Michigan experienced an 8.2 percent reduction in serious injury frequency, representing a considerable decrease over the study period. **Figure 43** shows the distribution of serious injury reductions from all 50 states (and Washington, D.C.) which is relatively normally distributed. Michigan's 8.2 percent reduction in serious injuries is slightly above the mean (6.8 percent) and just below the median (8.7 percent) of all states.

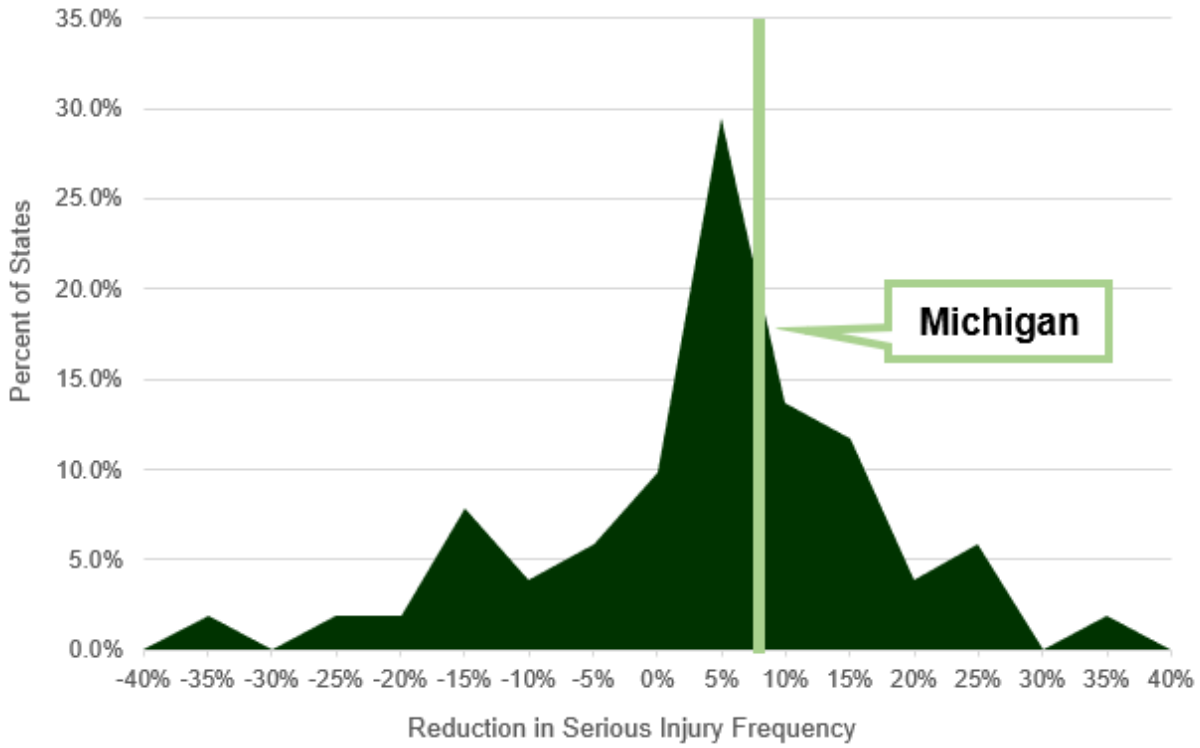


Figure 43. Distribution of Reductions in Serious Injury Frequency (2009-2013 to 2013-2017)

The list of the top ten states in serious injury frequency reductions (**Table 21**) includes two of the top states in safety funding per billion VMT and safety funding per capita (West Virginia and Vermont). Michigan ranked 27th in serious injury frequency reductions during the study period.

Table 21. Top States in Serious Injury Frequency Reductions (2009-2017)

State	Serious Injury Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	1,969.6	1,272.4	35.4%	1	$35.3	29	$1,653,668	11	$19.2	9
New Mexico	1,818.8	1,333.8	26.7%	2	$27.1	35	$1,038,310	24	$13.0	17
Virginia	10,798.6	7,992.0	26.0%	3	$52.6	18	$665,011	42	$6.3	43
Kansas	1,602.2	1,187.8	25.9%	4	$20.1	41	$653,495	43	$6.9	41
Maryland	4,019.8	3,016.2	25.0%	5	$47.0	23	$830,972	35	$7.9	34
New Jersey	1,394.8	1,081.8	22.4%	6	$39.1	25	$522,829	48	$4.4	50
Kentucky	3,883.4	3,124.8	19.5%	7	$39.9	24	$830,526	36	$9.1	29
Vermont	362.2	294.2	18.8%	8	$14.5	45	$1,987,604	8	$23.1	5
Connecticut	1,661.6	1,363.8	17.9%	9	$35.1	30	$1,117,905	19	$9.8	26
New Hampshire	553.8	457.2	17.4%	10	$12.5	48	$958,508	28	$9.4	27
Michigan	**5,833.0**	**5,355.0**	**8.2%**	**27**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**

The list of top ten states in safety funding per billion VMT (**Table 22**) includes several of the top performing states in serious injury frequency reductions (Alaska, Wyoming, Rhode Island, and Vermont).

Table 22. Serious Injury Reduction of Top States in Funding per VMT (2009-2017)

State	Serious Injury Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Alaska	403.6	346.3	14.2%	13	$61.1	15	$12,319,992	1	$83.3	1
Montana	1,058.6	926.6	12.5%	18	$47.8	22	$4,000,874	2	$46.7	2
South Dakota	817.8	742.8	9.2%	23	$29.1	33	$3,178,742	3	$34.3	4
D.C.	319.2	353.0	-10.6%	45	$11.2	49	$3,126,079	4	$17.0	11
Washington	2,275.6	2,092.2	8.1%	29	$161.5	5	$2,771,475	5	$22.7	6
Wyoming	525.4	435.4	17.1%	12	$25.1	37	$2,657,728	6	$43.4	3
Rhode Island	453.8	392.0	13.6%	14	$18.9	43	$2,373,916	7	$17.9	10
Vermont	362.2	294.2	18.8%	8	$14.5	45	$1,987,604	8	$23.1	5
New York	12,314.8	11,237.0	8.8%	24	$229.2	2	$1,791,005	9	$11.7	20
Arkansas	3,311.8	2,993.2	9.6%	21	$60.1	16	$1,751,773	10	$20.2	7
Michigan	**5,833.0**	**5,355.0**	**8.2%**	**27**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**

Figure 44 shows the potential relationship between the percent reduction in serious injury frequency and safety funding per VMT, excluding the unique cases of Alaska, Hawaii and Washington, D.C. While there is not a statistically significant relationship between the two, it is worth noting that the top performing states tended to be on the higher end of safety funding per VMT and the states which experienced serious injury frequency increases were on the lower end.

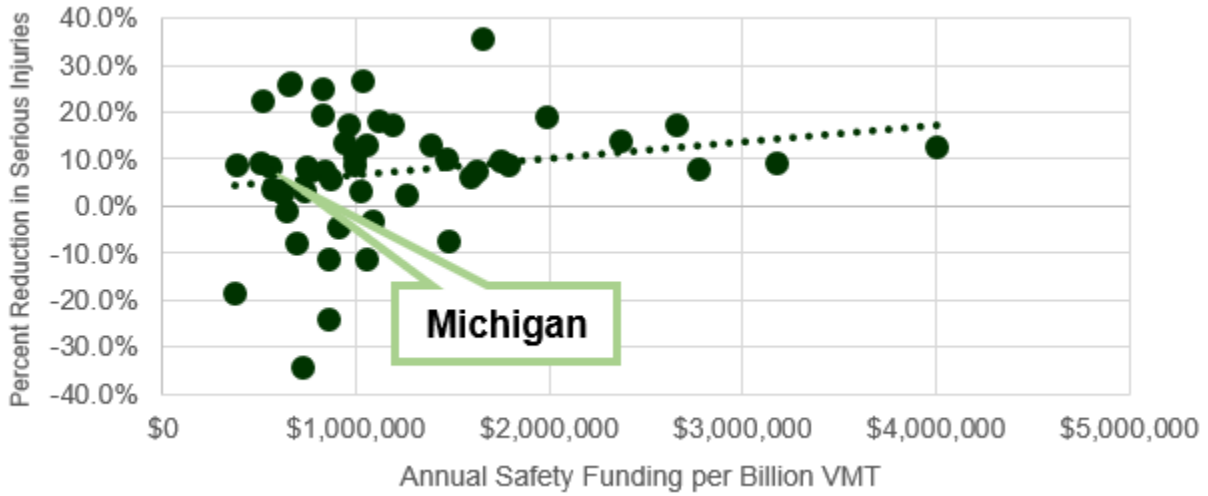


Figure 44. Percent Reduction in Serious Injury Frequency (2009-2013 to 2013-2017) vs. Safety Funding per VMT

Michigan ranked second in serious injury frequency reduction during the study period among peer states (**Table 23**), which is notable considering it ranks 47th in funding per billion VMT and 46th in funding per capita. Indiana, Pennsylvania and Minnesota all experienced increases in serious injury frequency and fell near the bottom of all states during the study period.

Table 23. Serious Injury Frequency Reduction – Michigan vs. Peer States (2009-2017)

State	Serious Injury Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Wisconsin	3,445.5	3,124.2	9.3%	22	$31.0	31	$504,420	49	$5.4	47
Michigan	**5,833.0**	**5,355.0**	**8.2%**	**27**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Ohio	9,725.0	9,013.0	7.3%	31	$185.2	4	$1,620,853	12	$16.0	13
Illinois	12,454.8	12,128.5	2.6%	38	$65.6	14	$622,911	45	$5.1	49
Indiana	3,346.6	3,387.2	-1.2%	40	$50.1	21	$643,773	44	$7.6	39
Pennsylvania	3,431.8	3,588.4	-4.6%	42	$91.6	8	$909,540	30	$7.2	40
Minnesota	1,221.0	1,447.2	-18.5%	49	$21.5	40	$372,532	51	$3.9	51

While the overall frequency of serious injuries is an important consideration, especially in support the state's goal to reduce both fatalities and serious injuries on Michigan's roadways [*45*], it is also important to recognize the potential impact of changes in traffic volume on serious injury frequency. In order to estimate recent progress in reducing serious injury rates per 100M VMT, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in serious injury rate. The serious injury rate reductions ranged from -24.8 percent (Georgia – representing an increase in serious injury rate) to 36.0 percent (West Virginia). Michigan experienced a 10.8 percent reduction in serious injury rate, representing a considerable reduction over the study period. **Figure 45** shows the distribution of fatality rate reductions from all 50 states (and Washington, D.C.) which is relatively normally distributed. Michigan's 10.8 percent serious injury rate reduction is slightly higher than the mean (10.4 percent) but lower the median (12.1 percent).

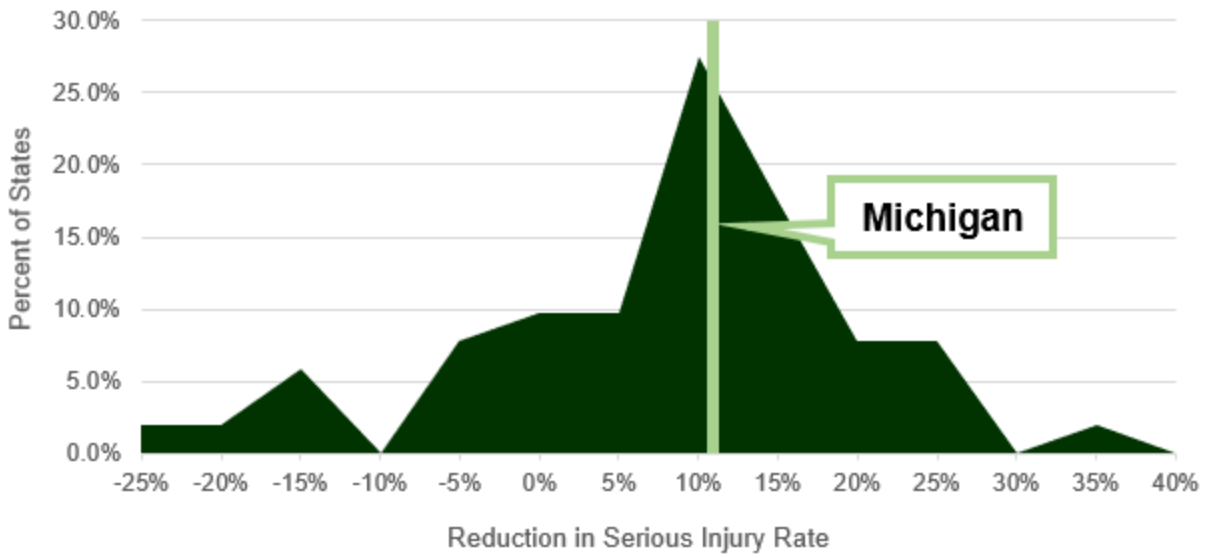


Figure 45. Distribution of Reductions in Serious Injury Rate (2009-2013 to 2013-2017)

The list of the top ten states in serious injury rate reduction (**Table 24)** includes two states which are near the top in safety funding per billion VMT and safety funding per capita (West Virginia and Missouri). Michigan ranked 29th in serious injury rate reduction among all states during the study period.

Table 24. Top States in Serious Injury Rate Reductions (2009-2017)

State	Serious Injury Rate Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	10.4	6.7	36.0%	1	$35.3	29	$1,653,668	11	$19.2	9
Virginia	14.1	9.9	29.4%	2	$52.6	18	$665,011	42	$6.3	43
Kansas	5.3	3.8	28.7%	3	$20.1	41	$653,495	43	$6.9	41
New Mexico	7.1	5.1	27.7%	4	$27.1	35	$1,038,310	24	$13.0	17
Maryland	7.2	5.3	26.2%	5	$47.0	23	$830,972	35	$7.9	34
New Jersey	1.9	1.4	24.9%	6	$39.1	25	$522,829	48	$4.4	50
Nevada	5.6	4.3	22.6%	7	$23.8	39	$996,057	27	$8.4	31
Kentucky	8.2	6.5	21.0%	8	$39.9	24	$830,526	36	$9.1	29
Missouri	8.3	6.6	20.8%	9	$84.5	9	$1,189,234	18	$13.9	15
New Hampshire	4.3	3.5	19.3%	10	$12.5	48	$958,508	28	$9.4	27
Michigan	**6.1**	**5.4**	**10.8%**	**29**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**

Figure 46 shows the potential relationship between the percent reduction in serious injury rates and safety funding per capita, excluding the unique cases of Alaska, Hawaii and Washington, D.C. While there is not a statistically significant relationship between the two, it is worth noting that the top performing states tended to be on the higher end of safety funding per capita and the states which experienced serious injury rate increases were on the lower end of funding per capita.

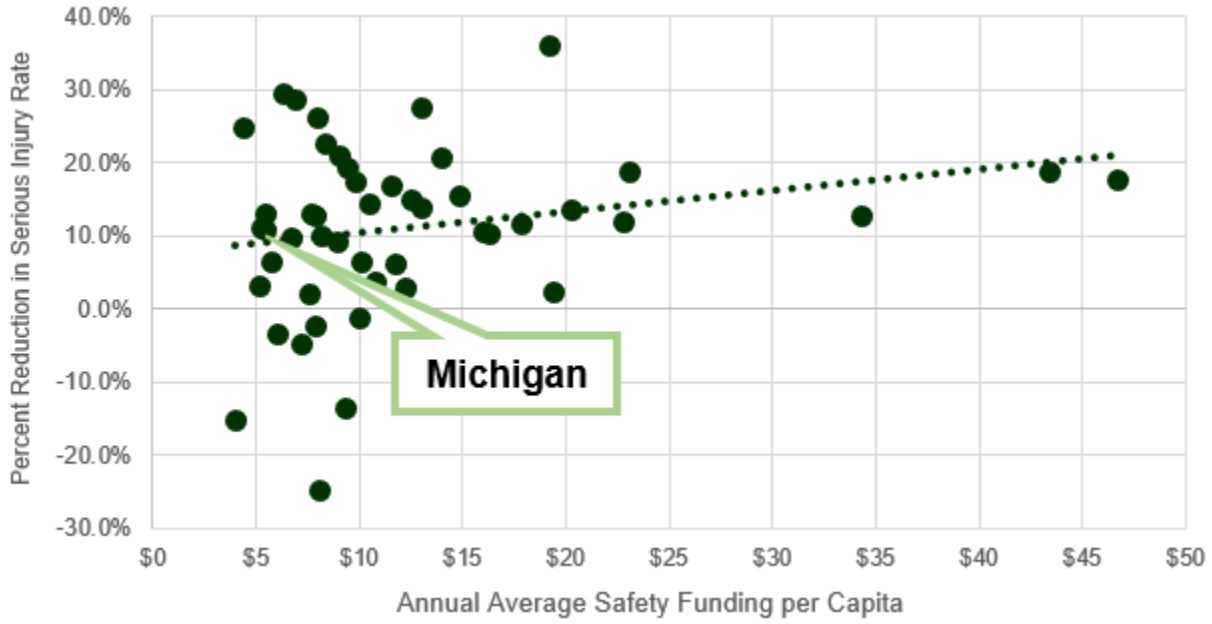


Figure 46. Percent Reduction in Serious Injury Rate (2009-2013 to 2013-2017) vs. Safety Funding per Capita

Michigan was second in serious injury rate reduction among the Midwest peer states (**Table 25**). It is also worth noting that Pennsylvania and Minnesota experienced serious injury rate increases during the study period and rank near the bottom of all states.

Table 25. Serious Injury Rate Reduction – Michigan vs. Peer States (2009-2017)

State	Serious Injury Rate Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Wisconsin	5.8	5.1	13.0%	23	$31.0	31	$504,420	49	$5.4	47
Michigan	**6.1**	**5.4**	**10.8%**	**29**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Ohio	8.7	7.8	10.6%	30	$185.2	4	$1620,853	12	$16.0	13
Illinois	11.9	11.5	3.3%	39	$65.6	14	$622,911	45	$5.1	49
Indiana	4.3	4.2	2.1%	42	$50.1	21	$643,773	44	$7.6	39
Pennsylvania	3.4	3.6	-4.7%	46	$91.6	8	$909,540	30	$7.2	40
Minnesota	2.1	2.5	-15.0%	50	$21.5	40	$372,532	51	$3.9	51

3.4 Non-Motorized Fatalities and Serious Injuries

Consistent with the current FHWA safety performance target metrics, non-motorized fatalities and serious injuries were combined for each state [*48*]. Additionally, given that each states definition and reporting of serious injuries may vary, no comparisons were made with respect to total non-motorized fatalities and serious injuries. Instead, to estimate recent progress in reducing non-motorized fatalities and serious injuries, five-year rolling averages were developed for each state with the first period representing 2009 to 2013 and the last period representing 2013 to 2017. The percent reduction from the first period to the last period was calculated and used as an estimate of relative improvement in non-motorized fatality and serious injury frequency. The non-motorized fatality and serious injury reductions ranged from -50.6 percent (Alaska – representing an increase in non-motorized fatalities and serious injury frequency) to 19.2 percent (West Virginia). Michigan experienced a -0.2 percent reduction in non-motorized fatality and serious injury frequency, with similar totals in both periods. **Figure 47** shows the distribution of non-motorized fatality and serious injury reductions from all 50 states (and Washington, D.C.) which is relatively normally distributed. Michigan's -0.2 percent reduction in non-motorized fatalities and serious injuries is above the mean (-6.3 percent) and the median (-5.4 percent) of all states.

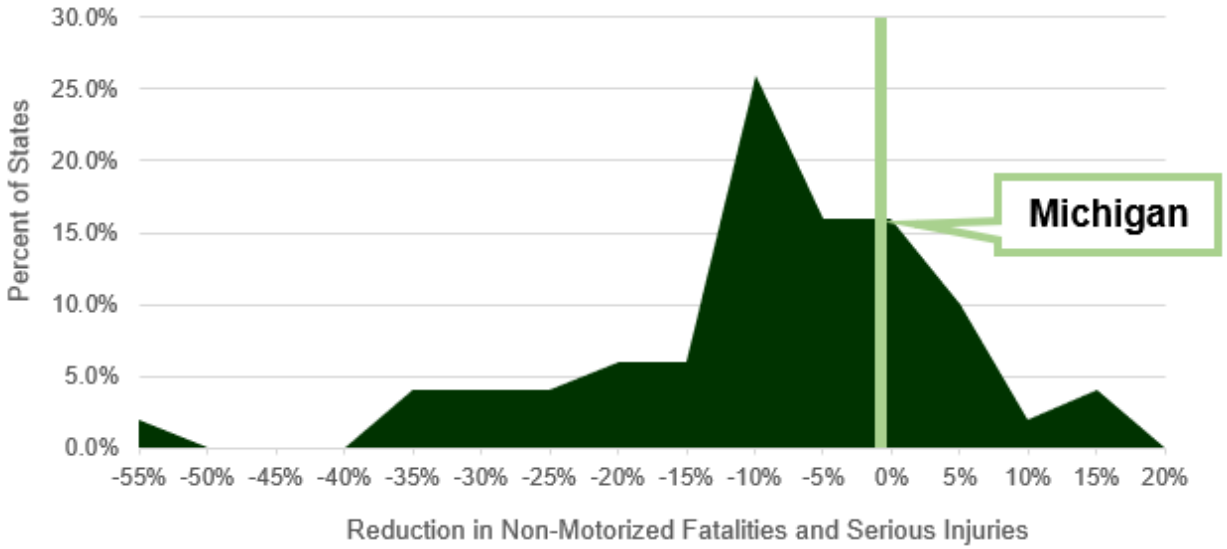


Figure 47. Distribution of Reductions in Non-Motorized Fatalities and Serious Injuries (2009-2013 to 2013-2017)

The list of the top ten states in non-motorized fatality and serious injury reductions (**Table 26**) includes several states which are near the top in safety funding per billion VMT (West Virginia, Rhode Island, New York, South Dakota, Vermont and Delaware) and safety funding per capita

(West Virginia, Rhode Island, South Dakota, Vermont and Delaware). However; caution should be used when interpreting these results as total annual obligated funding may provide a general measure of funding for safety improvements which address non-motorized safety concerns but does not directly identify how much was spent towards these types of treatments. Michigan ranked 17th among all states in non-motorized fatality and serious injury reduction during the study period.

Table 26. Top States in Non-Motorized Fatality and Serious Injury Reduction (2009-2017)

State	Non-Motorized Fatality and Serious Injury Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	116.8	94.4	19.2%	1	$35.3	29	$1,653,668	11	$19.2	9
New Jersey	449.8	378.2	15.9%	2	$39.1	25	$522,829	48	$4.4	50
Rhode Island	97.6	86.4	11.5%	3	$18.9	43	$2,373,916	7	$17.9	10
New York	3,003.6	2,734.8	8.9%	4	$229.2	2	$1,791,005	9	$11.7	20
Connecticut	305.8	281.6	7.9%	5	$35.1	30	$1,117,905	19	$9.8	26
South Dakota	50.2	47.0	6.4%	6	$29.1	33	$3,178,742	3	$34.3	4
Vermont	42.4	39.8	6.1%	7	$14.5	45	$1,987,604	8	$23.1	5
Alabama	401.5	377.4	6.0%	8	$25.4	36	$386,856	50	$5.3	48
Delaware	101.6	97	4.5%	9	$13.8	47	$1,469,168	15	$14.8	14
Maryland	570.2	547	4.1%	10	$47.0	23	$830,972	35	$7.9	34
Michigan	**745.8**	**747.4**	**-0.2%**	**17**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**

Michigan was second among Midwest peer states in non-motorized fatality and serious injury reductions during the study period (**Table 27**). It is also worth noting that all six Midwest peer states (Wisconsin did not report non-motorized serious injuries) experienced increases in non-motorized fatalities and serious injuries during the study period.

Table 27. Non-Motorized Fatality and Serious Injury Reduction – Michigan vs. Peer States (2009-2017)

State	Non-Motorized Fatality and Serious Injury Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013 Avg.	2013-2017 Avg.	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Illinois	1,495.4	1,494.8	0.0%	15	$65.6	14	$622,911	45	$5.1	49
Michigan	**745.8**	**747.4**	**-0.2%**	**17**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Indiana	410.4	412.6	-0.5%	18	$50.1	21	$643,773	44	$7.6	39
Ohio	833.4	852.8	-2.3%	20	$185.2	4	$1,620,853	12	$16.0	13
Pennsylvania	578.4	630.0	-8.9%	35	$91.6	8	$909,540	30	$7.2	40
Minnesota	186.8	246.4	-31.9%	48	$21.5	40	$372,532	51	$3.9	51

4.0 ESTIMATE OF FUNDING LEVELS TO ACHIEVE MICHIGAN'S SHSP SAFETY GOALS

The current SHSP identifies short-term safety goals for 2018 of less than 967 fatalities and less than 4,600 serious injuries for Michigan's roadways, shown in **Figures 48 and 49** [*45*]. While the long-term vision established in the SHSP is zero death on Michigan's roadways [*45*], these short-term goals provide an interim target towards reaching zero deaths. Given the potential relationship between safety funding levels and fatalities explored in **Section 3.0**, an important consideration as the department continues to evaluate changes to safety funding templates as a part of TSMO implementation is the level of safety funding required to reach these short-term safety goals. This section includes analysis to estimate the funding levels required to reach these statewide goals.

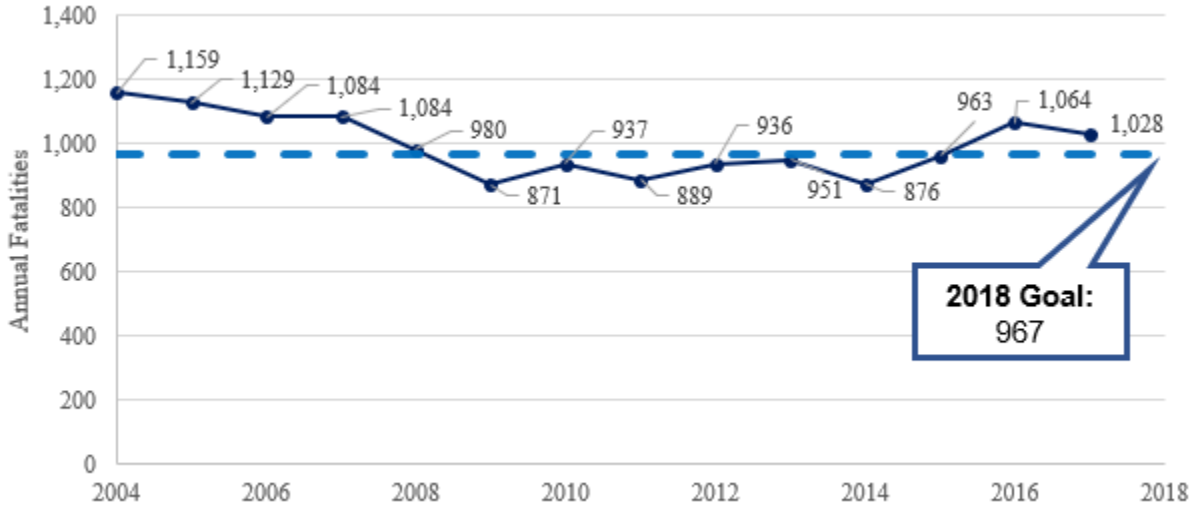


Figure 48. Annual Traffic Fatalities in Michigan (2004-2017) [*49*]

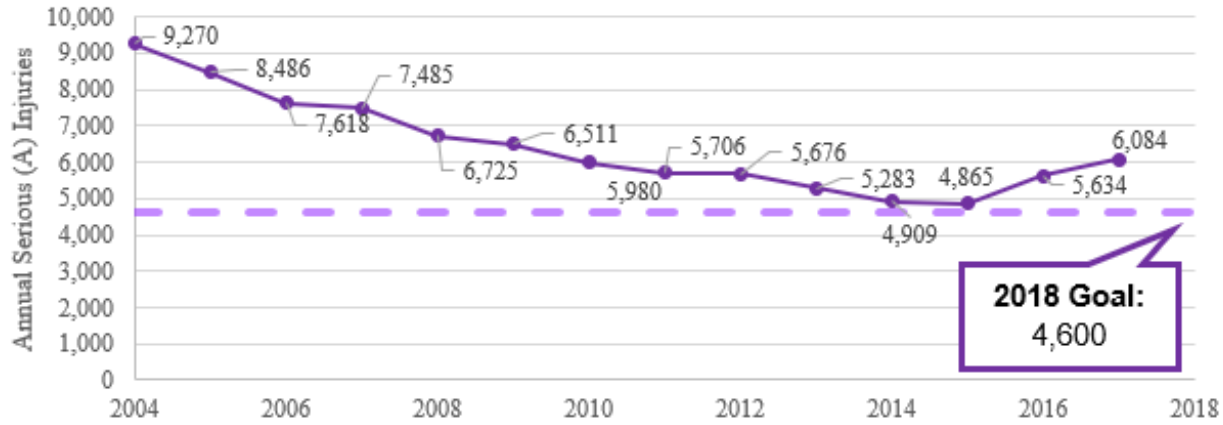


Figure 49. Annual Traffic Serious (A) Injuries in Michigan (2004-2017) [*49*]

In order to develop an estimate of funding levels necessary to reduce fatalities to less than 967 and serious injuries to less than 4,600 annually on Michigan's roadways, a broad range of data was collected and combined using the process outlined in **Figure 50**. It is important to note that while safety goals were assessed at the statewide level, trunkline and locally-owned highways were evaluated using separate datasets.

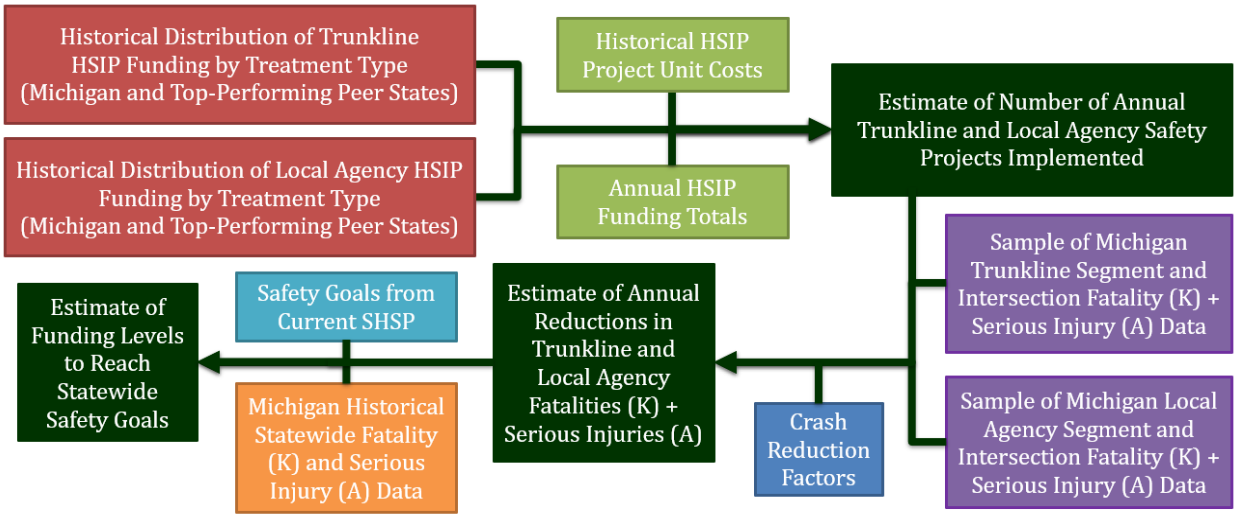


Figure 50. Flowchart of Estimation Process

First, the historical distribution of funding by treatment type was assessed using data collected from annual HSIP reports. Distinct distributions were developed for trunkline and locally-owned highways in Michigan as well as top performing Midwest peer states (Pennsylvania, Minnesota and Wisconsin) identified in **Section 3.2**. These data were also used to develop historical HSIP project unit costs for common treatment types. These unit costs, annual HSIP funding totals and the historical distribution of project funding were combined to estimate the number of annual trunkline and local agency safety projects implemented in a typical year.

It was also necessary to identify a sample of trunkline and locally-owned highway facilities where the estimate of annual projects could be hypothetically applied. Specifically, an estimate of the frequency of fatalities (K) and serious injuries (A) which occur along segments and intersections for both trunkline and locally-owned highway networks was developed using sample data from Michigan. These results were combined with the estimate of the number of projects implemented in a typical year, along with crash reduction factors developed from a variety of resources, to

approximate annual reductions in fatalities and serious injuries for both trunkline and locally-owned highways after the implementation of safety projects. Ultimately, these reductions were applied to the historical statewide fatality and serious injury totals to determine when the short-term goals identified in the SHSP would be reached. Additional analyses were conducted to determine how increasing the state's safety funding levels would impact the ability to reach these short-term goals.

4.1 Historical Distribution of Trunkline and Local Agency Safety Projects

As a part of each states' annual HSIP report, a listing of projects obligated during the reporting period is provided to FHWA [*46*]. The information specific to each project varies by state and report, but in general a basic description of the project, project costs and whether the project was implemented along the state or local highway network are included. The research team collected this historical project data for Michigan as well as top performing Midwest peer states (Minnesota, Pennsylvania, and Wisconsin) for the period from 2014-2018. It should be noted that Pennsylvania only implements selected local projects with HSIP funding due to the legal agreements necessary to complete work on local roadways and other structural limitations. The allocation of HSIP funding was also assessed by project category based upon the description included in the project listing. The research team reviewed each listing and aggregated projects into general categories in order to compare the distribution of project frequency and funding totals. It should be noted that in select cases, not enough information was included in the project listing to identify an appropriate category and were therefore aggregated as "Unknown, Other or Miscellaneous". **Table 28** shows the distribution of trunkline HSIP funding by project category where cost data were available and **Table 29** shows the distribution of local agency HSIP funding by project category where cost data were available.

Table 28. Distribution of Trunkline HSIP Funding by Category – Michigan and Peer States (2014-2018)

Distribution of Funding (Trunkline Only)					
Category	**Michigan**	**Minnesota**	**Pennsylvania**	**Wisconsin**	**Midwest Peers**
Access Management	0.0%	0.2%	1.1%	8.1%	2.1%
Add Travel Lanes	0.0%	1.3%	2.3%	0.0%	1.7%
Add Turn Lanes	4.6%	2.9%	0.6%	0.7%	1.0%
Add TWLTL	11.5%	1.1%	3.4%	3.1%	2.9%
Barrier	0.7%	5.1%	2.5%	7.7%	3.9%
Cable Barrier	7.8%	35.7%	11.9%	13.7%	16.8%
Curve Warning	0.0%	0.5%	0.0%	0.6%	0.2%
Delineation	5.9%	0.0%	0.8%	1.8%	0.8%
Fixed Object Removal	0.2%	0.0%	0.4%	0.0%	0.2%
High Friction Surface Treatment	1.1%	0.4%	3.5%	6.6%	3.5%
Horizontal Alignment	0.0%	0.0%	3.4%	3.5%	2.8%
Interchange Improvement	0.2%	2.5%	6.4%	0.0%	4.5%
Intersection Geometrics	3.0%	13.3%	14.1%	11.5%	13.5%
ITS	0.0%	0.4%	3.6%	1.0%	2.5%
Lighting	0.0%	4.6%	0.0%	1.0%	1.1%
Pavement Markings (restripe)	48.1%	2.3%	0.0%	0.0%	0.5%
Pedestrian	0.9%	1.4%	5.2%	1.6%	3.8%
Roadside Improvements	0.0%	0.0%	0.6%	0.0%	0.3%
Roundabout	7.1%	14.9%	1.2%	19.9%	7.2%
Rumble Strips	0.0%	6.0%	0.9%	2.0%	2.1%
Shoulder Treatments	0.1%	1.1%	0.9%	0.0%	0.7%
Sign Upgrades	0.2%	1.8%	4.1%	3.8%	3.6%
Signal Timing	0.0%	0.5%	1.3%	0.0%	0.9%
Superelevation	4.3%	0.0%	0.0%	0.0%	0.0%
Systemic Signal Improvements	0.3%	0.0%	0.2%	0.0%	0.1%
Traffic Signal Improvements	1.4%	0.0%	7.6%	1.9%	5.1%
Widen Shoulder	0.0%	0.2%	3.2%	0.1%	2.1%
Wrong Way Treatments	0.1%	0.0%	0.5%	0.0%	0.3%
Unknown/Other/Misc.	2.5%	3.8%	20.4%	11.7%	15.7%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Table 29. Distribution of Local Agency HSIP Funding by Category – Michigan and Peer States (2014-2018)

Distribution of Funding (Local Agency Only)				
Category	**Michigan**	**Minnesota**	**Wisconsin**	**Midwest Peers**
Add Travel Lanes	6.7%	0.0%	0.4%	0.1%
Add Turn Lanes	7.9%	1.3%	12.4%	3.3%
Advance Warning	0.0%	0.2%	0.1%	0.2%
Barrier	7.7%	0.0%	1.8%	0.3%
Curve Warning	0.2%	3.6%	0.2%	3.0%
Delineation	0.0%	0.8%	0.0%	0.6%
Drainage	0.8%	0.0%	0.0%	0.0%
Fixed Object Removal	6.5%	0.2%	0.1%	0.2%
High Friction Surface Treatment	0.7%	0.0%	3.8%	0.7%
Horizontal Alignment	2.0%	2.3%	3.3%	2.5%
Intersection Flashers	0.7%	0.0%	0.0%	0.0%
Intersection Geometrics	8.9%	1.9%	24.7%	6.0%
Intersection Warning System	0.0%	1.2%	0.0%	1.0%
ITS	0.0%	0.5%	0.0%	0.4%
Lighting	0.1%	4.1%	0.0%	3.4%
Pavement Markings	0.2%	25.8%	1.9%	21.5%
Pedestrian	0.8%	13.7%	0.8%	11.3%
Roadside Improvements	0.5%	0.0%	0.0%	0.0%
Roadway Reconfiguration	3.6%	1.6%	0.0%	1.3%
Roundabout	5.0%	7.8%	9.0%	8.0%
Rumble Strips	4.6%	12.8%	1.2%	10.7%
Shoulder Treatments	0.0%	1.6%	0.0%	1.3%
Sign Upgrades	0.8%	0.0%	15.0%	2.7%
Signal Timing	0.2%	1.8%	0.0%	1.5%
Superelevation	1.4%	0.0%	0.0%	0.0%
Systemic Signal Improvements	4.0%	0.0%	0.0%	0.0%
Traffic Signal Improvements	14.2%	9.4%	6.8%	8.9%
Vertical Alignment	6.3%	0.0%	0.0%	0.0%
Widen Lanes	1.3%	0.0%	0.0%	0.0%
Widen Shoulder	3.5%	8.0%	0.0%	6.5%
Unknown/Other/Misc.	11.5%	1.5%	18.5%	4.6%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

4.2 HSIP Project Unit Costs and Estimate of Annual Projects Implemented

The historical project data collected from each state's annual HSIP reports were also used to develop project unit costs presented in **Table 32 and 33** for each treatment category, with an average value being developed using data from all four states. These unit costs were combined with the annual funding levels identified in the current trunkline [*50*] and local agency [*51-53*] call for projects processes. It is important to note that funding levels were disaggregated by projects which were implemented on the basis of historical crash data at a particular site ("hot spots") or on a systemic basis as these are likely to have differing impacts on fatality and serious injury reductions. The trunkline call for projects process allows regions to spend between 25 to 50 percent of funding on systemic projects and therefore the research team assumed 37.5 percent of regional funding would be spent on such systemic projects. Trunkline annual funding levels, from the existing value up to 120-percent of the current level, are presented in **Table 30**.

Table 30. Trunkline Annual HSIP Funding Levels [*50*]

Funding Type		Annual Funding Levels						
		Existing	20% Increase	40% Increase	60% Increase	80% Increase	100% Increase	120% Increase
"Hot Spot" Funding	Regional Funding (Less 37.5% Systemic Portion)	$11.9	$14.3	$16.7	$19.1	$21.5	$23.9	$26.3
	Central Office Discretionary Funding	$1.0	$1.2	$1.4	$1.6	$1.8	$2.0	$2.2
	Safety Work Authorizations	$1.4	$1.7	$2.0	$2.2	$2.5	$2.8	$3.1
	Total	**$14.3**	**$17.2**	**$20.1**	**$22.9**	**$25.8**	**$28.7**	**$31.5**
Systemic Funding	Regional Funding (37.5% Systemic Portion)	$7.2	$8.6	$10.0	$11.5	$12.9	$14.3	$15.8
	Total	**$7.2**	**$8.6**	**$10.0**	**$11.5**	**$12.9**	**$14.3**	**$15.8**
Total Funding		**$21.5**	**$25.8**	**$30.1**	**$34.4**	**$38.7**	**$43.0**	**$47.3**

The local agency call for projects process includes the new Streamlined Systemic Safety application for 2018 [*51*]. These 1.5M in funds were associated with systemic funding, as well as an additional $500,000 of general HSIP funds for a total of $2M in annual systemic funding for local agencies. Local agency annual funding levels, from the existing value up to 120-percent of the current level, are presented in **Table 31**.

Table 31. Local Agency HSIP Annual Funding Levels [*51-53*]

Funding Type		Annual Funding Levels						
		Existing	20% Increase	40% Increase	60% Increase	80% Increase	100% Increase	120% Increase
"Hot Spot" Funding	Local HSIP (Less $500K)	$7.0	$8.4	$9.8	$11.2	$12.6	$14.0	$15.4
	High Risk Rural Road Program	$6.0	$7.2	$8.4	$9.6	$10.8	$12.0	$13.2
	Total	**$13.0**	**$15.6**	**$18.2**	**$20.8**	**$23.4**	**$26.0**	**$28.6**
Systemic Funding	Local HSIP (500K for Systemic)	$0.5	$0.6	$0.7	$0.8	$0.9	$1.0	$1.1
	Streamlined Systemic Safety	$1.5	$1.8	$2.1	$2.4	$2.7	$3.0	$3.3
	Total	**$2.0**	**$2.4**	**$2.8**	**$3.2**	**$3.6**	**$4.0**	**$4.4**
Total Funding		**$15.0**	**$18.0**	**$21.0**	**$24.0**	**$27.0**	**$30.0**	**$33.0**

After combing project unit costs, the historical distribution of HSIP project funding and the annual funding levels identified as a part of the call for projects processes, estimates for the number of projects which would be implemented in a typical year were developed for both trunkline highways (**Table 32**) and locally-owned highways (**Table 33**). The number of projects is provided in the same units as the project unit costs developed using the historical HSIP data and distinct totals are provided for both "hot spot" and systemic projects. It should be noted that separate estimates were developed for the allocation of projects using Michigan's historical distribution as well as average of the top-performing Midwestern peer states in order to provide a comparison of the differing treatment strategies.

Table 32. Summary of Trunkline Treatment Unit Costs and Annual Number of HSIP Projects

Treatment	Cost	Unit	Michigan		Peer States	
			Hot Spot	Systemic	Hot Spot	Systemic
Access Management	$590,252	per Mile	0.0	0.0	0.5	0.0
Add Travel Lanes	$606,755	per Mile	0.0	0.0	0.4	0.0
Add Turn Lanes	$409,547	per Intersection	1.6	0.0	0.4	0.0
Add TWLTL	$610,784	per Mile	2.7	0.0	0.7	0.0
Barrier	$60,915	per Mile	1.6	1.3	9.2	14.9
Cable Barrier	$73,974	per Mile	15.1	12.0	32.6	52.8
Curve Warning	$5,987	per Mile	0.0	0.0	4.8	7.8
Delineation	$5,636	per Mile	150.1	118.8	20.4	33.0
Fixed Object Removal	$24,118	per Mile	1.2	0.0	1.2	0.0
High Friction Surface Treatments	$182,928	per Mile	0.9	0.0	2.7	0.0
Horizontal Alignment	$1,248,938	per Mile	0.0	0.0	0.3	0.0
Interchange Improvement	$1,250,888	per Location	0.0	0.0	0.5	0.0
Intersection Geometrics	$579,967	per Intersection	0.7	0.0	3.3	0.0
ITS	$417,707	per Location	0.0	0.0	0.9	0.0
Lighting	$14,454	per Intersection	0.0	0.0	10.9	0.0
Pavement Markings (restripe)	$2,957	per Mile	2,332.4	1,846.5	24.2	39.3
Pedestrian	$40,914	per Location	3.2	0.0	13.3	0.0
Roadside Improvements	$443,003	per Mile	0.0	0.0	0.1	0.0
Roundabouts	$1,430,068	per Intersection	0.7	0.0	0.7	0.0
Rumble Strips	$9,203	per Mile	0.0	0.0	32.7	53.1
Shoulder Treatments	$24,485	per Mile	0.6	0.5	4.1	6.6
Sign Upgrades	$1,547	per Location	18.5	14.7	333.6	541.1
Signal Timing	$42,407	per Intersection	0.0	0.0	3.0	0.0
Superelevation	$1,264,659	per Mile	0.5	0.0	0.0	0.0
Systemic Signal Improvements	$44,800	per Intersection	1.0	0.8	0.3	0.5
Traffic Signal Improvements	$143,249	per Intersection	1.4	0.0	5.1	0.0
Widen Shoulder	$102,837	per Mile	0.0	0.0	2.9	4.7
Wrong Way Treatments	$45,000	per Location	0.3	0.0	1.0	0.0
Unknown/Other/Misc.	$262,461	per Location	1.4	0.0	8.6	0.0

Table 33. Summary of Local Agency Treatment Unit Costs and Annual Number of HSIP Projects

Treatment	Cost	Unit	Michigan		Peer States	
			Hot Spot	Systemic	Hot Spot	Systemic
Add Travel Lanes	$606,755	per Mile	1.4	0.0	0.0	0.0
Add Turn Lanes	$409,547	per Intersection	2.5	0.0	1.0	0.0
Advance Warning	$1,718	per Intersection	0.0	0.0	15.1	0.0
Barrier	$60,915	per Mile	16.4	12.0	0.6	0.2
Curve Warning	$5,987	per Mile	4.3	3.2	65.1	21.5
Delineation	$5,636	per Mile	0.0	0.0	13.8	4.6
Fixed Object Removal	$24,118	per Mile	35.0	0.0	1.1	0.0
High Friction Surface Treatments	$182,928	per Mile	0.5	0.0	0.5	0.0
Horizontal Alignment	$1,248,938	per Mile	0.2	0.0	0.3	0.0
Intersection Flashers	$22,781	per Intersection	4.0	0.0	0.0	0.0
Intersection Geometrics	$579,967	per Intersection	2.0	0.0	1.3	0.0
Intersection Warning System	$69,176	per Intersection	0.0	0.0	1.9	0.0
ITS	$417,707	per Location	0.0	0.0	0.1	0.0
Lighting	$14,454	per Intersection	0.9	0.0	30.6	0.0
Pavement Markings	$2,957	per Mile	8.8	6.4	945.3	312.1
Pedestrian	$40,914	per Location	2.5	0.0	35.9	0.0
Roadside Improvements	$443,003	per Mile	0.1	0.0	0.0	0.0
Roadway Reconfiguration	$437,725	per Mile	1.1	0.0	0.4	0.0
Roundabouts	$1,430,068	per Intersection	0.5	0.0	0.7	0.0
Rumble Strips	$9,203	per Mile	65.0	47.6	151.1	49.9
Shoulder Treatments	$24,485	per Mile	0.0	0.0	6.9	2.3
Sign Upgrades	$1,547	per Location	67.2	49.2	226.9	74.9
Signal Timing	$42,407	per Intersection	0.6	0.0	4.6	0.0
Superelevation	$1,264,659	per Mile	0.1	0.0	0.0	0.0
Systemic Signal Improvements	$44,800	per Intersection	11.6	8.5	0.0	0.0
Traffic Signal Improvements	$143,249	per Intersection	12.9	0.0	8.1	0.0
Unknown/Other/Misc.	$262,461	per Location	6.0	0.0	2.3	0.0
Vertical Alignment	$746,358	per Mile	1.1	0.0	0.0	0.0
Widen Lanes	$624,399	per Mile	0.3	0.0	0.0	0.0
Widen Shoulder	$102,837	per Mile	4.4	3.2	8.2	2.7

4.3 Sample of Michigan Highway Fatality and Serious Injury Data

In addition to the number of projects which are implemented via HSIP funds in a typical year, it was also necessary to develop estimates for the number of fatalities and serious injuries which occur along Michigan highway segments and intersections which would be hypothetically treated by such projects. This process included identifying a sample of Michigan highway facilities and collecting ten years of historical crash data (2008-2017) to determine fatalities and serious injuries per mile per year (for segments) and per intersection per year (for intersections). Ultimately, these results were combined with the estimate of annual projects implemented per year to develop estimates of annual reductions in fatalities and serious injuries. Distinct samples were collected for both trunkline and locally-owned highways as these facilities are likely to experience considerably different frequencies of fatalities and serious injuries given their varying design characteristics, traffic volumes, and trip characteristics. Trunkline safety funding targets identified in MDOT's most recent call for projects using historical K and A data are identified in **Table 34**.

Table 34. Trunkline Safety Funding Targets for FY 2024 [*50*]

Region	Fatalities (K) + Serious (A) Injuries (2014-2016)	Percent of K/As	FY 2024 Target	Percent of Regional Funding
Superior	334	4.4%	$1.5M	8%
North	579	7.6%	$1.9M	10%
Grand	1,378	18.0%	$3.1M	16%
Bay	1,033	13.5%	$2.9M	15%
Southwest	786	10.3%	$1.9M	10%
University	1,264	16.5%	$3.0M	16%
Metro	2,288	29.9%	$4.8M	25%
Discretionary (Central Office)	-	-	$1.0M	-
SWAs (Low-Cost Projects)	-	-	$1.4M	-
Total Annual Trunkline HSIP Funding	**7,662**	**100.0%**	**$21.5M**	**-**

Trunkline data were collected using a randomized process to represent the distribution of regional funding shown in **Table 34** in order to ensure the sample was representative of how trunkline funding is allocated. **Table 35** summarizes the sample of trunkline sites identified for crash data collection as a part of this process.

Table 35. Michigan Trunkline Highway Sample Site Summary

Site Type		MDOT Region							Total
		Bay	Grand	Metro	North	Southwest	Superior	University	
Urban	Freeway Segments	4	4	6	3	3	1	4	**25**
	Four-Lane with TWLTL Segments	4	4	6	3	3	1	4	**25**
	Four-Lane Divided Segments	4	4	6	3	3	1	4	**25**
	Four-Lane Undivided Segments	2	4	6	1	3	1	4	**21**
	Two-Lane with TWLTL Segments	4	4	3	3	3	1	4	**22**
	Two-Lane Undivided Segments	4	4	11	3	3	1	4	**30**
	Four-Leg Signalized Intersections	4	4	6	3	3	1	4	**25**
	Four-Leg Unsignalized Intersections	4	4	6	3	3	1	4	**25**
	Three-Leg Signalized Intersections	2	4	6	3	3	1	4	**23**
	Three-Leg Unsignalized Intersections	4	4	6	3	3	1	4	**25**
Rural	Freeway Segments	4	4	0	3	3	7	4	**25**
	Two-Lane Undivided Segments	4	4	6	3	3	8	4	**32**
	Four-Leg Unsignalized Intersections	4	4	6	3	3	1	4	**25**
	Three-Leg Unsignalized Intersections	6	4	6	3	3	1	4	**27**
Total		**54**	**56**	**80**	**40**	**42**	**27**	**56**	**355**
Percentage		**15.2%**	**15.8%**	**22.5%**	**11.3%**	**11.8%**	**7.6%**	**15.8%**	**100.0%**

It is important to note that sites were classified according to the typical site types used in the safety analysis processes identified in the *Highway Safety Manual* [*54*]. Additionally, sites were distinguished by urban facilities and rural facilities according the most recent Adjusted Census Urban Boundaries (ACUB) [*55*]. This categorization is important in that these facility types are likely to observe differing K and A frequencies and will also allow for associating the annual project types shown in **Tables 32 and 33** with the facilities predominately treated with these countermeasures. **Table 36** shows the locally-owned sample site summary and **Figure 51** shows a map of all sample sites.

Table 36. Michigan Locally-Owned Highway Sample Site Summary

Site Type		MDOT Region							Total
		Bay	Grand	Metro	North	Southwest	Superior	University	
Urban	Four-Lane with TWLTL Segments	3	3	3	0	3	1	3	**16**
	Four-Lane Divided Segments	3	3	3	0	3	0	3	**15**
	Four-Lane Undivided Segments	3	3	3	1	3	1	3	**17**
	Two-Lane with TWLTL Segments	3	3	3	3	3	3	3	**21**
	Two-Lane Undivided Segments	3	3	3	3	3	3	3	**21**
	Four-Leg Signalized Intersections	3	3	3	3	3	3	3	**21**
	Four-Leg Unsignalized Intersections	3	3	3	3	3	3	3	**21**
	Three-Leg Signalized Intersections	3	3	3	3	3	3	3	**21**
	Three-Leg Unsignalized Intersections	3	3	3	3	3	3	3	**21**
Rural	Two-Lane Undivided Segments	3	3	3	11	3	10	3	**36**
	Four-Leg Unsignalized Intersections	3	3	3	3	3	3	3	**21**
	Three-Leg Unsignalized Intersections	3	3	3	3	3	3	3	**21**
Total		**36**	**36**	**36**	**36**	**36**	**36**	**36**	**252**
Percentage		**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**14.3%**	**100.0%**

Given the sample of sites summarized in **Tables 35 and 36**, ten years of historical crash data were obtained (including the period from 2008-2017) from the annual databases maintained by the Michigan State Police (MSP). Crash records were assigned to segments based upon the Physical Road (PR) number and mile point included with each record according to the *Michigan Geographic Framework* (MGF) [*56*]. Crash records were assigned to intersections using a spatial analysis where records within 250 feet of each intersection were ultimately associated with that location. The total number of Ks and As occurring at each segment and intersection were aggregated and the top-20th percentile of sites was identified for each site type. **Tables 37-40** summarize the frequency of Ks and As for all segments, the top-20th percentile of segments, all intersections, and the top-20th percentile of intersections, respectively.

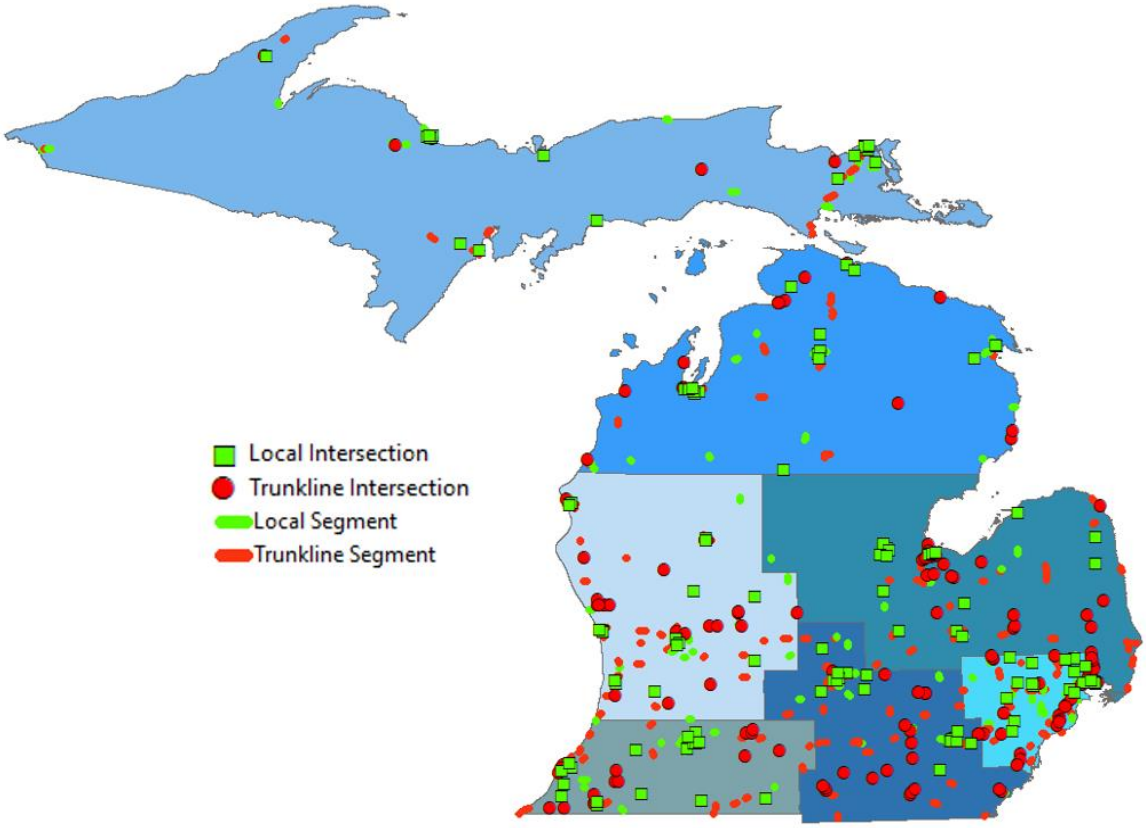


Figure 51. Map of Trunkline and Locally-Owned Highway Sample Sites

Table 37. Sample Highway Segment Fatalities (K) and Serious Injuries (A) (2008-2017)

Site Type			Miles	Fatalities (K)	Serious Injuries (A)	Total (K+A)	Total (K+A) per Mile per Year
Trunkline	Urban	Freeway Segments	47.1	10	48	58	0.123
		Four-Lane with TWLTL Segments	15.3	4	29	33	0.216
		Four-Lane Divided Segments	44.8	4	34	38	0.085
		Four-Lane Undivided Segments	16.7	5	8	13	0.078
		Two-Lane with TWLTL Segments	19.3	4	6	10	0.052
		Two-Lane Undivided Segments	32.2	7	35	42	0.130
	Rural	Freeway Segments	68.1	6	62	68	0.100
		Two-Lane Undivided Segments	49.3	9	25	34	0.069
All Trunkline Highways			**292.8**	**49**	**247**	**296**	**0.101**
Local	Urban	Four-Lane with TWLTL Segments	8.2	0	9	9	0.110
		Four-Lane Divided Segments	24.1	1	1	2	0.008
		Four-Lane Undivided Segments	9.2	0	6	6	0.065
		Two-Lane with TWLTL Segments	13.5	1	5	6	0.044
		Two-Lane Undivided Segments	14.5	2	8	10	0.069
	Rural	Two-Lane Undivided Segments	47.6	3	14	17	0.036
All Local Agency Highways			**117.1**	**7**	**43**	**50**	**0.043**

Table 38. Sample Top-20th Percentile - Highway Segment Fatalities (K) and Serious Injuries (A) (2008-2017)

Site Type			Miles	Fatalities (K)	Serious Injuries (A)	Total (K+A)	Total (K+A) per Mile per year
Trunkline	**Urban**	Freeway Segments	11.3	4	24	28	0.248
		Four-Lane with TWLTL Segments	3.3	3	11	14	0.431
		Four-Lane Divided Segments	10.9	1	21	22	0.202
		Four-Lane Undivided Segments	4.2	4	6	10	0.241
		Two-Lane with TWLTL Segments	5.8	2	5	7	0.120
		Two-Lane Undivided Segments	8.8	5	26	31	0.351
	Rural	Freeway Segments	17.0	2	35	37	0.217
		Two-Lane Undivided Segments	13.4	4	18	22	0.164
Top-20th Percentile Trunkline Highways			**74.7**	**25**	**146**	**171**	**0.229**
Local	**Urban**	Four-Lane with TWLTL Segments	2.8	0	6	6	0.213
		Four-Lane Divided Segments	5.1	1	1	2	0.039
		Four-Lane Undivided Segments	3.4	0	6	6	0.175
		Two-Lane with TWLTL Segments	3.5	0	5	5	0.143
		Two-Lane Undivided Segments	5.0	2	8	10	0.198
	Rural	Two-Lane Undivided Segments	10.9	2	13	15	0.138
Top-20th Percentile Local Agency Highways			**30.8**	**5**	**39**	**44**	**0.143**

Table 39. Sample Highway Intersection Fatalities (K) and Serious Injuries (A) (2008-2017)

Site Type			Intersections	Fatalities (K)	Serious Injuries (A)	Total (K+A)	Total (K+A) per Intersection per year
Trunkline	Urban	Four-Leg Signalized Intersections	25	9	65	74	0.296
		Four-Leg Unsignalized Intersections	25	3	24	27	0.108
		Three-Leg Signalized Intersections	23	0	33	33	0.143
		Three-Leg Unsignalized Intersections	25	1	16	17	0.068
	Rural	Four-Leg Unsignalized Intersections	25	1	20	21	0.084
		Three-Leg Unsignalized Intersections	27	1	9	10	0.037
All Trunkline Intersections			**150**	**15**	**167**	**182**	**0.121**
Local	Urban	Four-Leg Signalized Intersections	21	2	24	26	0.124
		Four-Leg Unsignalized Intersections	21	2	7	9	0.043
		Three-Leg Signalized Intersections	21	0	23	23	0.110
		Three-Leg Unsignalized Intersections	21	1	5	6	0.029
	Rural	Four-Leg Unsignalized Intersections	21	2	28	30	0.143
		Three-Leg Unsignalized Intersections	21	1	4	5	0.024
All Local Intersections			**126**	**8**	**91**	**99**	**0.079**

Table 40. Sample Top-20th Percentile Highway Intersection Fatalities (K) and Serious Injuries (A) (2008-2017)

Site Type			Intersections	Fatalities (K)	Serious Injuries (A)	Total (K+A)	Total (K+A) per Intersection per Year
Trunkline	Urban	Four-Leg Signalized Intersections	5	4	31	35	0.700
		Four-Leg Unsignalized Intersections	5	3	18	21	0.420
		Three-Leg Signalized Intersections	5	0	19	19	0.380
		Three-Leg Unsignalized Intersections	5	1	11	12	0.240
	Rural	Four-Leg Unsignalized Intersections	5	1	14	15	0.300
		Three-Leg Unsignalized Intersections	5	1	8	9	0.180
Top-20th Percentile Trunkline Intersections			**30**	**10**	**101**	**111**	**0.370**
Local	Urban	Four-Leg Signalized Intersections	5	1	17	18	0.360
		Four-Leg Unsignalized Intersections	5	2	6	8	0.160
		Three-Leg Signalized Intersections	5	0	15	15	0.300
		Three-Leg Unsignalized Intersections	5	0	5	5	0.100
	Rural	Four-Leg Unsignalized Intersections	5	2	22	24	0.480
		Three-Leg Unsignalized Intersections	5	1	4	5	0.100
Top-20th Percentile Local Intersections			**30**	**6**	**69**	**75**	**0.250**

Given the rare and random nature of fatalities and serious injuries, it was important to blend together the frequency of such severe crashes occurring at each site. While ultimately distinct values for fatalities and serious injuries will be required to conduct the analysis for each site type, this blended approach was critical due to the limited sample size of sites included as a part of this study. The total Ks+As occurring for each site type were aggregated to determine the frequency occurring per mile per year (for segments) and per intersection per year (for intersections) in **Tables 37-40**. The proportion of Ks out of the combined Ks+As was determined for all trunkline intersections (8.2 percent), all trunkline segments (16.6 percent), all locally-owned intersections (8.1 percent) and all locally-owned segments (14.0 percent). These values were used to disaggregate the K+A values shown in **Tables 37-40** into distinct K and A values in **Table 41** (segments) and **Table 42** (intersections). It is important to note that distinct values were developed for the top-20th percentile of sites which will be used to evaluate treatments applied to "hot spot" locations (or where a treatment is being applied due to historical crash data demonstrating a potential safety concern) and the mean of all sample sites which will be used to evaluate treatments applied on a systemic basis (or where a treatment is being applied without consideration of historical crash data at a particular location).

Table 41. Sample Highway Segment Fatalities (K) and Serious Injuries (A) per Mile

Site Type			"Hot Spot" (Top 20%)		Systemic (Average)	
			Fatalities (K) per Mile	Serious Injuries (A) per Mile	Fatalities (K) per Mile	Serious Injuries (A) per Mile
Trunkline	Urban	Freeway Segments	0.041	0.207	0.020	0.103
		Four-Lane with TWLTL Segments	0.071	0.359	0.036	0.180
		Four-Lane Divided Segments	0.033	0.168	0.014	0.071
		Four-Lane Undivided Segments	0.040	0.201	0.013	0.065
		Two-Lane with TWLTL Segments	0.020	0.100	0.009	0.043
		Two-Lane Undivided Segments	0.058	0.293	0.022	0.109
	Rural	Freeway Segments	0.036	0.181	0.017	0.083
		Two-Lane Undivided Segments	0.027	0.137	0.011	0.058
All Trunkline Segments			**0.038**	**0.191**	**0.017**	**0.084**
Local	Urban	Four-Lane with TWLTL Segments	0.030	0.183	0.015	0.094
		Four-Lane Divided Segments	0.005	0.033	0.001	0.007
		Four-Lane Undivided Segments	0.024	0.150	0.009	0.056
		Two-Lane with TWLTL Segments	0.020	0.123	0.006	0.038
		Two-Lane Undivided Segments	0.028	0.170	0.010	0.059
	Rural	Two-Lane Undivided Segments	0.019	0.119	0.005	0.031
All Local Agency Segments			**0.020**	**0.123**	**0.006**	**0.037**

Table 42. Sample Highway Intersection Fatalities (K) and Serious Injuries (A) per Intersection

Site Type			"Hot Spot" (Top 20%)		Systemic (Average)	
			Fatalities (K) per Intersection	Serious Injuries (A) per Intersection	Fatalities (K) per Intersection	Serious Injuries (A) per Intersection
Trunkline	Urban	Four-Leg Signalized Intersections	0.058	0.642	0.024	0.272
		Four-Leg Unsignalized Intersections	0.035	0.385	0.009	0.099
		Three-Leg Signalized Intersections	0.031	0.349	0.012	0.132
		Three-Leg Unsignalized Intersections	0.020	0.220	0.006	0.062
	Rural	Four-Leg Unsignalized Intersections	0.025	0.275	0.007	0.077
		Three-Leg Unsignalized Intersections	0.015	0.165	0.003	0.034
All Trunkline Intersections			**0.030**	**0.340**	**0.010**	**0.111**
Local	Urban	Four-Leg Signalized Intersections	0.029	0.331	0.010	0.114
		Four-Leg Unsignalized Intersections	0.013	0.147	0.003	0.039
		Three-Leg Signalized Intersections	0.024	0.276	0.009	0.101
		Three-Leg Unsignalized Intersections	0.008	0.092	0.002	0.026
	Rural	Four-Leg Unsignalized Intersections	0.039	0.441	0.012	0.131
		Three-Leg Unsignalized Intersections	0.008	0.092	0.002	0.022
All Local Intersections			**0.020**	**0.230**	**0.006**	**0.072**

4.4 Estimate of Annual Reductions in Fatalities and Serious Injuries

After the estimate of projects which could be implemented in a typical year was developed in **Tables 32 and 33**, as well as the estimates for K and A frequency for each site type in **Tables 41 and 42,** annual reductions in Ks and As could be calculated.

4.4.1 Crash Reduction Factors

This process required the identification of crash reduction factors (CRF) for each treatment group which defines the percentage of Ks and As predicted to be reduced after implementation. It is important to note that many of the CRFs available in prior research are not specific to K and A crashes and may apply to total crashes or all fatal and all injury crashes (K+A+B+C according to the KABCO scale), representing a potential limitation to this evaluation. The most applicable CRF was obtained from the available research with priority given to CRFs which were specific to fatal and all injury crashes if no K+A CRF was available. CRFs were obtained from the MDOT Time of Return Form [*57*] or the MDOT HSM Spreadsheet [*58*] first if an appropriate value was available, then from the FHWA CMF Clearinghouse [*59*] or other published research if no Michigan-specific value was available. In cases where multiple CRFs applied to one treatment group (such as the installation of exclusive right-turn or left-turn lanes at intersections), an average value was developed. In cases where multiple CRFs applied to one single treatment, the most conservative value was applied. Finally, there were instances were no CRFs available which were specific to one of the treatment groups (such was the "Unknown, Other or Miscellaneous category"), a conservative value of one or five percent was applied using engineering judgement.

4.4.2 Annual Reductions in Fatalities and Serious Injuries

The estimate for the number of "hot spot" and systemic projects (**Tables 32 and 33**) were combined with the CRFs identified (per **Section 4.4.1**) as well as the sample of Michigan segments and intersections (**Tables 41 and 42**) to determine the number of fatalities and serious injuries which would be reduced annually with implementation of HSIP projects. **Table 43** summarizes annual reductions in Ks and As along the trunkline network for both the Michigan distribution of projects as well as top-performing Midwestern peer states and **Table 44** summarizes the annual reductions along the locally-owned highway network. The last row in each table provides the total annual reductions in Ks and As for each network. The CRFs identified for each treatment are also provided in both **Table 43 and 44**.

Table 43. Summary of Trunkline Annual Reductions in Fatalities and Serious Injuries

Treatment	Crash Reduction Factor	Michigan		Peer States	
		Fatalities (K)	Serious Injuries (A)	Fatalities (K)	Serious Injuries (A)
Access Management	15%	0.000	0.000	0.003	0.016
Add Travel Lanes	5%	0.000	0.000	0.001	0.006
Add Turn Lanes	12%	0.006	0.066	0.001	0.014
Add TWLTL	20%	0.026	0.133	0.007	0.034
Barrier	55%	0.046	0.234	0.328	1.655
Cable Barrier	33%	0.265	1.336	0.736	3.708
Curve Warning	20%	0.000	0.000	0.044	0.221
Delineation	20%	1.535	7.738	0.265	1.334
Fixed Object Removal	38%	0.017	0.086	0.017	0.086
High Friction Surface Treatments	20%	0.007	0.037	0.023	0.118
Horizontal Alignment	30%	0.000	0.000	0.004	0.021
Interchange Improvement	18%	0.000	0.001	0.003	0.032
Intersection Geometrics	18%	0.004	0.045	0.018	0.204
ITS	5%	0.000	0.000	0.002	0.008
Lighting	5%	0.000	0.000	0.020	0.218
Pavement Markings	1%	1.193	6.013	0.016	0.079
Pedestrian	5%	0.006	0.048	0.027	0.201
Roadside Improvements	15%	0.000	0.000	0.000	0.002
Roundabouts	78%	0.020	0.222	0.020	0.225
Rumble Strips	32%	0.000	0.000	0.727	3.663
Shoulder Treatments	15%	0.003	0.016	0.028	0.142
Sign Upgrades	5%	0.041	0.318	0.932	7.072
Signal Timing	10%	0.000	0.000	0.014	0.151
Superelevation	30%	0.004	0.020	0.000	0.000
Systemic Signal Improvements	10%	0.006	0.063	0.002	0.026
Traffic Signal Improvements	10%	0.006	0.069	0.023	0.253
Widen Shoulder	5%	0.000	0.000	0.007	0.034
Wrong Way Treatments	5%	0.001	0.006	0.002	0.019
Unknown/Other/Misc.	5%	0.002	0.018	0.015	0.114
Total for All Treatments	**-**	**3.190**	**16.469**	**3.284**	**19.656**

Table 44. Summary of Local Agency Annual Fatality and Serious Injury Reductions

Treatment	Crash Reduction Factor	Michigan		Peer States	
		Fatalities (K)	Serious Injuries (A)	Fatalities (K)	Serious Injuries (A)
Add Travel Lanes	5%	0.002	0.012	0.000	0.000
Add Turn Lanes	12%	0.006	0.069	0.003	0.029
Advance Warning	20%	0.000	0.000	0.061	0.696
Barrier	55%	0.220	1.354	0.008	0.048
Curve Warning	20%	0.020	0.123	0.273	1.679
Delineation	20%	0.000	0.000	0.061	0.374
Fixed Object Removal	38%	0.266	1.636	0.008	0.050
High Friction Surface Treatments	20%	0.002	0.014	0.002	0.014
Horizontal Alignment	30%	0.001	0.009	0.002	0.011
Intersection Flashers	20%	0.014	0.154	0.000	0.000
Intersection Geometrics	18%	0.007	0.083	0.005	0.056
Intersection Warning System	26%	0.000	0.000	0.011	0.130
ITS	5%	0.000	0.000	0.000	0.001
Lighting	5%	0.001	0.010	0.028	0.323
Pavement Markings	1%	0.002	0.013	0.208	1.276
Pedestrian	5%	0.002	0.021	0.035	0.300
Roadside Improvements	15%	0.000	0.003	0.000	0.000
Roadway Reconfiguration	30%	0.008	0.048	0.003	0.017
Roundabouts	78%	0.007	0.075	0.011	0.120
Rumble Strips	32%	0.601	3.693	1.256	7.714
Shoulder Treatments	15%	0.000	0.000	0.022	0.133
Sign Upgrades	5%	0.083	0.727	0.251	2.204
Signal Timing	10%	0.002	0.019	0.012	0.139
Superelevation	30%	0.001	0.005	0.000	0.000
Systemic Signal Improvements	10%	0.039	0.443	0.000	0.000
Traffic Signal Improvements	10%	0.034	0.391	0.022	0.245
Unknown/Other/Misc.	5%	0.006	0.053	0.002	0.020
Vertical Alignment	20%	0.004	0.026	0.000	0.000
Widen Lanes	5%	0.000	0.002	0.000	0.000
Widen Shoulder	5%	0.005	0.031	0.009	0.053
Total for All Treatments	**-**	**1.335**	**9.014**	**2.292**	**15.633**

While **Tables 43 and 44** provide the predicted annual reductions in Ks and As given the existing funding levels, it was also necessary to extrapolate these totals if current funding levels were increased. **Table 45** summarizes annual fatality and serious injury reductions along both the trunkline and locally-owned highway networks assuming Michigan's current distribution of projects as well as the distribution applied by top-performing Midwestern peer states. The total annual predicted reductions are also provided for Michigan's highway network as whole (or the summation of trunkline and local highways) with funding levels ranging from the existing spending up to a 120 percent increase in annual funding.

Table 45. Summary of Annual Fatality (K) and Serious Injury (A) Reductions by Funding Level

Funding Level	Michigan						Top-Performing Peer States					
	Trunkline		Local		All Highways		Trunkline		Local		All Highways	
	K	A	K	A	K	A	K	A	K	A	K	A
Existing Funding	3.190	16.469	1.335	9.014	**4.525**	**25.483**	3.284	19.656	2.292	15.633	**5.576**	**35.289**
20% Increase	3.828	19.763	1.602	10.816	**5.430**	**30.579**	3.940	23.587	2.750	18.760	**6.691**	**42.347**
40% Increase	4.466	23.057	1.869	12.619	**6.335**	**35.676**	4.597	27.518	3.209	21.887	**7.806**	**49.404**
60% Increase	5.104	26.351	2.136	14.422	**7.240**	**40.772**	5.254	31.449	3.629	24.769	**8.883**	**56.218**
80% Increase	5.742	29.645	2.403	16.224	**8.145**	**45.869**	5.911	35.380	4.125	28.140	**10.036**	**63.520**
100% Increase	6.380	32.938	2.670	18.027	**9.050**	**50.965**	6.567	39.311	4.584	31.267	**11.151**	**70.578**
120% Increase	7.018	36.232	2.937	19.830	**9.955**	**56.062**	7.224	43.242	5.042	34.393	**12.266**	**77.636**

4.5. Summary of Results

Given the annual predicted fatality and serious injury reductions presented in **Table 45**, additional analyses were conducted to determine when the short-term goals from the SHSP would be met. The historical statewide five-year rolling averages of fatalities and serious injuries presented in **Section 3.0** were identified and the most recent five-year period (2013-2017) was used the baseline. **Figure 52** shows the time to reach the short-term fatality goal of less than 967 fatalities given the baseline of 976.4 fatalities at existing funding levels for both the Michigan (shown in red) and peer state (shown in blue) distribution of projects. It is important to note that this analysis relies upon the assumption that the baseline of 976.4 fatalities would continue annually with no treatments (or there would be no underlying structural changes such as no significant change in statewide annual travel). Additionally, this evaluation is based upon 2017 being the first year of the analysis and treatments are applied at the beginning of each subsequent year which reflect either the Michigan or top-performing peer state distribution.

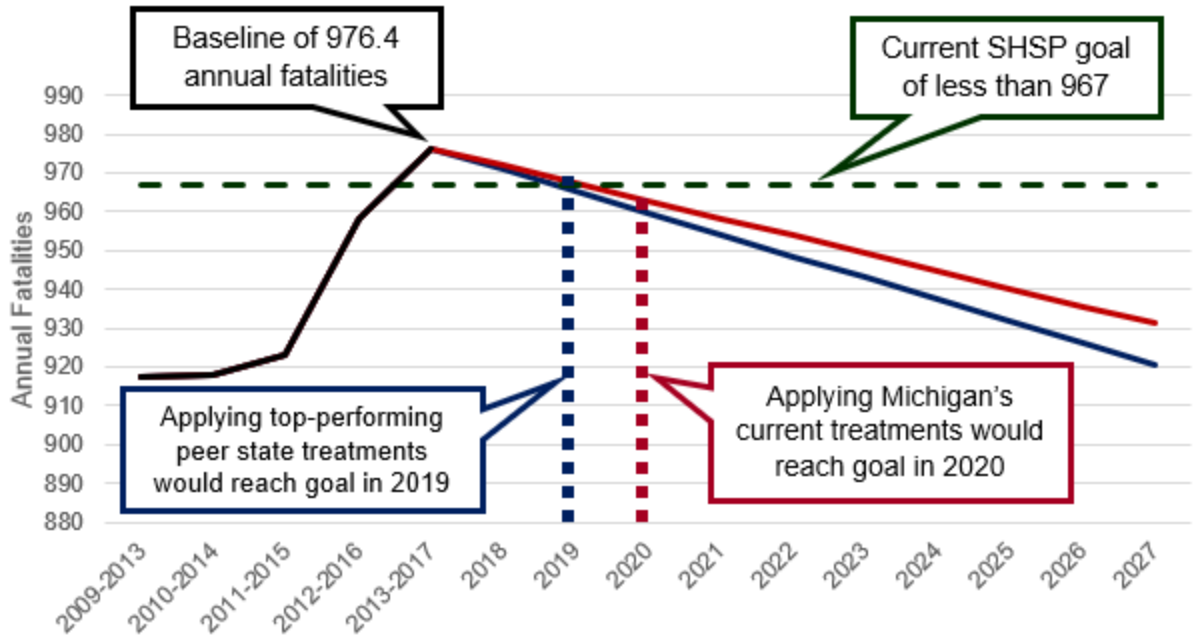


Figure 52. Annual Predicted Fatalities with Existing Funding Levels

Given the existing funding levels, it is predicted that the application of Michigan's current treatment strategy would reach the fatality goal in 2020, while using the top-performing peer states treatment strategy which achieves slightly larger annual reductions in fatalities would reach the goal in 2019. **Figure 53** shows the time to reach the short-term fatality goal if funding levels were increased to 120 percent of their current level.

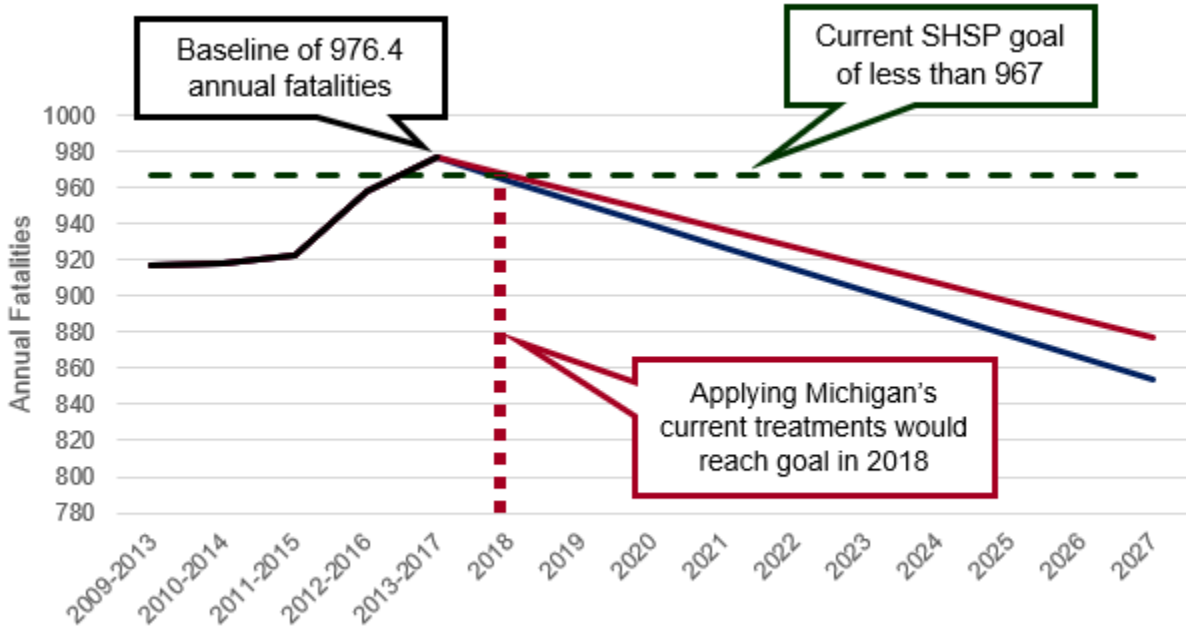


Figure 53. Annual Predicted Fatalities with 120-Percent Increase in Funding Levels

Figure 53 demonstrates that the short-term fatality goal in the SHSP would be met by 2018 with a 120-percent increase in funding using either Michigan's current distribution of projects or top-performing peer states distribution of projects. Results for serious injuries are presented in **Figure 54** (for existing funding levels) and **Figure 55** (for a 120-percent increase in funding). The results are less favorable for serious injuries with Michigan's treatment strategy expected to reach the goal of less than 4,600 annually by 2047 with existing funding and 2031 with a 120-percent increase. This largely reflects the aggressive goal in the SHSP for serious injuries – while the fatality goal represented an approximate 1 percent reduction, the serious injury goal represented an approximate 14.1 percent reduction.

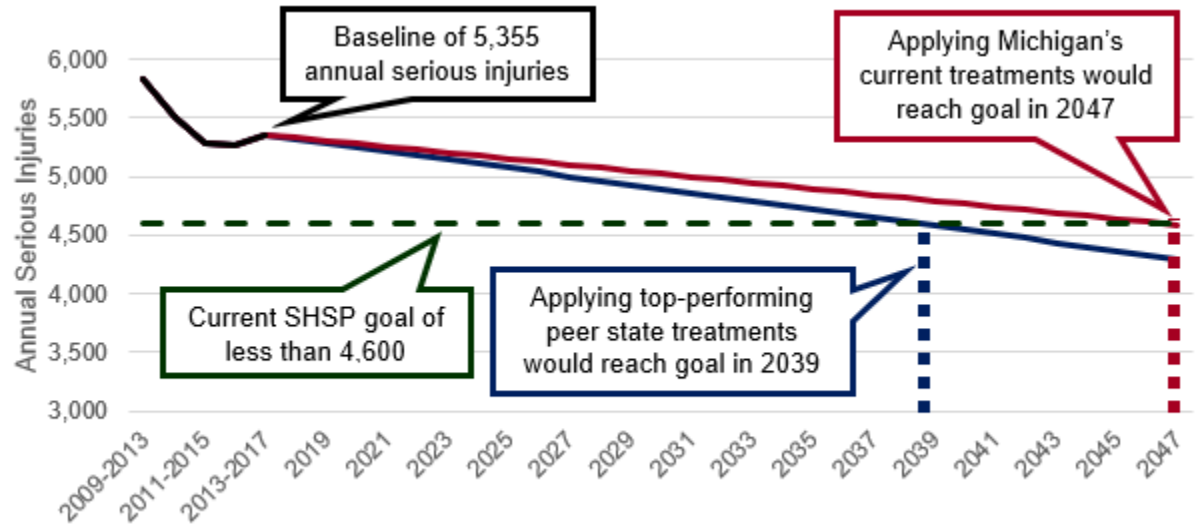


Figure 54. Annual Predicted Serious Injuries (A) with Existing Funding Levels

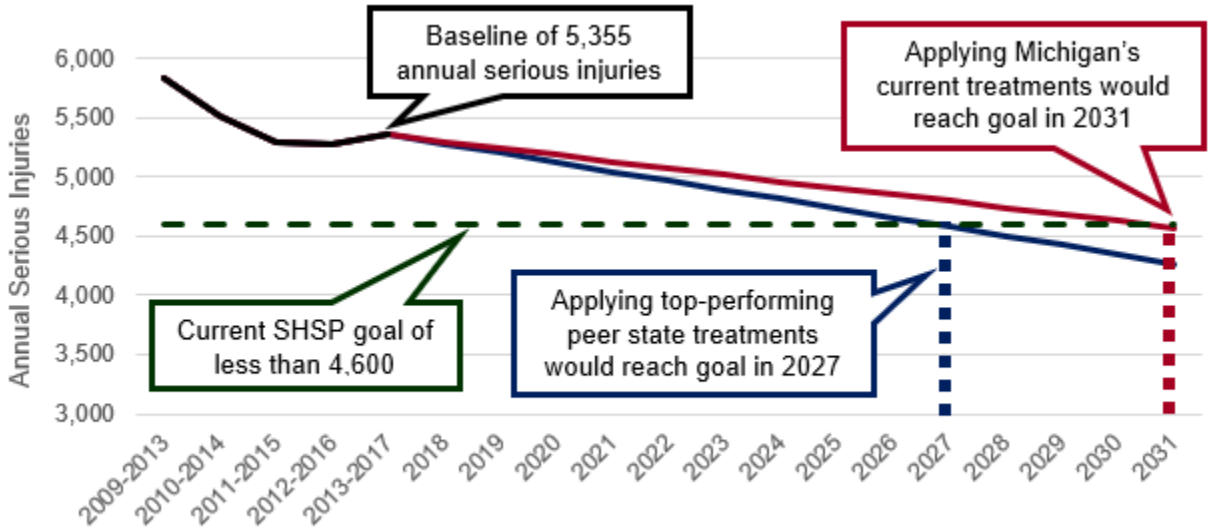


Figure 55. Annual Predicted Serious Injuries (A) with 120-Percent Increase in Funding Levels

5.0 RECOMMENDATIONS

Transportation System Management and Operations (TSMO) is an emerging concept being adopted by highway agencies across the United States. While the concept is currently defined very broadly depending on the objectives of the agency, TSMO represents one of the front-lines of the transportation system that is most visible and noticeable to the traveling public [*1*]. Given the limited financial resources and increasing demands for transportation improvements, TSMO integration into the core mission of state departments of transportation can yield significant benefits to both mobility and safety [*3*]. The Michigan Department of Transportation (MDOT) is one such state DOT which has embraced the potential of TSMO, recently developing a *TSMO Implementation and Strategic Plan* [*4*]. Within the strategic plan, MDOT established a TSMO mission statement of operating and managing an optimized, integrated transportation network by delivering high-quality services for the safe and reliable mobility of all users [*4*].

In order to make progress towards this mission, MDOT sponsored this assessment into the feasibility and traffic safety impacts associated with further implementing TSMO across the department. The intent of this study was to provide important guidance to allow MDOT to make informed decisions as to potential changes to the internal management structure of the systems and operations divisions. Within this framework, MDOT identified three specific objectives:

1. Perform a comprehensive literature review on TSMO conversions within state DOTs and contact select state DOTs that have converted or are considering TSMO conversion.
2. Research and identify the relationship between safety funding levels and traffic deaths per VMT in peer states.
3. Perform a predictive analysis to determine how much funding levels need to increase in order to reach safety goals identified in latest SHSP.

Table 46 summarizes the TSMO related recommendations developed by the research team for MDOT to consider. These recommendations were formulated by aggregating key findings from the review of TSMO in the United States presented in **Section 2.0**, the evaluation of the relationship between funding levels and safety performance presented in **Section 3.0**, and finally the estimate of funding levels required to reach the state's current safety goals presented in **Section 4.0.** A brief description of each recommendation is provided along with the location of where more detail can be obtained in the report.

Table 46. Summary of TSMO Related Recommendations for MDOT to Consider

TSMO Recommendation	Description	Report Section
Continue development and further updates to MDOT's *TSMO Implementation and Strategic Plan*	Currently in its third iteration, MDOT's plan represents the departments formal effort to document TSMO implementation efforts. Future iterations of the plan should include recommendations developed by each of the business areas and commonality area groups which were not ready for inclusion as a part of the third version. Additionally, as stated in Section 7 of the plan, maintenance of the plan and action items should be continued as these were intended to be "living documents". Findings from this report, specifically best practices identified from other States identified in **Section 2.0** of this report, should be considered when developing future iterations of MDOT's TSMO plan.	2.3.1
Continue application of the Capability Maturity Model (CMM)	MDOT's TSMO plan is founded upon the CMM, beginning with the 2013 CMM workshop and continuing with MDOT's 2018 CMM reassessment. This process represents a core component of the TSMO effort and is based upon the national guidance developed for TSMO integration. Similar efforts should continue as the department further implements TSMO concepts into agency activities.	2.2.1
Consider regional meetings or workshops similar to the regional operations forums conducted by the California Department of Transportation (Caltrans)	Caltrans conducted regional operations forums (ROFs) to provide an opportunity for staff and local partners to share TSMO experiences and strategies – as well as conducting CMM self-assessments – which were specific to each district [*22*]. Similar meetings or workshops at the region-level within MDOT may be beneficial.	2.3.3 (California)
Consider the implementation of TSMO evaluations for projects similar to the process developed by the Colorado Department of Transportation (CDOT)	An important component of CDOT's TMSO program are the TSMO evaluations conducted as a part of all new projects. The evaluation consists of a safety assessment, an operations assessment and an ITS assessment which are ultimately aggregated to make recommendations to the project team to improve safety and mobility [*25*]. A similar process could be developed by MDOT as a part of TSMO implementation.	2.3.3 (Colorado)
Fund additional TSMO research related to specific aspects of the TSMO program similar to projects funded by the Florida Department of Transportation (FDOT)	While this report represents an investment by MDOT in developing research specific to its TSMO program, FDOT has recently funded research related to specific aspects of the its TSMO program [*28, 29*]. As MDOT continues to develop its TSMO plan and integrate functions into agency activities, specific elements may be identified which could benefit from additional research. Sponsoring such projects may identify opportunities not well addressed by existing literature or best practice examples.	2.3.3 (Florida)

TSMO Recommendation	Description	Report Section
Consider the development of "Service Layer" plans such as those developed by the Iowa Department of Transportation (Iowa DOT)	Several state DOTs, including the work notably conducted by Iowa DOT, have developed separate service layer plans which provide additional detailed recommendations and actions specific to distinct service areas of TSMO. MDOT could consider the development of such service layer plans as a part of future iterations of its TSMO plan.	2.3.3 (Iowa)
Ensure that MDOT's TSMO plan provides a framework to implement TSMO functions identified in this report	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 52 categories of potential TSMO functions. It is important that the framework for TSMO developed by MDOT allows for the implementation of as many of these functions as possible given the potential benefits.	2.5.1
Consider the TSMO divisional structures and funding mechanisms implemented by other agencies	A variety of divisional structures and funding mechanisms have been implemented with success by state DOTs which have allowed for the integration of TSMO functions within agency activities. These best practices should be considered as MDOT is evaluating changes to its division structure and funding templates as a part of TSMO integration.	2.5.2
Ensure that MDOT's TSMO plan provides a framework to maximize the potential benefits of TSMO	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 31 categories of potential TSMO benefits. It is important that the framework for TSMO developed by MDOT allows for the maximization of the potential benefits which can be derived from TSMO implementation.	2.5.3
Ensure that MDOT's TSMO plan provides a framework to address the potential limitations of TSMO	As a part of the review of national and state TSMO materials, as well as interviews conducted with other state DOT TSMO staff, the research team identified 34 categories of potential limitations for TSMO. It is important that the framework for TSMO developed by MDOT attempts to address as many of these potential limitations as possible.	2.5.4
Seek opportunities to increase the level of safety funding and/or consider shifting safety funding priorities to align with top performing peer states.	Given the potential relationship between historical safety funding and recent progress in safety performance, an important consideration as MDOT evaluates changes to funding templates is to seek additional funding sources for safety-related engineering improvements for highway infrastructure. The TSMO implementation process represents a key opening to address this consideration as projects developed via non-safety related funding templates may offer opportunities to implement engineering countermeasures to improve highway safety performance.	3.0 – 4.0

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APPENDICES

- **Appendix A – State DOT TSMO Interview Questionnaire**
- **Appendix B – State DOT Interviews with TSMO Personnel**
- **Appendix C – State Funding and Safety Performance Data**

Appendix A – State DOT TSMO Interview Questionnaire

OVERALL THEME: How has TSMO impacted traffic safety within DOTs that have implemented TSMO?

1. What functions/divisions are included in your agency's TSMO structure?
    a. How were your affected divisions structured before the switch (provide org chart)
    b. How are your affected divisions structured after the switch to TSMO (provide org chart)
2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?
    a. Traffic Safety (HSIP, Signing and Marking)
    b. ITS
    c. Operations
    d. Signals
    e. CMAQ
    f. Maintenance
    g. Others?
3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?
4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,
    a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?
    b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?
    c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?
5. Were there challenges to incorporating TSMO into your organization?
    a. If yes, what challenges?
    b. What made the transition easier?
    c. How was the staffing and administrative transition handled?
    d. Do you have any advice on implementation of TSMO for another state agency?
6. How has TSMO changed the function of your organization?
    a. What improvements have been made vs. the prior divisional structure?
    b. What problems still linger?
7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
8. Along those lines, do you have any supporting documentation from your state's experience?

Appendix B – State DOT Interviews with TSMO Personnel

Alabama DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

    - **Congestion management**
    - **Traffic incident management**
    - **Smart work zones**

    a. How were your affected divisions structured before the switch (provide org chart)

        - **Traffic management center and service patrol**

    b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

    a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

    b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

    c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

    a. If yes, what challenges?

        - **Understanding the need for TSMO and managing the system that they have as opposed to thinking that they need to add lanes. Some folks are not buying into various TSMO strategies (hard shoulders, ramp metering).**

    b. What made the transition easier?

        - **Implemented TSMO regionally, one at a time. TMCs transitioned into 24/7 operation.**

c. How was the staffing and administrative transition handled?

- **Implemented TSMO regionally, one at a time. TMCs transitioned into 24/7 operation.**

d. Do you have any advice on implementation of TSMO for another state agency?

- **Put forth the effort to do good collaboration with other stakeholder agencies in your area (MPOs); educate upper management, and get a good staff trained.**

6. How has TSMO changed the function of your organization?

a. What improvements have been made vs. the prior divisional structure?

- **Cultural shift within the organization. Folks seem to understand the benefits of congestion management and 24/7 operations. Has made it easier to get funding allocated.**

b. What problems still linger?

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).

8. Along those lines, do you have any supporting documentation from your state's experience?

Arizona DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

- **ADOT about 3 years ago went to a division within the agency…. 7 groups underneath the TSMO division. TSMO division has $32 million in funding:**
  - **i. Systems Technology (emerging tech, system performance, ITS ops)**
  - **ii. System Maintenance (Signal ops, ITS maintenance, lighting)**
  - **iii. Operations and Traffic and Safety (regional traffic engineers, RSA, SHSP, HSIP, data)**
  - **iv. Traffic maintenance (statewide signing and striping)**
  - **v. Traffic management (TOCs, TIM, emergency management)**
  - **vi. Systems Management**
  - **vii. Business administration**

a. How were your affected divisions structured before the switch (provide org chart)

- **Intermodal transportation division was disassembled and TSMO was created mostly from that that**
- **IDO - infrastructure delivery and operations**

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

    a. Traffic Safety) - **Yes - they use HSIP funds for a variety of items.**
    b. ITS - **Yes**
    c. Operations - **Yes (wrong way driving pilot was an example)**
    d. Signals - **Yes**
    e. CMAQ - **Yes**
    f. Maintenance - **No**
    g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

    - **Yes. With TSMO being its own division, there are benefits in that the TSMO director sits at the table with the DOT director and is able to advocate for projects and funding that fit the TSMO themes. Technology is a huge element for TSMO.**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,
    a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

        - **Yes, using Safety Analyst to do performance measures analysis across all TSMO projects. AZDOT is looking at adding key performance measures on system health (not just safety related).**

    b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

        - **Will try to look at ways to utilized HSIP funds to help operations. Work zones for example.**

    c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?
    a. If yes, what challenges?

        - **3 years ago, nobody even knew what TSMO was. Very rare to restructure an agency by creating a new division. It takes time to change the culture and get people to buy in to what TSMO is. It was a challenge to get TSMO into the 5 year plan. Educating both internally and externally.**

    b. What made the transition easier?

- **Getting high level buy in from the director. Getting the state engineer involved.**

c. How was the staffing and administrative transition handled?

- **Added 2 FTEs, including TSMO director. Brent was previously the deputy state engineer for traffic operations at AZDOT.**

d. Do you have any advice on implementation of TSMO for another state agency

- **Be sure to take advantage of gathering information with peers from other states that have made the change (including AZDOT).**

6. How has TSMO changed the function of your organization?

a. What improvements have been made vs. the prior divisional structure?

- **Technology, state of art/practice especially with autonomous vehicles has really taken off.**

b. What problems still linger?

- **Mostly just making tweaks to the program….what can they do better?**

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).

8. Along those lines, do you have any supporting documentation from your state's experience?

Florida DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

- **Traffic Engineering (central office)**
- **Traffic Operations (districts)**

a. How were your affected divisions structured before the switch (provide org chart)

- **ITS section was all freeway management in the prior structure**
- **Operations section was all arterials (signals) in the prior structure**

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

- **Arterial management was now brought under ITS, so it includes freeway and arterials**

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

- **FDOT has a state safety office that does not fall under traffic engineering.**

a. Traffic Safety (HSIP, Signing and Marking) - **No**

b. ITS - **Yes**

c. Operations - **Yes**

d. Signals - **Yes**

e. CMAQ - **No**

f. Maintenance - **No**

g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

   a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?
   b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?
   c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

   a. If yes, what challenges?

      - **Position descriptions changed; Locations changed;**

   b. What made the transition easier?

      - **Buy in from the top (chief engineer, secretary)**

   c. How was the staffing and administrative transition handled?

   d. Do you have any advice on implementation of TSMO for another state agency

      - **Have regular (Monthly) progress updates with each district regarding the program plan progress.**

6. How has TSMO changed the function of your organization?

   a. What improvements have been made vs. the prior divisional structure?

      - **Arterial management has improved. DOT is more actively involved with signal management vs. just the local agencies managing them. More funding now available for arterial management and signal improvements.**

b. What problems still linger?

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
8. Along those lines, do you have any supporting documentation from your state's experience?

Iowa DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

- **Iowa did not make any structural changes. TSMO was created as a part of the traffic operations office under the operations bureau (under the highway division). They restructured one position (retirement) to be a TSMO office director (Donna). This position is also AV and ITS involved. In one of the 6 district offices, a TSMO coordinator was created. The other offices are also looking into adding a TSMO officer.**
- **Functions: Statewide TMC (Ankeny covers the whole state), service patrol, incident management, emergency management, 511, traffic incident management, smart work zone initiative, TMC, ITS (new install and maintenance).**
- **24 TSMO related items to address agency wide were identified last year…have addressed about half of them.**
- **They have a strategic plan, program plan (2016), and three service layer plans have just been finished (but don't have staffing): TIM, ITS, traveler information.**

   a. How were your affected divisions structured before the switch (provide org chart)

   b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

   a. Traffic Safety (HSIP, Signing and Marking) - **No**

   b. ITS - **Yes**

   c. Operations - **Yes**

   d. Signals - **Yes**

   e. CMAQ - **No**

   f. Maintenance - **No**

   g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

    a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

        - **No direct impact yet, but they are discussing HSIP funding for TSMO purposes.**

    b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

    c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

    a. If yes, what challenges?

        - **Yes, there were challenges. People think TSMO is the latest/greatest buzz word that will go away. They make an effort to NOT always refer to it as TSMO in meetings. They just call it "operations program". Another challenge is gaining mid level support. Getting the mid level areas to buy in is a challenge. They don't see how this affects them. Getting operational strategies into the early project development stages is also a challenge. Also work zone staging for operational improvements during the work zone staging. Work force development is a major focus….operations division staff does not have the correct skill sets.**

    b. What made the transition easier?

        - **They have a statewide TSMO steering committee with people from across the entire agency to help get a broad understanding across the agency. They also have a training and communications subcommittee that focuses on providing TSMO related training across various affected divisions. Buy in from the high level executives has been important.**

    c. How was the staffing and administrative transition handled?

        - **Added the TSMO manager as a part of the manager of the office of operations.**

    d. Do you have any advice on implementation of TSMO for another state agency

        - **Don't change structure first - put plan together then tweak the structure once you've figured things out. Make sure you have a plan together before you try to solve problems.**

6. How has TSMO changed the function of your organization?
    a. What improvements have been made vs. the prior divisional structure?
        - **TSMO has helped the DOT focus more. Aware of what staff is doing and why they're doing it. Seems to be invigoration/excitement for involved staff.**
    b. What problems still linger?
        - **Getting the right staffing…..working through the service layer plans….getting buy in from mid level staffing.**
7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
    - **National Operations Center of Excellence (NOCOE)**
8. Along those lines, do you have any supporting documentation from your state's experience?

Ohio DOT Response

1. What functions/divisions are included in your agency's TSMO structure?
    - **Don't have a TSMO division - Operations Division is the TSMO division….they decided to not rename it to "TSMO". They have a structure and program plan in place, but not a funded TSMO program**
        i. **Traffic Management**
        ii. **Traffic Operations**
        iii. **Aviation**
        iv. **Permits**
        v. **Traffic Management (was previously Emergency Operations)…this was a result of TSMO**
            1. **Weather management**
            2. **Emergency operations**
            3. **Traveler Information**
    - **TMC is centralized at ODOT**
        i. **Statewide TMC**
        ii. **http://tsmoatodot.com/timeline.html**
        iii. **Currently reorganizing (August 2017)**
        iv. **Each of the 12 districts has a TSMO coordinator**

a. How were your affected divisions structured before the switch (provide org chart)

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

- **TOAST - would be a new funding arm to include congestion and bottlenecks…this would be a funding program under TSMO. This will MIMIC the HSIP funding model for congestion and bottleneck hot spots.**

a. Traffic Safety (HSIP, Signing and Marking)

- **ODOT has discussed including TOAST and HSIP together.**

b. ITS

- **TSMO has definitely improved statewide ITS planning**

c. Operations

d. Signals

e. CMAQ

- **ODOT passes this onto the MPOs, but it had come into the conversation regarding including under TSMO**

f. Maintenance

g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

- **TSMO has definitely given more safety awareness and has brought it into once central conversation. Culture shift.**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?
    a. If yes, what challenges?
        - **Getting buy in from staff to realize they weren't going to have to change their day to day activities. Lack of funding.**
    b. What made the transition easier?
        - **Executive management buy-in. Chief engineer was sending the invitations. OVER communicated with everyone**.
    c. How was the staffing and administrative transition handled?
    d. Do you have any advice on implementation of TSMO for another state agency
        - **See 6b….need a champion at the top to provide clear communication with staff. Piggyback on the national conversation. Involving everyone throughout the decision making.**
6. How has TSMO changed the function of your organization?
    a. What improvements have been made vs. the prior divisional structure?
        - **Communications between the various DOT divisions has vastly improved. Cultural shift.**
    b. What problems still linger?
        - **Tug between new technologies vs. old technologies (Letting go of the old to make room for the new.) Districts operations have been a challenge….TSMO has been blended in and only one district has a full TSMO coordinator.**
7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
8. Along those lines, do you have any supporting documentation from your state's experience?

Oregon DOT Response

1. What functions/divisions are included in your agency's TSMO structure?
    - **Operations and ITS Division**
        - **Systems ITS**
        - **Traveler Info**
        - **Incident management**
        - **Dispatch operations**

- **Also, collaborate with signals and ramp metering**
- **Trying to figure out data sharing between safety and ITS is a result of TSMO (safety data is outdated, but robust…ITS data is recent but not as detailed)**

a. How were your affected divisions structured before the switch (provide org chart)

- **Remained the same, just been rebranded as "Systems Operations and ITS" added new positions (Traffic incident management coordinator position, for example.)**

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

   a. Traffic Safety (HSIP, Signing and Marking) - **No**

   b. ITS - **Yes**

   c. Operations - **Yes**

   d. Signals - **No**

   e. CMAQ - **No**

   f. Maintenance

   g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

   - **Traffic incident management program and training has increased awareness of safety related programs.**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

   a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

   b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

   c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

   a. If yes, what challenges?

- **Cultural….changing the old mentalities. Too new in the position**

b. What made the transition easier?

- **Upper management support has been strong**

c. How was the staffing and administrative transition handled? Do you have any advice on implementation of TSMO for another state agency?

6. How has TSMO changed the function of your organization?

a. What improvements have been made vs. the prior divisional structure?

- **Things have made it into the agency guidance document….3 of the 9 overall ODOT agency goals are (mobility, management, and coordination/communication/cooperation)**

b. What problems still linger?

- **Cultural mindset is the primary obstacle**

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).

8. Along those lines, do you have any supporting documentation from your state's experience?

Pennsylvania DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

- **Traffic ops/emerging tech (Doug)**
- **Arterial management and TTC (Doug)**
- **Incident and emergency management area (Other division)**

a. How were your affected divisions structured before the switch (provide org chart)

- **They are the same**

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

- **They are the same (see program plan)**

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

a. Traffic Safety (HSIP, Signing and Marking)

b. ITS

c. Operations

d. Signals

e. CMAQ

f. Maintenance

g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

   - **Capital grant funding carved out for TSMO ($5 M) annually and planning has to match the other $5 M ($10 M total annual funding) for fiber and conduit throughout the state to reduce congestion. This would never have happened without the TSMO structure. TSMO allowed for the conversation to be started amongst the various partners.**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

   - **Congestion first, but safety is considered as a secondary**

   - **Has had some effect on projects that prior to current admin would not have considered. Philadelphia area has an integrated corridor management, shoulder driving, signal coordination, etc. There has been a change towards considering the safety benefits.**

   a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

   b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

   c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

   a. If yes, what challenges?

      - **Aligning realistic delivery with finite human and financial resources.**

   b. What made the transition easier?

      - **Marketing**

   c. How was the staffing and administrative transition handled?

   d. Do you have any advice on implementation of TSMO for another state agency? Marketing to the Org chart folks…. and get MPOs/RPCs on board

6. How has TSMO changed the function of your organization?
    - **CMM - They aren't there yet. Goal for program plan is level 3. At level 1.5-2. They will be at a level 3 if they can get the actions in order.**
        a. What improvements have been made vs. the prior divisional structure?
        b. What problems still linger?
7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
    - **PennDOT is a leader and is constantly queried by other states. They are getting pulled into the national conversation quite frequently.**
8. Along those lines, do you have any supporting documentation from your state's experience?
    - **Pennsylvania has program plan with 93 action items and strategic framework**
    - **TSMO shouldn't be a new "silo", but should be more of the vision/mission of the department itself. Essentially the way to do business as a department.**
    - **Planning, design, construction and maintenance don't like the term.**
    - **Slogan: Addressing reliability mobility congestion by using strategies rather than just trying to build our way out.**
    - **Vision: Less congested more reliable network.**
    - **Mission: Moving people and goods from A to B safety, efficiently, and reliably**
    - **Basically anyone on the congestion pie chart is under TSMO: incident management, signals, work zones. They do a rebalancing each year to try to make sure the TSMO is calibrated correctly.**
    - **Highway Safety and Traffic Operations**
        - **Primary TSMO:**
            - **Traffic operations and emerging technology**
            - **Arterial management and TTC**
        - **Secondary TSMO:**
            - **Traffic engineering**
            - **Highway safety**
    - **Formulated the TSMO plan with the regions, broke into six groups and had facilitators help scope the plan.**
    - **Used CMM to develop action items and develop program plan**

- **Including MPOs/RPCs in the process…. if they are on board, then the planning partners will do it (TIPs/Long Range plans).**
- **Preparing for a TSMO Guidebook series (Part 1 - Planning Regional Operations Plans; Part 5 - Operations, Design, Maintenance are in the work)**
- **Ensure performance metrics that paint a picture.**

Tennessee DOT Response

1. What functions/divisions are included in your agency's TSMO structure?
    - **Assistant Chief of Operations, who oversees**
        - **Traffic Operations Division - this is the TSMO**
            - **Transportation Management Office (oversees the TMC and incident management programs, and traveler information services)**
            - **ITS Office**
            - **Traffic Engineering Office (analysis, safety, lighting, signing and marking, work zones)**
        - **Regions**
        - **Maintenance Division**
        - **Safety Division**
        - **Construction**
        - **M&T Division**
        - **Note: Strategic Transportation Investment Division - Safety programs (HSIP) falls OUTSIDE of the Traffic Operations Division**
        - **Occupational Health and Safety Division - also include work zones (worker safety)**
    - **Traffic operations program plan represents TSMO plan**
        - **Headquarters level division**
        - **Each region has a regional operations director who oversees incident management and TMCs**
        - **Central office more involved with policy and guideline development**

    a. How were your affected divisions structured before the switch (provide org chart)

- **Changed form of the traffic operations division. Prior the traffic operations office was under the maintenance division. ITS and signals was in the design division. Transportation management was called office of incident management.**

b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

   a. Traffic Safety (HSIP, Signing and Marking)

      - **HSIP does not fall under the Traffic Operations**
      - **HSIP funds are used to support operational endeavors, - moneys were used to build TIM training center and to perform the TIM training.**

   b. ITS

      - **All TMCs have been made 24/7**

   c. Operations

      - **Yes**

   d. Signals

      - **TnDOT does not operate signals….purely local**

   e. CMAQ

      - **Yes**

   f. Maintenance

      - **No**

   g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

      - **To some degree….wrong-way pilot projects**
      - **Safety has been spread across the bureau**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

   a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?
c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

    a. If yes, what challenges?

        - **Decentralized has created issues with program consistency and TSMO vision. Getting everyone on the same page at the region level. Regions have for years simply thought about the TMCs and did not ever have a centralized division that the regions report to. Trying to break through the region dynamic at the central office has been a challenge.**

    b. What made the transition easier?

        - **Have had a lot of buy in from the top. The Chief engineer provides support and makes things happen. Still changing culture, getting beyond the traditional mentality and more on the systems operation.**

    c. How was the staffing and administrative transition handled?

        - **Started at 0, so finding the right people has been a challenge and now has 40 FTEs.**

    d. Do you have any advice on implementation of TSMO for another state agency?

        - **Took some offices that were already in existence (traffic engineering, which used to be in maintenance, ITS office was brought over, TIM office and added positions). They had the buy in, laid out organization chart, number of positions, and built from there. They did have a clean slate and had buy in from the top down to do this.**

6. How has TSMO changed the function of your organization?

    a. What improvements have been made vs. the prior divisional structure?

        - **It has really helped for collaboration with other stakeholders (DPS/highway patrol, local partners) has also helped to institutionalize performance measures related to operations. Traffic operations is a part of the conversation. Success in the TIM training (collaborations), other agencies have been brought into two of the TMCs (highway patrol). Expansion of service patrol (added about 45 trucks (have 110 total).**

    b. What problems still linger?

        - **Still dealing with some of the culture associated with the change. Particularly the "build it first" mentality. Technology is a challenge in that all of the emerging technologies that don't work with the legacy systems. It is difficult to plan and grow the program when there is uncertainty out there.**

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
8. Along those lines, do you have any supporting documentation from your state's experience?

Texas DOT Response

1. What functions/divisions are included in your agency's TSMO structure?

   - **TxDOT does not have a formal "TSMO" structure. The Traffic Operations Division (abbreviated as TRF) was recently renamed the Traffic Safety Division, September 1, 2018. The TRF abbreviation remains the same after the recent name change to Traffic Safety Division. The roles and responsibilities of TRF remain the same despite the name change. The name change was motivated by the high awareness and priority for system safety among TxDOT leadership. TRF is divided into various sections; one of those sections is the traffic management section, which is responsible for statewide guidance, standards and policy related to TSMO. The Information Management Division (IMD) is the division that is responsible for managing information technology at TxDOT. TRF works closely with one of the sections of IMD, to evaluate, test, and procure statewide technology solutions such asset management, video sharing and private sector data (e.g. Inrix, Waze, etc.). TxDOT has a decentralized agency structure – there are 25 districts which have their own budgets and separate organizational structures, and are responsible for the construction and maintenance of the highway system in the geographic boundary of the respective district. The various TxDOT divisions serve as central offices (i.e. headquarters) and provide technical support and guidance to the various functions carried out by the districts. See the TxDOT TSMO webpage which includes the Statewide TSMO Strategic Plan which was updated in the summer of 2018. The appendix of the strategic plan includes memos from TxDOT's Chief Engineer, which provide directives for prioritizing TMS (broad term used to reference both ITS and traffic signals systems) and TSMO planning. The TxDOT TSMO webpage includes links to other documents which you might find useful.**

     a. How were your affected divisions structured before the switch (provide org chart)

        - **As mentioned above, TxDOT has not changed its organizational structure for TSMO specifically.**

     b. How are your affected divisions structured after the switch to TSMO (provide org chart)

2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?

     a. Traffic Safety (HSIP, Signing and Marking) – **Used for traffic signals, but not typically for other TSMO related elements such as ITS.**

b. ITS – **There is not a dedicated funding category to fund ITS.**

c. Operations -

d. Signals

e. CMAQ – **Considered a funding source for ITS/TSMO**

f. Maintenance – **TSMO/ITS has to compete with roadway construction and maintenance needs, nonetheless, a large portion of the funding directing to toward ITS/TSMO come out of maintenance funds (category 1 funding).**

g. Others?

- **The Transportation Planning and Programming Division (TPP) provided some insight on the various categories of funding, what they can be used for and what entities control them. The Unified Transportation Program (UTP) which is updated annually authorizes funding amounts for each of the twelve funding categories. When we ask the districts to use "their" money to fund TSMO or TMS, it is important to keep in mind that the districts have limited control over the funding.**

- **Category 2, 4, 12 – Mobility funding type category (i.e. TMS). Can be used for pure ITS projects.**

- **Category 5 – Congestion Mitigation and Air Quality Improvement (CMAQ) - only goes to certain districts that have areas that fail to meet National Ambient Air Quality Standards (NAAQS); "non-attainment areas". TSM&O, ITS and TMS projects can be funded by this category due to the relationship to congestion mitigation. Driven by federal allocation. Can be used for pure ITS projects.**

- **Category 7 – Goes to Transportation Management Areas (TMA) (> 200,000 population). Can be used for pure ITS projects.**

- **Category 10 – Most flexible funding category, driven by MPOs.**

- **Category 9 –has some flexibility in what its used for; used a lot for non-highway projects.**

- **Category 1, 11 – Districts govern these categories. Cat 1 is for preventative maintenance and rehabilitation – highway expansion is done under this category, but ITS can be included as secondary element.**

- **Category 2, 5, 7 and portion of 9 – MPO governs this category; selects projects in consultation with TxDOT**

- **Category 4, 12 – TxDOT Commission governs these categories. Cat 12 – the TxDOT Commission controls this category and the funds get used for**

projects prioritized by them. Cat 4 – The TxDOT Commission distributes these funds to the districts.

- **Category 3 – Not tied to a specific category of work; local funds, toll road funds**

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)?

   - **I am not sure that TSMO has increased traffic safety awareness in those areas. There currently is a high awareness to safety aside from TSMO, hence the Traffic Operations Division being renamed the Traffic Safety Division. In order to further promote TSMO at TxDOT, perhaps it would be good to show how TSMO solutions can enhance safety.**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

   a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

      - **The Department has moved towards a System Safety approach of which each project includes safety improvements which would have historically been applied for and potentially funded through HSIP, such as rumble strips.**

   b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

      - **The types of projects funded continue to be related to the Texas Strategic Highway Safety Plan (SHSP) emphasis areas.**

   c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

      - **We currently fund around $255 million annually in HSIP and an additional $15 million on a systemic widening program**.

5. Were there challenges to incorporating TSMO into your organization?

   a. If yes, what challenges?

      - **The initial process of educating personnel on what TSMO is and how it relates to the status quo. TSMO represents a lot of what we already do and have been doing for quite some time (e.g. traffic incident management, traveler information, traffic signal timing optimization, etc.) yet it places more of an emphasis on applying a strategic approach with respect to planning, funding, technology, and collaboration. Challenges remain for**

advancing the culture of the organization to see TSMO as a core agency priority along with construction, maintenance and safety.

b. What made the transition easier?

- **We are still in transition. But thus far the process has been made easier because of the directives from TxDOT administration that has identified TMS and TSMO planning as objectives that need to be elevated in priority.**

c. How was the staffing and administrative transition handled?

- **We are still in transition so much is yet to be seen. Personnel that work in operations or closely tied to operations have mostly embraced the TSMO philosophy. There is still more work to do as far as engaging other units of the organization. But thus far the process has been made easier because of the directives from TxDOT administration that has identified TMS and TSMO planning as objectives that need to be elevated in priority. More work needs to be done to plan and implement processes that enable those objectives to be carried out.**

d. Do you have any advice on implementation of TSMO for another state agency?

- **Gain endorsement from agency leadership at the beginning; which provides authority/credibility to the initiative. Initially focus outreach/education toward personnel that are the most integral to TSMO; make the case, develop understanding, get their support and buy-in. This can include internal and external personnel (e.g. MPOs, cities). Develop an initial broad/statewide strategy on how to plan/implement TSMO. Expand outreach/education to other units and refine strategy as needed. Apply strategy at the regional/district level.**

6. How has TSMO changed the function of your organization?

a. What improvements have been made vs. the prior divisional structure?

- **The TRF Traffic Management Section has added more of a strategic focus (e.g. Traffic Incident Manage coordination, TSMO business processes, performance measures, statewide systems & technology solutions, etc.) in the way it provides support to the districts, as opposed to a focus that was formerly geared more toward technical support of ITS equipment and guidance on construction specs and standards.**

b. What problems still linger? The operations personnel in the districts have mostly bought in to the TSMO philosophy.

- **The challenge now is to get more collaboration, cooperation and buy-in from other units of the district (e.g. planning, design, maintenance, and construction). Also, as mentioned previously, formal processes need to be established (or updates to existing processes) which support/enable the TMS/TSMO objectives to be carried out. All of the districts will be**

developing TSMO program plans over the next 2 years which is expected to help address that problem.

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc. (AASHTO, ITE, etc.).
   - **https://ops.fhwa.dot.gov/plan4ops/index.htm**
   - **http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(345)_FR.pdf**
   - **http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(365)_FR.pdf**
   - **https://ops.fhwa.dot.gov/plan4ops/index.htm**

8. Along those lines, do you have any supporting documentation from your state's experience?
   - **See TxDOT TSMO webpage and attachments in email response.**

Washington DOT Response

1. What functions/divisions are included in your agency's TSMO structure?
   - **They don't have a specific TSMO division. TSMO is defined by functional areas and NO realignment was performed. Includes - multimodal planning, connected vehicles, ITS, traffic engineering (signs, signals, roundabout, delineation, channelization, work zone), travel demand management. They are about to start with the strategic planning…and asking how to implement across divisions. How to bring these divisions to a unified mission.**
   a. How were your affected divisions structured before the switch (provide org chart)
   b. How are your affected divisions structured after the switch to TSMO (provide org chart)
2. Similar to the previous question, recognizing that the systems management approach of TSMO seeks to integrate the various funding areas/templates within the agency. What funding areas/templates fall under TSMO in your state?
   a. Traffic Safety (HSIP, Signing and Marking) - **No for HSIP, yes for signing and markings**
   b. ITS - **Yes**
   c. Operations - **Yes, Also yes to Connected Vehicles**
   d. Signals - **Yes**
   e. CMAQ - **No**

f. Maintenance - **No**

g. Others?

3. Continuing from the prior question, has TSMO increased traffic safety awareness throughout those funding areas where traffic safety was not previously a primary emphasis (e.g., maintenance, operations, ITS, signals, CMAQ, etc)? **No**

4. Along those same lines, has the TSMO changed the funding and/or selection of projects for your agency in the areas outside of the traditional safety programs? Specifically,

    a. Has the safety performance been implemented as a part of non-safety programs project (rehab/reconstruction for example)?

        - **Project that ultimately recommended ramp meters, work zone policy using ITS technology, some ramp closures**

    b. Are you committing funds for safety improvements to projects in areas that have not traditionally been required to emphasize safety performance?

    c. What is your overall funding amount for statewide safety programs (not limited to HSIP)?

5. Were there challenges to incorporating TSMO into your organization?

    a. If yes, what challenges?

        - **Just the word TSMO is nebulous/ambiguous. Also, non-traditional items (permits, land use planning) has been difficult to change the mentality for many of the non-operational divisions. Selling these folks on the virtues of TSMo has been difficult.**

    b. What made the transition easier?

        - **Preparing for a strategic plan has helped. Developing performance measures. Also, exploring going away from a siloed funding program. Strong support from the secretary, but it tends to weaken at the division level, specifically design and construction areas.**

    c. How was the staffing and administrative transition handled?

        - **TSMO manager position was created. Some regions have also created TSMO positions.**

    d. Do you have any advice on implementation of TSMO for another state agency

        - **Restating that TSMO is NOT a competing interests and should be viewed as streamlining and integrating funding. It can't be thought of strictly as a DOT idea….also needs to include local agency buy-in, but the education at the local level is quite significant.**

6. How has TSMO changed the function of your organization?

    a. What improvements have been made vs. the prior divisional structure?

- **Roadway widening is not necessarily the first scenario anymore.**

b. What problems still linger?

- **Still trying to get buy in from middle management. Funding is still an issue…too low compared to, say, mobility.**

7. As TSMO is an emerging and evolving area in state DOTs, can you provide any recent documentation or examples from peer exchanges, working groups, etc (AASHTO, ITE, etc).
8. Along those lines, do you have any supporting documentation from your state's experience?

Appendix C – State Funding and Safety Performance Data

C.1 Annual Average Safety Funding Data (2014-2018)

State	Funding (Millions) Value	Rank	VMT (Billions) Value	Rank	Population (Millions) Value	Rank	Funding per Billion VMT Value	Rank	Funding per Capita Value	Rank
California	$415.1	1	329.1	1	38.55	1	$1,261,278	17	$10.8	22
New York	$229.2	2	128.0	4	19.58	4	$1,791,005	9	$11.7	20
Texas	$213.2	3	247.8	2	26.99	2	$860,597	32	$7.9	35
Ohio	$185.2	4	114.2	5	11.60	7	$1,620,853	12	$16.0	13
Washington	$161.5	5	58.3	19	7.10	13	$2,771,475	5	$22.7	6
Florida	$113.6	6	198.7	3	19.98	3	$571,696	46	$5.7	45
North Carolina	$92.8	7	108.1	7	9.96	9	$858,320	33	$9.3	28
Pennsylvania	$91.6	8	100.7	9	12.77	6	$909,540	30	$7.2	40
Missouri	$84.5	9	71.0	15	6.06	18	$1,189,234	18	$13.9	15
Georgia	$81.8	10	113.3	6	10.10	8	$721,523	40	$8.1	33
Tennessee	$79.7	11	73.1	14	6.55	17	$1,090,498	20	$12.2	19
Massachusetts	$78.0	12	56.1	22	6.75	15	$1,391,962	16	$11.6	21
Louisiana	$75.4	13	47.3	27	4.63	25	$1,593,120	13	$16.3	12
Illinois	$65.6	14	105.3	8	12.84	5	$622,911	45	$5.1	49
Alaska	$61.1	15	5.0	50	0.73	47	$12,319,992	1	$83.3	1
Arkansas	$60.1	16	34.3	29	2.97	32	$1,751,773	10	$20.2	7
Michigan	**$54.1**	**17**	**97.2**	**10**	**9.93**	**10**	**$556,998**	**47**	**$5.5**	**46**
Virginia	$52.6	18	79.0	11	8.29	12	$665,011	42	$6.3	43
Arizona	$51.9	19	62.0	17	6.76	14	$837,102	34	$7.7	37
Oklahoma	$50.4	20	47.9	26	3.87	28	$1,051,782	23	$13.0	16
Indiana	$50.1	21	77.8	12	6.59	16	$643,773	44	$7.6	39
Montana	$47.8	22	11.9	42	1.02	44	$4,000,874	2	$46.7	2
Maryland	$47.0	23	56.6	21	5.94	19	$830,972	35	$7.9	34
Kentucky	$39.9	24	48.1	25	4.41	26	$830,526	36	$9.1	29
New Jersey	$39.1	25	74.7	13	8.86	11	$522,829	48	$4.4	50
South Carolina	$38.1	26	50.7	23	4.84	23	$752,824	37	$7.9	36
Mississippi	$37.3	27	39.7	28	2.99	31	$940,615	29	$12.5	18
Colorado	$35.8	28	48.7	24	5.37	22	$735,042	39	$6.7	42
West Virginia	$35.3	29	21.3	37	1.84	38	$1,653,668	11	$19.2	9
Connecticut	$35.1	30	31.4	32	3.58	29	$1,117,905	19	$9.8	26
Wisconsin	$31.0	31	61.5	18	5.75	20	$504,420	49	$5.4	47
Utah	$29.5	32	28.0	34	2.95	33	$1,052,047	22	$10.0	25
South Dakota	$29.1	33	9.1	47	0.85	46	$3,178,742	3	$34.3	4
Iowa	$27.9	34	32.2	31	3.11	30	$865,432	31	$9.0	30
New Mexico	$27.1	35	26.1	35	2.09	36	$1,038,310	24	$13.0	17
Alabama	$25.4	36	65.8	16	4.84	24	$386,856	50	$5.3	48
Wyoming	$25.1	37	9.4	45	0.58	51	$2,657,728	6	$43.4	3
Oregon	$24.0	38	34.3	30	3.99	27	$699,250	41	$6.0	44
Nevada	$23.8	39	23.9	36	2.84	35	$996,057	27	$8.4	31
Minnesota	$21.5	40	57.7	20	5.45	21	$372,532	51	$3.9	51
Kansas	$20.1	41	30.7	33	2.89	34	$653,495	43	$6.9	41
Nebraska	$19.7	42	19.8	38	1.88	37	$997,811	26	$10.5	23
Rhode Island	$18.9	43	7.9	48	1.06	43	$2,373,916	7	$17.9	10
Idaho	$16.5	44	16.2	39	1.64	39	$1,021,912	25	$10.0	24
Vermont	$14.5	45	7.3	49	0.63	50	$1,987,604	8	$23.1	5
North Dakota	$14.1	46	9.5	44	0.73	48	$1,478,510	14	$19.4	8
Delaware	$13.8	47	9.4	46	0.93	45	$1,469,168	15	$14.8	14
New Hampshire	$12.5	48	13.1	41	1.33	41	$958,508	28	$9.4	27
D.C.	$11.2	49	3.6	51	0.66	49	$3,126,079	4	$17.0	11
Maine	$10.9	50	14.6	40	1.33	42	$747,464	38	$8.2	32
Hawaii	$10.7	51	10.1	43	1.41	40	$1,055,406	21	$7.6	38

C.2 Percent Reduction in Fatality Frequency (2009-2013 vs. 2013-2017)

State	Fatality Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Fatality	
	2009-2013	2013-2017	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
Rhode Island	69.0	59.2	14.2%	1	$18.9	43	$2,373,916	7	$294,598	4
West Virginia	336.2	288.6	14.2%	2	$35.3	29	$1,653,668	11	$113,795	16
Vermont	69.4	60.6	12.7%	3	$14.5	45	$1,987,604	8	$224,252	7
North Dakota	142.2	128.6	9.6%	4	$14.1	46	$1,478,510	14	$105,090	19
New York	1,182.4	1,079.6	8.7%	5	$229.2	2	$1,791,005	9	$204,097	9
Arkansas	555.2	514.2	7.4%	6	$60.1	16	$1,751,773	10	$111,491	17
Maryland	526.4	488.6	7.2%	7	$47.0	23	$830,972	35	$92,758	23
Pennsylvania	1,276.8	1,185.6	7.1%	8	$91.6	8	$909,540	30	$74,271	31
Oklahoma	692.2	645.4	6.8%	9	$50.4	20	$1,051,782	23	$75,363	30
Iowa	360.6	338.0	6.3%	10	$27.9	34	$865,432	31	$78,962	27
Hawaii	109.8	103.4	5.8%	11	$10.7	51	$1,055,406	21	$99,844	22
California	3211.0	3033.4	5.5%	12	$415.1	1	$1,261,278	17	$131,508	12
Minnesota	396.4	381.8	3.7%	13	$21.5	40	$372,532	51	$55,203	45
Montana	211.8	204.2	3.6%	14	$47.8	22	$4,000,874	2	$232,217	5
Wyoming	126.8	123.4	2.7%	15	$25.1	37	$2,657,728	6	$193,757	10
Wisconsin	579.0	563.8	2.6%	16	$31.0	31	$504,420	49	$54,171	46
New Mexico	358.4	352.6	1.6%	17	$27.1	35	$1,038,310	24	$76,363	29
New Jersey	579.6	577.2	0.4%	18	$39.1	25	$522,829	48	$67,079	37
Maine	153.0	152.8	0.1%	19	$10.9	50	$747,464	38	$70,884	32
South Dakota	130.0	130.0	0.0%	20	$29.1	33	$3,178,742	3	$224,668	6
Virginia	756.6	759.6	-0.4%	21	$52.6	18	$665,011	42	$69,146	35
Tennessee	993.0	1001.2	-0.8%	22	$79.7	11	$1,090,498	20	$79,934	26
Connecticut	266.2	268.4	-0.8%	23	$35.1	30	$1,117,905	19	$131,097	13
Kentucky	730.4	737.4	-1.0%	24	$39.9	24	$830,526	36	$53,649	47
Kansas	391.6	396.0	-1.1%	25	$20.1	41	$653,495	43	$50,369	48
Massachusetts	361.6	366.6	-1.4%	26	$78.0	12	$1,391,962	16	$215,524	8
New Hampshire	114.2	116.4	-1.9%	27	$12.5	48	$958,508	28	$110,875	18
Louisiana	729.8	745.2	-2.1%	28	$75.4	13	$1,593,120	13	$101,727	20
Mississippi	633.2	655.4	-3.5%	29	$37.3	27	$940,615	29	$57,599	43
Ohio	1,045.8	1,083.4	-3.6%	30	$185.2	4	$1,620,853	12	$172,564	11
Florida	2,568.0	2,688.2	-4.7%	31	$113.6	6	$571,696	46	$42,869	50
Missouri	813.6	854.4	-5.0%	32	$84.5	9	$1,189,234	18	$100,281	21
North Carolina	1,291.6	1,359.0	-5.2%	33	$92.8	7	$858,320	33	$69,775	34
Alabama	865.2	911.4	-5.3%	34	$25.4	36	$386,856	50	$28,505	51
Illinois	940.6	997.75	-6.1%	35	$65.6	14	$622,911	45	$68,106	36
Michigan	**917.2**	**976.4**	**-6.5%**	**36**	**$54.1**	**17**	**$556,998**	**47**	**$57,196**	**44**
Indiana	752.6	816.4	-8.5%	37	$50.1	21	$643,773	44	$63,819	38
D.C.	23.0	25.2	-9.6%	38	$11.2	49	$3,126,079	4	$455,883	2
Oregon	355.6	390.2	-9.7%	39	$24.0	38	$699,250	41	$63,619	39
South Carolina	831.2	914.0	-10.0%	40	$38.1	26	$752,824	37	$43,107	49
Arizona	812.4	895.8	-10.3%	41	$51.9	19	$837,102	34	$60,728	42
Delaware	108.2	119.4	-10.4%	42	$13.8	47	$1,469,168	15	$120,124	14
Nebraska	203.4	225.6	-10.9%	43	$19.7	42	$997,811	26	$91,778	24
Utah	235.4	261.6	-11.1%	44	$29.5	32	$1,052,047	22	$117,226	15
Idaho	200.0	222.6	-11.3%	45	$16.5	44	$1,021,912	25	$78,267	28
Washington	456.0	510.0	-11.8%	46	$161.5	5	$2,771,475	5	$330,758	3
Georgia	1,227.4	1,376.6	-12.2%	47	$81.8	10	$721,523	40	$62,144	41
Texas	3,214.8	3,609.4	-12.3%	48	$213.2	3	$860,597	32	$62,486	40
Alaska	60.4	70.4	-16.6%	49	$61.1	15	$12,319,992	1	$911,515	1
Nevada	254.6	303.8	-19.3%	50	$23.8	39	$996,057	27	$84,891	25
Colorado	463.6	554.4	-19.6%	51	$35.8	28	$735,042	39	$69,904	33

C.3 Percent Reduction in Fatality Rate (2009-2013 vs. 2013-2017)

State	Fatality Rate Data				Funding (Millions)		Funding per Capita		Funding per Fatality	
	2009-2013	2013-2017	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
North Dakota	1.55	1.28	17.3%	1	$14.1	46	$19.4	8	$105,090	19
Rhode Island	0.86	0.75	13.0%	2	$18.9	43	$17.9	10	$294,598	4
Vermont	0.96	0.83	12.9%	3	$14.5	45	$23.1	5	$224,252	7
Arkansas	1.67	1.46	12.1%	4	$60.1	16	$20.2	7	$111,491	17
Iowa	1.15	1.03	10.0%	5	$27.9	34	$9.0	30	$78,962	27
Hawaii	1.10	1.00	9.2%	6	$10.7	51	$7.6	38	$99,844	22
Maryland	0.94	0.85	9.1%	7	$47.0	23	$7.9	34	$92,758	23
Montana	1.83	1.66	9.0%	8	$47.8	22	$46.7	2	$232,217	5
Oklahoma	1.46	1.34	8.0%	9	$50.4	20	$13.0	16	$75,363	30
California	0.98	0.92	7.0%	10	$415.1	1	$10.8	22	$131,508	12
Pennsylvania	1.27	1.18	7.0%	11	$91.6	8	$7.2	40	$74,271	31
Wisconsin	0.98	0.91	6.7%	12	$31.0	31	$5.4	47	$54,171	46
New York	0.91	0.85	6.5%	13	$229.2	2	$11.7	20	$204,097	9
Minnesota	0.70	0.66	5.8%	14	$21.5	40	$3.9	51	$55,203	45
Tennessee	1.41	1.33	5.2%	15	$79.7	11	$12.2	19	$79,934	26
Virginia	0.98	0.94	4.5%	16	$52.6	18	$6.3	43	$69,146	35
Wyoming	1.36	1.30	4.2%	17	$25.1	37	$43.4	3	$193,757	10
Massachusetts	0.67	0.64	4.2%	18	$78.0	12	$11.6	21	$215,524	8
South Dakota	1.45	1.39	4.0%	19	$29.1	33	$34.3	4	$224,668	6
West Virginia	1.58	1.52	4.0%	20	$35.3	29	$19.2	9	$113,795	16
New Jersey	0.79	0.76	3.6%	21	$39.1	25	$4.4	50	$67,079	37
Kansas	1.30	1.26	3.3%	22	$20.1	41	$6.9	41	$50,369	48
New Mexico	1.39	1.35	3.2%	23	$27.1	35	$13.0	17	$76,363	29
Louisiana	1.58	1.54	2.8%	24	$75.4	13	$16.3	12	$101,727	20
North Carolina	1.25	1.21	2.6%	25	$92.8	7	$9.3	28	$69,775	34
Maine	1.06	1.04	2.4%	26	$10.9	50	$8.2	32	$70,884	32
Kentucky	1.54	1.52	1.0%	27	$39.9	24	$9.1	29	$53,649	47
New Hampshire	0.88	0.88	0.4%	28	$12.5	48	$9.4	27	$110,875	18
Ohio	0.93	0.93	0.2%	29	$185.2	4	$16.0	13	$172,564	11
Missouri	1.18	1.18	-0.1%	30	$84.5	9	$13.9	15	$100,281	21
Alabama	1.35	1.36	-0.6%	31	$25.4	36	$5.3	48	$28,505	51
Utah	0.89	0.89	-0.6%	32	$29.5	32	$10.0	25	$117,226	15
Florida	1.32	1.33	-1.1%	33	$113.6	6	$5.7	45	$42,869	50
Connecticut	0.85	0.86	-1.3%	34	$35.1	30	$9.8	26	$131,097	13
Mississippi	1.61	1.64	-1.8%	35	$37.3	27	$12.5	18	$57,599	43
South Carolina	1.70	1.75	-2.8%	36	$38.1	26	$7.9	36	$43,107	49
Delaware	1.19	1.23	-3.0%	37	$13.8	47	$14.8	14	$120,124	14
Texas	1.36	1.40	-3.2%	38	$213.2	3	$7.9	35	$62,486	40
Michigan	**0.96**	**0.99**	**-3.3%**	**39**	**$54.1**	**17**	**$5.5**	**46**	**$57,196**	**44**
Arizona	1.35	1.40	-3.7%	40	$51.9	19	$7.7	37	$60,728	42
Georgia	1.13	1.17	-4.0%	41	$81.8	10	$8.1	33	$62,144	41
Idaho	1.28	1.34	-4.7%	42	$16.5	44	$10.0	24	$78,267	28
Nevada	1.14	1.20	-5.0%	43	$23.8	39	$8.4	31	$84,891	25
Illinois	0.90	0.94	-5.2%	44	$65.6	14	$5.1	49	$68,106	36
Oregon	1.06	1.12	-5.3%	45	$24.0	38	$6.0	44	$63,619	39
Nebraska	1.06	1.12	-5.9%	46	$19.7	42	$10.5	23	$91,778	24
Indiana	0.97	1.04	-6.7%	47	$50.1	21	$7.6	39	$63,819	38
Washington	0.80	0.86	-6.9%	48	$161.5	5	$22.7	6	$330,758	3
Alaska	1.26	1.38	-8.8%	49	$61.1	15	$83.3	1	$911,515	1
D.C.	0.64	0.70	-9.0%	50	$11.2	49	$17.0	11	$455,883	2
Colorado	0.99	1.10	-10.5%	51	$35.8	28	$6.7	42	$69,904	33

C.4 Percent Reduction in Serious Injury Frequency (2009-2013 vs. 2013-2017)

State	Serious Injury Frequency Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013	2013-2017	Perc. Red	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	1,969.6	1,272.4	35.4%	1	$35.3	29	$1,653,668	11	$19.2	9
New Mexico	1,818.8	1,333.8	26.7%	2	$27.1	35	$1,038,310	24	$13.0	17
Virginia	10,798.6	7,992.0	26.0%	3	$52.6	18	$665,011	42	$6.3	43
Kansas	1,602.2	1,187.8	25.9%	4	$20.1	41	$653,495	43	$6.9	41
Maryland	4,019.8	3,016.2	25.0%	5	$47.0	23	$830,972	35	$7.9	34
New Jersey	1,394.8	1,081.8	22.4%	6	$39.1	25	$522,829	48	$4.4	50
Kentucky	3,883.4	3,124.8	19.5%	7	$39.9	24	$830,526	36	$9.1	29
Vermont	362.2	294.2	18.8%	8	$14.5	45	$1,987,604	8	$23.1	5
Connecticut	1,661.6	1,363.8	17.9%	9	$35.1	30	$1,117,905	19	$9.8	26
New Hampshire	553.8	457.2	17.4%	10	$12.5	48	$958,508	28	$9.4	27
Missouri	5,744.8	4,756.4	17.2%	11	$84.5	9	$1,189,234	18	$13.9	15
Wyoming	525.4	435.4	17.1%	12	$25.1	37	$2,657,728	6	$43.4	3
Alaska	403.6	346.3	14.2%	13	$61.1	15	$12,319,992	1	$83.3	1
Rhode Island	453.8	392.0	13.6%	14	$18.9	43	$2,373,916	7	$17.9	10
Mississippi	635.6	549.4	13.6%	15	$37.3	27	$940,615	29	$12.5	18
Massachusetts	3,595.2	3,132.4	12.9%	16	$78.0	12	$1,391,962	16	$11.6	21
Oklahoma	16,088.2	14,023.0	12.8%	17	$50.4	20	$1,051,782	23	$13.0	16
Montana	1,058.6	926.6	12.5%	18	$47.8	22	$4,000,874	2	$46.7	2
Nebraska	1,731.8	1,548.4	10.6%	19	$19.7	42	$997,811	26	$10.5	23
Delaware	640.0	577.4	9.8%	20	$13.8	47	$1,469,168	15	$14.8	14
Arkansas	3,311.8	2,993.2	9.6%	21	$60.1	16	$1,751,773	10	$20.2	7
Wisconsin	3,445.5	3,124.2	9.3%	22	$31.0	31	$504,420	49	$5.4	47
South Dakota	817.8	742.8	9.2%	23	$29.1	33	$3,178,742	3	$34.3	4
New York	12,314.8	11,237.0	8.8%	24	$229.2	2	$1,791,005	9	$11.7	20
Nevada	12,64.8	1,154.4	8.7%	25	$23.8	39	$996,057	27	$8.4	31
Alabama	8,915.0	8,139.2	8.7%	26	$25.4	36	$386,856	50	$5.3	48
Michigan	**5,833.0**	**5,355.0**	**8.2%**	**27**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Maine	851.2	781.6	8.2%	28	$10.9	50	$747,464	38	$8.2	32
Washington	2,275.6	2,092.2	8.1%	29	$161.5	5	$2,771,475	5	$22.7	6
Arizona	4,581.8	4,232.4	7.6%	30	$51.9	19	$837,102	34	$7.7	37
Ohio	9,725.0	9,013.0	7.3%	31	$185.2	4	$1,620,853	12	$16.0	13
South Carolina	3,359.6	3,115.8	7.3%	32	$38.1	26	$752,824	37	$7.9	36
Louisiana	1,447.4	1,361.4	5.9%	33	$75.4	13	$1,593,120	13	$16.3	12
Iowa	1,586.8	1,498.8	5.5%	34	$27.9	34	$865,432	31	$9.0	30
Florida	21,620.8	20,872.4	3.5%	35	$113.6	6	$571,696	46	$5.7	45
Idaho	1,335.6	1292.2	3.2%	36	$16.5	44	$1,021,912	25	$10.0	24
Colorado	3,221.2	3,122.2	3.1%	37	$35.8	28	$735,042	39	$6.7	42
Illinois	12,454.8	12,128.5	2.6%	38	$65.6	14	$622,911	45	$5.1	49
California	11,295.0	11,014.4	2.5%	39	$415.1	1	$1,261,278	17	$10.8	22
Indiana	3,346.6	3,387.2	-1.2%	40	$50.1	21	$643,773	44	$7.6	39
Tennessee	7,008.8	7,226.0	-3.1%	41	$79.7	11	$1,090,498	20	$12.2	19
Pennsylvania	3,431.8	3,588.4	-4.6%	42	$91.6	8	$909,540	30	$7.2	40
North Dakota	453.2	486.8	-7.4%	43	$14.1	46	$1,478,510	14	$19.4	8
Oregon	1,537.0	1,655.8	-7.7%	44	$24.0	38	$699,250	41	$6.0	44
D.C.	319.2	353.0	-10.6%	45	$11.2	49	$3,126,079	4	$17.0	11
Texas	15,502.8	17,235.4	-11.2%	46	$213.2	3	$860,597	32	$7.9	35
Utah	1,290.8	1,435.2	-11.2%	47	$29.5	32	$1,052,047	22	$10.0	25
Hawaii	396.4	455.4	-14.9%	48	$10.7	51	$1,055,406	21	$7.6	38
Minnesota	1,221.0	1,447.2	-18.5%	49	$21.5	40	$372,532	51	$3.9	51
North Carolina	2,304.4	2,860.8	-24.1%	50	$92.8	7	$858,320	33	$9.3	28
Georgia	17,201.4	23,126.8	-34.4%	51	$81.8	10	$721,523	40	$8.1	33

C.5 Percent Reduction in Serious Injury Rate (2009-2013 vs. 2013-2017)

State	Serious Injury Rate Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013	2013-2017	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	10.4	6.7	36.0%	1	$35.3	29	$1,653,668	11	$19.2	9
Virginia	14.1	9.9	29.4%	2	$52.6	18	$665,011	42	$6.3	43
Kansas	5.3	3.8	28.7%	3	$20.1	41	$653,495	43	$6.9	41
New Mexico	7.1	5.1	27.7%	4	$27.1	35	$1,038,310	24	$13.0	17
Maryland	7.2	5.3	26.2%	5	$47.0	23	$830,972	35	$7.9	34
New Jersey	1.9	1.4	24.9%	6	$39.1	25	$522,829	48	$4.4	50
Nevada	5.6	4.3	22.6%	7	$23.8	39	$996,057	27	$8.4	31
Kentucky	8.2	6.5	21.0%	8	$39.9	24	$830,526	36	$9.1	29
Missouri	8.3	6.6	20.8%	9	$84.5	9	$1,189,234	18	$13.9	15
New Hampshire	4.3	3.5	19.3%	10	$12.5	48	$958,508	28	$9.4	27
Vermont	5.0	4.1	18.8%	11	$14.5	45	$1,987,604	8	$23.1	5
Wyoming	5.7	4.7	18.7%	12	$25.1	37	$2,657,728	6	$43.4	3
Alaska	8.4	6.9	17.9%	13	$61.1	15	$12,319,992	1	$83.3	1
Montana	9.2	7.6	17.6%	14	$47.8	22	$4000,874	2	$46.7	2
Connecticut	5.3	4.4	17.6%	15	$35.1	30	$1,117,905	19	$9.8	26
Massachusetts	6.6	5.5	17.0%	16	$78.0	12	$1,391,962	16	$11.6	21
Delaware	7.0	6.0	15.5%	17	$13.8	47	$1,469,168	15	$14.8	14
Mississippi	1.6	1.4	15.0%	18	$37.3	27	$940,615	29	$12.5	18
Nebraska	9.0	7.7	14.5%	19	$19.7	42	$997,811	26	$10.5	23
Oklahoma	33.8	29.1	13.9%	20	$50.4	20	$1,051,782	23	$13.0	16
Arkansas	9.9	8.6	13.6%	21	$60.1	16	$1,751,773	10	$20.2	7
Arizona	7.6	6.6	13.0%	22	$51.9	19	$837,102	34	$7.7	37
Wisconsin	5.8	5.1	13.0%	23	$31.0	31	$504,420	49	$5.4	47
South Dakota	9.1	8.0	12.8%	24	$29.1	33	$3,178,742	3	$34.3	4
South Carolina	6.9	6.0	12.7%	25	$38.1	26	$752,824	37	$7.9	36
Washington	4.0	3.5	12.1%	26	$161.5	5	$2,771,475	5	$22.7	6
Rhode Island	5.7	5.0	11.7%	27	$18.9	43	$2,373,916	7	$17.9	10
Alabama	13.7	12.2	11.1%	28	$25.4	36	$386,856	50	$5.3	48
Michigan	**6.1**	**5.4**	**10.8%**	**29**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Ohio	8.7	7.8	10.6%	30	$185.2	4	$1,620,853	12	$16.0	13
Louisiana	3.1	2.8	10.4%	31	$75.4	13	$1,593,120	13	$16.3	12
Maine	5.9	5.3	10.0%	32	$10.9	50	$747,464	38	$8.2	32
Colorado	6.9	6.2	9.9%	33	$35.8	28	$735,042	39	$6.7	42
Iowa	5.0	4.6	9.2%	34	$27.9	34	$865,432	31	$9.0	30
Idaho	8.6	8.0	6.6%	35	$16.5	44	$1,021,912	25	$10.0	24
Florida	11.1	10.4	6.5%	36	$113.6	6	$571,696	46	$5.7	45
New York	9.5	8.9	6.1%	37	$229.2	2	$1,791,005	9	$11.7	20
California	3.5	3.3	3.7%	38	$415.1	1	$1,261,278	17	$10.8	22
Illinois	11.9	11.5	3.3%	39	$65.6	14	$622,911	45	$5.1	49
Tennessee	9.9	9.6	2.9%	40	$79.7	11	$1,090,498	20	$12.2	19
North Dakota	4.9	4.8	2.5%	41	$14.1	46	$1,478,510	14	$19.4	8
Indiana	4.3	4.2	2.1%	42	$50.1	21	$643,773	44	$7.6	39
Utah	4.9	4.9	-1.0%	43	$29.5	32	$1,052,047	22	$10.0	25
Texas	6.5	6.7	-2.3%	44	$213.2	3	$860,597	32	$7.9	35
Oregon	4.6	4.7	-3.4%	45	$24.0	38	$699,250	41	$6.0	44
Pennsylvania	3.4	3.6	-4.7%	46	$91.6	8	$909,540	30	$7.2	40
D.C.	8.9	9.8	-10.1%	47	$11.2	49	$3,126,079	4	$17.0	11
Hawaii	4.0	4.4	-11.2%	48	$10.7	51	$1,055,406	21	$7.6	38
North Carolina	2.2	2.5	-13.5%	49	$92.8	7	$858,320	33	$9.3	28
Minnesota	2.1	2.5	-15.0%	50	$21.5	40	$372,532	51	$3.9	51
Georgia	15.8	19.8	-24.8%	51	$81.8	10	$721,523	40	$8.1	33

C.6 Percent Reduction in Non-Motorized Fatalities and Serious Injuries (2009-2013 vs. 2013-2017)

State	Non-Motorized Fatalities and Serious Injuries Data				Funding (Millions)		Funding per Billion VMT		Funding per Capita	
	2009-2013	2013-2017	Perc. Red.	Rank	Value	Rank	Value	Rank	Value	Rank
West Virginia	116.8	94.4	19.2%	1	$35.3	29	$1,653,668	11	$19.2	9
New Jersey	449.8	378.2	15.9%	2	$39.1	25	$522,829	48	$4.4	50
Rhode Island	97.6	86.4	11.5%	3	$18.9	43	$2,373,916	7	$17.9	10
New York	3,003.6	2,734.8	8.9%	4	$229.2	2	$1,791,005	9	$11.7	20
Connecticut	305.8	281.6	7.9%	5	$35.1	30	$1,117,905	19	$9.8	26
South Dakota	50.2	47.0	6.4%	6	$29.1	33	$3,178,742	3	$34.3	4
Vermont	42.4	39.8	6.1%	7	$14.5	45	$1,987,604	8	$23.1	5
Alabama	401.5	377.4	6.0%	8	$25.4	36	$386,856	50	$5.3	48
Delaware	101.6	97.0	4.5%	9	$13.8	47	$1,469,168	15	$14.8	14
Maryland	570.2	547.0	4.1%	10	$47.0	23	$830,972	35	$7.9	34
Nebraska	146	141.4	3.2%	11	$19.7	42	$997,811	26	$10.5	23
North Dakota	36.6	35.6	2.7%	12	$14.1	46	$1,478,510	14	$19.4	8
Iowa	149.2	146.4	1.9%	13	$27.9	34	$865,432	31	$9.0	30
Virginia	749.2	738.4	1.4%	14	$52.6	18	$665,011	42	$6.3	43
Illinois	1,495.4	1,494.8	0.0%	15	$65.6	14	$622,911	45	$5.1	49
Montana	72.4	72.4	0.0%	16	$47.8	22	$4,000,874	2	$46.7	2
Michigan	**745.8**	**747.4**	**-0.2%**	**17**	**$54.1**	**17**	**$556,998**	**47**	**$5.5**	**46**
Indiana	410.4	412.6	-0.5%	18	$50.1	21	$643,773	44	$7.6	39
Idaho	117.8	120.4	-2.2%	19	$16.5	44	$1,021,912	25	$10.0	24
Ohio	833.4	852.8	-2.3%	20	$185.2	4	$1,620,853	12	$16.0	13
South Carolina	369.6	381.0	-3.1%	21	$38.1	26	$752,824	37	$7.9	36
Arizona	720.6	744.6	-3.3%	22	$51.9	19	$837,102	34	$7.7	37
Oklahoma	633.4	659.4	-4.1%	23	$50.4	20	$1,051,782	23	$13.0	16
D.C.	132.8	138.6	-4.4%	24	$11.2	49	$3,126,079	4	$17.0	11
Missouri	418.8	441.4	-5.4%	25	$84.5	9	$1,189,234	18	$13.9	15
Arkansas	141.2	149.0	-5.5%	26	$60.1	16	$1,751,773	10	$20.2	7
Wyoming	28.0	29.6	-5.7%	27	$25.1	37	$2,657,728	6	$43.4	3
Kansas	123.6	131	-6.0%	28	$20.1	41	$653,495	43	$6.9	41
Kentucky	261.4	277.8	-6.3%	29	$39.9	24	$830,526	36	$9.1	29
California	3,843.4	4,087.6	-6.4%	30	$415.1	1	$1,261,278	17	$10.8	22
Nevada	271.0	290.2	-7.1%	31	$23.8	39	$996,057	27	$8.4	31
Maine	83.2	89.4	-7.5%	32	$10.9	50	$747,464	38	$8.2	32
Florida	3,030.6	3,274.2	-8.0%	33	$113.6	6	$571,696	46	$5.7	45
Washington	473.6	511.8	-8.1%	34	$161.5	5	$2,771,475	5	$22.7	6
Pennsylvania	578.4	630.0	-8.9%	35	$91.6	8	$909,540	30	$7.2	40
North Carolina	394.0	431.4	-9.5%	36	$92.8	7	$858,320	33	$9.3	28
Utah	240.4	264.0	-9.8%	37	$29.5	32	$1,052,047	22	$10.0	25
Oregon	228.4	252.8	-10.7%	38	$24.0	38	$699,250	41	$6.0	44
Massachusetts	491.6	551.2	-12.1%	39	$78.0	12	$1,391,962	16	$11.6	21
Colorado	479.2	548.2	-14.4%	40	$35.8	28	$735,042	39	$6.7	42
New Mexico	161.8	187.2	-15.7%	41	$27.1	35	$1,038,310	24	$13.0	17
New Hampshire	50.6	58.6	-15.8%	42	$12.5	48	$958,508	28	$9.4	27
Louisiana	274.0	326.4	-19.1%	43	$75.4	13	$1,593,120	13	$16.3	12
Tennessee	385.0	469.2	-21.9%	44	$79.7	11	$1,090,498	20	$12.2	19
Texas	1,674.8	2,054.6	-22.7%	45	$213.2	3	$860,597	32	$7.9	35
Mississippi	94.4	118.4	-25.4%	46	$37.3	27	$940,615	29	$12.5	18
Hawaii	100.2	128.0	-27.7%	47	$10.7	51	$1,055,406	21	$7.6	38
Minnesota	186.8	246.4	-31.9%	48	$21.5	40	$372,532	51	$3.9	51
Georgia	734.8	978.4	-33.2%	49	$81.8	10	$721,523	40	$8.1	33
Alaska	34.4	51.8	-50.6%	50	$61.1	15	$12,319,992	1	$83.3	1