

# Expanding Transportation Systems Management and Operations (TSM&O) from Planning to Construction Primer



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## **FINAL REPORT**

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## **DISCLAIMER**

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

# CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
<b>LENGTH</b>				
<b>in</b>	inches	25.4	millimeters	mm
<b>ft</b>	feet	0.305	meters	m
<b>yd</b>	yards	0.914	meters	m
<b>mi</b>	miles	1.61	kilometers	km
<b>AREA</b>				
<b>in<sup>2</sup></b>	square inches	645.2	square millimeters	mm <sup>2</sup>
<b>ft<sup>2</sup></b>	square feet	0.093	square meters	m <sup>2</sup>
<b>yd<sup>2</sup></b>	square yard	0.836	square meters	m <sup>2</sup>
<b>ac</b>	acres	0.405	hectares	ha
<b>mi<sup>2</sup></b>	square miles	2.59	square kilometers	km <sup>2</sup>
<b>VOLUME</b>				
<b>fl oz</b>	fluid ounces	29.57	milliliters	mL
<b>gal</b>	gallons	3.785	liters	L
<b>ft<sup>3</sup></b>	cubic feet	0.028	cubic meters	m <sup>3</sup>
<b>yd<sup>3</sup></b>	cubic yards	0.765	cubic meters	m <sup>3</sup>
NOTE: volumes greater than 1000 L shall be shown in m <sup>3</sup>				
<b>MASS</b>				
<b>oz</b>	ounces	28.35	grams	g
<b>lb</b>	pounds	0.454	kilograms	kg
<b>T</b>	short tons (2000 lb)	0.907	Mega grams (or "metric ton")	Mg (or "t")

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

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16. Abstract The Florida Department of Transportation (FDOT) has initiated business plans to promote the Transportation Systems Management and Operations (TSM&O) program throughout the State. TSM&O is traditionally managed by traffic engineers that focus on optimizing efficiency and operations within a particular corridor utilizing common techniques such as re-timings and access modifications. With the emphasis moving towards maximizing current infrastructure, the Department envisions that the practice of managing TSM&O can be applied to all district units and disciplines for increasing efficiency. One main reason that the integration has stagnated is the lack of policies that support the integration of TSM&O strategies within the planning or design stages. This primer provides detailed guidance on how to apply TSM&O strategies from the planning stages to the construction phase of any general transportation project. TSM&O programs established around the nation are discussed to understand the current initiatives underway. A summary of the best practices for creating a robust and performance-based program is discussed. A detailed narrative highlighting the inclusion of all units within the TSM&O program is included. The report also provides background on financial programs that have the potential to provide funding for TSM&O programs. Continuous evaluation must be undertaken by the agency to ensure that the performance of the system is at an optimal level. Developing performance measures that accurately describe the objectives of the agency is critical to ensure that the plan is brought to practice.			
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## **EXECUTIVE SUMMARY**

The Florida Department of Transportation (FDOT) has initiated business plans to promote the Transportation Systems Management and Operations (TSM&O) program throughout the State. The main purpose of this program is to maximize the safety, reliability, and efficiency of all modes of the transportation system. Increasing the benefits of an existing infrastructure improves operational performance, reduces long-term costs and saves time. Due to limited resources and fiscal constraints involving new infrastructure to mitigate congestion, new strategies are needed to get the most capacity and efficiency out of the existing or planned transportation system.

TSM&O is traditionally managed by traffic engineers that focus on optimizing efficiency and operations within a particular corridor utilizing common techniques such as re-timings and access modifications. With the emphasis moving towards maximizing current infrastructure, the Department envisions that the practice of managing TSM&O can be applied to all district units and disciplines for increasing efficiency. Unfortunately, so far, it is a common practice to apply TSM&O only when problems arise on the traditional infrastructure.

Many agencies at the State, regional, and local level have found great use of managing and operating the transportation system as well as implementing Intelligent Transportation Systems (ITS) strategic plans and architectures and have made progress in applying TSM&O strategies. It is still noticeable: however, that even with this progress, there is a disconnection between infrastructure design and the needed long-term results. One main reason is the lack of policies that support the integration of TSM&O strategies within the planning or design stages as a routine method of business practice.

This primer provides detailed guidance on how to apply TSM&O strategies during all phases of any general transportation project, from planning to construction. TSM&O programs established around the nation are discussed to understand the current initiatives underway. Various examples are used to show the effectiveness of applying TSM&O strategies in infrastructure design, including the early stages of a project. Application of these strategies can allow improvement in regional transportation system efficiency, reliability, and options over the long-term of a project's life span.

A summary of the best practices for creating a robust and performance-based program is discussed. A detailed narrative highlighting the inclusion of all units within the TSM&O program is included. The report also provides background on financial programs that have the potential to provide funding for TSM&O programs.

The program has to be rooted in goals that provide a roadmap for the practices to be implemented. Ensuring that the course is taken and stuck to is a very important part of ensuring the success of such a program. Continuous evaluation must be undertaken by the agency to ensure that the performance of the system is at an optimal level. Projects implementing these

strategies are typically short-term fixes that need to be reviewed for their purpose and effectiveness. Developing performance measures that accurately describe the objectives of the agency is critical to ensure that the plan is brought to practice.

Moving from plan to practice also requires the units of the FDOT to cooperatively integrate themselves into the culture that a TSM&O program brings to an agency. Not only is it important for the agency to integrate TSM&O techniques into their projects but it needs to be discussed between the units and phases of the project. It has to be shared with all applicable groups that may have a valid opinion to share regarding the use of these strategies. The framework of this concept is showcased in the interaction chart presented in the document.

The resulting primer document is just a starting point. It is suggested that the FDOT should distribute the document internally to all applicable parties that could potentially be involved in the promotion of TSM&O activities. All departments of the agency are important to consider as the FDOT moves toward a standard practice for TSM&O activities that would be adopted by the entire organization.

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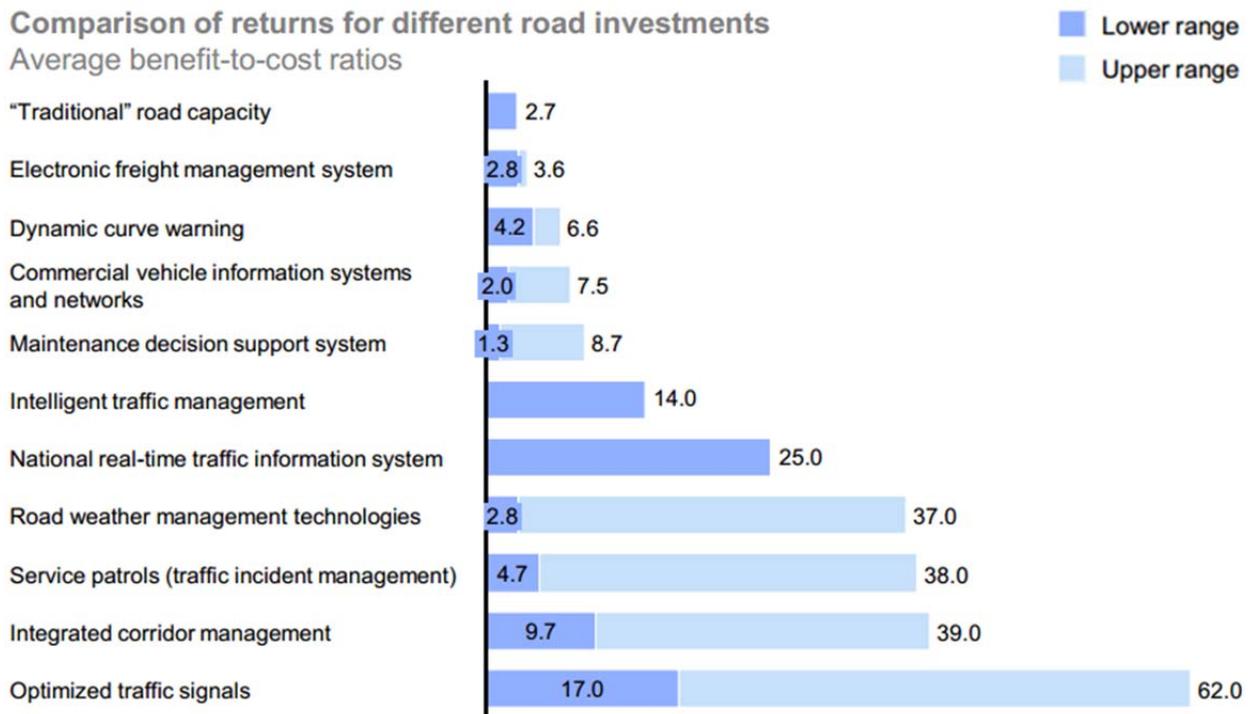
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## 1. INTRODUCTION

The Florida Department of Transportation (FDOT) has initiated business plans to promote the Transportation Systems Management and Operations (TSM&O) program throughout the State. The main purpose of this program is to maximize the safety, reliability, and efficiency of all modes of the transportation system. Increasing the benefits of an existing infrastructure improves operational performance, reduces long term costs and saves time. According to the Federal Highway Administration (FHWA), TSM&O is defined as, “an integrated program to optimize the performance of the existing infrastructure through implementation of multi-modal, cross-jurisdictional systems, services, and projects” (Atkinson et al., 2013). Due to limited resources and fiscal constraints involving new infrastructure to mitigate congestion, new strategies are needed to get the most capacity and efficiency out of the existing or planned transportation system. Strategies such as traffic incident management, traveler information dissemination, traffic signal coordination, and work zone management are considered part of TSM&O and have proven to be quite effective thus far in many categories compared to the traditional capacity improvement projects. For example, the study below from the McKinsey Global Institute (2008) shows an average benefit-to-cost ratio of certain Intelligent Transportation Systems (ITS) strategies which are regarded as a successful TSM&O approaches.



SOURCE: *Intelligent transportation systems*, Capitol Research, Council of State Governments, April 2010; *Transport for London*, 2007; *Intelligent transportation systems benefits, costs, deployment, and lessons learned desk reference: 2011 update*, US Department of Transportation, September 2011; *Urban mobility plan*, Seattle Department of Transportation, January 2008; McKinsey Global Institute analysis

**Figure 1 TSM&O Strategies Benefit-to-Cost Ratio Using ITS Technologies**



TSM&O is traditionally managed by traffic engineers that focus on optimizing efficiency and operations within a particular corridor utilizing common techniques such as re-timings and access modifications. With the emphasis moving towards maximizing current infrastructure, the Department envisions that the practice of managing TSM&O can be applied to all district units and disciplines for increasing efficiency. This would include Planning (e.g. in corridor management studies), Emergency Services (e.g. in incident management), Public Transportation (e.g. in effective use of transit services and transit system design), Environmental Management (e.g. in project development studies), Design (e.g. roadway design for freeways and arterials), and integration of Intelligent Transportation Systems (ITS) on the roads and railways. Unfortunately, so far, it is a common practice to apply TSM&O only when problems arise on the traditional infrastructure. Such an approach can negatively affect the end result of the project over time. Although it reduces the initial capital cost to construct a roadway or project, other costs can exponentially increase due to needed modifications when capacity is met. It also creates inconsistencies in the overall roadway system/infrastructure and possible compatibility problems when designing according to a particular condition. This approach is limited in its effectiveness due to being constrained to an existing built roadway, possibly resulting in an inability to implement the best strategy for the situation.

Many agencies at the State, regional, and local level have found great use of managing and operating the transportation system as well as implementing ITS strategic plans and architectures and have made progress in applying TSM&O strategies. It is still noticeable; however, that even with this progress there is a disconnection between infrastructure design and the needed long term results. One main reason is the lack of policies that support the integration of TSM&O strategies within the planning or design stages as a routine method of business practice. For example, including facility operators in planning not only provide the ability to identify necessary operations, but also give guidance on designs that will be more effective with maintenance, provide support for future deployed infrastructure, and be more easily operable.

This primer provides detailed guidance on how to apply TSM&O strategies from the planning stages to the construction phase of any general transportation project. There are also tools included that will assist the FDOT in developing a TSM&O program that best benefits the needs of the state. TSM&O programs established around the nation are discussed to understand the current initiatives underway. Various examples are used to show the effectiveness of applying TSM&O strategies in infrastructure design including the early stages of a project. Application of these strategies can allow improvement in regional transportation system efficiency, reliability, and options over the long term of a project's life span.

## **1.1 Objectives**

The main objective of this report is to provide an overall understanding of TSM&O practices and concepts. Included in the report is a synopsis of several Statewide and Nationwide TSM&O programs that were implemented or in the process of adopting TSM&O strategies in their



planning process. A summary of the best practices for creating a robust and performance based program is discussed. A detailed narrative highlighting the inclusion of all units within the TSM&O program is included. The report also provides background on financial programs that have the potential to provide funding for TSM&O programs. The objectives of this research are summarized as follows:

1. Share and compare TSM&O program initiatives in Florida and nationwide
2. Discuss the best practices that involved implementation of TSM&O in planning
3. Provide guidance from the lessons learned and benefits of these practices on how to best use TSM&O in personal practices.
4. Provide guidance for establishing a TSM&O program that achieves Department-defined benchmarks and implements a performance-based measurement of success.
5. Discuss the integration of all units of the Department within the TSM&O program.
6. Provide a summary of funding programs that can potentially be used for a TSM&O program.
7. Explain the best practices as they relate to the cost-benefit ratio of TSM&O practices and their return on investment.

The final results of the Primer provides the needed detailed guidance to the State (and local agency partners) as to the benefits, processes and effectiveness of implementing TSM&O in all areas and disciplines.

## **1.2 Summary of Project Tasks**

- Task 1: Research of Statewide and Nationwide Programs
- Task 2: Primer Document (from Planning to Construction)
- Task 3: Draft and Final Report**

## **1.3 History and Comparison of TSM&O Programs**

Steps in implementing TSM&O into the planning phase and gaining a better understanding of how to effectively use these strategies have been taken in various state DOTs. Looking at some of the examples in this section, it is possible to see major strides are being made to incorporate TSM&O strategies. TSM&O is still in the early stages for many DOTs, but momentum is starting to build from the success stories of the applied strategies.

### **1.3.1 Colorado DOT**

Around January 2013, the Colorado Department of Transportation (CDOT) put together the Division of TSM&O in order to focus on implementing low-cost high-value improvements for their existing transportation system. The formation of this division included the merging of their previous ITS division, the Traffic Engineering and Safety Branch, as well as the ramp meter maintenance and High-Occupancy Vehicle/High-Occupancy Toll (HOV/HOT) operations personnel. Through the successful development of this division, goals were set to be accomplished including improved accuracy & timeliness of traveler information, reducing delays



at critical bottlenecks by 5%, reducing clearance times by 5% in congested areas, work zone lane closure delays reduced by 10%, and improvements to existing highly used roadways/freeways (Rice, 2013).

With the formation of their Strategic Operations Plan, the CDOT TSM&O Division covers a few initiatives that the DOT has set out for. One of these initiatives include developing command-level partnerships with law enforcement and other stakeholders that can be applied to integrated events, corridor and incident management strategies. Other initiatives include implementing peak period shoulder lanes, improving operations through Active Traffic Management (ATM), ramp metering, managed lanes, and programs such as the Heavy Tow and Courtesy Patrol programs (Colorado Department of Transportation (CDOT), 2013). In the 2014-2015 Performance Plan it has been mentioned that system reliability is also a major target to be pushed and so new performance measures are being developed to assist in collecting travel time data for future system improvements.

### 1.3.2 Tennessee DOT

The Tennessee Department of Transportation (TDOT) has also added focus in developing a TSM&O unit, one that will be funded through the federal Congestion Mitigation and Air Quality Improvement (CMAQ) program for the fiscal year of 2014. TSM&O was included as one of their 2014 strategic air quality initiatives to assist in traffic improvements in the state. At this time, the TDOT has formed a TSM&O committee which has been tasked with planning and implementing innovative systems with focus on improved travel times and congestion reduction throughout the state. Though still early in the program stages, TSM&O influence is already showing in their more recent design/construction projects (I-24 Multimodal Corridor Study, 2014).

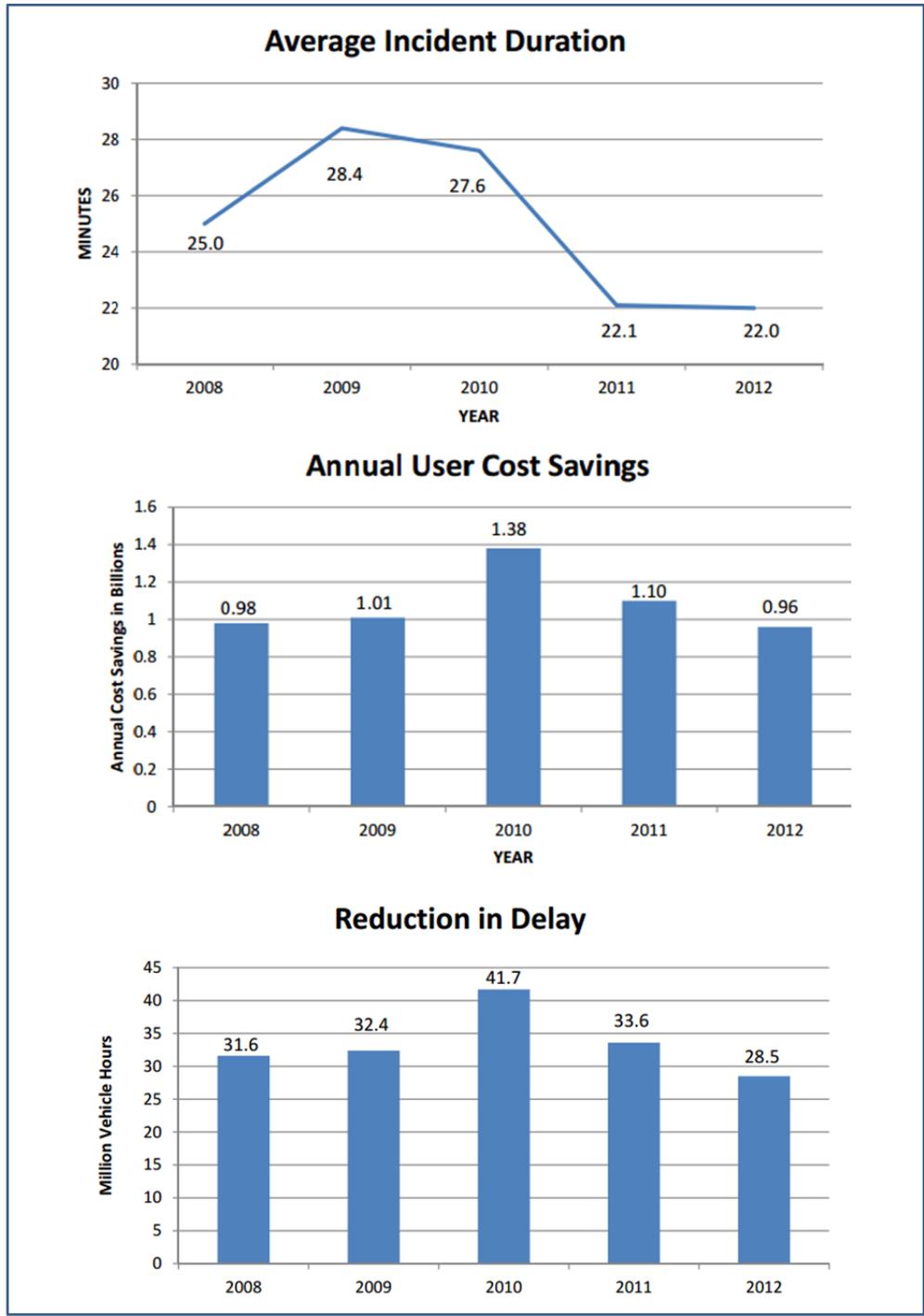
### 1.3.3 Maryland DOT

Maryland has developed their own TSM&O program which is now joined with their Coordinated Highways Action Response Team (CHART), a joint effort of Maryland Transportation Authority Maryland Department of Transportation (MDOT) and Maryland State Police (with cooperation of other federal, state and local agencies). The mission of CHART is to “Improve mobility and safety for the users of Maryland’s highways through the application of ITS technology and inter-agency teamwork” (Flanigan, 2013). CHART has an advanced command and control center called the Statewide Operations Center (SOC) which has been established for advanced traffic management all day every day. This hub station is supported by smaller scattered satellite Traffic Operations Centers (TOC) to assist in handling peak period traffic.

Established in the mid-1980’s and with the SOC open in 1995 (with a Business Plan developed soon after), the program has grown and developed over the years to cover various sub-systems such as traffic monitoring, traveler information, incident management, and traffic management using the latest in ITS technologies. Along with the ITS improved infrastructure, MDOT has mainstreamed TSM&O within their agency. The CHART program has funded various programs



containing TSM&O with their operating budget, including the Statewide Transportation Improvement Program (STIP) and the MDOT Consolidated Transportation Program (CTP). The various benefits received in traffic improvements through its area of coverage can be seen in Figure 2 from recent mobility and performance reports (Mahapatra & Wolniak, 2013).



**Figure 2 MDOT CHART Program Benefits**



### 1.3.4 Washington DOT

Washington State Department of Transportation (WSDOT) took a unique approach in the way they approached TSM&O through the collection of years of data to confirm the usage and benefits of ITS & TSM&O application. Thus far, the WSDOT Traffic Operations covers incident response, system operations, traditional traffic engineering, ITS research, ITS planning, tolling/HOV/HOT lane usage, and various other traffic systems/strategies. Early on, Washington has benefitted from continual deployment of innovative ITS technologies and operational traffic management strategies over the years. Roadways are continually monitored with real-time information 24/7 through many various ITS implementations, the Washington State Patrol (WSP), road crews, WSDOT incident response teams, as well as media traffic reporters. Recent implementation of Active Traffic Management (ATM) technology on four corridors has made Washington the first state in the US to use the system, showing their commitment to innovation (Flanigan, 2013).

One of their great achievements was in the development of the “Gray Notebook”, a quarterly accountability report that started back in May 2001. This report documents the latest information on system performance and project delivery, holding years of hard facts that have demonstrated the abilities of both ITS and TSM&O strategies through their benefits in safety, mobility, and efficiency. The report covers many various topics that the public and decision-makers can search through to know the latest studies using these strategies, performance records, and possible ways to implement the strategies more effectively into projects. Subjects covered include statistics and information on ITS technologies, multi-modal freight, travel information, pedestrian & bicycle safety, worker safety, and many other strategies and their uses and benefits. Through this information it is possible for both the public and project decision-makers to see the benefits of ITS and TSM&O on the transportation systems, thus improving public acceptance and helping other DOTs find more favor towards investing in these strategies.

Washington State has benefitted a lot from a strong history of cutting-edge operations strategies, but has also received improvements in their transportation systems due to programs that were established such as Moving Washington. Moving Washington is a framework that drives the project planning processes and provides a transportation program guiding investment principles (Moving Washington, 2014). The main focus and highest priority of the program is to “Maintain and Keep Safe”. It branches into three overarching strategies:

1. Operate Efficiently
2. Manage Demand
3. Add Capacity Strategically

Rather than pitting capital projects against operations strategies for funding, the Moving Washington program supports and encourages the implementation of combined strategies to maximize their efficiency and throughput. This program also affirms the states commitment to



mainstream the consideration of TSM&O strategies with other DOTs into all planning and programming activities.

### 1.3.5 Kansas/Missouri DOT

The program called Operation Green Light (OGL) is unique in that TSM&O strategies are implemented while backed and shared by many regional partners. The main idea of OGL was derived from the effort to synchronize traffic signals on major routes throughout the region, including that beyond city limits. This project/program is a major undertaking in that it is meant to provide benefits in the following categories:

- Improving traffic flow on majorly used roads in the covered region.
- Improve regional air quality.
- Derive a method in which state and local governments can better manage traffic patterns.

The project currently involves many supporters including Kansas & Missouri DOT, the Mid-America Regional Council (MARC), 21 area cities, and the Federal Highway Administration, all working together to deliver optimal results from the program (Mid-America Regional Council , 2015)).

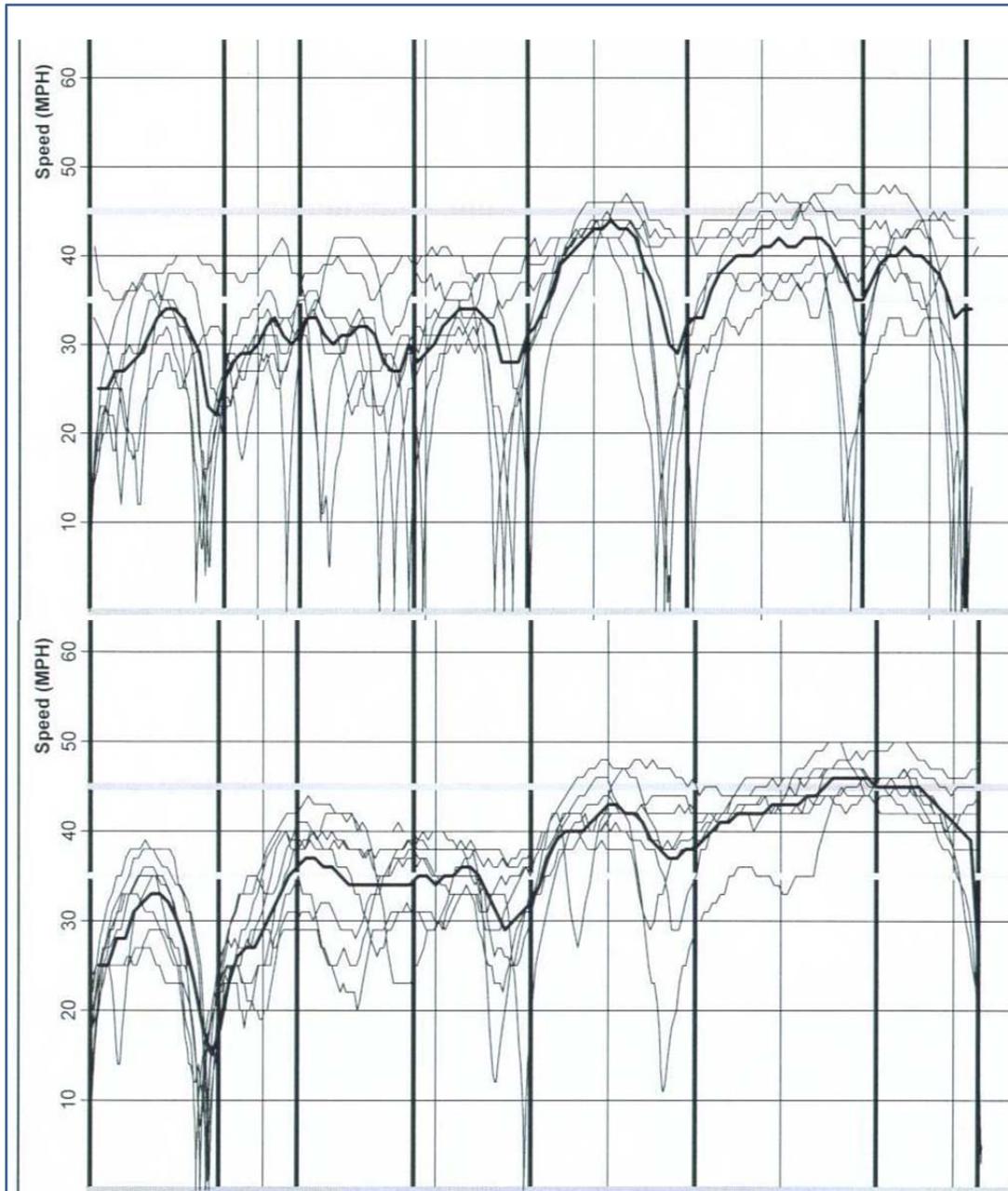
The mutual program works through cooperation of both the state and local governments that own traffic signals in the area with one another to use timing plans to improve the efficiency of traffic flow for intersections on major routes. Though currently established signal technology can be used in this project, new ITS technology is implemented to assist in communications between the equipment, software, and the central operations center. Using this infrastructure will help to keep the signals in sync when new timing plans are applied.

The OGL agreement that was established for the program describes the organizational structure of the program and the tasks to be performed by the program partners. Also, in the agreement also, the costs to sustain and maintain the system are split and shared including insurance requirements, equipment ownership and maintenance obligations, and other important elements of the program. The annual operation costs are proportionally split between each local entity based on their total number of traffic signals owned to the total number of traffic signals operated by MARC in the program (Balke & Voight, 2011). This agreement was signed by the appropriate authorities in the program and has thus far experienced no major struggles or disagreements between the partners.

Operation Green Light has proven to be quite successful thus far since the start of the program. Signs of reduced vehicle emissions, delays, fuel consumption, and vehicle stops have been noticeable and in some cases quite significant. In an update on the program in 2011, studies showed that during the morning peak there was a 74 sec reduction in travel time, a 33% increase in travel speed, an 18% reduction in fuel consumption, a 19% reduction in vehicle emissions and a 64% reduction in vehicle stops. For the noon peak there was even more improvement with



travel time reduction of 137 sec, travel speed increase of 58%, 26% reduction in fuel consumption & vehicle emissions, and a 73% reduction in vehicle stops. Overall annual savings totaled \$4,157,188 for users in the area while reducing the total pollutant emissions by 233,531 kilograms (Chandra, 2014).



**Figure 3 Operation Green Light Speed Profile: Before and After (over 6,000 ft traveled)**

(Source: [www.pcb.its.dot.gov/t3/s070911/Op%20Green%20Light\\_update1.ppt](http://www.pcb.its.dot.gov/t3/s070911/Op%20Green%20Light_update1.ppt))

From a recent Strategic Report produced by the MARC, goals and objectives were formed on items that need to be improved on with the OGL program. One goal to improve on was



technology, or keeping the hardware and software of the system relevant and up to date. Little had been planned in the long run regarding replacements once the product lifecycle passes in 10 years and it is expected that in 30 years there will be at least two to three replacements or major upgrades to the system. To keep partner support in the program it is needed to keep the system relevant and valuable. Another goal of improvement is funding, knowing in 2013 approximately \$610,000 spent on operations and \$490,000 on system maintenance and improvement. The program currently receives funding support from the federal Surface Transportation Program (STP), Congestion Management and Air Quality (CMAQ), and American Recovery and Reinvestment Act (ARRA) funds, not including local funding. According to an FHWA audit, even though the system has performed very well in improving traffic control and air quality many participants in the program have expressed concern in regards to the continued costs in operating the OGL system. This is due to constrained local and state revenues as well as funding cuts to other priorities. Due to future changes in federal funding, alternative funding needs to be found, and thus ideas of possibly implementing services in the OGL program have been considered.

A third goal currently being sought for (as recommended by the FHWA) is to develop a strategic plan and determine the best routes for the OGL program in the future. Based on the three aforementioned goals, objectives has been set to change the system in possible beneficial ways including system usage in non-peak hours, including incident management, adding more Closed-Circuit Television (CCTV) cameras to better manage, and establish performance measures to express the value of the OGL system. Lastly it has been reported by the FHWA that even though the program is successful, very few know about it and thus the fourth goal was formed, to market the program and educate the public to make people aware of its services. Accordingly, they continue to share the successes with others over the long term and prove the sustainability of the program (Operation Green Light Strategic Plan: 2013-2016, 2013).

### **1.3.6 Federal Highway Administration (FHWA)**

To assist in improving general transportation initiatives in the nation, the FHWA has produced multiple programs over the years that provide guidance for DOTs towards their own program improvements. Active in research and innovative thinking, great strides were achieved in producing efficient program delivery which in turn provide benefits towards the planning, design, construction, and operations to follow. In recent years TSM&O has been a major focus and has been reflected through their “Planning for Operations” and “Every Day Counts” initiatives.

Planning for Operations is a major push to create a connection between planners and operators to work as one towards an improved final product. The focus is not only on applying the latest in innovations, but also taking key points and advice from those who will operate them. Therefore, it is possible to consider the operational performance during the planning stages as well as merge operations solutions into the project early on that can result in major long term cost savings.



These benefits would include easier maintenance and operation of the final product which in turn improve system performance and reliability. Consideration of M&O strategies in the planning process will be included to improve transportation system operations. Transportation plans will receive overall improvement through the guidance of M&O strategies as well as the support of operations management.

This program has a major emphasis in not just linking planning with operations, but also expresses the importance of regional cooperative projects. Regional ITS architecture is an example to improve surface transportation systems through the use of integrated and interoperable systems for easy exchange of information when joint operations are formed (Regional Transportation Systems Management and Operations, 2014). Regional TSM&O is another factor of Planning for Operations that provides guidance to DOTs towards producing integrated programs that will improve and optimize existing infrastructure performance for cross-jurisdictional systems. Multiple examples of successful implementation have been given to promote the programs' successes including the Kansas City Operation Green Light (OGL), which is a joint project between Missouri & Kansas DOT as well as the Mid-America Regional Council (MARC) as described previously.

Every Day Counts (EDC) is a newer program established by the FHWA with a unique approach towards implementing TSM&O strategies. Through EDC, the FHWA works with others at a state, local, and industry partner level to deploy initiatives that will be carefully tested over a given term. The initiatives will then be gauged in their success rates to see if they will be included in a growing toolbox of effective strategies for others to learn from and implement within their own projects. These innovative strategies cover multiple areas including technologies/strategies unrelated to transportation, with transportation improvements being only a part of the grand goal of this program. The program has thus far gone through two phases consisting of innovations that have been tried through rigorous testing and a new phase; EDC-3 was announced August 28, 2014. Focuses in the transportation field of study have consisted of shortening project delivery, roadway safety improvements, congestion reduction, and environmental sustainability (Every Day Counts, 2013).

### **1.3.7 Oregon Metro MPO**

The Oregon Metro MPO works with multiple organizations within the greater Portland, Oregon area to enhance the mobility of the region. As such, the major focus of the organization is its multi-modal system and transit-oriented development to increase transit usage throughout the region. This agency has a broader perspective of its intended purpose because transportation is one facet of the responsibility of Oregon Metro. They maintain parks and venues in addition to their transportation duties. The interconnectivity of the disciplines they provide guidance for is one of the reasons that this organization is regarded highly. They see the development of transportation facilities as a part of a bigger picture of the new urbanization. They have a



comprehensive set of goals and structure for the implementation of TSM&O into their program, which will be discussed further.

Oregon Metro has implemented the use of Bus Rapid Transit (BRT) for the heavily traveled Burnside Road corridor. This project was accomplished by installing adaptive traffic signals with transit priority for the corridor. The project increased on-time performance and reduced route time on the line. The region has also implemented a bike signal program because of its integrative approach with bike trail planning and maintenance. The bike signals were implemented to reduce delay and decrease conflicts with bikes at intersections, especially those that transition from bike lanes on the roadway to bike trails. The organization was also an early adopter of the pedestrian countdown clock, which has quickly become standard in most states. Other innovations include one of the earliest commute forecast in partnership with Washington State Department of Transportation. This tool provides drivers of a chosen corridor to access a travel forecast based on data obtained by roadway infrastructure.

### 1.3.8 Florida DOT

Around April 2010, it was found that the population in Florida had grown to over 18.7 million, a growth of roughly 3 million residents each decade since 1990. Daily Vehicle Miles Traveled (VMT) increased by 83 percent, rising to nearly 540 million miles in December of 2010. A study produced by the Texas A&M Transportation Institute's 2011 Urban Mobility Report expressed Florida as holding seven of the top congested urban areas in the nation. In the report, it was found that 66 million gallons of fuel are wasted and 201 million person hours spent in traffic congestion, producing a total annual cost of \$3.874 billion. In 2010 Florida faced about 2,445 traffic fatalities, and comparing the Florida fatality rate per VMT of 1.25 to the national average of 1.11, safety became a growing concern (Shrank, 2011). With the FDOT's commitment to providing quick response and effective solutions towards these growing concerns, TSM&O strategies became a greater focus which has grown over the years.

The establishment of the TSM&O program in Florida brought forth a change in how planned and designed solutions were produced. The program's main vision and mission are:

- **Vision:** To operate our transportation system at the highest level of cost-effective performance.
- **Mission:** To deploy a customer-driven TSM&O Program focused on mobility outcomes through real-time and effective management of the existing transportation system toward its maximum efficiency.

The TSM&O program required leadership and task team in each district. These individuals would help build and strengthen a TSM&O strategy initiative that was compatible with their district and they were called the team of champions.



A series of workshops were produced by the FDOT during spring 2012, providing helpful guidance for each district on how they could implement the program in their individual area, taking into account their unique characteristics and local needs. This period helped to bring awareness not only to each district but external participants as well. From conclusion of these workshops, the districts were given a toolbox of strategies to begin implementing into their covered areas. These strategies provided focus areas to apply in the everyday design process from the planning stages of a project to operations and maintenance. Examples of these strategies include ramp signals, incident management, managed lanes, and traveler information. Other strategies are planned to join these tool box strategies in 2015, including active traffic management (ATM), a virtual freight network, and a push towards connected vehicle utilization.

One general project in Florida that has shown great success is the Road Ranger service patrols, first implemented in December of 1999. These patrols are tasked with various jobs that assist vehicle users on the roadways through providing roadway assistance while maintaining the roadway cleanliness. Over recent years, there has been a drastic increase in rate of return from the program, with very positive reviews from users who have received assistance from the Road Rangers. For the fiscal year of 2012/2013, 7,029 respondents to a survey of 7,164 expressed excellent experiences, with only five mentioning fair or poor performance. From the same pool of participants, 6,098 received assistance within 15 minutes while 780 received it between 15 to 30 minutes. The Florida Turnpike has also received a large response of 15,372 survey participants expressing very positive feedback (Road Ranger Service Patrol Comment Card Report, 2013).

New additions are being developed for the FDOT's currently existing performance dashboard, which is accessible through their website. The dashboard at this time gives recent updates and trends in FDOT performance regarding transportation safety, project delivery, maintenance, mobility, and accountability. A new update is planned to expand on this functionality with added updates in regards to TSM&O-related performance measures. Categories such as delay, incident clearance times, travel time reliability, and work zone management will be broken down into details that can be easily analyzed to gauge overall DOT monthly/annual performance. This new addition is listed as one of the 2013-2015 operations and planning actions planned for the near future.

In recent years, the FDOT districts produced various effective outcomes and progress towards the implementation of TSM&O. Some examples from each district include:

- District 1: Creation of an ITS Management Team, a single regional traffic management system.
- District 4: System integration into arterials, freeways, and transit. Defined a TSM&O network and production of an advanced traffic management system in central Broward County.



- District 5: Actively monitored travel times on I-4 and SR-417 as well as diversion message displays on I-4 where needed. CCTV footage of construction zones monitored at Operations Centers and the implementation of managed lanes on I-4.
- District 6: A combination of congestion pricing, ramp management, express bus, and carpools on I-95 in Miami-Dade (I-95 Express).
- Turnpike: New lane configurations to increase throughput, replacement of the Anderson Toll Plaza and realignment of the road ramps.

For further details regarding TSM&O influence in the FDOT, each district is explored in regards to their recent projects and developments:

### *District 1*

Prior to the workshop presentations in 2012, the FDOT District 1 was hard at work pushing various projects for their TSM&O initiative. For their workshop presentation they mentioned improvements in the following areas:

1. Arterial Management through a regional traffic signal coordination program, signal retiming, and Advanced Traffic Management System (ATMS).
2. Incident Management with a rapid incident scene clearance program and Road Rangers
3. Freeway Management
4. Special Event Management
5. Work Zone Management with temporary detectors and signal timing during construction
6. Transit Operation and Management using cross agency coordination to implement Bus Rapid Transit (BRT) corridors
7. Traveler Information through providing traffic and weather info through Florida's 511
8. Travel Demand Management with ride matching for carpool, telework policies, and park & ride.

One area that has flourished in this district was traffic incident management. A website has been designed to share performance measures, meeting material, and various other information that benefit employees and roadway users alike. For recent projects ITS has been the major focus thus far. A successful launch of ITS operations has been made in Charlotte, Lee, and Collier counties to utilize new strategies and help regulate traffic flow. The latest completed project is the addition of ITS on I-75 which include dynamic message signs (DMS), highway advisory radio (HAR) stations, roadside sensors and fiber optic cable for communications (Birosak, 2014). The completion of this feat successfully finishes the goal of installing ITS throughout District 1.

The monthly progress reports provide a vast amount of data in regards to incident timing and event details in the counties covered. Data includes lane blocking event numbers and durations for each county and I-75, DMS statistics, Road Ranger assistance are examples to give a general view on performance with incident management in District 1 using SunGuide software.



**Table 1 Lane-Blocking Durations (Average) in District 1 Counties (HR:MIN)**

<b>LANE BLOCK INCIDENTS PERIOD (2013)</b>	<b>COLLIER</b>	<b>LEE</b>	<b>CHARLOTTE</b>	<b>SARASOTA</b>	<b>MANATEE</b>	<b>OTHER D-1</b>	<b>OTHER DIST. TMCS</b>	<b>ALL</b>
<b>JANUARY</b>	1:28	1:21	2:08	1:43	1:17	0:50	0:07	1:28
<b>FEBRUARY</b>	1:50	1:35	0:45	1:43	1:15	0:00	0:00	1:37
<b>MARCH</b>	1:40	1:21	1:18	1:39	1:33	0:50	0:07	1:30
<b>3RD QUARTER</b>	1:10	1:30	1:13	1:28	1:30	2:19	0:00	1:24
<b>NOVEMBER</b>	1:39	1:30	1:43	1:15	1:39	0:00	0:43	1:30

***District 2***

Several improvements in TSM&O have been made all over District 2 over the recent years and lofty goals have been set to further expand on their recent project completions. For freeway management, actions are being made to move towards migrating to a new Regional Traffic Management Center (RTMC) and interconnections as well as continue incorporating incident management within Advanced Traffic Management System (ATMS) operations. Signal operations are being improved through the continuation of moving towards real-time management and adaptive signals. To prepare for Hurricane scenarios, an I-10 contraflow plan was produced and road weather information sensors were installed on bridges to detect high winds.

To achieve reliability and consistency of travel speeds and durations, truck & freight management has been improved through Bluetooth information collection, shipment tracking, a mass notification system at Dames Point terminal (to tie into their District 2 ITS system), and improvements on fiber communications for JaxPort. Bus travel in the district is also improved through real-time Automatic Vehicle Location (AVL) technology installed on all Jacksonville Transit Authority (JTA) Buses. Other special bus projects include ITS transit signal priority, bus priority signal phasing, and bus rapid transit corridors. Performance measures (travel times/delays) are also being produced through SunGuide software and support these measures for both arterials and freeways (Vega, 2012).

***District 3***

The focus areas for this district regarding TSM&O strategies have been mainly consisting of intelligent transportation systems and traffic management. For ITS technology, a joint partnership between District 3 and the City of Tallahassee was formed to construct an RTMC within the city of Tallahassee, making this the second RTMC in this district (the first in Pensacola). From this agreement also is an 18 mile freeway management system for Interstate 10. Integrated corridor management has become an addition to support arterials and I-10. Included in this projects are the installation of various traffic cameras, DMS, vehicle detectors,



and a new weather station. The Road Ranger program has also found major success thus far with very positive feedback and quick turnover time with the events confronted.

To improve traffic management, an Advanced Traffic Management System (ATMS) was under development and finalized late 2013. This project was expanded to cover a larger region over the course of its design and now provides a useful tool for traffic engineers to monitor signal timings and maintain issues remotely. Communications for the network are via closed-circuit television cameras, DMS, and traffic sensors (Williams, 2012).

#### ***District 4***

Multiple projects have been established in this area. In October 2012, a partnership with the Palm Beach County Traffic Division started an arterial management pilot project that covered a network of six corridors in Palm Beach County. This initiative has an overall focus of helping refine management strategies and help improve incident management in the covered areas. ITS equipment was utilized for the purpose of observation and vehicle data collection to help identify and mitigate the causes of congestion. In November 2013, six additional arterial corridors were added to the Broward County arterial management program as well.

Strides have been made in implementing managed lanes into freeway projects such as I-595, I-95, and I-75. ATMS technology has also been incorporated through the district with many projects commenced and currently in development throughout Broward and Palm Beach counties. The most significant of these projects are the inclusion of Adaptive Traffic Control System (ATCS) hardware/software to integrate into the signal controllers to help manage traffic demand. Other recent projects include additions of Severe Incident Response Vehicles (SIRV), more Road Rangers, and Rapid Incident Scene Clearance (RISC) equipment (Sun Guide ITS Program District Progress Report, 2014).

#### ***District 6***

South Florida has made a major push in TSM&O strategies over the past years. In fact, currently ITS deployment work has become mainstreamed into the regular production processes (Sun Guide ITS Program District Progress Report, 2014). Improvement and maintenance projects are performed frequently on the existing infrastructure with the inclusion of ITS and various strategies to better improve the final project outcomes. From actively working on their mission of TSM&O strategy implementation, they have been able to produce some projects that were seen as great examples for others with similar project ideas in mind.

District 6 has mapped out a preliminary draft for a TSM&O network goal in their region that covers a vast amount of their major roadways. One of the major roadways is the I-95 strip running through Miami which has been mentioned and will be discussed later. I-75 is going through a study phase in preparation for future transportation mode additions and various technologies to relieve existing and future congestion. I-395 improvements are also underway to



provide potential realignment, capacity improvements, and alternative modes of transportation as well as developing an aesthetically pleasing pedestrian friendly corridor. Projects on SR 826 and SR 836 will improve access ways and further developments will tie into the ultimate TSM&O network goal that connect all of these routes together. Other routes will be worked on, but currently the draft plan is still subject to change if needed.

### *District 7*

ITS has become a highly emphasized technology for this district coverage area. The Tampa Bay Sun Guide Freeway Management System has been an ongoing project over the past years that continue to grow through Hillsborough, Pinellas, Polk, and Manatee counties. During their TSM&O presentation on September 7<sup>th</sup> of 2012 they claimed their system covered 167 miles of roadway that implemented closed-circuit television, dynamic message signs, traffic detection stations, and fiber optic cable for communications between the equipment. The project continues to expand within its Sun guide ITS 5-year work program with many of the projects currently in Phase III & IV development as well as new additions in Pasco and Hernando County (Chandler, 2012).

Along with their progress in freeway traffic management, they have also made strides in active arterial traffic management. Traffic is monitored through BlueTOAD system by TrafficCast from collecting travel times, analyzing them, and giving traffic condition results through weekly, monthly, quarterly, and annual reports. Bluetooth-based receivers have been installed through many of the major streets as means of data collection. This data helps in pinpointing abnormal traffic situations that could require further attention or countermeasures to correct. At intersections, the flashing yellow arrow and active signal retiming are being highly utilized and proving to be highly beneficial in their covered corridors. One study shows that for six corridors there was an annual reduction of 249 crashes, present value of benefits amounting to \$41,200,000, and very low cost of improvements/maintenance, and an overall benefit/cost ratio of 55:1 (Gonzalez, 2013). Based on District 7 results, it really shows how much TSM&O has benefitted their area of coverage.

Table 2 provides a summary comparison between the different State DOT TSM&O programs and practices which were mentioned previously and describes the program goals, strategies implemented and specific applied projects.



**Table 2 Comparison of TSM&O Programs/Practice**

<b>DOT/DIVISION</b>	<b>APPLIED PROGRAM</b>	<b>PROGRAM FOCUS/GOALS</b>	<b>STRATEGIES IMPLEMENTED</b>	<b>APPLIED PROJECTS</b>
<b>COLORADO</b>	TSM&O Division	Improved accuracy & timeliness of traveler information, reducing delays at critical bottlenecks by 5%, reducing clearance times by 5% in congested areas, work zone lane closure delays reduced by 10%, and improvements to existing highly used roadways/freeways	Incident Management, Advanced Traffic Management, Ramp Metering, Managed Lanes	I-70 Mountain Corridor, I-25 Metro Corridor
<b>TENNESSEE</b>	TSM&O Unit	Plan and implement innovative systems with a focus of improved travel times and congestion reduction throughout the state	Managed Lanes, Multi-Modal	I-24 Multimodal Corridor Study
<b>MARYLAND</b>	Coordinated Highways Action Response Team (CHART)	Provide traffic monitoring, traveler information, incident management, and traffic management using the latest in ITS technologies. Mainstream TSM&O in design	Advanced Traffic Management, Traveler Information, Incident / Traffic Management	Statewide / Traffic Operations Centers (SOC & TOC)
<b>WASHINGTON</b>	Moving Washington	Apply TSM&O in design and share system performance & project delivery data to further push TSM&O initiative. Form a framework that drives the	Incident Response, Managed Lanes, ITS Research / Planning, System Operations,	Gray Notebook, I-5 Auxiliary Lane, SR 150, SR 285, North Spokane Corridor,



**Table 2 Comparison of TSM&O Programs/Practice, continued**

<b>DOT/DIVISION</b>	<b>APPLIED PROGRAM</b>	<b>PROGRAM FOCUS/GOALS</b>	<b>STRATEGIES IMPLEMENTED</b>	<b>APPLIED PROJECTS</b>
		project planning processes and provides transportation program guiding investment principles	Advanced Traffic Management	Statewide Highway Safety Program
<b>KANSAS / MISSOURI</b>	KC SCOUT, Operation Green Light (OGL)	Improve traffic flow on majorly used roads in the covered region. Improve regional air quality. Develop method for state and local governments to better manage traffic patterns	Advanced Traffic Management, Ramp Metering, Arterial / Freeway Management	684 signals through central system, coverage on many main roads
<b>FHWA</b>	Planning for Operations (PO), Every Day Counts (EDC)	Enhance planning & operations functions to improve TSM&O implementation. Deploy various new initiatives and develop performance measures to gauge their success	PO: All strategies apply, focus on regional application. EDC: Adaptive Signal Control, construction efficiency, Work Zones	OGL, Austin TMC, HOV project drive coordination WDOT, SR 436, Pinellas County ASC, SR 100, Highway 99W, US Route 19,
<b>FLORIDA</b>	TSM&O Program	Apply TSM&O focus area initiatives to each district and statewide in order to better understand and best apply TSM&O strategies. Implement TSM&O into the planning and operations phase of projects	General Road Management, Work Zones, Traveler Information, Multi-Modal, Incident Management, ATMS	SunGuide, I-10, I-595, I-95, I-75, I-395, SR 826, SR 836, JaxPort bus system, Arterial Management in Palm Beach / Broward



**Table 2 Comparison of TSM&O Programs/Practice, continued**

<b>DOT/DIVISION</b>	<b>APPLIED PROGRAM</b>	<b>PROGRAM FOCUS/GOALS</b>	<b>STRATEGIES IMPLEMENTED</b>	<b>APPLIED PROJECTS</b>
				County
<b>CALIFORNIA</b>	CALTRANS	Provide a safe, sustainable, integrated and efficient transportation system to enhance California’s economy and livability	Integrated Corridor Management (ICM), Managed Lanes, Active Traffic Management	I-15, I-80, I-110, I-120, SR-57, SR-91, I-5
<b>OREGON</b>	Oregon Metro MPO	Provides guidance for Transit-Oriented Development, promotes the use of differing modes of transportation and championed the development of smaller city centers throughout the urban boundary	Transit-Oriented Development, Multi-Modal, Transit Prioritized Signals, Bicycle Signals, Traveler Forecast	Burnside Road Adaptive Signals, Region-wide Bicycle Signals, Region-wide Pedestrian Countdown Signals, I-5, Regional Travel Options (RTO)



## **1.4 Florida Tier II TSM&O Business Plan**

For the Florida Department of Transportation, strides have been made to implement a fully operational TSM&O program in the state of Florida. One clear indicator is the Tier II business plan. In 2008, the FDOT Executive Board recommended the idea of establishing a TSM&O Task Team with a primary role of developing the Tier II business plan. The plan was endorsed by the board on May 20<sup>th</sup> of 2010 along with the endorsement of the TSM&O program in Florida and updated in 2011 to include the latest changes. This business plan is produced with multiple organizational tiers that transitions from statewide level to district level to program focus. This type of framework is used as an effective means to identify further levels of detail to consider during TSM&O program analysis and development. The business plan is currently managed at multiple levels by Atkins. Tier II is of course a step in the grand plan of producing a focal point to implement various elements embodied within the various categories of their strategic plan. Tier I was produced to be the FDOT's statewide business plan, which was monitored quarterly and updated annually. The Tier II plan then provides further detail through core processes and major areas of function that may cross organizational lines. Tier III will then further provide details down to the district level, where each district will produce their own business plan (Turnbull, 2005).

The mission statement of the TSM&O business plan is, "To deploy a customer driven TSM&O program focused on mobility outcomes through real-time and effective management of the existing transportation system toward its maximum efficiency". A vision statement was also made to go alongside the mission, which falls in line with the main TSM&O objective stating, "to operate our transportation system at the highest level of cost effective performance" (Transportation System Management & Operations Tier 2 Business Plan, 2011). Currently Tier II holds the primary categories of leadership, strategic planning, customer & market focus, human resources focus, performance measures, process management, and organizational performance results. These categories further break down into details regarding activities to be performed, performance indicators, target goals, progress, and who is responsible for each category. This plan is supported by the included development of a strategic plan which presents a high-level structure for establishing and maintaining the program. Both of these plans will help ensure that TSM&O is implemented and kept in the forefront through the FDOT's operations, planning, project development, and policy/procedure changes. This same framework used in the tier II business plan has been used in workshops which are produced to assist DOT, partner agency managers and staff to self-identify the areas where improvement would provide the greatest payoff in the TSM&O program.

## **1.5 Legislative Impacts**

The Florida Senate revises and continually updates many of the bills and statutes yearly as necessary. They also make addendum or amendments as necessary for the transportation needs of the state. Most of the statutes related to the transportation field and its management can be



found in Title XXVI named Public Transportation. That title encompasses Chapter 334 through Chapter 349. Chapter 334, which is titled Transportation Administration, is the anchor of Title XXVI. The chapter lays down statuses of how the Transportation Administration should operate in the form of guidelines. Chapter 334.035 showcases the purpose of the transportation code is "to establish the responsibilities of the state, the counties, and the municipalities in the planning and development of the transportation systems serving the people of the state and to assure the development of an integrated, balanced statewide transportation system. The prevailing principles to be considered in planning and developing these transportation systems are: preserving the existing transportation infrastructure; enhancing Florida's economic competitiveness; and improving travel choices to ensure mobility. This code is necessary for the protection of the public safety and general welfare and for the preservation of all transportation facilities in the state" (The Florida Senate, 2015). A TSM&O program is one of the many purposes that falls under this code that can save resources and improve the state's facilities with an investment in capital improvements.

Chapter 339 of Title XXVI, Transportation Finance and Planning, is the most related to Traffic Management and Operations. Many of its statutes are related to the management of funds and facilities of the Transportation Administration. Statute 339.155, Transportation Planning, focuses on the development and operation of the Florida Transportation Plan that "consider the needs of the entire state transportation system and examine the use of all modes of transportation to effectively and efficiently meet such needs" (The Florida Senate, 2015). TSM&O relies heavily on implementing effective and efficient solutions to complex issues on the transportation network. The practice supports the consideration of the entire system. It also establishes long-range transportation goals and objectives to be accomplished on a 20 year horizon. That is the timeframe for which the plan is expected to be active within the context of the State Comprehensive Plan and other mandates or authorizations based on many principles including the preserving the existing transportation infrastructure and improving travel choices to ensure mobility among others. (s. 334.046). (The Florida Senate, 2015)

Another important statute is 339.175 that supports the implementation of TSM&O focuses on the Metropolitan Planning Organization. It encourages and promotes "the safe and efficient management, operation, and development of surface transportation systems that will serve the mobility needs of people and freight and foster economic growth and development within and through urbanized areas of this state while minimizing transportation-related fuel consumption, air pollution, and greenhouse gas emissions through metropolitan transportation planning processes identified in this section" (The Florida Senate, 2015). For this statute to be effective the MPOs must work in cooperation with state and public transit operations, transportation plans and programs (s. 339.177) (The Florida Senate, 2015)



## 1.6 Keys to a Good TSM&O Program

Success in implementing a good TSM&O program has varied among the state DOT's over the years. Regardless of the successes, however, many research efforts show that there are areas that can be improved to bring TSM&O application to its full potential. According to research conducted by the Transportation Research Board (TRB) and American Association of State Highway Transportation Officials (AASHTO), the following critical dimensions have been brought up as key to focuses in the TSM&O program development:

- Processes that support effective applications, such as integration of TSM&O in planning, consistent use of systems engineering, standardization and documentation, and performance management.
- Institutional characteristics that support the processes, such as leadership commitment, organizational consolidation, staff development, and external collaboration (Creating an Effective Program to Advance Transportation System Management and Operations, 2014).

Further development in understanding an effective program versus an ineffective program was introduced through the Strategic Highway Research Program (SHRP2). In a recent SHRP2 study, Flanigan & Strasser (2014) found that technical knowledge, an understanding of basic strategies, and relative funding levels did not play as key roles in the effectiveness of TSM&O application. However, customization of the business and technical processes for the planning stage, programming, systems engineering, asset management, and performance monitoring had the largest impacts. Instead, customization of the business and technical processes for the planning stage, programming, systems engineering, asset management, and performance monitoring made the largest impacts. Overall, how effective the program will become over time is closely related to both the specific processes and institutional arrangements that are required to support TSM&O strategies. These changes of course would most certainly bring adjustments in the overall architecture of an agency, which would affect leadership and staff as well as the supporting institutional framework of programs and resources.

Breaking down key elements for an effective program resulted in six dimensions that require improvements or focus:

1. Business Processes: TSM&O is rarely included in state or regional planning processes and is typically used for certain particular reasons only, without a means to sustain or improve a program. Despite the potential in the applied strategies to address problems with major delay and unreliability, few DOTs have spent more than 2% of their total budget on TSM&O.
2. Systems and Technology: Though current technical staff have an understanding of recent technology, there is a struggle in standardizing, upgrading, and integrating the latest technologies due to rapid improvements in technology development. Private-sector and



service provider systems are increasingly playing larger parts in operations and maintenance.

3. Performance Measures: Increasing the effectiveness of TSM&O strategies is heavily reliant upon performance measurement. Many DOTs have a very limited knowledge in how the TSM&O activities affect items such as delay, reliability, and crashes. Such studies have been largely fragmented throughout the nation making procedure and policy production very difficult and overall unjustly devalue the benefits of a program.
4. Culture: Most DOT senior leadership have a limited vision of the potential in TSM&O and focus on maintaining a legacy culture where capital improvements are made. Some TSM&O programs were not implemented until a major crisis came along, while others may have had one star middle-manager that put forth the effort to make their program a success.
5. Organization and Workforce: TSM&O is not a major focus in the state DOT organizational structure and is typically fragmented into various separate programs such as ITS and traffic operations. These programs can also tend to be very understaffed due to agency constraints and limited qualifying staff. There is a very limited drive for potential future employees to become professionals in implementing TSM&O strategies.
6. Collaboration: Many of the most crucial and beneficial strategies need collaboration with various other services and agencies such as law enforcement, emergency services, and towing. Divided jurisdictions and responsibilities can make it difficult for DOTs to use TSM&O at peak efficiency. Regionally, collaboration can tend to be informal and disrupted as employees come and go.



## 2. BEST PRACTICES & CASE STUDIES

### 2.1 Business & Funding Best Practices

In order to show TSM&O techniques are improving the financial performance of projects, a closer look at the programs must be made to dissect their benefits in comparison to possible lower costs of operations. Since TSM&O programs are more mature in some states, the focus on funding is as important as the improvements that were made by using lower-cost strategies. There was a shift from deployment activities to operations activities which used the system already established. This includes some collaboration bridges across departments to be more efficient. As organizations build better relationships and communication practices the results of efforts like this will continue to improve.

#### 2.1.1 Traffic Management Center

##### **Houston, TX - TranStar**

In 1993, the Houston TranStar partnership was created which included the Texas Department of Transportation (TxDOT), the Metropolitan Transit Authority of Harris County (METRO), Harris County, and City of Houston. From this partnership, the main objective was in the management of traveler information systems in Houston. Information regarding traveling conditions on the major roadways consisted of dynamic message signs (DMS), highway advisory radio, internet and local media broadcasting. The project has expanded over the years to include over 81 DMS on more than 250 miles of freeway in Houston. Data would be collected through their “EZ-Tag” Automatic Vehicle Identification (AVI) toll transponders, which is collected from reader stations at most 5 miles apart and sent to the TranStar Traffic Management Center (TMC) for analysis (Travel Time Messaging on Dynamic Message Signs, 2005).

TranStar is a unique system in that it was planned and organized to encompass multiple transportation systems including traffic, transit, and emergency planning. The system is open to expansion and adapting to technology over the years including one of the later additions of traffic information for the railway system in Sugar Land. Through implementing this strategy results were reported in a study declaring a 12% reduction in nonrecurring congestion and a 3% reduction in recurrent congestion (Mahmassani et al., 1998).

In the development phase, the TranStar system was originally designed with the idea of using manual operators to update all DMS boards with travel times. The extra overtime did not seem feasible for future developments and thus work was performed with the Texas Transportation Institute (TTI) and Southwest Research Institute (SwRI) to create an automated system that is currently used.



## ***Benefits***

Implementing such a vast system has shown positive results through surveys taken by the public. These studies have shown that the alert systems of the TranStar have provided major positive results in incident alerts (93%), freeway travel time (82%), real-time road work advisories (81%). About 85% of respondents claimed their route was changed due to the information forecasted and many claimed they depend on the system.

Since its inception, TranStar has produced many major benefits for both the citizens and the partnership itself. Through actively managing traffic in the city it was found in a 2009 study that TranStar offset travel delays in Houston by 11.3 million vehicle hours, providing a monetary benefit of \$227 million (Houston TranStar, 2015).

## ***Lessons Learned***

With such a robust project and desire to improve/expand the system there can be many problems unfortunately. Though TxDOT and FHWA funds paid for the majority of the initial capital cost, recurring costs (maintenance, software, communications, etc.) are still a problem to this day to manage and are being looked into. A high deal of turnover is also experienced for operators at the TMC as a result of the high learning curve for the position. All new operators require at least 1 to 2 years of experience working with the equipment in order to make their own decisions during operation. TranStar also requires feedback from the public regularly in order to improve the system for travelers such as; which information is important to display at times and simplifying messages so the public can understand the alerts being sent out.

During the planning phase of this project there were a few lessons learned for any other cities that plan to implement a similar system. For example, public agencies should ensure the software used is owned in the system in order to prevent problems later on when modifications are required. One of the major recurring problems the agencies experience with TranStar is communications between the Traffic Management System (TMS) and DMS, thus planning out the right communications method can be a major cost saving mechanism later. An agency should seek to apply standards-based procurements in order to facilitate system interoperability, due to difficulties of legacy systems in automation. A project of this extent requires a systematic and well thought approach in order to solve problems in a controlled manner (example approach would be corridor-by-corridor implementation and examining performance over time). Though very expensive, the TranStar partnership finds that there is tremendous benefit that comes in return through the DMS, processing, and automatic data collection systems and should be taken into account (Travel Time Messaging on Dynamic Message Signs, 2005).



### 2.1.2 Transit Management

#### **Portland, Oregon – Tri-Met**

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) is a mass transit public agency known well in the Portland Metropolitan area Oregon. First started in 1969 from the Oregon legislature, it has now expanded and grown to where it currently supports 625 buses and runs a commuter rail system. During the Fiscal Year of 2009 the overall system ran on average nearly 325,000 rides per weekday (TriMet At-a-Glance, 2014) and still maintains a strong ridership with the citizens today.

Prior to Tri-Met becoming what it is today it used to run the bus system through costly manual data recovery measures like most other transit systems at the time. In the mid 1990's however this changed dramatically when they shifted to a Computer Aided Design/Automatic Vehicle Location (CAD/AVL) system to manage operations.

#### ***Benefits***

From this change benefits began to show in the new system implementation in travel and delay times. Estimated waiting times declined by 0.11 minutes, resulting in an annual system-wide waiting time savings of about 114,000 hours. Including the median wages at the time it is found that the annual savings in wait time was \$1.6 million. The study also concluded that each passenger also saved approximately 0.42 minutes of travel time on average with the new system, which gives an annual savings nearly 400,000 hours. The estimated running time improvement of 1.45 minutes per trip summed over all the weekday trips totaled annual savings of 45,400 hours, reducing the operating costs by a fair margin. The total annual savings from the improvement was \$5.4 million while the total value during the study (1999) became \$47.8 million (Strathman et al., 2000).

#### ***Lessons Learned***

With these successes Tri-Met gave words of advice on how to approach such a large project. They first recommended it was important to take a “hands on” project management approach through the designing and implementation of the Bus Dispatch System (BDS). This was due to the fact that the transit industry market for Advanced Public Transportation Systems (APTS) technologies was small and vendors lacked experience and insight in this area at the time. One item they found to be of greatest help in the success of this project was in the selection of the person to manage the project. This person had a diverse background and a considerable amount of operations experience which included service as an operator, trainer, and data analyst for Federal Transit Administration (FTA) Section 15 reporting. Management of the BDS project up to implementation was his sole responsibility, and using his experience he was able to assemble a team that held similar strengths. The inclusion of dispatchers on the team (who held strong



interest in the real time applications of the BDS) also proved to be beneficial; ensuring a large amount of attention was given to the details of the project (Furth, 2003).

Vendor selection was another crucial part of the project success, with their selection proving to be highly motivated to deliver a successful product. Because the Tri-Met project was the first AVL job in the transit industry and the clients satisfaction was important, a very talented programming, specialist, and analysis team was put together to work closely with the vendor to ensure success. Other items that brought success to the project include bringing in people with prior experience in Automatic Passenger Counts (APCs) and synergistic price reductions in an AVL system and APCs due to compatibility with existing systems.

### **2.1.3 Regional Traffic Management / Incident Management**

#### **Kansas City – Kansas City SCOUT**

Prior to the implementation of this system, the highway system in Kansas City metropolitan area operated at full capacity during peak periods. Any sort of congestion, whether recurring or non-recurring, created unnecessary delay. Increasing capacity only brought increasing construction costs and environmental concerns, both which needed to be taken into account prior to any actions with the limited funding provided (Kansas City Scout – Kansas and Missouri, 2014). To produce an alternative solution, both the Kansas Department of Transportation (KDOT) and Missouri Department of Transportation (MoDOT) formed a partnership to produce what would become the called the Kansas City Scout (launched in 2002).

Kansas City Scout is a traffic management system that manages traffic on more than 125 miles of continuous freeways. This system does not hold any traffic controlling capabilities, but can detect and manage various traffic situations on its system. The KC SCOUT implements various technologies including integrated CCTV cameras, VMS, VDS, highway advisory radio (HAR) system, and a dynamic website for users (Mehran, 2013). The system also provides users with real-time travel information so that they can plan out the best routes to take to their destination.

One of the crowning aspects of the KC SCOUT system is the incident management program implemented later on, which has given major improvements to delay times for incidents. After this program was a follow up of a ramp metering system in March of 2010, another low cost project to add onto the growing KC SCOUT system. This system took a corridor adaptive approach to controlling the ramp signals, called Corridor Adaptive Ramp Metering Algorithm (CARMA). It is considered a “smart” system in that it activates based on traffic demand, specifically more so for the morning and afternoon rush hour periods (Ramp Metering Delivers – Again, 2011).

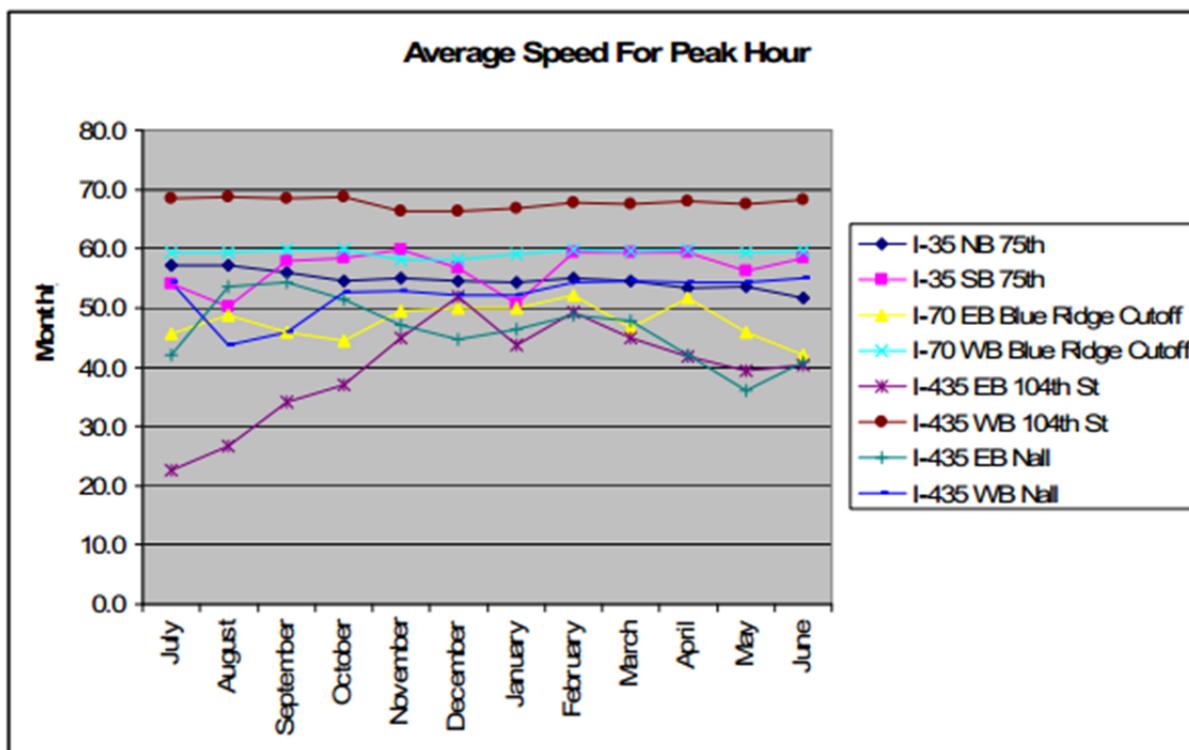
Overall the KC SCOUT system has been a very popular system with the public. Though new additions such as ramp metering did cause temporary concerns, research performed showing the benefits of these added traffic strategies have proven the system efficiency and reclaimed



favorable acceptance with the areas covered. The project initial cost was \$43 million, with the majority (80-90%) funded by the Federal Highway Administration (FHWA) while the remainder paid for by KDOT and MoDOT. Any added costs from add-ons to the system have been taken care of by the DOT's and public support through tax dollars (Kansas City Scout – Kansas and Missouri, 2014).

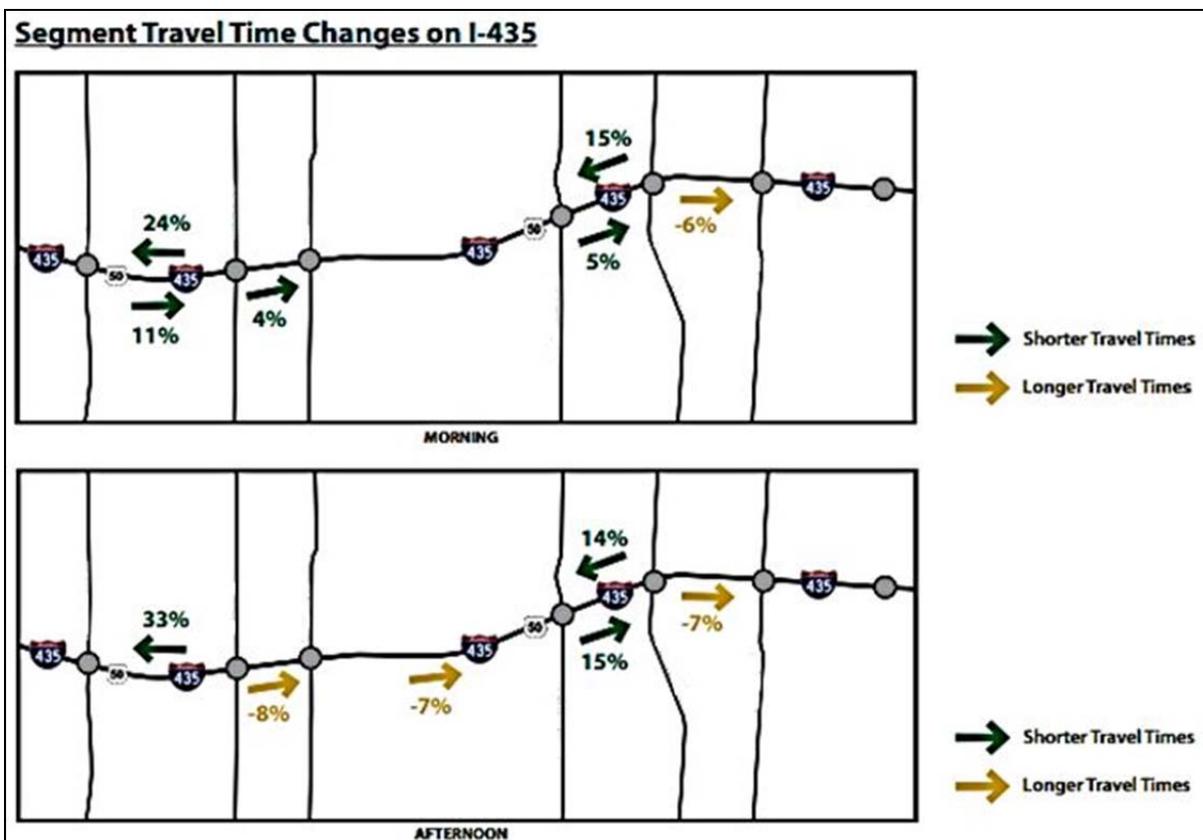
### **Benefits**

Many benefits were achieved by the system after its implementation. The KC SCOUT produced a benefit-cost ratio of 8:1 for both system users and management agencies (Kansas City Scout – Kansas and Missouri, 2014). For incident management, a research study comparing 2009 to 2006 showed there were 201 fewer hours of lane closure due to accidents. On average it reduced per lane closures from 15.82 minutes per accident with 980 incidents in 2006 to 14.91 minutes per lane even with twice as many accidents (2,315) in 2009 (Mehran, 2013). An annual Traffic Management Center report in 2007 shows the average speed for peak hours have managed to stay quite stable for most major highways in the area of the year as shown in Figure 4 (Kansas City Scout Traffic Management Center Annual Report, 2007).



**Figure 4 Month-to-Month Variation in Average Speed in 2006-2007**

With ramp metering there has also been major improvements in both incident prevention and travel time reductions. Using this technology has decreased freeway merging crashes on I-435 by 64% (Ramp Metering 2011 Evaluation Report, 2012). Travel times, though with mixed results on some segments, have overall reduced significantly for the public as shown in Figure 5.



**Figure 5 Increase/Decrease in Travel Time after Ramp Metering Implemented**

### *Lessons Learned*

Of course with the advantages of a mutual partnership there are some items to keep in mind. As far as operational agreements are concerned, they should be negotiated regionally with all at the table. With technical requirements, comes the need for the team of the program to understand the implications. The communications infrastructure is also a major priority when not only starting such a program, but expanding the program in the future. It is also highly recommended to work with City Councils to discuss the results of the program as well as take in concerns and areas to improve (Webb, 2011).

### 2.1.4 Multimodal Transportation

#### **Maryland/Virginia – New Woodrow Wilson Bridge**

The Woodrow Wilson Bridge has played a large means of connection between Maryland and Virginia since 1961. This major piece of infrastructure plays a significant role for I-95 traffic along with its regional connections, thus making it a vital connection for both local and long distance users. Originally designed to carry at most 75,000 veh/day, growth over the years has resulted in traffic volumes reaching 195,000 veh/day in 2004 (Recent Examples of the Economic Benefits from Investing in Infrastructure, 2011). Heavy traffic congestion and increasing delays



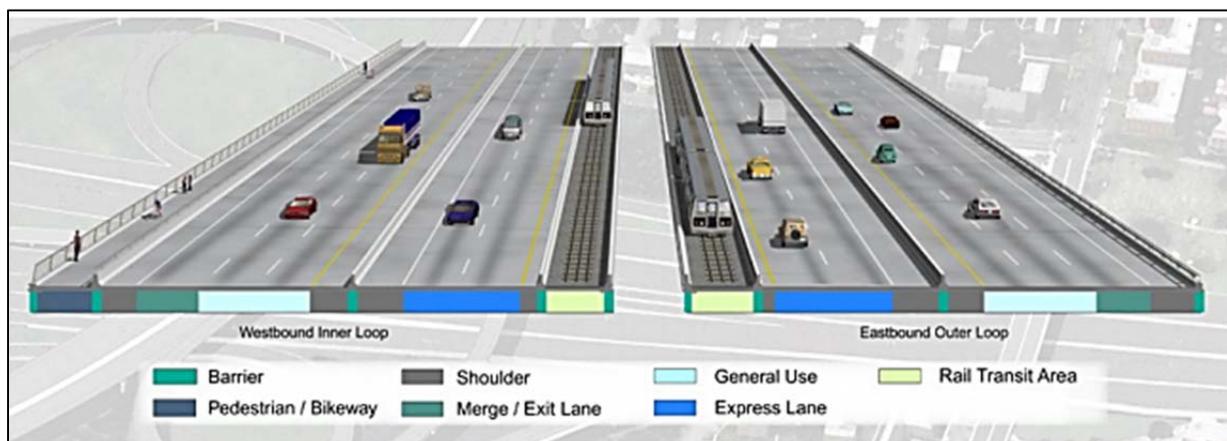
became the bane of this old bridge as demands for action in the region rose sharply for something to be done.

With the excessive traffic running across the bridge increasing its deterioration over the years a project commenced into the planning stages at last in 1989. Due to the bridge being owned by the federal government, the Federal Highway Administration (FHWA), Maryland, and Virginia worked together to petition congress for the needed funding to replace. A final Environmental Impact Statement (EIS) was completed in 1997, but soon challenged in court as questioning came regarding the sufficiency of the number of lanes (Virginia/Maryland – Woodrow Wilson Bridge, 2014). Adding to this problem was how the FHWA would address interagency and community coordination with the bridge impacting two states. Through careful planning and action, the design was able to overcome these obstacles and commence to the next stages of development.

There were multiple objectives to achieve from this project as follows:

- Adequate capacity to both existing and future travel demand through improvements in the operating conditions and the bottleneck problem (eight lanes converged to six at the bridge).
- Include intermodal travel into the design including HOV lanes, bicycling, possible train routes, and maritime access for the Potomac River.
- Improve safety for users through reducing accidents and improving emergency response times (Virginia/Maryland – Woodrow Wilson Bridge, 2014).

With completion of the bridge following these objectives the final design included ten automobile lanes and two lanes that can be designated for HOV or rail (see Figure 6) depending on demand, providing future public transportation opportunities. In addition, a 12 foot wide multiuse trail was included to provide access for both bikers and pedestrians to travel between the counties connected by the bridge. This path is guarded from traffic by a barrier and also includes location on the path to provide information and sightseeing for users.



**Figure 6 Cross-section of Woodrow Wilson Bridge**



Due to the scale of the project there were major concerns regarding the environmental impact of the construction to the surrounding wildlife. Great care was taken into ensuring these concerns were stayed and in the end the results of the work were quite in favor of the surrounding habitat. Commitments were incorporated into the final design before construction contracts were made along with a leadership, mitigation, and construction inspection team formed to help ensure the project left little mark. Turbidity, pH levels, and many other water qualities were constantly measured every 15 minutes at multiple monitoring stations to keep track of their influence on the water quality during construction. Taking advantage of the surroundings also allowed the elimination of dredging midway through the project, protecting aquatic vegetation in the process. A major item that caught public attention was the inclusion in the planning phase of using the pre-existing concrete and steel of the old bridge towards recycling into five major fish reefs within the Chesapeake Bay and lower Potomac River. This restored popular fishing spots and diving locations which really brought forth enthusiastic support from the local community. For their many achievements in protecting and supporting the environment the project received public acclaim through receiving multiple Globe Awards for Environmental Excellence from the American Road and Transportation Builders Association (Baker, 2014).

### ***Benefits***

The new bridge gave a time savings for drivers and truckers of 40 minutes a day. Along with the delay reduction it was able to save regular commuters roughly \$4,600 in time savings each year (Unlocking Gridlock, 2010). The addition of the bicycle/pedestrian path has also made changes to the local area and culture. Crossings of the bridge on this trail have been on the rise, where in March 2012 there were 13,998 and March of 2013 it doubled to 26,827 crossings. A boom in bike commuting has resulted in actions that further increase multimodal usage such as events to promote cycling (Bike to Work Day) and growth of bicycle-sharing rental business. To complement and add to the new bicycle/pedestrian trail, nearby roads have been getting renovated including a major county road to include bike lanes for nearby residential communities. The project in general was highly acclaimed and received multiple awards for its innovation including the OPAL Trophy for Outstanding Civil Engineering Achievement Award and the Nationwide America's Transportation Award (Recent Examples of the Economic Benefits from Investing in Infrastructure, 2011).

### ***Lessons Learned***

With the complexity of this project there were many lessons developed through its existence. With the initial litigation that had to be addressed, the FHWA had to find a method to address interagency and community coordination. Multiple strategies were used to fix this problem:

- Put together a team of experienced federal and state project managers, an environmental impact review staff, & consultants that can ensure environmental impact questions can be fully addressed involving dredging as well as aquatic and cultural resources involved.



- Reopen direct and effective communication with both Federal & State resource agencies
- Involve the community and citizens through organizing a collaborative decision making team.
- Effectively collaborate with the US Army Corps of Engineers
- Develop consensus towards a context-sensitive bridge design.
- Negotiating a comprehensive set of mitigation requirements.
- Organize a monitoring program that is transparent towards the mitigation requirements (ICF International, URS Corporation, and Marie Venner Consulting, 2010)

### 2.1.5 Maryland CHART Program Case Study

This Maryland Coordinated Highways Action Response Team (CHART) program started in the mid-1980s as the “Reach the Beach” initiative, focused on improving travel to and from Maryland's eastern shore. The program became so successful that it has turned into a multijurisdictional and multidisciplinary program which has grown in scope from the beach corridor to the Baltimore-Washington, D.C. corridor and, eventually, the entire state. CHART encompasses a number of systems, including traffic monitoring, traveler information, incident management and traffic management. The implementation far preceded any TSM&O program or requirements. It uses a large number of field components and devices, such as a closed circuit television (CCTV) system, for traffic monitoring and complex interfaces to existing and new detection systems for traffic monitoring. It also uses dynamic message signs, highway advisory radio transmitters, and MD 511 Interactive Traveler Information Service to support traveler's information needs.

In 1995, Maryland created the Statewide Operations Center (SOC) which was the nation's first statewide incident management and traffic management program. From here, the program has continued to grow and mature by adding more ITS infrastructure as well as mainstreaming TSM&O within the agency for optimal results. Subsequently, in 1997, CHART was made an official office under the Maryland Department of Transportation and, with that designation, has its own operating budget. They are required to function with transparency and funding line items containing TSM&O in their State Transportation Improvement Program (STIP) and the MDOT Consolidated Transportation Program (CTP), which is fed by projects included in the CHART Long-Range Strategic Deployment Plan (LRS DP) and CHART Deployment Plan.

The CHART Non-constrained Deployment Plan (NCDP) plans and depicts an ideal vision of how the program should operate for several years in the future by tracking latest technologies and operational applications available. A document called the CHART System Business Area Architecture helps define the current and future system operational vision including business process for relationships to organizations, technology, and facilities. The CHART Management and Operations (M&O) Rural Strategic Deployment Plan defines strategies to support weather, evacuation, seasonal and everyday traffic, special events, and safety issues within the rural parts of Maryland. Once capital projects are approved, project summaries are created containing

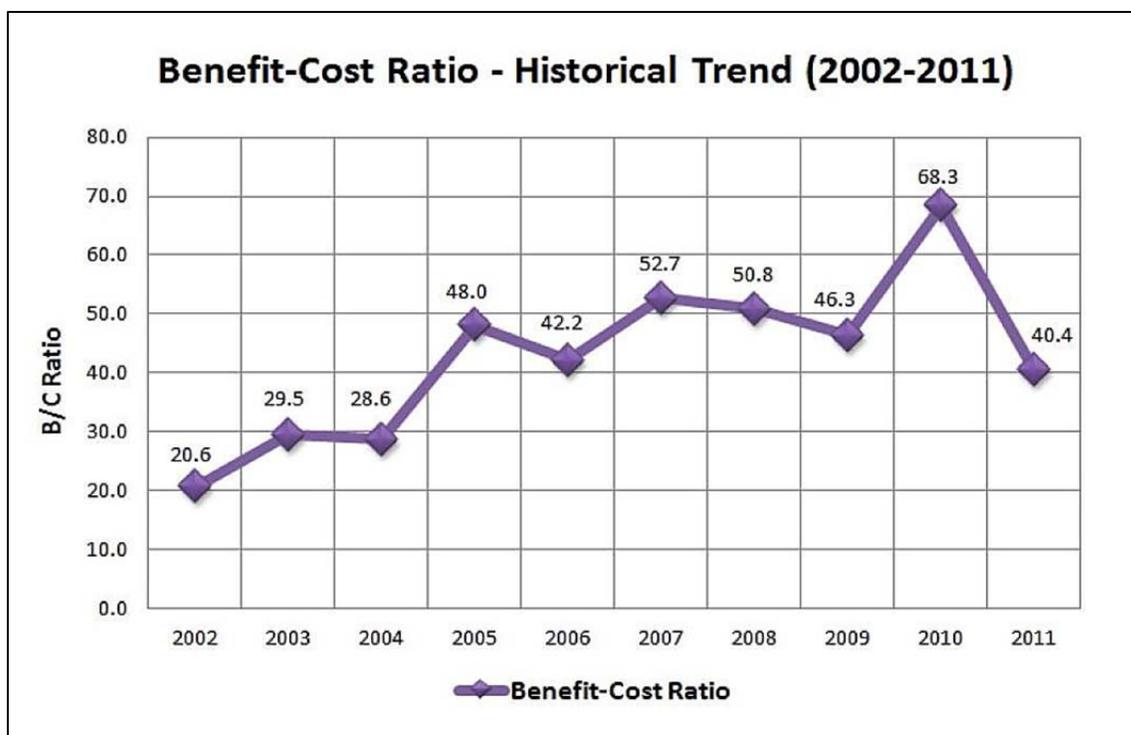


scope definitions, preliminary cost estimates; implementation schedules, needs addressed, and anticipated benefits.

"TSM&O cost estimates are explicitly included in the CHART Non-constrained Deployment Plan (NCDP) as an estimated percentage of capital costs" (Flanigan & Strasser, 2014). For field and infrastructure deployments, integration, and communications deployments, TSM&O operation estimates are around 15% of the total capital costs. However, in software deployments, the estimates are around 4.6%. This is lower because its operations are focused on break-fixes in the originally developed software and not added features or new software. This is also because the NCDP defines operations and maintenance costs associated with the upkeep of "future deployments, not current expenditures" (Flanigan & Strasser, 2014) and thus perhaps saving capital in this effort. TSM&O has been an active part of the culture of MDOT and as such the funding commitment backs this statement.

Most of the CHART Operations focus on the short-term, high priority operational needs such as the "immediately necessary repairs and restoration needed after winter weather" (Flanigan & Strasser, 2014) when funding is available. Because of this, CHART has taken the approach of having a backlog of projects that are immediately ready for deployment. This requires on-call engineering contract vehicles so that the project can be quickly contracted, saving time. By doing this, CHART in 2011 had 41,000 responses which resulted in a reduction in delay of 33.6 million vehicle hours and saved \$1.1 billion in cost savings.

In another manifestation of the effects of TSM&O operations in Maryland, a ten-year period analysis from 2002 to 2011 is shown in Figure 7 from (Flanigan & Strasser, 2014). The graph of the Benefit-Cost Ratio shows that by saving or reducing costs of operation to enhance, repair or maintain facilities under their control have trended toward increasing on a per-year basis.



**Figure 7 Benefit-Cost Ratio Graph for the CHART Program**

Another area that has benefited from the CHART Program is safety. The program has a longstanding track record of improving incident management and reducing nonrecurring congestion. The implementation of these TSM&O pillars has resulted in a 41 percent reduction of average incident durations between 2000 and 2007. The resulting congestion and travel time reduction benefits of this implementation are enormous. The Maryland CHART Program demonstrates that integrated funding of TSM&O projects as a portion of capital investments by the state can have a great impact without being a burden to the state.

#### **2.1.6 Minnesota Department of Transportation (MnDOT) Case Study**

This program began in 1972 with a small traffic management center (TMC) in downtown Minneapolis and has expanded due to increased traffic demand. In 1991, Minnesota Guidestar was formed and represents the overall statewide ITS program initiatives. The initiatives are controlled under the Regional Transportation Management Center (RTMC) in Roseville, Minnesota. The RTMC monitors three areas of transportation monitoring and incident response:

- Freeway and Arterial Traffic and Incident management
- Metro District Maintenance Dispatch
- State Patrol Dispatch

The RTMC's ITS program has a dedicated emphasis on continued research, targeted enhancements, expansion, operations and preservation of the existing system. It consistently performs a broad range of ITS activities, including operations of the existing system, needs



assessments, research and development, full-scale operational testing, and deployment of ITS strategies and technologies.

Minnesota Guidestar is managed by the MnDOT Office of Traffic, Safety and Technology (OTST). Its original focus was on the Twin Cities metropolitan area and now is been a key in advancing ITS technologies and programs to help achieve statewide and local transportation objectives as it partners numerous public, private and academic partners to conduct ITS research, operational tests, and deployments.

The ITS program of MnDOT in 2004 used designated funding along with the state funding to meet the required matching funds for federal assistance with projects. This early experience with its funding allowed upper management in the agency to understand the benefits of a strong and efficient and effective ITS program. When the dedicated money no longer was allocated to the state, a matching level of fund remained available to further the program. In 2006, the dedicated money was once again reached in a funding program and currently \$2.5 million per year is its budget from the state, and an additional \$1.5 million per year in State Transportation Planning (STP) Federal District C funds and other sources such as the United States Department of Transportation (USDOT) project initiatives that are completed for and require a state match (Flanigan & Strasser, 2014).

The MnDOT Planning Group has a State Transportation Improvement Program (STIP) that has a 20 year horizon and supports the state's guiding principles. The STIP joins the policies and strategies laid out in the Statewide Multimodal Transportation Plan to capital improvements on the state highway system. It involves having a smaller four-year STIP project cycle and an additional six-year look at a higher-level, more broadly based highway investment plan. ITS projects that would be categorized as capital preservation projects (not operations) are included in the group "asset management" and category "roadside infrastructure condition". ITS capital improvement projects fall under many categories such as the Twin Cities Mobility, Inter-regional Corridor Mobility and Traveler Safety. The MnDOT is also responsible for the Congestion Mobility Safety Plan, which focuses on mobility issues addressed with low-cost solutions. Performance data analysis out of the RTMC supports this effort.

The ITS program used to focus on congestion issues and now has shifted its mission to focus on safety as top priority. Their techniques are generally experimental and regarded as a research base for testing out ideas. The Minneapolis RTMC now focuses on an "operate and maintain" mode, utilizing ITS elements as supplemental and if needed: Advanced Traffic Management strategies such as High Occupancy Toll (HOT) lanes, Dynamic Lanes, Shoulder Lanes, Lane Control Signs and Dynamic Speed Signs to be employed in areas currently covered by traditional freeway management techniques.

After MAP-21 was enacted, the federal funding component moved to a performance reporting basis, a number of ITS performance measures have been identified and are being tracked and



monitored as part of the MnDOT Highway Systems Operations Plan (HSOP). The plan is an example of the performance measures that can be applied to TSM&O projects. The plan is also responsible for the Congestion Mobility Safety Plan which focuses on mobility issues addressed with low-cost solutions, a TSM&O benchmark.

The Minneapolis RTMC has learned that a greater emphasis on quality design and installation can greatly reduce operational expenses long term, noting that a bit more effort spent on the design and installation stages results in loop detection that are more accurate and reliable. As public agencies across the country are being asked to do more with less, MnDOT was ready to face this challenge. Expanding and maintaining existing systems is necessary but is now done with less staff and funding. Between 2000 and 2011, its ITS program expanded with additional field devices, increases by 68%. Meanwhile, staffing for the RTMC was reduced, decreased by 38% (Flanigan & Strasser, 2014). This is a result of the equipment becoming more advanced and reliable, less field workers are required. These changes see the benefit-cost ratio increase with less overall funding.

One of the best practices that in use at MnDOT is the Regional Transportation Management Center's ITS program. This program has a dedicated emphasis on continued research, targeted enhancements, expansion, operations and preservation of the existing system. They accomplish the objectives of the "operate and maintain" philosophy with a broad range of ITS techniques that are generally experimental and regarded as a research base for testing out ideas. In the long-term, this commitment to research and testing assists the MnDOT project staff implement techniques that can mitigate challenges in new and efficient ways. Among these advanced traffic management strategies have been High Occupancy Toll (HOT) Lanes, Dynamic Lanes, Shoulder Lanes, Lane Control signs and Dynamic Speed Signs. After MAP-21 was put into place, many of these measures are now part of the MnDOT Highway Systems Operations Plan (HSOP) which is responsible for the Congestion Mobility Safety Plan which focuses on mobility issues addressed with low-cost solutions, a TSM&O benchmark. It also serves as a way to fund smaller projects and break large scale projects into affordable components that can be absorbed more easily by a traditional fiscal budget.

### **2.1.7 TSM&O Cost-Benefit Analysis Case Study**

A case study is provided to demonstrate the Cost-Benefit ratio with a small-scale TSM&O Project and demonstrate the effectiveness of analyzing and assessing alternatives throughout the project.

While more equitable management of funding for projects can be one of the financial benefits of TSM&O, there are techniques that offer low-cost solution with large benefits. Small investment projects that improve the overall long term operation of a facility can be a huge advantage in maintaining a financially responsible agency.



Stop-sign controlled intersections account for approximately 30% of fatal crashes in the United States (Federal Highway Administration, 2014C). Studies have found that visibility of stop signs and other markings in such intersections are the primary reasons for drivers failing to react to the situations. Therefore, addressing this in a low-cost method can go a long way in reducing the crash percentages, one of the TSM&O benchmarks. The City of Winston-Salem had a problem with these types of intersection crashes controlled by stop signs. Noting that visibility of their signs was the issue, the low-cost installment of additional signs, replacing old ones and having clearly visible markings was a top priority. In a number of different combinations of treatments, the results were studied for the time period from 1988 through 2002. The results of the study compared results before and after, based on four differing methods that were used.

The first method was to install 30-inch stop signs that were 6 inches larger than the previous ones along "Stop Ahead" traffic control signs so that drivers would be aware that they are approaching a "Stop" sign ahead. In addition, 12-inch thick stop bars along a short segment of double-yellow centerlines were placed at the intersection. Before this combination was installed, data showed that 45 crashes occurred, whereas after 20 crashes occurred. Of the intersections tested with this low-cost alternative, Winston-Salem experienced an average crash reduction of 56.9% on an annualized basis.

The second method of improvement involved adding double-yellow centerline pavement markings and stop bars to the regular sized (24-inch) "Stop" signs already existing at the selected locations tested. This was done if it was thought that additional delineation at the intended stop location would yield significant results. At these intersections, 45 crashes had occurred before the changes were made. After the markings were added 21 crashes occurred. Being more cost effective than the first method, the improvement in pavement markings alone managed to reduce the crashes by 52.7% on an annualized basis.

The third method involved the replacement of the older 24-inch "Stop" sign to a larger 30-inch counterpart but would be on the right and left side of the road. This method emphasized the issue of the sign being too small. The assumption is that the sign would be inadvertently missed. Enhancing the sign visibility alerts drivers about the upcoming intersection resulting in the driver safely navigating to a full-stop. Having the second sign on the left side raises the driver awareness of the intersection. Data showed that 68 crashes occurred before the improvements were made; after the changes were made, 35 crashes occurred. This was an improvement of 48.3% at these locations. This case reaffirmed that for some drivers the signs were too small to read on time. Some drivers may have also neglected the sign due to their size. By also having them on the left side of the road, they would be harder to disregard.

The fourth method involved the larger 30-inch "Stop" signs with the additional pavement markings mentioned in some of the methods previously presented. This also involved adding the additional stop sign on the left side of the road. The stop bars continued to be 12 inches thick. The short segments of double-yellow centerlines were also added. Data showed that before the



changes were implemented, 41 crashes had occurred; after installation, 14 crashes occurred thereafter. This combination resulted in a 65.9% reduction on an annualized basis. The Cost-Benefit analysis for each method is described on Table 3:

**Table 3 Cost-Benefit Analysis for Stop-Controlled Intersections**

	Crashes Before	Crashes After	Crash Percentage Reduction	Cost per Intersection	Value (% reduction/ \$1)
Method 1 <b>Stop Ahead Sign, 30-inch Sign &amp; Pavement Markings</b>	45	20	56.9%	\$7800	.0073
Method 2 <b>Pavement Markings</b>	45	21	52.7%	\$5000	.0105
Method 3 <b>Left and Right 30-inch Signs</b>	68	35	48.3%	\$2800	.0173
Method 4 <b>Left and Right 30-Inch Signs &amp; Pavement Markings</b>	41	14	65.9%	\$7800	.0084

Combining all the results of countermeasure deployment at the stop-controlled intersections, reduced total crashes by approximately 55% and total injuries by approximately 70% per year (Federal Highway Administration, 2014C). Method 3 resulted in being the least costly but least improved of all four methods. Considering the benefits of the method versus the cost to implement it, it was the most favorable. However, the largest reduction in crashes was accomplished by Method 4 and may be more desirable for this reason. All of the intersection improvements are simple techniques that embody the elements of TSM&O. These low-cost strategies can save the state money in the long-run and curtail more extensive improvements such as introducing a traffic signal.



## 2.2 Long-Term Best Practices

### 2.2.1 Managed Lanes

#### **California - Managed Lanes/Dynamic Message Boards (I-15 Express Lanes)**

In 1988 the I-15 Express Lanes were opened to the public as an HOV expressway system before transitioning to a HOT Express in January 2000 (I-15 Express Lanes Fact Sheet, 2014). Though originally used to demonstrate value pricing with vehicle usage, this express lane was designed with the objective of providing capacity for a highly underutilized HOV facility at the time as well as support future growth for the lanes through its toll revenues. Although originally designed as a reversible 8-mile HOV expressway, San Diego Association of Governments (SANDAG) expanded these lanes afterwards (Federal Highway Administration (FHWA), Office of Operations, 2007). This expansion was broken into segments and completed between the years 2009 and 2012, extending the original 8 miles into 20 miles in length and converting the reversible facility into four bi-directional HOT lanes with multiple access points.

At this time the average daily traffic experienced on I-15 ranged between 197,000 and 312,000 vehicles and has proven that SANDAG's focus on value pricing was a very effective tool in the success of these hot lanes. The effective use in dynamic pricing through the day not only ensured the lanes maintain a level of service C or higher, but also assisted in alleviating stress of congestion on the main freeway. In 1996, a demonstration congestion pricing project was initiated to gauge the performance of the express lanes and their value as HOT lanes compared to the standard I-15 freeway. During this study solo drivers were offered the option to use these lanes for a fee which would be posted at the entrance to the lanes. In the conclusion of this study it was found that the median value of time reduction for the users was \$30 per hour, showing that users are willing to pay a premium to avoid congestion of the standard freeway (Brownstone et al., 2003).

From this study, other user identifiable information was gathered to gain an idea of who was attracted to the express lanes. The results indicated that most users were commuters, individuals from high income families (ranging from \$100,000 or more), women, were between the age of 35 and 45, higher education individuals, and homeowners. It was also found that solo driving on the express lanes increased positively when a time savings was apparent and decreased as the dynamic pricing increased due to peak hours. Most users of I-15 have found beneficial use of these lanes through their time savings, improved driving conditions and overall safety from being constructed completely separated from the main freeway. Figures 7 and 8 show time savings on the express lanes and average daily variations experienced during the AM peak hour.

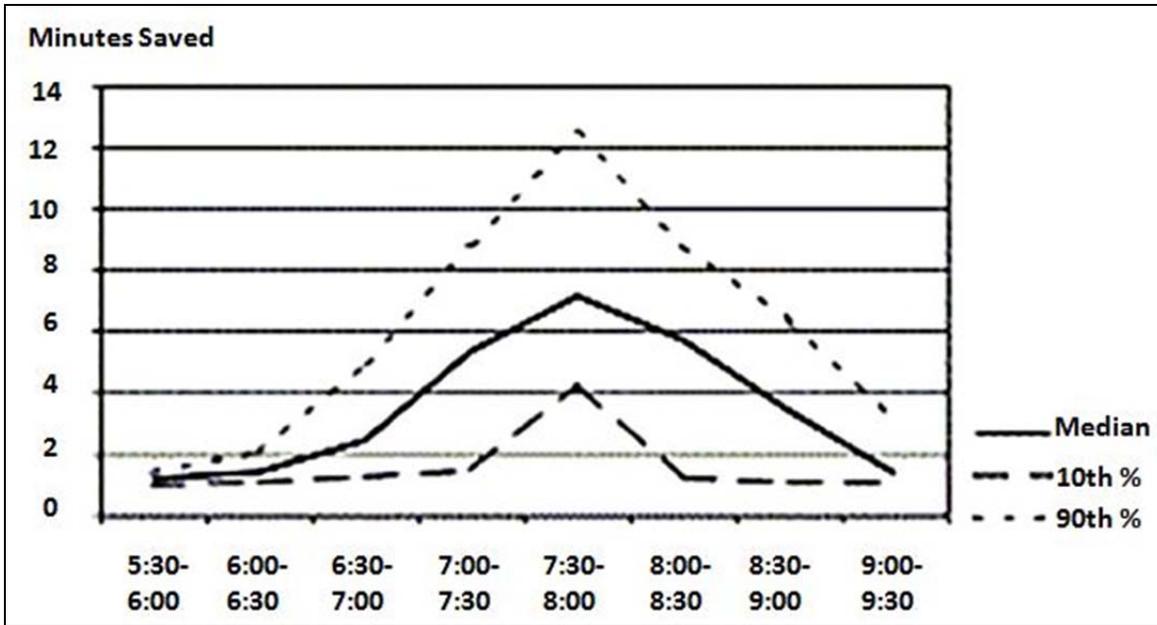


Figure 8 Time Saved through Express Lane (October-November, 1998)

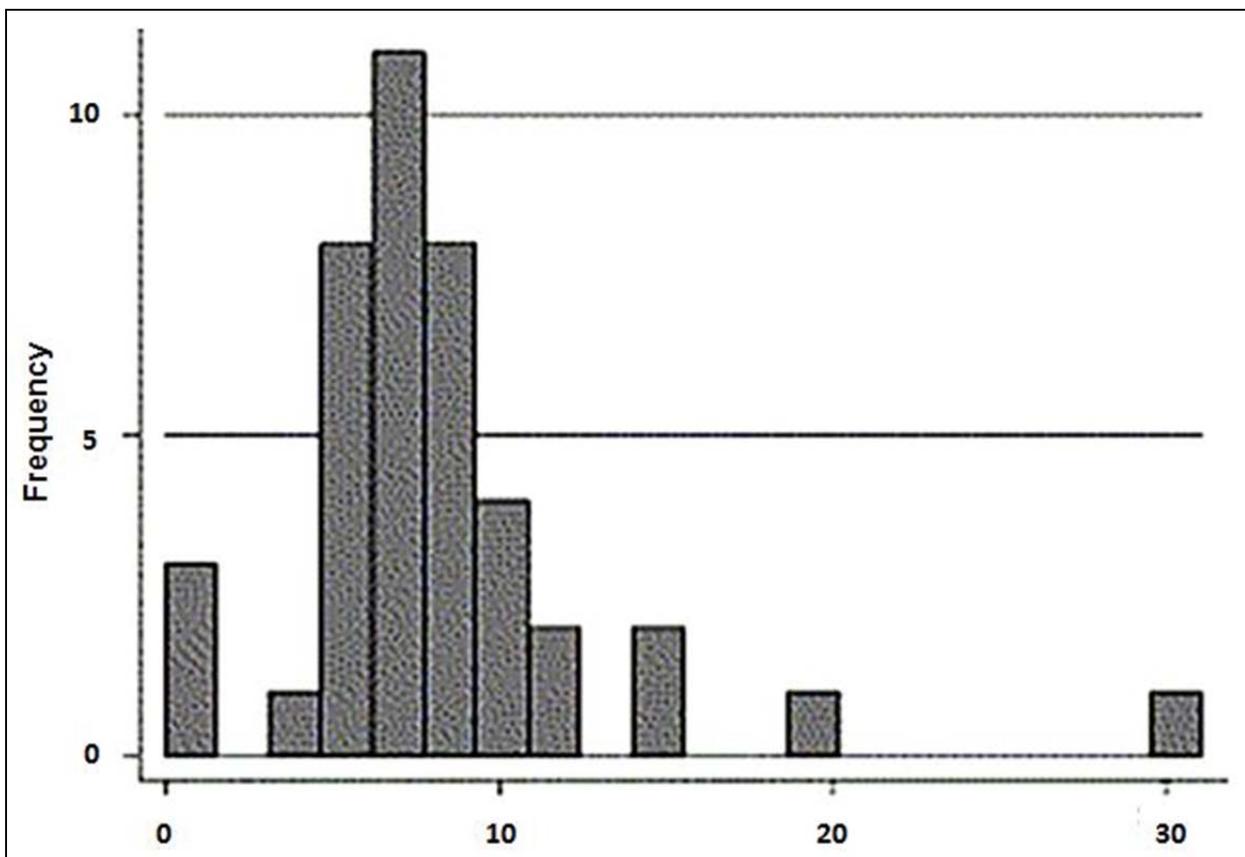


Figure 9 Daily Variation in Average Time Savings, 7:31 to 8 am (Oct-Nov, 1998)



Through the use of the dynamic signage installed at the entrance of the lanes, users were able to benefit from other aspects of the I-15 Express Lanes. Through a user seeing the current toll price prior to the entrance of the lanes a driver is able to gauge the traffic conditions experienced up ahead for the freeway (Brownstone and Small, 2005). Therefore, the signage fulfills the purpose of not only pricing, but signaling for freeway users. Because the pricing is established in a way to allow constant speed on the express lanes this approach can assist in drawing more users who need a reliable route to their destinations under time constraints.

### ***Benefits***

Through implementing the idea of HOV lanes (and later HOT lanes) in construction of these express lanes many benefits were gained. The separation of the express lanes from the freeway has given the ability of future expansion as seen today due to public funding and collected tolls. The dynamic pricing approach has assisted in controlling usage of the express way to not only give a premium experience for users, but also allow control during congestion periods. Having local and state leadership involved in discussions early and often during both the planning and design phase also helps in project support and public awareness.

### ***Lessons Learned***

Challenges experienced and lessons learned from this project include the necessity to effectively prevent toll violations as the express lanes were converted. After expansion and adding multiple access points (along with limited shoulder widths from the expansion) preventing toll violations now requires mobile enforcement rather than manual enforcement when there was only one entry point. Dynamic pricing use also required local public and political support in order to build public awareness and acceptance. Early and frequent pushes in public awareness including public outreach, surveying and active marketing are imperative for a successfully utilized project when the lanes are open to the public. Research prior to project design is another important strategy to take into account when using approaches such as HOV lanes to ensure when completed they will be of value to the public. The I-15 express lanes were highly unutilized due to the HOV limitations and the type of freeway users at that time and did not truly flourish until changed into HOT lanes (Federal Highway Administration (FHWA), Office of Operations, 2007).

### **Miami-Dade – I-95 Express Project**

Prior to the planning of this project, it was found that managing congestion through construction of new lanes for heavily used corridors was not effective or financially feasible at the time. Some of the reasons for this included limited availability of federal and state funds, the high construction and environmental costs. Another reason for an alternative approach was due to public and legislative opposition to widening the roadways any further. Because of these items of concern, it was needed that the existing system should be improved and made more efficient through the addition of pricing mechanisms, transit, and Transportation Demand Management



(TDM) strategies (Strategic Highway Research Program 2, 2012). Discussing these concerns and effectively planning a design to meet the restricted demands resulted in the I-95 Express Project.

The I-95 Express project originally started tolling the initial segment on December 5, 2008 and combined Bus Rapid Transit with Managed-Lane usage. The project was supported by multiple agencies and programs with the FDOT taking the lead. Funding was provided by the Urban Partnership Agreement (UPA) program and the Florida Turnpike Enterprise provided tolling and violation enforcement operations. The project consisted of about 21 miles of managed lanes which connect the Miami Central Business District (I-395 in Miami-Dade County) to Broward County (I-595). The system is dynamic in that it can adjust the fee for lane usage every 3 minutes to adapt to changing levels of congestion. The system includes multiple major components including electronic toll collection, video (for pricing enforcement), traffic management, and ways to spread traffic information through traffic monitoring and travel information for users (Loudon, 2009).

### ***Benefits***

Many benefits were accomplished from initiation of the newly formed stretch of highway. 80% of the highway users agreed that the new express way provided a more reliable trip than before. Bus riders increased dramatically (more than doubled) compared to pre I-95 Express conditions. Travel time reliability increased along with improved speeds in both express and general purpose lanes. All the goals established by the UPA were also met or exceeded for the project (Strategic Highway Research Program 2, 2012).

Delving deeper into the details of the lanes, it is possible to see the efficiency of the lanes from the day they were open. The major Federal goal of the express lanes was to maintain speeds greater than 45 mph at least 90% of the time. Seeing the history of the average peak periods of the express lane (EL) usage shows that even at the worst time the average speed consistently stayed above this mark. It is also found that even the regular lanes (LL) were able to maintain speed above the mark (not including the northbound lanes).

Overall, since the commencement of the express lanes it has been found that the peak speeds have stayed constant and no major fluctuations have raised alarm for the project. Knowing the average speed for the HOV and general purpose lanes in 2008 for the AM peak period were 20.3 mph and 15.3 mph, respectively, it is very noticeable in Figure 10 how the project has improved travel speeds drastically. Though demand for the express lanes continues to grow over the years they have proven to be consistent in not only meeting but exceeding the reliability standards given. Though required to surpass 45 mph at least 90% of the time, the express lanes have proven to surpass these speeds nearly 100% of the time as shown in Figure 10. Even the general purpose lanes have met this goal every year.

Since its opening in 2008, I-95 Express has experienced continual growth in user volume by over 21% for the peak periods. It has also been noticed that over this period there have been more



users turning to the express lanes for the added benefits given. This can be seen in Table 4 when comparing the volumes over the years in the following table, where in 2008 the general purpose lanes were most used.

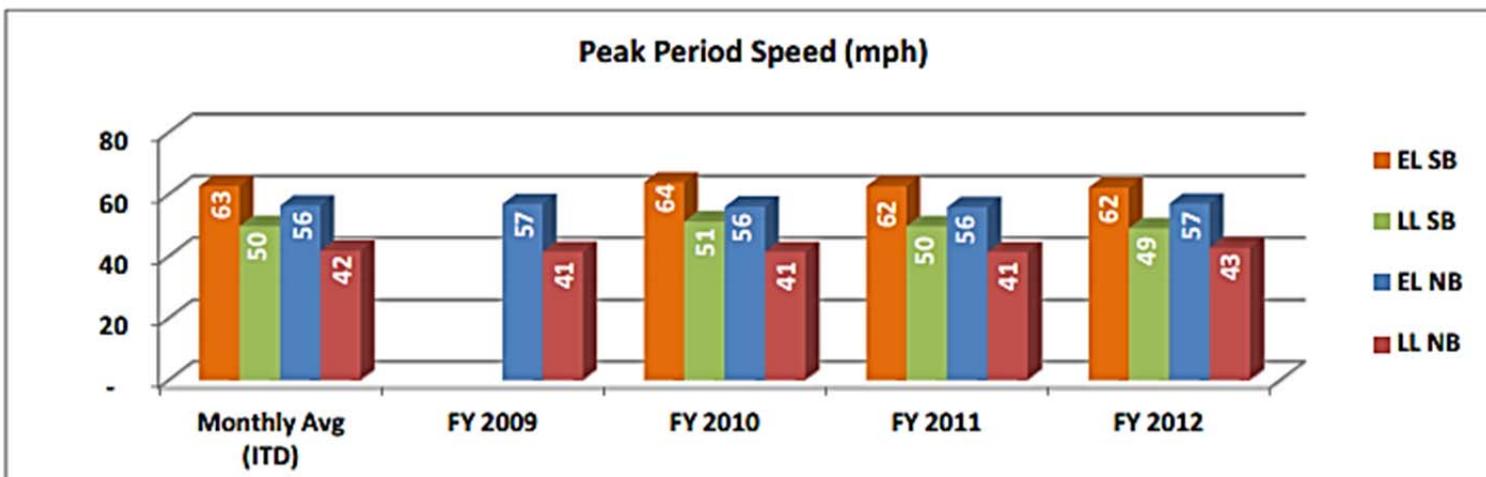


Figure 10 Peak Period Average Speed for each Fiscal Year

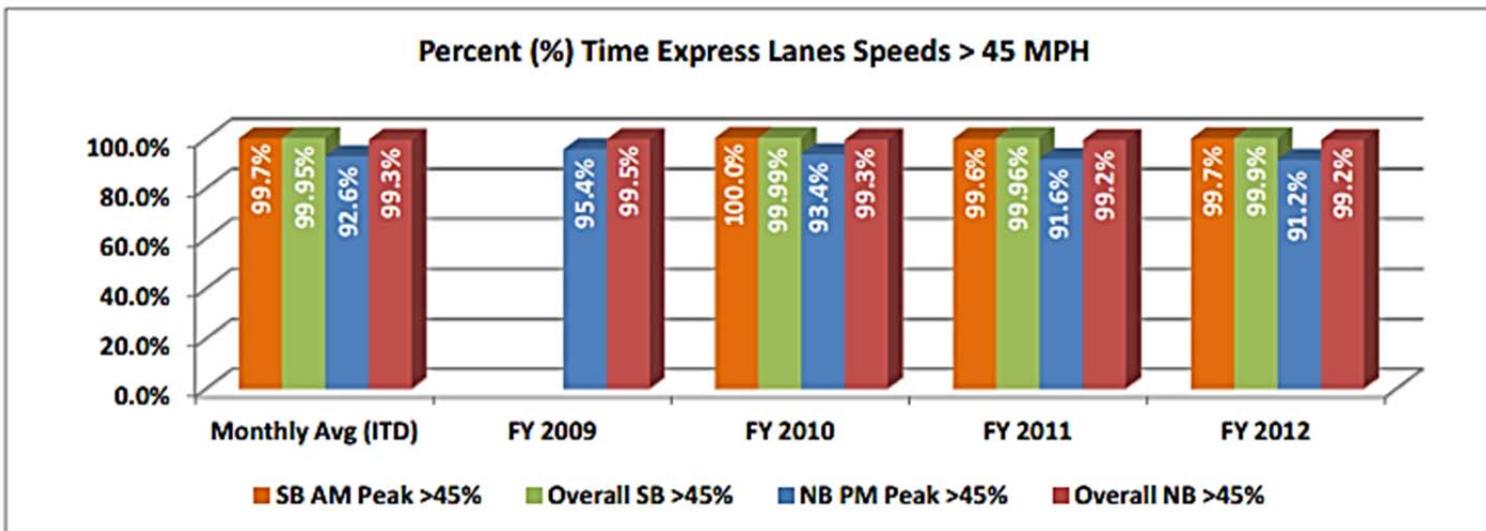


Figure 11 Percent Time in Exceeding 45 mph



**Table 4 Average Volumes and Switch in Users to Express Lanes**

	<b>Average Volume (vphpl<sup>4</sup>)</b>											
	2008 HOV Study <sup>1</sup>				FY 2011 <sup>2,3</sup>				FY 2012 <sup>2</sup>			
	SB		NB		SB		NB		SB		NB	
	HOV	GPL	HOV	GPL	EL	GPL	EL	GPL	EL	GPL	EL	GPL
AM Peak Period	1,548	1,331	/	/	1,389	1,535	/	/	1,607	1,506	/	/
PM Peak Period	/	/	1,455	1,597	/	/	1,377	1,394	/	/	1,413	1,345
Overall (Weekdays)	--	--	--	--	616	1,085	614	957	647	1,138	643	999

<sup>1</sup>AM Peak Period for 2008 HOV Study was 7:00-9:00am; PM Peak Period was 4:00-6:00pm; HOV was one lane in each direction

<sup>2</sup>AM Peak Period for 95 Express Project is 6:00-9:00am; PM Peak Period is 4:00-7:00pm

<sup>3</sup>First full year of EL operations in both directions.

<sup>4</sup>vphpl: volume per hour per lane



Along with the improved performance and reliability of the new managed lanes it was found that revenue from lane usage continually increased over the years. Annual revenue goals have been surpassed on multiple occasions with a 115% increase over the projected goal in 2011 and another 113% increase from the projected in 2012 as shown in Figure 12 (Florida Department of Transportation (FDOT), District 6, 2013). This continual increase in income helps produce further value to the express lanes and is beneficial towards supporting and improving the user experience.

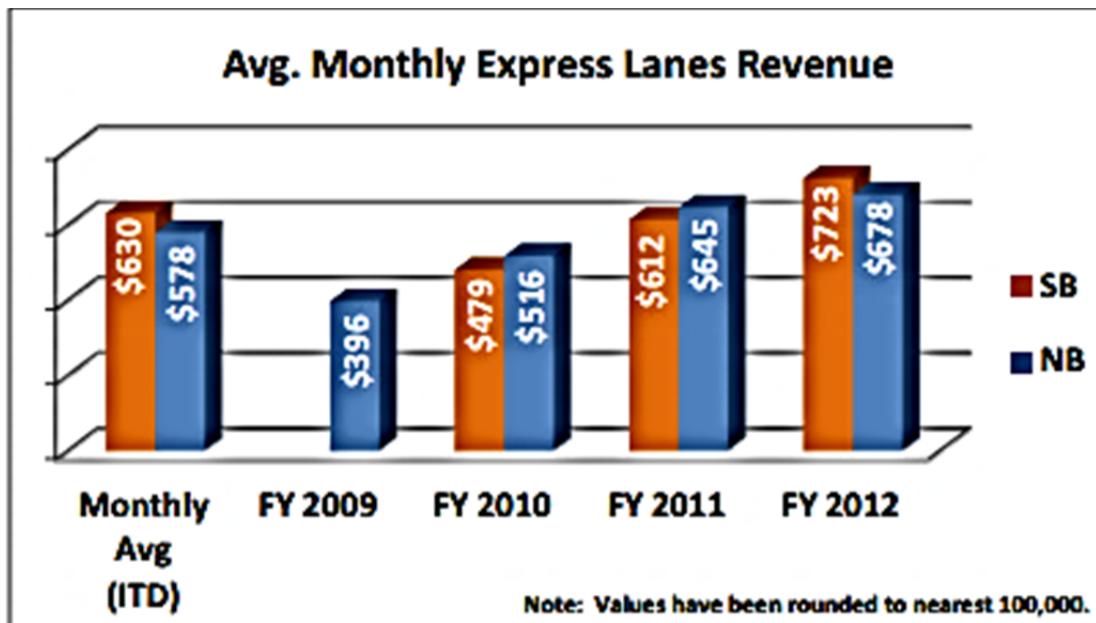


Figure 12 Average Monthly Express Lane Revenue over the Years

### *Lessons Learned*

As far as lessons learned, an investigation was performed by consultants for the FDOT District IV Office of Planning in order to share best practices and lessons learned since implementation of the express lanes. The interviews were conducted prior to the toll implementation of the new express lanes and thus were entirely focused on the upbringing of the actual project. Many points were mentioned and expounded upon giving great insight to those who may share similar visions for a managed lane and bus system (South Florida Interstate 95 Express Project: Lessons Learned, 2009). These points are categorized as follows:

### *Overall Project*

- Define a strong project vision
- Establish a comprehensive schedule
- Build upon prior efforts and support
- Focus on Transit
- Manage project expectations
- Balance project development with funding status
- Plan for the future



### Institutional and Organizational Approach

- Develop a concept of operations early
- Involve design/operations professionals in planning process
- Determine organizational structure from the onset
- Coordinate with approval agencies in the initial stages
- Plan for the future phases of the project

### Project Management

- Appoint a strong project manager
- Delegate responsibility to team members
- Provide project manager with direct authority
- Identify the need for consultant project management
- Communicate effectively with team on regular basis
- Consider using current contract consultants

### Technical Data/Information Sharing

- Prepare for limited national or state standards for managed lane networks
- Anticipate Transit Technical Challenges
- Expect design exceptions
- Utilize microsimulation tools for evaluating all alternatives
- Collaborate with partners on a signage plan
- Account for time to develop dynamic tolling software
- Perform environmental screening early in the process
- Plan additional resources for project opening

### Outreach/Media

- Keep public officials informed of project changes
- Be prepared for a shift in marketing approach to that of selling a product
- Implement innovative public outreach efforts
- Conduct more public outreach related to construction milestones
- Consider implementing corridor enhancements gradually
- Manage the media effectively
- Utilize all available methods and tools



### 2.2.2 Ramp Metering / Freeway Management

#### **Denver, Colorado – Denver Metering System**

In 1981, the Colorado Department of Transportation (CDOT) initiated a ramp metering system with five ramps situated on I-25 as a pilot project. This system operated during the AM peak over a 3-mile stretch of the interstate and was attempted as a means of improving safety and efficiency of the highway (Wisconsin Statewide Ramp Control Plan, 2006). A study was performed to find the details pertaining to how the metering system performed, which after 18 months, returned positive results. Implementing the metering system returned an average peak period driving speed increase of 57%, an average travel time decrease of 37%, and a 5% decrease in traffic accidents (Saito et al., 2003).

Through success of the initial project, expansion began immediately. In 1984, a central computer was installed, and a system coordination plan was produced that would permit central monitoring and control of the meters.

#### ***Benefits***

Usage of metering provided major improvements in traffic flow on I-25, with a flow capacity exceeding 2,450 vphpl (vehicles per hour per lane) on multiple occasions. With such an impressive flow rate, stop-and-go traffic became non-existent, which made it a huge success with the public. Through becoming familiar with the timing, motorists were able to alter their arrival times so that at arrival, they could avoid ramp delays. Area arterials also received an increase from 100 to 400 vph (vehicles per hour), providing the added benefit of little degradation to street conditions at ramp entrances. With the completion of the freeway C-470, the AM peak increased from 6,200 vph to 7,350 vph in 1989 on the three lanes. Speeds slightly decreased due to the higher travel volumes in 1989, but higher speeds than before meters were implemented were still maintained. However, the added traffic volume did not cause an increase in traffic crashes; instead, there was a significant reduction in crashes (including 50% reduction in rear-end and sideswipe crashes).

#### ***Lessons Learned***

Though met with major success, CDOT gained a few lessons during the implementation and expansion of this system in Colorado. On one occasion, an attempt was made to accommodate daylight savings time. All individual ramp controllers were adjusted one hour ahead, but the central computer clock was overlooked, resulting in all changes being overwritten. With the metering now an hour behind, this setback resulted in some of the worst traffic seen in years, yet still came out positive in the end with increased support from the media on ramp metering (Wisconsin Statewide Ramp Control Plan, 2006). From this lesson, it is found how imperative it is to have a properly configured system that will adjust to changes.



A later evaluation of the system provided more insight on how to properly run a metering system. It was found that central coordination was best fit for times of congestion where traffic speeds are less than 55 mph. Any more for the average travel speed would show that central coordination was of little benefit. Still during times of congestion the metering system was found to produce a speed increase of 35.5% and a vehicle hour travel time reduction of 13.1% making the system valuable for these scenarios (Wisconsin Statewide Ramp Control Plan, 2006). In the design/planning phase it is important to take into account the needed queuing space needed to run a metering system due to the temporary holding delays for vehicles. This can save a lot of trouble with preventing backup to arterials as well as possibly reduce meter violations through the ramp. A planner must be careful however regarding the space and money required in extended ramps. Two common ramp styles used now are the single and two lane ramp method with ample length and should be selected carefully for the demand of the ramp and the situation. Denver originally designed short ramps in the early phases.

### 2.2.3 Traveler Information / Weather & Emergency Management

#### **New York – 511NY**

Around June 2006, a major storm caused major flooding, property damage and many roads impassable over the state of New York. The New York State Department of Transportation (NYSDOT) realized there was a serious problem considering all the details regarding the storm and how it affected the transportation infrastructure and that it was largely internal, and there was no way at the time to convey this information to the public effectively. Though some sources provided information (including the news and Highway Advisory Radio), there was a problem in informing the public of the extent of the damages as well as the roadway closures to take place after the storm. With this problem, the NYSDOT planned out a means of producing a comprehensive and reliable system to convey traffic, transit, and emergency notifications for travelers, which is where the 511NY system was formed (Information Communications Technology Innovations Nomination: 511NY, 2010).

The project in its initial planned phase consisted of merging multiple databases & systems into one source. From the planning and development of the system, 511NY was activated in the New York Metro area in November 2008 and expanded statewide in June 2009. Today they have been integrated into the 511NY system as a single public source for multi-state, real time and static highway and transit information, as well as provide coordination of information for call transfers, highway data points, voice recordings, and modal information. This system is accessible through multiple methods including Internet, phone, and mobile devices as well as more recently through social media including Facebook and Twitter.

Information supplied from the system is continuously growing and adapting to new methods of conveying the information. Some items provided for travelers include traffic and transit conditions such as incidents and construction, paratransit, major-crossings such as bridges and tunnels, weather, transit trip-planning, carpools, airports, tolling, and commercial vehicle



information. The system is free to use and allows users to customize features according to their preferences. Currently the New York State Transportation Improvement Program (STIP) has a four-year (2011-2014) program operational cost of \$27 million that is provided through Congestion Mitigation and Air Quality (CMAQ) funds (511NY, New York State, 2014).

### ***Benefits***

Acceptance and positive public feedback regarding the program has allowed and encouraged further growth of additional features for 511NY system. The NYSDOT has been very receptive to feedback from users and continues to make improvements that further benefit the user and the traffic conditions in New York. The system gained traction on social media and will disseminate information to travelers regarding highway construction, winter road conditions, incident information, and other vital traffic updates that users have claimed to be of high value and give reason to visit the pages. By 2010, 511NY was nominated for an award by the National Association of State Chief Information Officers (NASCIO); the system had already received 863,808 phone calls and more than 1 million web visits. A research study estimated that the environmental benefits of the 511NY system could remove more than 71 kg/day of VOC, 4 kg/day of NO<sub>x</sub> and 767 kg/day of CO (Tario et al., 2011). Early stages of the weather alert capabilities on the main website had also proved to be quite accurate during an evaluation of the system in 2011 (Yohanan et al., 2011). The alerts in turn help the NYSDOT to give quick response to traffic management according to the changing conditions on the roadway.

### ***Lessons Learned***

Through condensing multiple of their transportation services down into one package system the NYSDOT has not only found they personally receive great benefit from its use but have developed enthusiasm to continue expanding on the system. Having one system has made it easier for the DOT and the users to use their resources at the fullest extent. Feedback from occasional tests and evaluation phases with user input have proven valuable in developing new goals and directions on where to head next with the system.

#### **2.2.4 Work Zone Management**

##### **Michigan – I-94 Work Zone Management Program**

On May 2, 2008, the Michigan Department of Transportation (MDOT) established a new policy focused on work zone safety and mobility. This policy followed the publication of the Work Zone Safety and Mobility Rule established in 2004 by the Federal Highway Administration (FHWA) which was designed to address issues of increasing work zone numbers, growing traffic volumes as well as congestion produced from these work zones. Michigan, at the time of their new policy being formed, had major non-recurring work zone congestion caused from construction/maintenance during peak hours of travel. This especially affected I-94, a major interstate running across the lower end of the state. Holding up to 54,000 average daily traffic



(ADT) with 32% of truck freight value miles, 30% of the jobs in Michigan, and 28% of the population within 20 miles reach this route was crucial to the citizens as well as the economic health of area it serviced (Doyle, 2013). Initially the policy set a threshold of 10 minutes of delay for individual projects, but due to the whole I-94 corridor not being addressed on what was acceptable with this threshold, 2010 delays projected major problems. With 19 projects on I-94 this totaled over 3 hours of delay, bringing the total user-delay cost to \$13.4 million when adding in winter weather, work zones, and incidents together (Doyle, 2013).

From this situation, a new approach was implemented to address the delay problems through formation of the MDOT I-94 Corridor Operation Partnership, bringing unification to the entire I-94 corridor with one focus. Ambitious goals were set for 2011 following this partnership including a 40 minute delay allowed for the entire 275 miles of the interstate and a maximum user-delay cost of \$10 million for the southwest region. Between January 1<sup>st</sup> and June 13<sup>th</sup> of 2011 user-cost delays reduced to \$4.21 million and later to October 10<sup>th</sup> rose to \$7.47 million, just below the target of \$7.77 million at that time (Cranson, 2011). The drastic reduction in delay costs and the successful partnership resulted in MDOT receiving a prestigious national award along with their improved traffic operations and systems reliability from the program changes made. During this year there was also a transition in performance measuring elements from time at the corridor level to using speed and Maintenance of Traffic (MOT) Implementation.

Continued changes were made to the program, especially in the southwest region to further push the goals initially set. In 2011 a 20 minute max delay from Indiana to the southwest region boundary had to be met 95% of the time, speed compliance 90%, and delay per project couldn't exceed 10 minutes. This continued through 2012 with work zone compliance. In 2013 these requirements were kept along with the additions of huddles involving the maintenance of traffic, CO3 predicted delay vs actual delay, and performance measure elements of cost & communication. This same year also included a goal of cost performance measure to limit user delay cost to \$108 million for the entire corridor (Doyle, 2013). From the start of this program to now MDOT began shifting their focus more into operations and staffed more in that department to track user-delay due to incidents, work zone, and winter weather.

### ***Benefits***

Results since the implementation of this program were quite noticeable through the course of its existence. User delay costs that were gained from the work zones, weather, and incidents reduced by 25% between 2010 and 2011 for the southwest region during their initial study. Team communication and partner collaboration has improved through the inclusion of bi-weekly meetings and construction meetings. The work zones included throughout the corridor are now coordinated and procedures standardized at this point to further improve the efficiency of this goal-driven approach. Performance metrics have improved significantly through the course of this program through use of accountability and reporting software. Overall the cost of implementing this strategy primarily includes the traffic data collection, performance



management software, and the staff hired. Accordingly, the savings achieved from the user delay costs far exceed the cost of the capital and labor. Along with the savings incurred there is an improvement to the traffic quality on the roadways for meeting their goals, benefitting not only themselves but the users of the corridor as well (Firman, 2012).

### ***Lessons Learned***

In a workshop conducted by the MDOT in 2013, a representative shared the lessons they learned and best practices from their experience through the partnership. They felt that keeping score through establishing the goals sought really made a significant change to their behavior and culture as a DOT. If there was one item that influenced their ability to meet the goals established it was speed, more specifically ensuring the posted speeds were maintained. Project development is also crucial to a program's success and requires special attention. Based on that they added; "If a project is designed to minimize work zone delay then it will have minimal delay". Having experience on the team can also be beneficial to further improve program efficiency like in their case, where applied experience helped refine lane restrictions and work operations. Huge culture changes were made down to the construction level from the implementation of user delay cost and using it to evaluate construction staff. Doing so kept delay on their minds and questions started to be asked for designers in regards to anticipated delay during project reviews (Doyle, 2013).

The practice and focus of performance measures has brought continued improvements in their measure approach as well as added inclusions to further bring sophistication to the overall strategy. A more recent addition is the inclusion of region work zone Gantt Charts, which incorporate the maintenance activities for all the work zones. This method not only laid out project location and construction durations with all current projects in one summary, but also improved scheduling of construction projects while ensuring the user delay cost goals were not exceeded. The inclusion of ITS infrastructure (such as in the southwest region) with such a program can give added benefits through being able to monitor delay issues from the office as well as post relevant messages to motorists ahead of time so they can make informed decisions. The emphasis of continued improvement can truly reflect and show in both traffic conditions as well as customer satisfaction (Doyle, 2013).

### **Albuquerque, New Mexico – Big I Reconstruction**

Being one of the largest transportation projects in New Mexico history, the intersection of I-25 and I-40 was definitely one of extreme importance for the Albuquerque downtown area. Originally designed in 1966 for a daily volume of 40,000 vehicles, the intersection later on around the reconstruction time was ranked the 10<sup>th</sup> most congested interchange in the nation. Three items of concerns came from this aging structure:

1. Recurring congestion on the freeways and ramps: With roughly 300,000 vpd (vehicles per day) going through the interchange, 90% being local traffic and 30% of all trips



within the region using the Big I there were major capacity deficiencies in the current design.

2. Significant accident rates and follow-up congestion: 1.7 accidents per day with an annual cost of \$11.9 million. Incident response times were also affected severely due to congestion.
3. Aging bridge structures and pavement: The facility was 33 years old and had an estimated \$70 - \$100 million to repair yet would not include the required improvements.

Corrections needed to be made quickly so a fast-track design was established where the project would be designed within 16 months. Using CORSIM for analysis it was found that the project could be split in half, using two way lanes while the other side is reconstructed. This could be done while maintaining 80% of the traffic at that time.

For the construction there were various programs established to maintain and control traffic. These plans included a Traffic Management Plan (TMP), Travel Demand Management (TDM) program, Neighborhood Traffic Management Program (NTMP), Maintenance of Traffic (MOT) provisions, and Construction Intelligent Transportation System (CITS). Also used during the construction phase was various ITS technologies to ensure traffic quality was maintained during this time. These technologies included CCTV cameras, Dynamic Message Signs, Highway Advisory Radio, courtesy patrols (for major incident response), a Construction Traffic Management Center (CTMC), a Police/Fire substation, as well as a Big I web page providing real time traffic information for the public (Simmons, 2001).

### **Benefits**

The inclusion of the programs established and ITS technology used during the project construction led to many benefits. Directional ramp volumes reduced from 7%-46% while the mainline volume reductions reduced 3%-7%. The overall volume reduction goal of 20% made by the TDM goal was achieved as shown in Table 5. Accident occurrence was reduced by 44% for the first several months while transit ridership increased by 25%-30%.

**Table 5 Traffic Volumes within Each Corridor, before vs. during Construction**

<b>AM Peak</b>				<b>PM Peak</b>			
<b>Location</b>	<b>1999</b>	<b>2000</b>	<b>% Change</b>	<b>Location</b>	<b>1999</b>	<b>2000</b>	<b>% Change</b>
I-25 SBD	5,750	4,563	-20.6	I-25 SBD	6,736	4,536	-32.7
I-40 EBD	6,181	4,098	-33.7	I-40 EBD	5,017	3,846	-23.3
I-40 WBD	6,550	3,361	-48.7	I-40 WBD	6,620	3,789	-42.8

Note: 2000 count data were raw, unadjusted counts for general comparison only.

(Source: <http://www.ite.org/Membersonly/techconference/2001/CCB01A41.pdf> )

Other benefits were included from the ITS additions. Through the course of the construction there were absolutely no fatalities that took place and crashes as well secondary crashes overall



reduced by 32%. Incident management times were also reduced from 45 to 25 minutes (Regional Operations Forum: Work Zones, 2014).

### ***Lessons Learned***

Key items of success were shared with the FHWA. With the limited time frame, it was important to rapidly construct the segmental concrete bridges and apply the correct techniques for the precast bridges. This project also applied many design-build concepts as well as selected a project designer who remained with the team on-site. The FHWA played a role in the construction through providing an on-site bridge engineer to work with the New Mexico State Highway and Transportation Department (NMSHTD) for the entire project to help speed up construction changes and work order adjustments. Applying ITS technologies made a major difference through providing better communication methods for the incident management community. Lastly public trust and support can come easily through the actions taken in the construction phase (Hauswirth et al., 2013).

### **2.2.5 Washington State Department of Transportation Case Study**

The Traffic Operations Division of the Washington State Department of Transportation (WSDOT) has emphasis on incident response, system operations, traditional traffic engineering, ITS research and planning. Working together with the Toll Division, they used HOT lanes to establish their own distinct source of funding. Their integrated approach to operating is a large part of WSDOT's culture. WSDOT has benefited from the continual deployment of innovative ITS strategies and operational traffic management techniques over the years. The use of a Gray Notebook since 2001 has instilled a sense of confidence to the public that WSDOT knows what is happening on the roadways and how traffic operations and management strategies have impacted travel conditions. It includes ITS and TSM&O strategies that has demonstrated important benefits in safety, mobility, and efficiency.

WSDOT operates seven regional Traffic Management Centers (TMCs) where real-time information is gathered 24 hours a day, 7 days of the week. The center uses different assets including traffic detectors, CCTV cameras, ramp meters, road crews, incident response teams and reporters. They are most known for their long-standing real-time traffic monitoring and management program which provides essential information to support real-time operations, performance-based planning and informed decision making, all of which contribute to the success of a fully integrated TSM&O infrastructure.

The TMC also uses Variable Message Signs (VMS), Road Weather Information Systems (RWIS), Highway Advisory Radio (HAR), ramp meters and HOV lanes that also work as HOT lanes. The HOV to HOT strategy has been a successful use of TSM&O that leaves lanes open to solo drivers that are willing to pay a dynamically priced toll. The strategy ensures that traffic in this lane is free flowing at a desired speed at all times. Washington was also the first state to use Active Traffic Management (ATM) technology that uses overhead speed limit signs to provide



advance notice of traffic conditions such as slowdowns, backups, and crashes ahead to increase driver awareness, hitting the TSM&O goal of providing traveler information.

Traffic management strategies in Washington State are part of the “Moving Washington” program, an effort to integrate investments for cost-effective solutions. Their motto is to “Maintain and Keep Safe” with their main strategies being to operate efficiently, manage demand, and add capacity strategically. These three operationally focused strategies will integrate TSM&O strategies into all planning and programming activities to ensure that they are all considered. Operational strategies are low cost, high return, and quicker to implement than traditional capacity improvements. Investments in operational strategies bring in value in the short term, can have a lasting impact, can postpone the need for a major capital project, and will eventually serve to complement the inevitable big investment later.

The 20-year Washington Transportation Plan (WTP) is based on a continual system-wide performance measuring and monitoring program. The WTP serves as the federally compliant statewide Long-Range Transportation Plan (LRTP) for the State of Washington. The plan is required by the U.S. Code of Federal Regulations Title 23 and offers policy guidance for all jurisdictions statewide on matters related to the transportation system. Its purpose is to promote data-driven decision making resulting in the identification of the top transportation investment priorities, while it establishes a vision and goals for the development of the statewide transportation system. Assets that don't meet established performance threshold criteria are identified as needs. WSDOT develops cost-effective strategies, based on analysis of performance outcomes and best management practices, to provide high-benefit solutions for the identified needs. WSDOT aims first to maintain, preserve, and improve the operating efficiency of the existing highway system before adding to the system (Flanigan & Strasser, 2014). The most recent update to the WTP covers the period of 2010 to 2030 and identifies six policy goals: economic vitality; preservation; safety; mobility; environment; and stewardship.

The Washington State Multimodal Transportation Plan (SMTP) is the state's overall 20 year transportation plan. It was created by the State of Washington to ensure the continued mobility of people and goods within regions and across the state in a safe and cost-effective manner. The SMTP covers all the facilities the state owns and those in which the state has a stake in. Examples of these facilities include highways, bicycle and pedestrian facilities and state ferries. Those the state has a stake in are in the areas of aviation, marine ports and navigation facilities, freight rail, passenger rail and other forms of public transportation. The plan also recommends action regarding the coordination with appropriate private transportation providers to ensure that the state's interest in these modes of transportation are met.

The Washington State Highway System Plan (HSP) is the state highway component under the SMTP. The HSP is reviewed and updated every two years and includes lists of identified congested segment needs, specified prioritized strategies for addressing them, and performance measures to determine the effectiveness of these strategies. As it does this, the HSP informs the



10-year Capital Improvement and Preservation Program (CIPP) with a biennial budget discussion. The first priority is to operate and maintain the existing system to maximize efficiency and effectiveness. Another priority of the program is to improve performance of the system through variable pricing and other traffic management tools. TSM&O investments can be funded under traffic operations and highway construction, among others. Once Moving Washington was introduced, the 10-year planning process helped discussions of trade-offs, timing, and strategic investments, resulting in more consistent and complementary capital programs.

As required by the Federal Transportation Act, the 2013-2016 State Transportation Improvement Program (STIP) is a fiscally constrained prioritized program of transportation projects, compiled from local and regional plans along with the guidance of the WTP. However, since the WSDOT is limited to a two-year capital construction program and local programs are adopted annually, it is difficult to cover for a four-year horizon, and therefore, they only implement those projects tied to current or funds that are reasonably assumed to be available in the horizon period.

Best practice in Washington State has the Department of Transportation using technology and advanced techniques to address traffic issues. They are most known for their long-standing real-time traffic monitoring and management program. This program has assisted in the short term and long-range planning for the state. It provides essential information to support real-time operations, performance-based planning and informed decision making for officials. These consist on Variable Message Signs, Road Weather Information Systems, Highway Advisory Radio and Active Traffic Management to provide advance notice of traffic conditions such as slowdowns, backups and crashes ahead to increase driver awareness in their effort to provide driver traveler information. With a log of data, the team can better understand where the priorities should lie for long-range planning of the transportation network.

### **2.3 Summary of Best Practices in Projects**

Table 6 provides as summary of specific projects that implemented TSM&O practices. The lessons learned include the successes from each of the projects, the areas which needed improvement for future applications and recommendations for implementation of these practices. The benefits cover the capacity improvements for the facility, cost savings of the strategy, speed improvements and the time savings for users.



**Table 6 Strategy Comparison for Projects**

Strategy	Example Projects	Lessons Learned		
		Successes	Challenges	Suggestions
<b>Managed Lanes</b>	<b>I-15 Express Lanes, I-95 Express Project</b>	Dynamic pricing controls lane usage, can increase bus ridership, improve congestion on freeways, increased popularity of freeway usage.	How to prevent toll violations. Adding new dynamic pricing system will need local public & political support. Must ensure correct express lane type is selected (HOV, HOT, etc.).	Have local & state leadership involved in discussions early and often during planning and design phase for added project support and public awareness. Develop concept of operations early & plan for future phases of the project. Develop a revenue plan which includes a transit component. A HOT program should provide viable and recognized travel options for the public.
<b>Traffic Management Center</b>	<b>TranStar, Operation Green Light</b>	Traffic management on a wide scale. Can be highly automated. Positive feedback from users. Can reduce overall pollutant emissions.	Recurring costs must be planned for and manageable. Communications can be the largest expense. High learning curve for new operators. Standards must be set for system interoperability.	Plan out communications method between TMS & DMS early on and understand/budget for the long term expenses to be expected. Plan a systematic and well thought approach to solve problems of the system in a controlled manner. Ensure the software for the system is fully owned by your agency. Seek to implement standards-based procurements for the purpose of system interoperability.
<b>Ramp Metering / Freeway Management</b>	<b>Denver Metering System</b>	Can improve traffic speed tremendously during congestion periods. All around travel time improvements for mass commuting. Promotes easier and safer ramp merging. Encourages motorists to shift travel times, change travel modes, & use arterials for shorter trips.	Ramp timing is key to success/failure of system. Can have varying success depending on time of day. Queuing space needs to be planned for to prevent arterial backup. Vender selection can play a role in project success. Ramps experience increased delay time and emissions.	Central coordination is best fit for times of congestion where traffic speeds are less than 55 mph. Pay special attention to queuing space to ensure backup is prevented and to help reduce toll violations. Plan for a system that will adjust well to changes (ex. day light savings time). Be aware of the queuing space required for metering. When trying for the first time, start small and simple. Avoid conflicting solutions (ramp metering with HOV lanes).



**Table 6 Strategy Comparison for Projects, continued**

Strategy	Example Projects	Lessons Learned		
		Successes	Challenges	Suggestions
<b>Transit Management</b>	Tri-Met	Can improve general wait time and provide time savings in travel for users.	Setting up a transit system and its success relies heavily on successful collaboration of the project manager, the teams formed, the skills of those developing the program, vendors selected, and dispatcher involvement.	A project manager with operations, training, and data analysis experience to lead the project is of benefit. Inclusion of dispatchers in planning team can help provide added detail to the project.
<b>Traveler Information / Weather &amp; Emergency Management</b>	511NY	Can provide system wide real-time coverage for users regarding highway conditions and transit info. Capable to expand with additional features & user benefits as well as provide interactivity of information between providers & users.	Merging multiple information servers into one can simplify management, but will possibly require system framework modifications.	This strategy can provide environmental benefits that can open doors to funding options. Are there any currently offered systems that can be merged as a single source of information for users?
<b>Work Zone Management</b>	I-94, Big I Reconstruction	Provide goal setting and management abilities for recurring/non-recurring traffic scenarios. Reduction in delays and delay costs. Can be a very cost efficient strategy. Improved traffic quality. Reduces crashes & fatalities.	How the program is formed, run, and managed make the difference between the success/failure of it. Results must be seen of the program for public support.	Team communication & partner collaboration can improve through bi-weekly meetings and construction meetings. Keeping score and establishing goals can improve the program tremendously. Gantt charts of construction scheduling can help enforce delay goals. Applying ITS technology for communications can help.
<b>Regional Traffic Management / Incident Management</b>	Kansas City SCOUT	Provides real-time info to users to help select the best routes. Improved delay times from incident management. Reduce lane closure hours. Provides highly stable flow of traffic. Traffic signal system benefits up to 40:1.	Communications infrastructure is high priority when planning for such a system, taking current and future infrastructure into account. Technical requirements need the team of the program to understand the implications.	Recommended to work with City Council to discuss results of the program as well as take concerns and areas to improve. Review priority corridors in the system as well as the system software to be utilized.
<b>Multi-Modal Transportation</b>	New Woodrow Wilson Bridge	Multi-modal infrastructure working together can provide a large time savings while supporting growth of mass transit & ride sharing options. Increases bike/pedestrian/shared ride/mass transit usage.	Further expansion and success of a multi-modal strategy is dependent on the initial success of project when completed. Major construction projects can cause concern on environmental implications.	Put together a team of experienced federal and state project managers, environmental impact review staff, & consultants to ensure environmental impact reviews can be addressed. Involve the community and citizens through organizing a collaborative decision making team. Produce a financial plan



**Table 6 Strategy Comparison for Projects, continued**

Strategy	Example Projects	Benefits			
		Capacity	Cost Savings/Value	Speed	Time Savings
<b>Managed Lanes</b>	<b>I-15 Express Lanes, I-95 Express Project</b>	Vehicle volumes increased 70% during peak am period and 20% peak pm period. Increased bus ridership by 170%.	Annual revenue goal surpassed by 113-115%. Total revenue of roughly \$16.8 million. Users paid up to \$7.00 for HOV lane usage.	Average speed increase for HOV lanes to 56-63 mph and general purpose lanes to 42-50 mph.	median savings up to 7 min/commuter/day (I-15).
<b>Traffic Management Center</b>	<b>TranStar, Operation Green Light</b>	12% reduction in nonrecurrent congestion, 3% reduction recurring	Monetary benefit of \$227 million per year. Annual savings of \$4,157,188 (OGL).	Travel speed increase of 33-58% during peak hours (OGL).	offset travel delay by 11.3 million vehicle hours. Travel time reduction of 74-137 sec (OGL).
<b>Ramp Metering / Freeway Management</b>	<b>Denver Metering System</b>	30% decrease in traffic incidents (50% reduction in rear end collision). Increased flow rate from 100 vph to 400 vph (Denver). Increased throughput in excess of 2,100 vph.	Annual savings of \$40,028,000 and benefit-cost ratio of 5.1:1 (Twin Cities).	Speed increase up to 35.5-57%	Travel time decrease down to 13.3-37%. Annual savings of 25,121 hours of travel time & 2.6 million hours of unexpected delays (MDOT).



**Table 6 Strategy Comparison for Projects, continued**

Strategy	Example Projects	Benefits			
		Capacity	Cost Savings/Value	Speed	Time Savings
<b>Transit Management</b>	Tri-Met	Eliminates 207,750 daily car trips.	Annual wait time savings of \$1.6 million and in-vehicle time savings of \$1.88 million. Total annual benefits of \$5.4 million.		Estimated wait time decrease of 0.11 min (114,000 hours saved per year). User time savings of 0.42 min (400,000 hours annually)
<b>Traveler Information / Weather &amp; Emergency Management</b>	511NY				
<b>Work Zone Management</b>	I-94, Big I Reconstruction	Directional ramp volume reduction of 7-46%, mainline reduction of 3-7%. Accident occurrence reduced by 44%. Ridership increase of 25-30%.	Reduction in user delay costs of \$0.3-\$3.56 million a year. Delay costs from work zone, weather, & incidents reduced by 25%. Reduced delays by 50% in work zones.	Speed compliance met above 90% of the time.	Delays per project reduced below 10 min. Reduce incident delays to 25 min. Reduce incident management times to 25 min.
<b>Regional Traffic Management / Incident Management</b>	Kansas City SCOUT		Provide a benefit-cost ratio of 8:1 for users & agency.	More stable speeds during incident periods.	Reduced lane closures roughly 1 min per lane per accident.
<b>Multi-Modal Transportation</b>	New Woodrow Wilson Bridge		Saves commuters \$4,600 in time savings annually for commuters.		Provide time savings of 40 min per day.

### 3. DEVELOPING A TSM&O PROGRAM

#### 3.1 TSM&O Goals

The elevation of TSM&O program to a level of optimization, as determined by AASHTO, requires the implementation and effective use of performance measures that accurately describe the effects that a project has on an improved facility. Established by Oregon Metro (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010), an effective TSM&O program has four main goals to achieve as a practice of excellence within an organization. We chose this organization as a model to represent the development of a robust TSM&O program because of their comprehensive approach present in their plan. It is intended to provide guidance for the Florida Department of Transportation to establish a successful program to suit the needs of the agency.

The presented goals should be seen as a guiding principle for the purpose of implementing TSM&O practices in projects. While many projects accomplish several of the goals, it is to note that these are the basis for ensuring that fully integrated TSM&O program remain focused on the delivery results. As long as a project can deliver on one of these goals, it can be considered a viable application of TSM&O practice. The four goals are defined on Figure 13.



**Figure 13 TSM&O Goals as Demonstrated by Oregon Metro**

Reliability is defined as the ability to “Provide reliable travel times for people and goods movement” (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010). A roadway network that is predictable gives the user a degree of dependability and the power of choice in their commute. While the promotion of modal choice is a key priority of many TSM&O program efforts, there must also always be consideration for the users continuing to utilize their vehicle as their primary mode of choice on the transportation network. Users



experience with their perception of reliability involves incidents that are responded to quickly and efficiently and that signaling priorities are given during peak commuting periods to the peak direction of travel. An erratic and unpredictable reliability is undesirable as users will not be able to depend on the system. Getting users to establish patterns of travel based on the knowledge of the network performance benefits both parties. Traffic engineers can better predict and provide support for traffic situations with this knowledge. When the network is reliable the ability to plan and prepare for unexpected or planned events is significantly improved.

Quality of Life is defined with the purpose to “Enhance the environment and quality of life by supporting state and regional greenhouse gas reduction and air quality goals” (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010). The environmental factors involved in the transportation network traditionally focus on the reduction of congestion. While this still plays a huge role in meeting environmental standards for transportation, more areas are looking to capitalize on this goal. Modal choice to encourage livable communities is a big player in changing the number of vehicles on the roadway network. By shortening commutes and keeping business local, we reduce the need for everyone to use the same facilities. Although not directly transportation policy, these initiatives encourage the use of passenger trains, buses, walking and biking. The crossover comes into play with the implementation of “Complete Streets”. This concept ensures that all users have modal choice within their roadway network. These initiatives encourage the development of “Healthy Communities” which is becoming more prominent and requested by the public. Livable communities support health lifestyles and choices to be made when people want or need to commute throughout the community. With the advent of modal choice, the number of vehicles being used and vehicle miles traveled can go down. Optimizing signals is another major contributor to the reduction in environmental concerns. With less stops, vehicles are not working as hard to operate and therefore are emitting less greenhouse gases into our atmosphere. Keeping vehicles moving not only operates them more efficiently; the reduction in stops also reduces the risk for minor crashes.

Safety and Security is defined with the purpose to “Enhance transportation safety and security for all modes” (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010). This goal can be accomplished in a variety of differing methods. The projects range from transit security/police and railroad grade crossing improvements to rumble strip installation, traffic calming techniques and pedestrian accommodations. This goal is accomplished by ensuring that every user of the roadway facility is considered and that the interfaces between them are appropriately designed, delineated and useable. As users, every person must be able to use the facility safely with an acceptable level of security that does not endanger the user when following all of the recommendations.

Traveler Information is defined as the ability to “Provide comprehensive multimodal travel information to people and businesses” (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010). The ability to inform users of the transportation network conditions by giving them information is invaluable today. Not only by traditional methods of installing



dynamic message signs, the power of information can be online, on an app or within the vehicle itself. Users are able to even customize their routes and choose a mode. This technology infrastructure is only possible through the implementation of TSM&O techniques. Traveler information is a direct result of the want to operate facilities more efficiently by giving the end user as much information as possible.

### **3.2 TSM&O Performance Measures**

To establish effective performance measures the agency needs to “identify the operational activities to be monitored” (AASHTO, 2014A). The outputs of the performance measures are of paramount importance to make key decisions on the TSM&O program’s direction. The measures need to demonstrate the ability to assess the program’s needs, work toward agency goals and support the mission and culture established at the agency. AASHTO terms the effective performance measures as “actionable” (AASHTO, 2014A) and can typically be directly controlled by the agency’s management. Performance measures also need to come with a set of actions and thresholds in which adjustments or further improvements will be implemented. Just measuring the outputs is not enough for a performance based system of improvement to flourish. The data must continually be interpreted and understood to be able to enhance upon. Significant changes in the outputs should be met with procedures of what the next steps are toward mitigating the change in performance.

The targets for performance have to be both reasonable and attainable to be an effective measure of the system. They should also have a meaningful impact on performance of the roadway system. “Performance measures help to determine whether resources are being prioritized properly to meet goals and objectives” (Federal Highway Administration, 2004). Similar projects should also be analyzed so that a base performance measure can be logged to determine the impacts of certain strategies. It is important to note that all mitigations will not yield similar results even under similar circumstances. The in-depth understanding of a project and mitigation is essential to ensure that an equitable comparison is being made. Operational analyses must be conducted to determine the potential causes of differing results. The FHWA admittedly calls the performance based system a challenging effort and has offered the following guidance:

- The measures should provide a realistic view of system performance improvements achievable through management and operations investments.
- They should provide operations managers with guideposts and goals that provide some measure of how operations programs are contributing to the long-term goals of the entire system.
- They should also support policy that is realistic about system constraints and that supports the role of management and operations in maintaining acceptable transportation performance.



The full integration of a TSM&O infrastructure and performance measurement system requires that it is implemented and presented as a continuous improvement program. The project does not stop at deployment but is rather a fully functioning machine that evaluates the network condition constantly and makes swift adjustments when conditions change. While in the early stages of establishing a performance measuring system the focus is on the system itself, the program needs to eventually evolve to gathering user-based data and responding to feedback given by the end user. The collaboration of the data can result in a system of performance reporting that is understandable and able to be discussed by multiple offices within the agencies. These measures pinpoint issues that can be addressed before they turn into a pattern.

### **3.3 TSM&O Functional Areas**

TSM&O in broad scope has generally been divided into four functional areas that support the implementation of the program's core areas and support the established goals. The functional areas are, Multimodal Traffic Management, Traveler Information, Traffic Incident Management and Transportation Demand Management. The auxiliary effects of the efforts of TSM&O are the environmental benefits, which can be quantified and measured. These factors are included because they are having more of an impact on infrastructure project standards. These environmental measures look to have a larger impact moving forward as more funding is tied to and requires environmental analyses to be conducted.

#### **3.3.1 Multimodal Traffic Management**

The push to make transportation systems more efficient has had an integral part in making multimodal traffic management more of an important part of the transportation network. The advent of modal choice has brought about the need to track the measures and impacts of the transit network and freight movement, while considering the impact on pedestrians and bicycles. Ensuring that all modes are considered at conflict points is imperative to ensure that all users are provided an acceptable level of service. Throughput and delay are the largest impact factors of multimodal traffic management and the performance measures are divided as such. The performance measures recommended are:

##### **Throughput**

- **Passenger trips per vehicle revenue hour:** This is a measure of the effectiveness of the transit route based on a time scale. Used more for transit efficiency to maximize ridership, this measure can be a good tool to optimize bus routes. This is most useful in determining the savings that delay avoiding techniques can provide.
- **Passenger trips per vehicle revenue mile:** Similar to that of the revenue hour, this is a measure of effectiveness of the transit route based on a distance scale. The distance based scale can be more useful in the determining the effects of re-routing buses in the event of congestion on the normal route.



- **Passenger load (ridership/capacity):** This is an additional measure of effectiveness of a transit system that can be taken instantaneously or over time. A percentage based measure; this parameter would show a successful run with the emulation of a normal distribution.
- **Passengers per stop:** A count of the passengers boarding and debarking at each station. This impacts the pedestrian and bicycle treatments in the vicinity of the transit stop.
- **Pedestrian/Bikes per approach:** At each intersection this measurement can be taken to optimize the movements of the vehicles and the pedestrians and bicycle. An intersection with high volumes from all approaches can be considered for pedestrian only phases.
- **Bike Travel Time:** Considering the bicycle travel time is important to consider the impact of biking on a facility. It also can provide guidance on separated facilities.
- **Pedestrian/Bike arrival rate:** This factor can influence the adjustment for additional pedestrian/bicycle time at a signal. In urban areas where transit is prevalent, it can help reduce illegal crossing due to delays or being caught in the intersection after the pedestrian phase has ended.
- **Freight volume:** This measure determines if appropriate accommodations should be made for freight traffic.
- **Travel-times on key freight corridors:** Travel times on freight routes are expected to be reliable and predicable to provide an accurate account of goods' arrival time.

#### **Recurring & Non-Recurring Delay**

- **Freight Delay:** This is an account of all delay incurred by freight traffic. While recurring delay is to be expected during peak hours and typically avoided by freight, non-recurring delay should be minimized and tracked for fluctuations.
- **Transit Delay:** This is an account of the delay of the transit vehicle compared to free flow conditions. The figure is expected to fluctuate based on the traffic volume along the transit route.
- **On-Time Performance:** A standard measurement of transit agencies, this measurement is a percentage based account of the number of transit stops that have been "on schedule" compared to all transit stops. Some agencies buffer with 1-2 additional minutes but in its purest form the vehicle arrives at the scheduled time.
- **Pedestrian Signal Delay:** A measurement of the average time that a pedestrian has to wait to cross a conflicting signalized movement. Agencies vary this standard by location, venue and number of pedestrians using the signal.

### **3.3.2 Traveler Information**

Traveler information is becoming a vital component to drivers in the handheld technology age. Users want instant information to make sound judgement decisions. A fully optimized TSM&O program strives to provide a well-integrated network of information tools available to the user. Not only to make better decisions as a traveler but impact the transportation network by avoiding problem areas. The information provides benefits both the user and those operating the network.



User based reporting is becoming a valuable source of information for the transportation network as well. As more user fees are introduced, the need to deliver on service has increased. It is important that agencies also include and listen to what the users' needs and desires are. Without a two-way communication channel neither can learn what is most important to better the transportation network. These are some of the most common factors when performance measurement is introduced to a system:

### **Customer Satisfaction**

- **Percent of population highly satisfied with travel conditions:** This user-based measure demonstrates the traveler perception of travel conditions. This measure should be taken into consideration with the typical idea of the general public to expect no congestion.
- **Percent of population satisfied with travel conditions:** Satisfaction with a condition generally shows that the user understands and tolerates a certain amount of adverse conditions on the transportation network. A majority answering favorable at this category and above demonstrates good management of the system and expectations of its performance.
- **Compliment Rate:** Compliments are rarely given to an agency of this type but should be tracked and read to gather important perception information.
- **Complaint Rate:** Complaints are a helpful tool, although typically negative in nature. These can be used to assess problem areas and issues with perception with the public. To be effective this feedback has to be taken seriously and solutions implemented to improve the process.
- **Number/type of calls to 511:** Demonstrating a use of this system, this measure can be used to optimize the system and also improve communications about roadway network conditions.
- **Number/type of calls to transit advisory telephone:** This measure is important for transit agencies to know and understand the types of issues that are being faced on their system.
- **Number/type of hits on traveler information website:** Being in a technology driven world, website traffic is important to keeping information relevant and up to date. This is also a way to measure if the communication methods being used are effective.
- **Number/type of app data hits:** With transit developed applications, agencies have the ability to track the information being requested by its users to better understand their needs. Route planning data can also be gathered from these applications to have a detailed origin-destination set of data. This can help the agency minimize transfers and adjust transit runs.
- **Number of apps providing data:** Either by coordination or by user-driven data there are many apps that provide travel related data to the end user. The best way to obtain this information is by directly providing information to developers. In the case that others are



not involved, the information provided on mainstream apps should be monitored for accuracy.

### **Travel-Time Reliability**

- **Travel-Time Index:** The travel time index measures the travel time under peak conditions as a comparison to free flow conditions. While it is not realistic to ever obtain a value of 1.0, it is desirable to keep this number as close as possible. An agency will typically establish their acceptable rates for this index.
- **Planning Time Index:** A derivation of the travel-time index, this measure takes the travel time on the most congested day of the month (typically the 95<sup>th</sup> percentile) and compares it to the free flow condition travel time. An agency will typically establish their acceptable rates for this index.
- **Buffer Time Index:** This index stems from the use of the average travel time of a roadway rather than free flow conditions. The average travel time is subtracted from the 95<sup>th</sup> percentile travel time and divided by the average travel time. The buffer time index is represented as a percentage of average travel time. An agency will typically establish their acceptable rates for this index.
- **On-Time Performance:** This measure applies as a Travel-Time Reliability factor for transit just the same as Multimodal Traffic Management. However, the use of factor varies by agency as to how it gets to the end user. It is usually is represented as a delay and not reported explicitly as the traditional measure in the Multimodal Traffic Management section.

### **Travel-Time**

- **Average Travel-Time:** The time it takes to get somewhere is most often the most important measure to a user. Ensuring that these values adhere to the TSM&O goal of being reliable is important for the success of a transportation network. In transit especially, travel time is a very important factor in a user's decision to change their mode of transportation.
- **Average Speed:** This is a basic performance measure that can impact the operation of the facility. Implementing techniques to avoid a congestion breakdown can be implemented by knowing the average speeds of a facility. In the long term, this is an effective way to determine changes occurring on the roadway network.
- **Event Travel Time:** This is specifically an event management performance measure that is a calculated time from the designated start location or multiple locations to the event location/parking lot. The measure should include all delay associated with the event.
- **Work Zone Speed Reduction:** This is a measure of the difference between the free flow speed and the speed of vehicles while the work zone is present. These can be used to process vehicles efficiently through the work site or ensure that drivers are slowing down during working conditions.
- **Work Zone Lane Shifts/Closures:** Changing traffic patterns can have a huge impact on network performance. Lane shifts and lane closures are important to track to ensure that



they are done at an acceptable time for the facility. This is typically a measure that includes the number of lanes shifted/closed, the distance of the occurrence and the time period of the occurrence.

- **Evacuation Travel Time:** In the event of an evacuation of a region, the travel time along a designated route is important to capture under peak conditions. With this information transportation officials can work closely with emergency management to implement schemes to minimize these times.

### 3.3.3 Traffic Incident Management

The ability to clear an incident from travel lanes is a large component of reducing the non-recurring delays on the transportation network. Incident management has to be responsive and timely with their ability to report to a scene and ensure that the facility is brought back to full operation in the shortest time possible. This functional area of TSM&O has been in place for many decades and has become technology driven by employing the use of sensing equipment and camera detection to identify potential incident locations before a report is called in. Performance measures under this category can also impact the safety of the facility as first responders themselves are a hazard to users on the roadway. Some of the measures recommended are:

#### Incident Response

- **Number/type of incident responses:** A simple, yet powerful statistic, this can provide a picture of the type of issues that are being experienced by drivers on the roadway network. Understanding the severity and collision types can lead to better information for the decision makers when programming a project.
- **Incident Duration:** A key indication of the congestion impacts the incident may have on the transportation network. As the duration goes up, it can exponentially increase the congestion on a facility. It can also judge the performance of the incident response teams that are in place on the system.
- **Incident Response Time:** An indication of the performance on incident management teams. The more efficiently the incident is responded to, the lower the duration of the incident.
- **Average Incident Clearance Time:** This shows the incident response team's performance on the ground. In all instances safety is a top priority, however, the clearance of the incident must be measured to ensure that crews are operating efficiently to keep the roadway moving.
- **Number of Lanes Blocked:** Essential to the traffic flow of the facility, emergency responders are evaluated on their ability to keep facilities open and traffic moving. As such, the number of lanes blocked, duration of the blockage and distance closed are important feeders to this parameter.
- **Number of Lanes Closed:** In some cases the first response team deems it necessary to close lanes of the facility. As with the blockage parameter, this is measured in



conjunction with the number of lanes closed, duration of the closure and the distance of the closure. It is important to also notate if the closure affects the entire facility.

### **Collision Rate**

- **Rate/number of primary collisions:** Collisions are a measure of the user safety rating in a particular section of roadway. This measure can assist in identifying safety and user behavior issues that may be present on the system. While we are human and the number will never be zero, the aim is to reduce the number of primary collisions on the network.
- **Rate/number of secondary collisions:** A result of primary collisions, secondary collisions are sometimes caused by other drivers that are affected by the primary collision. Ensuring that education and enforcement are in place will decrease the amount of secondary collisions. These collisions can more easily be reduced as they are typically driver error or behavior. A reduction of these collisions can have a dramatic effect on the roadway network that already has been adversely affected by the primary collision.
- **Rate/number of fatalities:** Traditionally a measure of safety and severity of crashes on a roadway, this measure emphasizes that there may be safety issues that need to be addressed at the location.
- **Rate/number of injuries:** A measure of severity of crashes and safety on a roadway, this measure indicates that there may be safety issues to be addressed at the location.

### **3.3.4 Transportation Demand Management**

Transportation demand management is a functional area of TSM&O that is rooted in the distribution of users across the network in an even fashion. This branch of the TSM&O effort focuses on ensuring that the demand for the network is managed effectively, alternative routes are available and congestion management is executed to the best of the agency's ability. With a network approach, this area focuses on the extent of congestion, the throughput and recurring and non-recurring delay on the transportation network. Modal choice is a huge component of demand management by encouraging biking, walking and use of transit facilities to get vehicles off of the roadway network during peak hours. A fully functioning transportation network has the ability to choose a mode and while doing so is able to do so knowing that the mode can be traveled safely and efficiently in whichever mode is chosen. Sample performance measures in this area are the following:

#### **Extent of Congestion**

- **Spatial:** Understanding the congestion that occurs on the roadway network is very important to the success of alternative mode promotion. The best case is where congestion is isolated to the main arteries of the roadway network. Users are able to choose to use longer but less congested routes if their travels allow them to do so. When the congestion is severe, the entire network will suffer and be placed into a pattern of gridlock.
- **Temporal:** The progression of congestion is important to understand and measure. Knowing when the congestion occurs informs the agency of the when the congestion



issues occur. Measuring when certain areas breakdown and cascade onto other roadways of the network is imperative in the application of ramp metering, re-routing and transit promotion.

### **Throughput**

- **Vehicle volume per hour:** A traditional and simple measure to obtain. This gives an excellent perspective on what the facility can realistically handle under any condition. Although there are many guidelines and thresholds for this measure, all networks and links of a roadway system have their own conditions and geometry that can affect this measure.
- **Persons per hour:** This measure can be a summation of all modes for a corridor or broken down by mode type to draw comparisons. The value should include those in vehicle, transit vehicles, bicycles and pedestrians.

### **Recurring & Non-Recurring Delay**

- **Vehicle Delay:** This is an account of all delay incurred by vehicle traffic. This is a basic performance measurement and is the starting point for most TSM&O programs. As indicated previously, recurring delay is to be expected during peak hours; non-recurring delay should be minimized and tracked for fluctuations.
- **Duration of Congestion:** While vehicle delay is important, it is also a great service to know the macro effects on the system. The length of time that the network is congested is an important factor to gauge the distribution of congestion and assign severity ratings for congestion on the roadway network. Durations may decrease but could be more widespread throughout the network.
- **Vehicle Class Distribution on Network:** Whereas commuters typically travel on a set schedule and path the idea is to keep track of the distribution of vehicles on the network to ensure that the facilities are being optimized. This has led to the implementation of lane restrictions and discounts for drivers using alternate facilities on the network.
- **Event Delay:** The calculated additional amount of time that a special event is causing on a facility for drivers that are not attending. This measure can be effective in ensuring that transportation officials can work with operators to ensure that impacts to transportation facilities during events are isolated to a specified area where the event is taking place. This can also apply to delay due to a closed road.
- **Work Zone Delay:** The calculated delay due to work zone activity. This measure assists in the recommendation of alternative routes and officials can provide drivers with the information to potentially change their mode of travel when it is significant. This can also apply to delay due to a closed road.

## **3.4 Environmental Benefits**

The environmental benefits of a comprehensive TSM&O program do not fall under a specific functional area of the TSM&O infrastructure but rather are side effects of many improvement projects that involve practices championed by the program. As the need for trackable



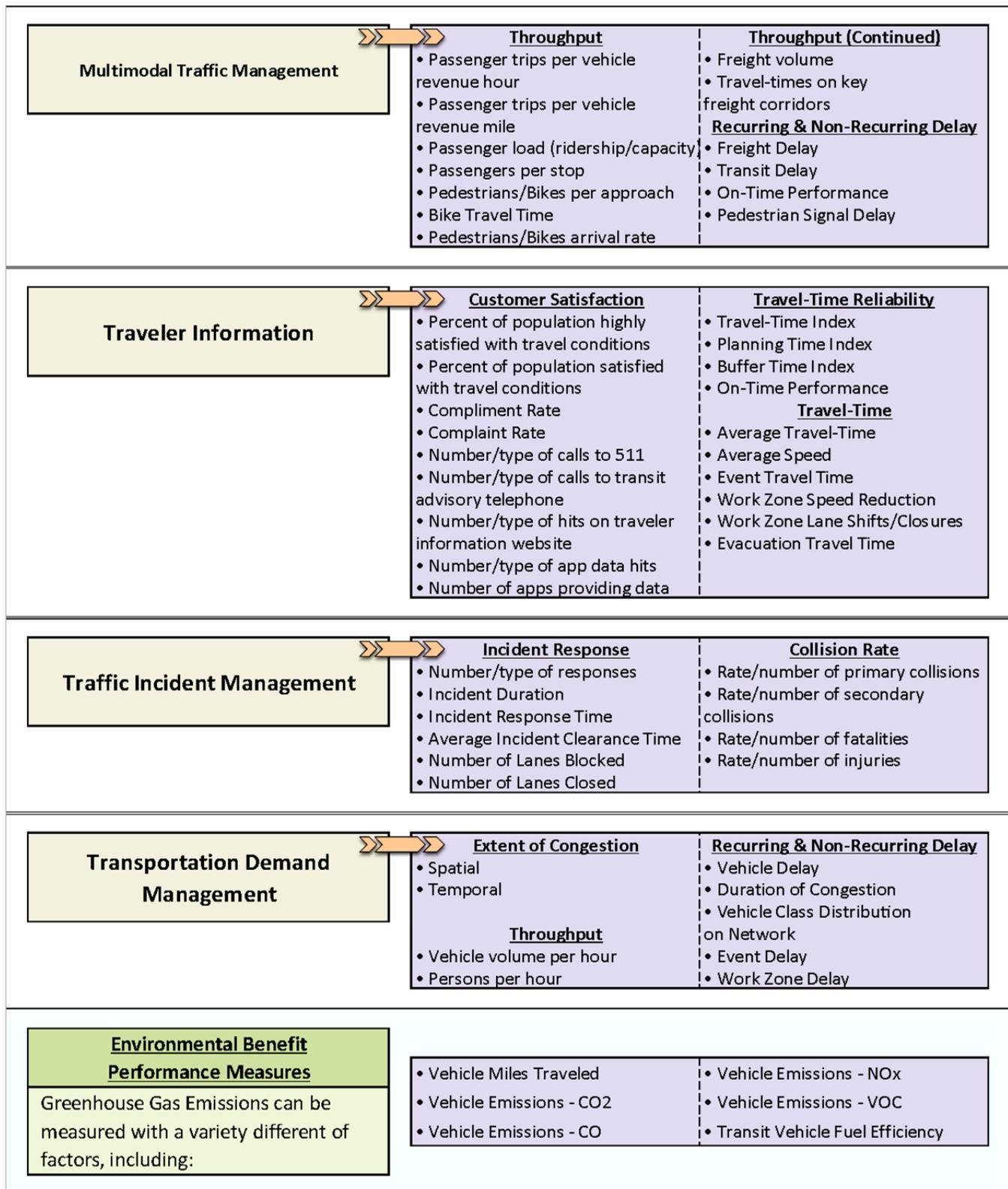
environmental statistics increase we can begin to include these in relevant reports as additional support to projects which exhibit a high impact on Greenhouse Gas Emissions. Some measurements that can be taken are:

- **Vehicle Miles Traveled:** With fluctuations in Vehicle Miles Traveled the environmental impacts can be staggering. Even with increased vehicle efficiency standards, fewer vehicles miles on the road have a great impact on environmental factors such as noise pollution, landfill reduction and reduced vehicle turnover.
- **Vehicle Emissions – CO<sub>2</sub>:** The emission of CO<sub>2</sub> into the atmosphere is a naturally occurring process but not at the rate that vehicles are producing it. Reductions in CO<sub>2</sub> are important to tracking the impact on the Earth's atmosphere and levels present in the air we breathe.
- **Vehicle Emissions – CO:** The emission of CO can be dangerous for people, especially for vehicles in a confined environment. CO is still emitted, although at a smaller rate, it is typically converted to CO<sub>2</sub> by our vehicles.
- **Vehicle Emissions – NO<sub>x</sub>:** Although much lower than emissions of CO<sub>2</sub> and CO, NO<sub>x</sub> emissions have been linked to causing health problems and early death. These emissions can have some of the most direct impacts for people.
- **Vehicle Emissions – VOC:** VOCs react with sunlight to create ozone at ground level and contributes to the generation of smog. Among the health impacts caused by ozone, these compounds can cause environmental damage.
- **Transit Vehicle Fuel Efficiency:** A change in the fuel efficiency of a vehicle can have a positive environmental impact and changing an entire fleet of transit vehicles magnifies that impact.

There are many other factors that can be measured based on the specific needs of a project or region. The Environmental Protection Agency (EPA) has an established performance measures system that can be used as a guide for regions exhibiting their environmental results. As a TSM&O goal, it is important that these projects continue to support the increased sustainability and efficiency that is being required by law and expected by the public.

### 3.5 Sample Performance Measures

A summary of the functional areas and potential performance measures are shown in Figure 14. It is imperative to understand that these are sample performance measures and an agency should go through their own process to determine which ones are best suitable for their needs. It is also not meant to be an all-inclusive list but rather a compilation of the best practices available for the basic building blocks of a robust TSM&O program. There are many considerations that may vary from state to state and district to district.



**Figure 14 TSM&O Functional Areas with Sample Performance Measures**



The most critical aspect of making the concept of establishing performance measures a success is to “publish regular reports documenting the implemented TSM&O projects, performance outcomes and key agency functions that need to be maintained throughout the life of the TSM&O plan” (Oregon Metro Joint Policy Advisory Committee on Transportation, 2010). The reports should be meaningful and deliver results on what is working effectively and what needs to be improved upon. Requiring performance-based assessments and using these methods are only an advantage if the results are acted upon and changes are made to implement measures to bring future results within a favorable range for the agency. Performance measures are just one of the keys to the continued success of a TSM&O program and all transportation improvement projects moving forward. Once a successful program is established the implementation requires a carefully crafted and followed process to be most effective.



## **4. THE TSM&O PROJECT DEVELOPMENT PROCESS**

Performance measures are a key component of the TSM&O Project Cycle. As a program it holds the key for decision makers to effectively utilize their resources and focus on the most important parts of the transportation network. This judgement and performance measures is the main evaluation tool when it comes to improving an existing facility.

### **4.1 Facility Evaluation & Systemwide Evaluation**

A decision must be determined to see if the facility is meeting its TSM&O goals (if established) and performance standards established by the agency. A typical project cycle as demonstrated by the FHWA should include:

- An Assessment of Deficiencies
- Developed Alternative Scenarios
- An Evaluation of Alternatives
- A Selection Superior Options

The Operations and Maintenance teams should conduct reviews concurrently and regularly to assess existing facility's condition, performance and its potential for TSM&O applications. If the existing facility adheres to the established requirements, it should be regularly re-evaluated based on agency standards. If the existing facility is in need of improvement, Maintenance must be involved with operations to discuss the realistic maintainability of projects and issues that may arise. This team should be involved from start to finish ensuring the essence of the project is not changed by other processes of the TSM&O Project Cycle. They should be informed of any major changes to the project and be represented at project meetings. The needs of the facility must be assessed accurately and that knowledge should be discussed among local agencies and affected departments within the agency. The project should also be evaluated as part of the overall transportation system for regional planning with multiple facilities. An example of the potential invitees and the progression of this step of the project are shown on Figure 16.

### **4.2 TSM&O Project Determination**

Once the facility assessment is completed and it is determined that the performance criteria is not being met, it is time to assess for the ability to implement a TSM&O focused project. Based on FHWA's categories for the necessity of a project, there are three project types that require more than TSM&O strategies alone to be an effective solution:

- If the facility needs a major repair or replacement of the existing physical structure.
- The demand of the facility, even with TSM&O considerations, exceeds the available capacity,



- There are safety concerns related to the physical geometry of the facility and requires reconstruction.

Even with the three project categories noted above, TSM&O can be integrated into the new facility, however, TSM&O strategies alone cannot mitigate the circumstances of these conditions. Once the determination is made, the project should then be evaluated for its TSM&O merits by comparing them to the TSM&O Benchmarks established as a compilation of AASHTO, Oregon Metro and Southwest Washington Regional Transportation Council in Figure 15:

<b>TSM&amp;O Benchmarks</b>	• Improve travel time reliability	• Reduce travel delay
	• Reduce crashes	• Reduce fuel use
	• Improve transit on-time arrival	• Reduce air pollution
	• Expand Modal Choice	• Reduce greenhouse gas emissions

**Figure 15 TSM&O Benchmarks**

With the establishment of the benchmarks that the TSM&O techniques will achieve, the project is then taken through the TSM&O Project Lifecycle by starting in the Project Concept & Programming phase.

#### **4.3 Project Concept & Programming** (*Feasibility Study/Concept Exploration*)

The Project Concept phase is the first step that the Planning Department is primarily responsible for. They must consider the range of TSM&O strategies that are available for the project. Based on the performance measures that have been established the team can formulate a Purpose and Need statement for the project. This statement is a guiding principle for the project and should be linked to a TSM&O benchmark or goal. The statement should also fall in line with what the facility evaluation determined by supporting the recommendations of the evaluation. At this stage, no alternative should be denied and every idea should be considered as a viable solution to the addressed concerns of the facility. This stage should involve input from stakeholders and early considerations from other groups that may potentially be involved in the project.

Prioritization comes into play with the next phase of Programming. Projects that involve TSM&O strategies are typically smaller scaled projects that curb the need for a large investment in the short term. As such, these projects should be given the appropriate priority to be completed in a timely manner. As determined by the FDOT, the Work Program group does not integrate TSM&O into their regular activities. This group is imperative to the success of these projects as they have a broader scope of the other projects under execution by the department.

Closely linked to the Project Concept, this phase can dramatically change the scope of the project if it programmed beyond the realistic time period that the performance measures have been taken



for or enough time has passed that “Purpose and Need” require modification. One of the key advantages to a TSM&O Project is the swift progression and deployment of the techniques into the field. Programming has to also establish a priority for TSM&O Projects that are based on need, not necessarily the first project in the sequence. The team should evaluate the effectiveness and logical progression of the projects to establish a work program that best suits the needs of the public. Those involved with the work program should be evaluating potential applications and linkage opportunities to other projects in the work program. These employees should also have the ability to share input on project priorities and project timeframe details as it relates to other projects. All of these processes are at the discretion of the agency but significantly smooth the process out. The Planning Department should be actively involved in discussing the priorities with stakeholders and other potentially impacted groups, as outlined in Figure 16.

### ***Stakeholder Involvement***

“According to the Project Management Body of Knowledge a stakeholder is ‘a person or organization such as a customer, sponsor, a performing organization or even the public that become part of a project, with interests that can positively or negatively be affected by the execution or completion of a project. A stakeholder can also have the power to exert influence over the project and its deliverables’” (The Braintrust Consulting Group, 2010). The involvement of stakeholders is very important as they can become great assets that can clear organizational roadblocks and support projects when needed.

Communication is key when having stakeholders involved in a project. By understanding their needs, how best they can be communicated to, and keeping them well informed, they are engaged in the project throughout the length of the development cycle. The best way to foster communication is by developing working trust, establishing inter-agency agreements, identifying performance goals and objectives, achieving consensus on team actions, eliminating jurisdictional barriers, and minimizing resource and funding constraints. Stakeholders feel more at ease when they feel like they are a partner in the process rather than someone who is told what is going to have them. Keeping them constantly involved, to their liking, is important to ensuring that they are vested in the project.

On occasion, agendas are bound to collide, and stakeholder management can become an arduous task. It is imperative that for the success of the project, points of contention are addressed reasonably and timely. A disagreement can negatively impact the project and create roadblocks for the future. Requirements and deadlines can be missed and funding can be pulled when relationships are not maintained in an equitable manner. When managed properly and respectfully addressed and regarded, the stakeholders can be great assets as they can be a source to push the progress of the project. These individuals can also serve as mentors to bounce ideas off of and help raise the acceptance or approval rate of the project output by the end users. In times of need, they can be valuable support to project staff. Coordination of stakeholder



involvement is needed throughout all phases of a project, and their satisfaction needs to be of paramount importance to the project staff.

Below are a select group of the Braintrust Consulting Group's best practices for managing stakeholder involvement that can be applied to transportation:

- Uncover all stakeholders in the initiating phase
- Manage stakeholder communication requirements
- Involving your stakeholders throughout the project is key
- Always remember to manage your stakeholders or they will manage you

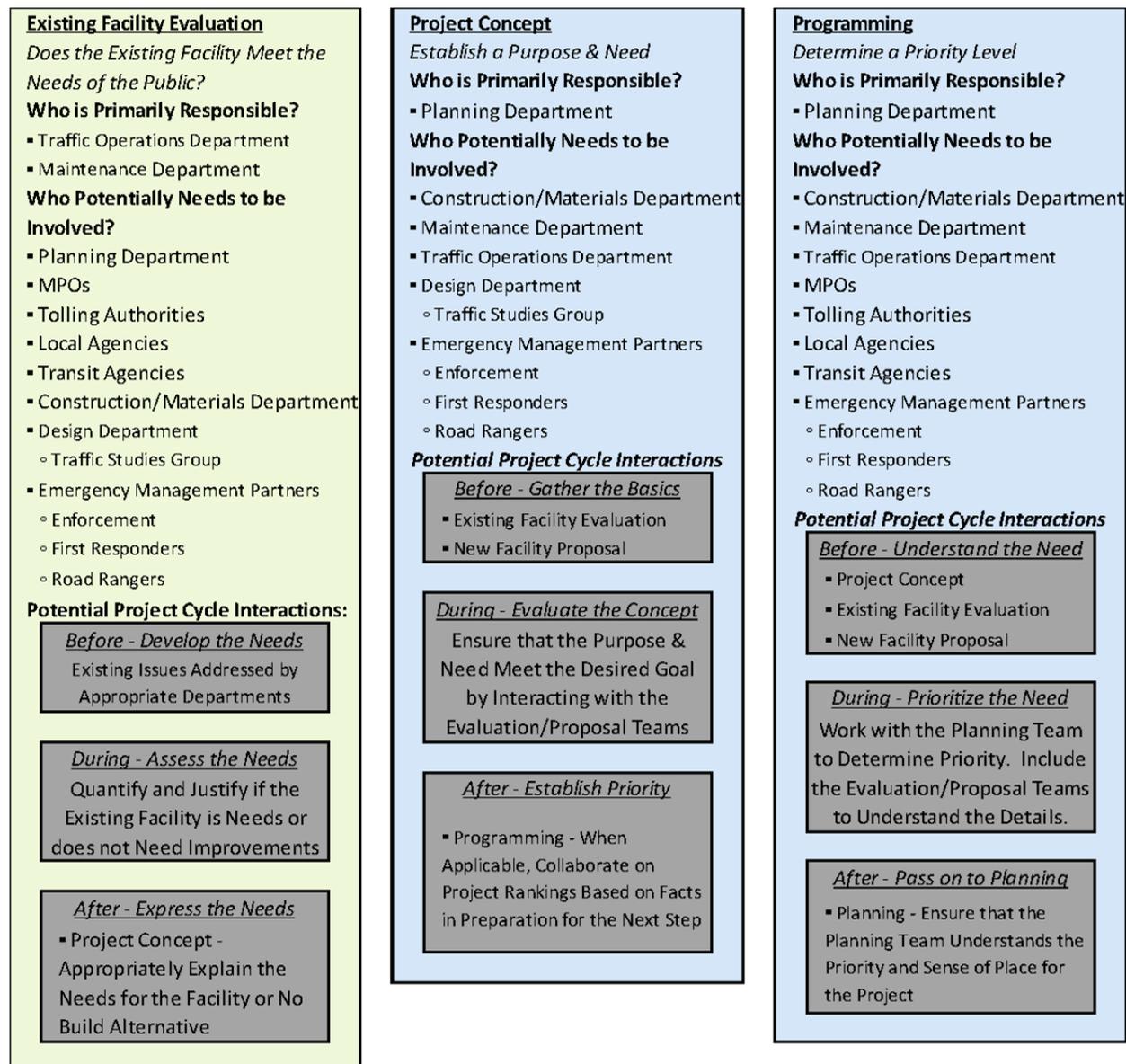


Figure 16 TSM&O Project Lifecycle – Existing Facility Evaluation through Programming



#### **4.4 Planning**

*(Concept of Operations & Systems Engineering Management Plan)*

The Planning Department continues with its last phase of primary responsibility with the Planning phase. At this point the team is to use the established Purpose and Need statement to analyze and specify the alternative of choice with the input of the Operations and Maintenance teams and stakeholders. If the Design team is not already actively involved in the project, they should be brought in to collaborate. A collaboration effort of the group is important to pass on the appropriate information to the next group of employees that are responsible for pushing the project forward. Planning should also involve the Construction group (if necessary) to consult on best practices for the project at hand. The Environmental Management Office should be involved in gathering the applicable performance measures that are expected to be used for any required Project Development & Environmental (PD&E) studies. They can establish and track standards for the agency based on the state's standards. The office should also be involved in ensuring that TSM&O projects integrate their environmental standards adequately.

The planning team should identify if the project is small and simple enough to be forwarded directly to design (Brennan, 2015), typically projects that are standard and simple to implement. In addition to direct to design projects, some projects may be able to be handled directly by the Operations and Maintenance teams but had to formally go through the project cycle. These efficiencies can shorten the project cycle and save money for the agency. Lastly, if applicable, the Planning Department should be prepared to share a completed range of Concept of Operations Reports (Brennan, 2015) for the Design Department and ensure that they fully understand and execute the agreements presented by having their Project Manager involved with the staff producing documents for PD&E studies. Additional interfacing can be found on Figure 17.

The TSM&O Project Cycle at this point has come to a very important juncture in the process. From this point projects can take the direction of continuing into the Physical Construction Phase of Preliminary Design, Final Plans, Final Design & Specifications and Construction or go directly to an Operations and Maintenance deployment. In many cases, TSM&O Projects lend themselves to minimal construction, therefore streamlining the traditional project cycle. Those projects would then transfer over to the Operations and Maintenance group. In best practice, these groups, although their phase is skipped, continue to be involved through the deployment of the project.

#### **4.5 Preliminary Design**

*(Component Level Design)*

Preliminary Design involves the finalization of the TSM&O Project's input from Operations and Maintenance to be placed in the design of the project. Even though alternatives have been established and one selected in prior phases, the design team should examine the alternatives as a check to see if any design expertise can assist in a more effective design for the project. The



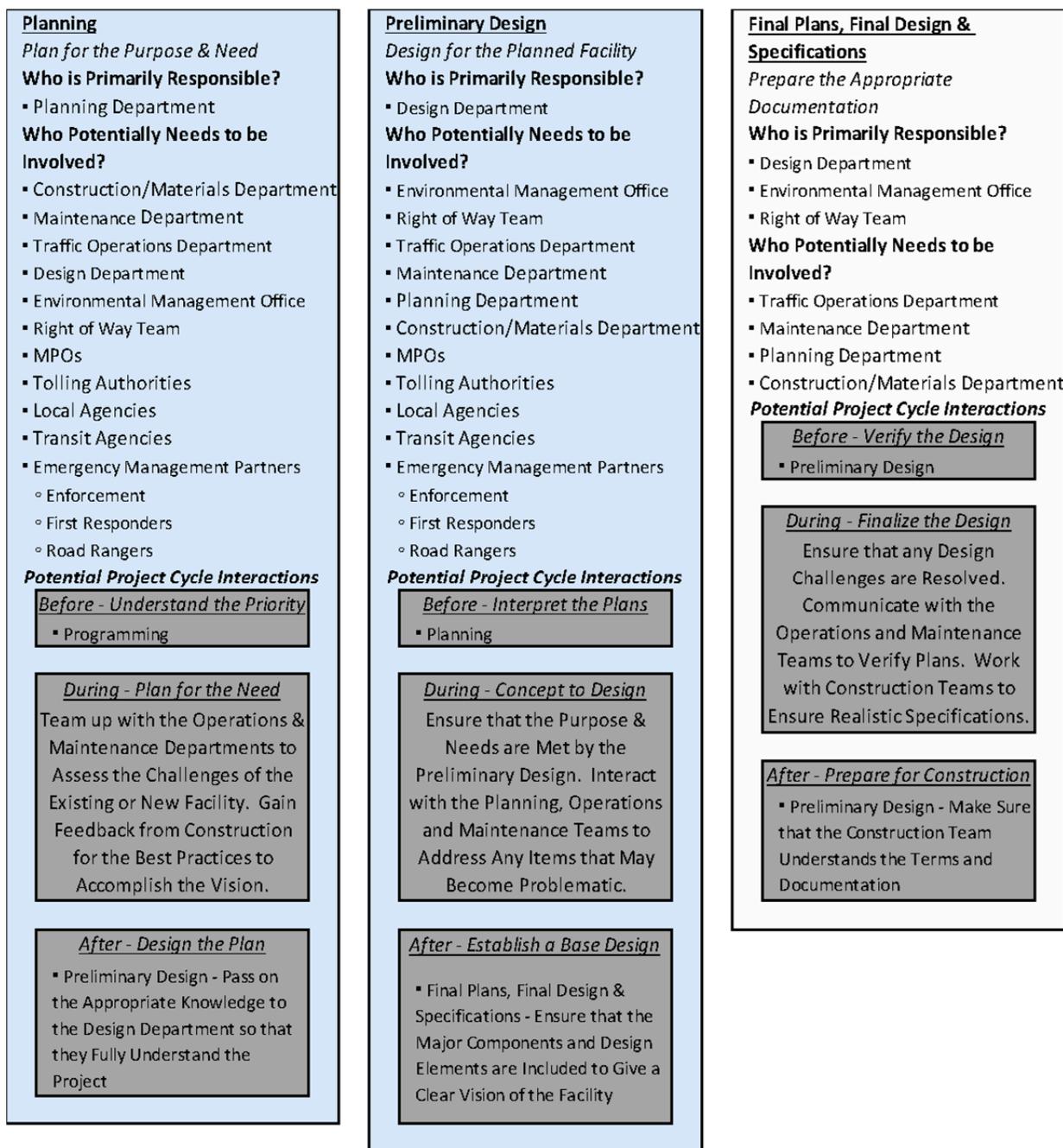
designer should be thinking of the operation and not necessarily confine themselves to the best design. Survey and Mapping teams should support the effort of the project by collaborating with the design teams to, as much as possible, limit their design to areas already owned by the department. If the purchase of right-of-way is involved in the project, their feedback, in addition to the Survey and Mapping team, is important to minimize or possibly eliminate the need for additional right-of-way. With the implementation of additional TSM&O strategies, such as reducing lane widths or eliminating a two-way left-turn lane the costs can be dramatically reduced.

The Planning Department should continue their involvement into the early design stages to ensure that the TSM&O benchmarks are not being lost in translation and that the design supports the Purpose and Need of the project. The Construction team should also be involved to discuss constructability and assess the plans for construction efficiencies. The Design team should be regularly sharing feedback between the groups to ensure that they are continually improving the communication of changes in standards or procedures that can affect the pass off from Planning to Design. They should ensure that the TSM&O goals are attainable through quality design. The Drainage group should work with the Design, Operations and Maintenance teams to ensure drainage facilities are maintainable without blocking traffic and that there is adequate channelization to provide a surface that supports the project goal. The Preliminary Design should continue to be shared among many groups as indicated in Figure 17 on Page 80.

#### **4.6 Final Plans, Final Design & Specifications**

*(Software/Hardware Development)*

The linkage to the Construction phase of the TSM&O Project Cycle is the Finalization of the Plans, Design & Specifications. At this point, public involvement is expected to be reduced to a minimal level, conceptually for the project, as the agency's team move into high gear. Verification and validation of all design related changes and their impact to the overall Purpose and Need and any assumptions that were made should be final at this point. Applicable teams can conduct their pre-construction activities. Construction team members should have a heavy involvement in the review of all of the information presented in this phase as they are responsible for delivering the finished product including reviewing the specifications and contract documents. The Materials Department should consider any items that can have an influence on the performance measures that are to be obtained and should share the appropriate feedback prior to construction. All parties involved should ensure that all information is realistic and able to be met by their respective teams, see Figure 17.



**Figure 17 TSM&O Project Lifecycle – Planning through Final Design and Specifications**

#### 4.7 Construction

*(Field Installation & Unit/Device Testing)*

The Construction process plays a role in the active execution of TSM&O principles. The Maintenance of Traffic throughout a construction project is one of the ways that the team can contribute to achieving TSM&O goals. Construction is a part of every transportation network and should not be left out of the culture and procedures related to implementing TSM&O.



Leaders should be mindful of lane closures, traffic shifts and detours as they all can have an impact on performance measures being used for the overall project. There should be established performance measures that are specific to construction projects that take the operation of the facility into account throughout the project. In many cases, projects are becoming more complex as the transportation network increases in size, scope and integration with multi modal facilities.

Additionally, the Construction Department should be holding regular meetings with the Operations and Maintenance groups to ensure that their original intentions for the project are being reasonably executed. They should also be interfacing regarding the operations throughout the construction project, maintainability of construction materials used and understand what the intended uses of the system are after the project is completed. They should also be developing a list of items to be addressed by the Construction team so that cascading issues can be avoided. The project team should be holding “meetings Construction, Design and Right of Way to discuss issues, commitments and answer questions” (Brennan, 2015). Environmental concerns should continue to be addressed through the Environmental Management Office throughout the life of the project and the Construction team should know and follow all agreed upon standards and procedures. Construction should also be sharing vital information about the execution of the final design plan for the project so that a continuous improvement program can be followed. They should also be involved in sharing improvements regarding the design criteria and specifications for projects as a “Lessons Learned” exercise. This phase should take the entire project to an operational ready facility; more details are shown in Figure 18.

#### **4.8 Operations and Maintenance**

*(System Deployment, Verification & Validation/Changes & Upgrades)*

The Operations and Maintenance phase of a project is an indefinite phase of any TSM&O project. As indicated on the flow chart in Figures 19 and 20, it is critical that Operations and Maintenance work very close together for the life cycle of the project. The success of the project there should be continuous interaction between the two groups about what system elements are performing to the best of their ability. The operational plan may have maintenance implications on the facility and these items must be addressed on a regular basis. A TSM&O Project in this phase is typically always improving and an ever-evolving through the review of system performance measures. At this level small scale changes that do not require a project cycle can be implemented and deployed.

The ITS group is especially responsible for ensuring that all communication equipment is operating correctly and generating realistic, useable results to compare to performance measures standards. They should be heavily involved in ensuring that the correct tools are deployed to accomplish the goals set forth by any project. The Operation and Maintenance teams should have an in-depth understanding of the project from their involvement with the previous groups. They should continue to execute agreements and ensure that all previously required agreements are being followed. The Maintenance Department in particular should be focused on delivering



on TSM&O standards by adhering to them throughout all maintenance activities and consult with Operations teams about best practices and policy improvements to make both teams more efficient in their function. The teams should also both be involved in the assessment of facilities on a regular basis. As the teams closest to the daily operation of the project, these teams are best suited to provide recommendations for improvement and assess the need for new projects. A continuous improvement program should be kept and logged as lessons are learned and projects are executed. Regular re-evaluation of performance measures and standards are key in contributing to the success of a TSM&O Project and an integrated transportation network.

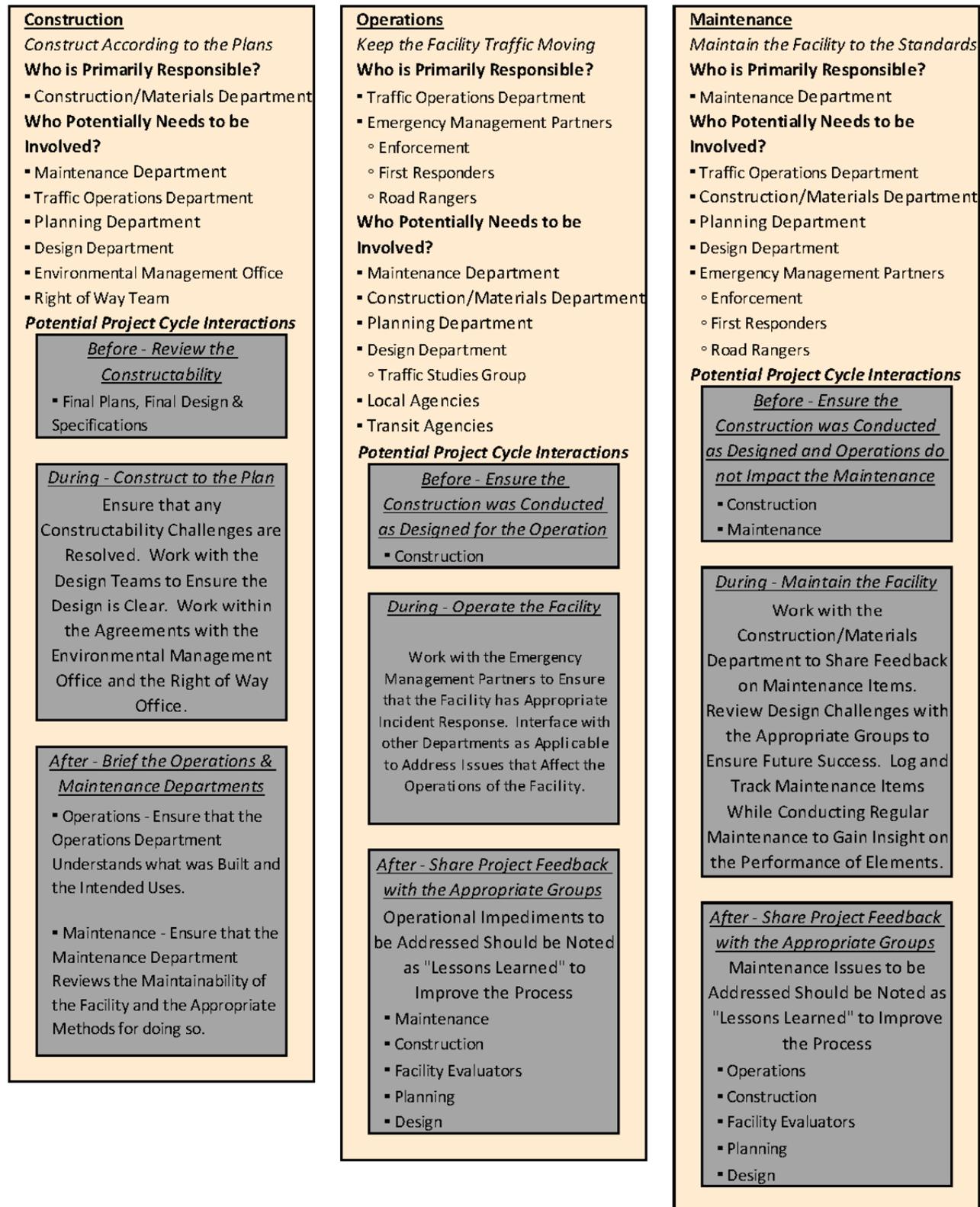


Figure 18 TSM&O Project Lifecycle – Construction through Maintenance



#### **4.9 Applying TSM&O into the Project Processes**

Each TSM&O focused project can produce varying degrees of success depending on multiple factors. That's why; it is difficult to gauge what truly brings forth the successes and/or issues that result in each one. It is possible, however, to find some matching characteristics that can be seen in most projects that implement TSM&O strategies, playing a strong part in a successful project outcome. The following are items to consider for any project to help merge the uses of TSM&O into all processes:

##### *Prepare to Plan*

Early on in the planning stages, it is good to collect the resources needed for a successful planning period. It is important to evaluate alternative technologies and gauge their performance in their given scenarios while applying those findings to the given project at hand. It is also good to start coordinating with approval agencies, gauge environmental impacts, and look into any other impacts or time consuming matters that should be tackled early. Look into involving other agencies if applicable. Involvement of multiple agencies can provide many benefits and bring forth more project ideas as well as new approaches to meet the ultimate goal. These types of larger projects involving multiple agencies can give greater flexibility in use of federal funds with multiple fund sources. When involving project partners, it is wise to balance project goals versus the constraints and abilities of these partners to assist in making the proper decision for the particular project in mind. To take this approach, look into common issues, strategies, and trade-offs that could get multiple agencies motivated to join. Taking the consensus organization model has helped in forming agreements and assuring support/participation in a project. Regardless of the method used, it is imperative to work together and stay proactive through the project.

Knowing systems engineering is a major player with TSM&O, some DOTs recommend conducting systems engineering process improvement reviews. Doing so can help find, prioritize, and improve systems engineering procedures in areas that may be lacking. It is also a good point to start looking into cross-training the planning department personnel so that they can understand and familiarize themselves with any issues and technical tools in relation to operations planning.

##### *Design/Operations Professional Involvement*

One item that has been commonly found to be useful in recent research efforts shows that including design and operations personnel in the planning phases can make a large difference in producing well thought project outcomes. Linking operations with transportation planning can result in a common understanding of the mobility, safety, and efficiency benefits. This coordination can ensure that investment decisions reflect full consideration of all known strategies and approaches to reach a common goal, including regional goals. No matter the size of the project, experience of operations in planning can help take major items into account that



may get overlooked and could cost money in the long run such as the operations usage, maintenance, as well as keep future technological compatibility in mind. Including design professionals in planning not only helps in gaining an equal understanding and vision of the final product, but can also provide more efficient design options as well as more sensible long term design decisions that can save money and/or provide possibly better results. Overall it is good to involve these personnel in at least project selection and prioritization processes. This may also be a good time to form a Concept of Operations (ConOps) to help possible project partners stay focused on what is truly needed in the final project outcome.

### *Plan for the Future*

One of the largest problems that can be experienced post project are the long term expenses, and this is applicable for the implementation of TSM&O projects too if not planned or designed for in a proper manner. Even in successful scenarios, some TSM&O case studies expressed an extreme need to look into the possible long term expenses that could be involved. One example would be communications infrastructure costs when using certain TSM&O or ITS methods that cover a large area (see TranStar case study). Another example would be compatibility with the adjacent infrastructure that could be involved.

This stage doesn't just include the initial planning stages, but applies throughout the project. All possible problems that could come up or have come up in previous cases need to be taken into account, and preemptive actions should be made. Proper sequencing should be made through the project and delays should be anticipated with the needed time and funds prepared in advance. Awareness with possible problems like deployment delays (which can produce ripple effects of further challenges to deployment) can help tremendously in a project. Risks should be anticipated, understood, and managed accordingly. ITS can provide great benefits, but can be risky or troublesome without the needed planning as well. Items such as ITS contracting can be complex and subject to changes in technology and the market over time. ITS standards are no exception and are also bound to possible future changes.

### *Appoint a Strong Project Manager*

Leadership is a crucial part of any project and can make a major difference on the overall success and efficiency of the work performed. Though the required skill traits can vary from project to project there are some items to keep an eye out for during project management selection. The experience of some projects including Tri-Met expressed success stories through having a leader with training abilities, holding data analyzing skills, and having a background history as an operator. There are many qualities to look for, but overall the main key factor of this is to be able to recognize champions, the leaders that have the drive to make the project a success.



### *Effectively Communicate and Work as a Team*

It is crucial to establish some form of effective means of communication between those involved in the project. It is good to plan for staffing and communications needs early on as well as determine the training needed for a project. To provide a better understanding of the project goal and TSM&O for others, transferring technical knowledge on the design and implementation of TSM&O to those in the design and construction departments can be of great benefit. This can be done through training/seminars or even assigning operations personnel to these departments.

### *Conduct Outreach*

Projects that apply TSM&O strategies can tend to be unique to others and draw attention, especially larger projects; therefore it is good to maintain outreach with the locals of the area. Keeping the public and city officials informed regularly can keep people more at ease and even open some possible support opportunities for the project. Another item to build support can be through recognizing opportunities and challenges posed by political timetables



#### 4.10 TSM&O Project Lifecycle Diagrams

As identified by the FDOT, several components of the project cycle had little or no involvement with TSM&O. Below, Table 7 presents a summary of the recommendations for additional TSM&O involvement in areas that the department identified as in need.

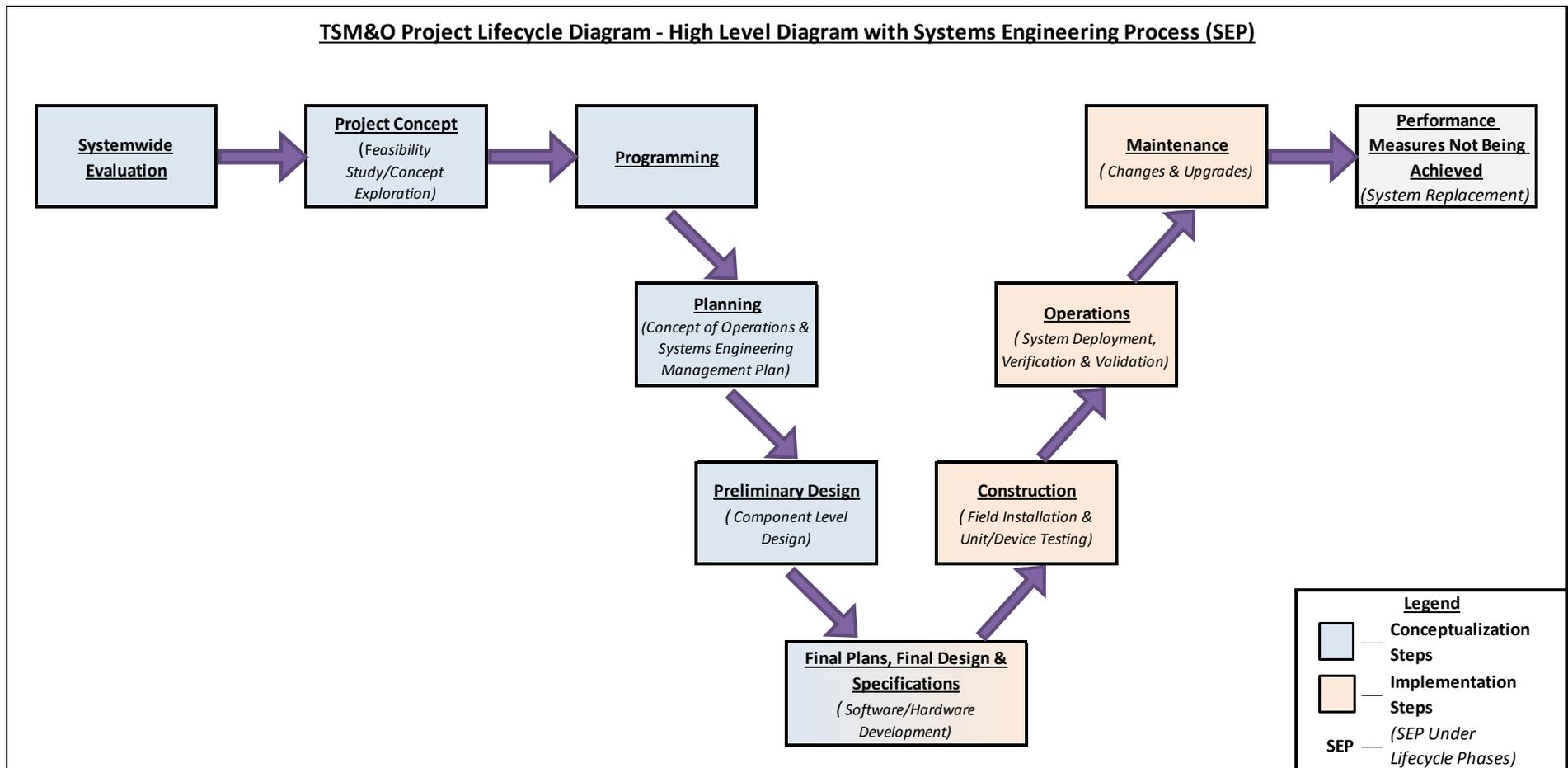
**Table 7 TSM&O Integration for Identified FDOT Departments**

<u>Unit</u>	<u>Current Program</u>
Work Program	Consider other programmed projects and establish a prioritization system for integrating TSM&O projects due to ensure a timely solution.
Design	Ensure that TSM&O goals are attainable through Design and provide alternative ideas as necessary.
Drainage	Facilities should be designed to take TSM&O into account by designing efficiencies for Operations and Maintenance.
Right-of-Way	By collaborating with Surveying & Mapping and Design, evaluate and suggest viable TSM&O strategies to reduce Right-of-Way costs.
Surveying & Mapping	By collaborating with Right-of-Way and Design, evaluate and suggest viable TSM&O strategies to reduce Right-of-Way costs.
Environmental Management Office (EMO)	Establish, track and evaluate performance measures based on environmental factors. Integrate TSM&O as an asset to mitigate environmental issues.
Traffic Operations – ITS	Involve in TSM&O performance measurement data collection to ensure that the performance evaluators are getting applicable data. In addition, ensure that the data gathering equipment is adequate for the desired outcomes.
Construction	TSM&O should be included in MOT techniques and should also be carried out through the involvement of Operations. Establish and maintain TSM&O performance measures for construction projects.
Maintenance	Ensure TSM&O is considered while performing maintenance activities. They should be involved with observing the system in the field to interface with Operations.

Figure 19 provides a high level approach to the TSM&O Project Lifecycle Diagram. This diagram includes the concepts presented in the Systems Engineering Process. These components are integrated as part of the structure of a traditional project.



The TSM&O Project Lifecycle Diagram in Figures 20 and 21, provide a detailed structure of the TSM&O Project Cycle and the potential interactions that are present between phases of a project. It gives a visual representation of the ideas presented in leading sections of the report.



**Figure 19 TSM&O Project Lifecycle – High Level System Engineering Process (SEP)**

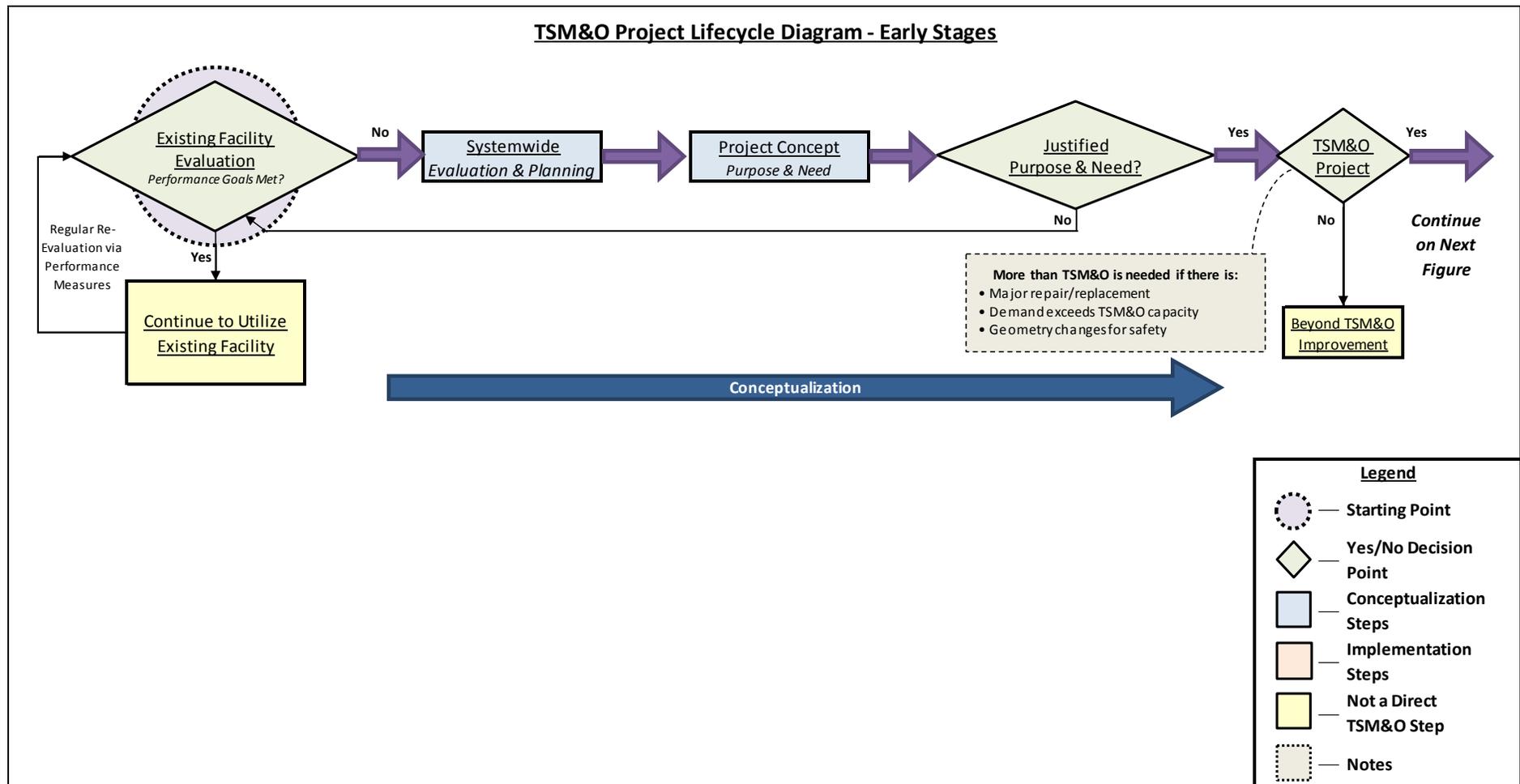


Figure 20 TSM&O Project Lifecycle Diagram – Early Stages

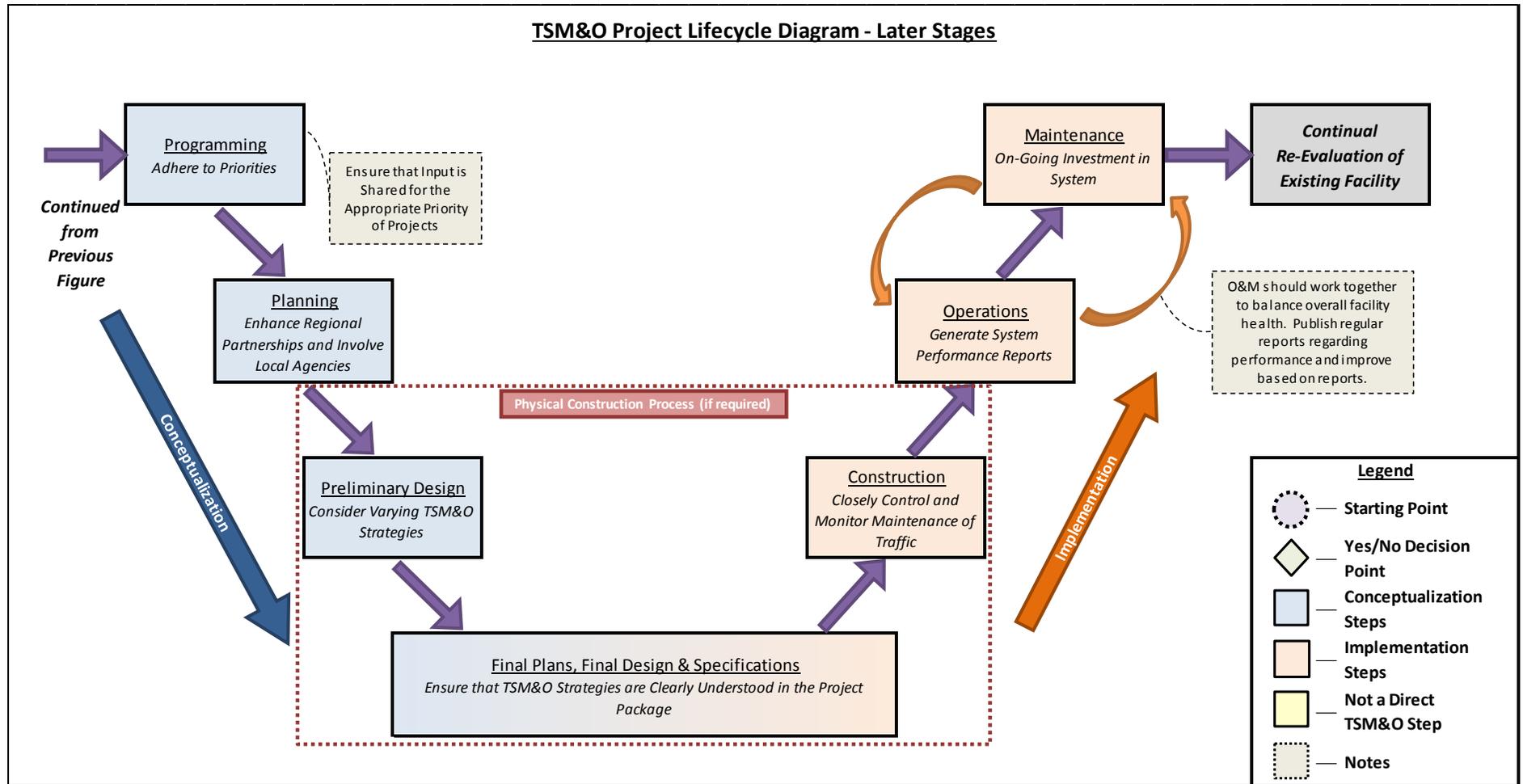


Figure 21 TSM&O Project Lifecycle Diagram – Later Stages



## **5. STATE OF FLORIDA FINANCIAL ASSISTANCE PROGRAMS**

Generally for government to finance the construction of any project, overall appropriation is undertaken. Appropriations can take place in the form of taxation or special bonds issued for the project. If the project dictates long-term funding, the funds may be obtained from general tax revenues from the local, state or federal government. Depending on the project type and impact it may consider a combination of the three. TSM&O projects can be funded in variety of differing ways that take advantage of all of the revenue bases.

### **5.1 Highway Safety Improvement Program (HSIP)**

The Highway Safety Improvement Program (HSIP) is a federally funded, state administered, program. The objective of the HSIP is to significantly reduce traffic fatalities and serious injuries on all public roads, including non-State-owned public roads and roads in tribal lands. This objective is achieved through the implementation of highway safety improvement projects throughout the roadway network. The program is based on a data-driven, strategic approach to improving highway safety that focuses on performance. The Federal Highway Administration (FHWA) establishes the program requirements under the Code of Federal Regulations (CFR). Located in 23 CFR 924, the states develop and administer a program that fits the needs of their individual state. To be eligible for HSIP funds, the following requirements are necessary:

- Develop, implement and update a State Strategic Highway Safety Plan
- Produce a program of projects or strategies in order to reduce the identified safety concerns
- Evaluate the Strategic Highway Safety Program (SHSP) on a recurring basis
- Develop and submit a report that describes the progress being made to implement highway safety improvement projects and the effectiveness of those improvements

The Moving Ahead for Progress in the 21st Century (MAP-21) Reporting Guidance provides information to document HSIP progress by including the procedures for reporting content, requirements for the structure of the report, reporting frequency and schedule. The document also includes provisions related to the protection of data from discovery and admission into evidence. In addition to the guidance document, the HSIP has a reporting tool for each state to utilize. The information gathered from the states supports the annual HSIP reporting process nationally.

Under MAP-21 the HSIP Reporting Guidance requires that the project information to be included for reporting is:

- Improvement Category
- Project Output
- Project Cost



- Relationship to the State's Strategic Highway Safety Plan (SHSP)
- Funding Category
- Functional Classification
- AADT
- Posted Speed Limit
- Roadway Ownership

The FHWA compiles the information from each state's report and produces the National Summary Report. The report provides aggregate information detailing the progress of implementing HSIP projects across the country. The aggregate information described is based on the amount of HSIP funds available and the number of projects in the general listing during the reporting period. This data is an observation of the cost of different types of projects listed and it is compared on an annual basis to note the changes over time. In 2013, thirty-eight (38) states participated using the reporting tool provided to satisfy the requirements. FHWA's effort to streamline toward a country-wide use of the improvement system has resulted in the increase to forty-three (43) states using the online reporting tool to satisfy reporting requirements and be eligible for funds under the HSIP (Federal Highway Administration, 2014B).

23 CFR 924 has been active since 2006, allocating funding for HSIP related projects. The reporting guidance tools were enacted 2009 to provide a standard reporting process and make the process of funds distribution based on performance. The HSIP is an essential part of the TSM&O program's success. Projects under HSIP can help reduce crashes, which is a TSM&O benchmark. The reduction of crashes also lowers the number of incident response calls, a key performance measure of TSM&O. Implementing a safety component to a TSM&O project can bring it to eligibility under the HSIP.

More than 9,000 projects from 2009 through 2012 were implemented in the HSIP with a total cost of \$6.5 billion. These obligations include not only the HSIP funds apportioned during the reporting period but also HSIP funds available from previous years' apportionments. It must also be noted that all states did not provide reports. A distribution of these projects is shown in Figure 22 from (Federal Highway Administration, 2013B).

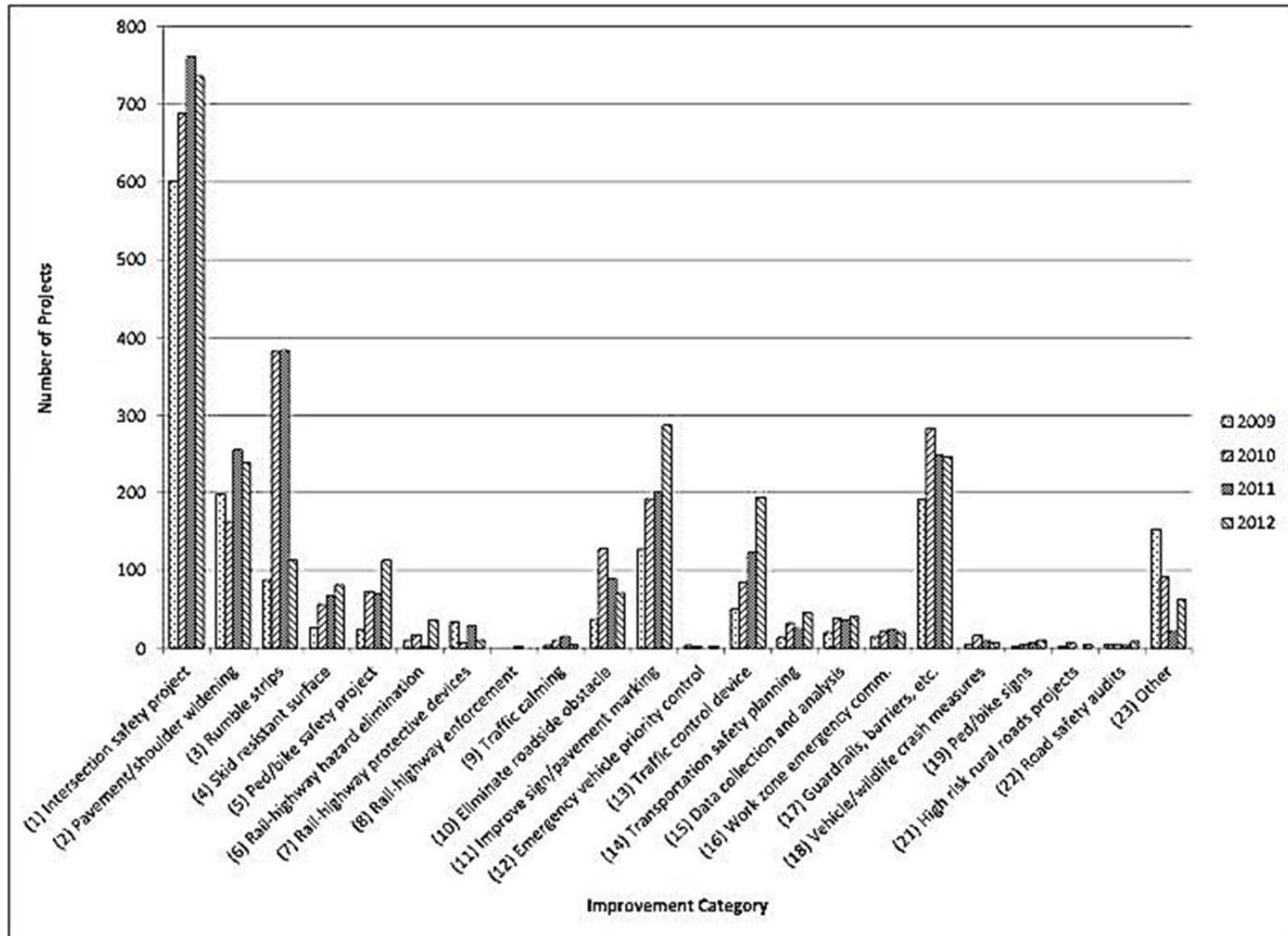


Figure 22 Number of Projects per Improvement Category



Figure 22, shows that most of the projects are concentrated toward (1) Intersection Safety Projects, (2) Pavement/Shoulder Widening, (3) Installation of Rumble Strips, (11) Improvement of Signs and Pavement Markings, and (17) Installation of Guardrails and Barriers. All of these categories can be applied as TSM&O projects under varying benchmarks as outlined by the TSM&O Project Cycle.

The introduction of MAP-21 (implemented for the 2013 project cycle) had a significant funding effect on the HSIP, as shown in Table 8 from (Federal Highway Administration, 2013B) and (Federal Highway Administration, 2014A).

**Table 8 HSIP Total Number and Costs of Projects by Year**

Year	2009	2010	2011	2012	2013	Total
Number of Projects	1,684	2,386	2,523	2,429	3,292	12,314
Number of projects with cost information	1,609	2,348	2,449	2,374	3,254	12,034
Cost of Projects	\$1.61B	\$1.46B	\$1.77B	\$1.65B	\$3.09B	\$9.59B
Avg. Cost per Project	\$1.00M	\$620,684	\$725,550	\$695,721	\$950,834	\$797,206

It is worth noting that the implementation of MAP-21 nearly doubled the funding for the HSIP. In 2013 it managed a greater number of projects and the average cost for them also increased. This may be due to the increased number of HSIP projects requiring heavy construction where geometric features of the roadway are changed and the technology infrastructure to bring ITS and TSM&O projects on line using new traffic control devices and the standard use of dynamic message signs. The opportunity to use the HSIP for funding of projects is great at this time and should be seized. Although there is much to be reported and track, the additional requirements of the federal government are not significantly greater than the current performance reporting structure of the FDOT.

## 5.2 Federal and Statewide Operations Funds

“The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users” (SAFETEA-LU) was the funding and authorization bill that governed federal surface transportation spending until expiring on September 30, 2009 (Federal Highway Administration, Office of Legislation and Strategic Planning, 2007). After its expiration it was renewed ten more times until it was replaced by the "Moving Ahead for Progress in the 21st Century Act" (MAP-21) on July 6, 2012. SAFETEA-LU was a \$286.4 billion measure to improve and maintain the surface transportation in the United States which MAP-21 would build onto. The funding was directed to the Interstate Highway System, transit systems, bicycle facilities, pedestrian

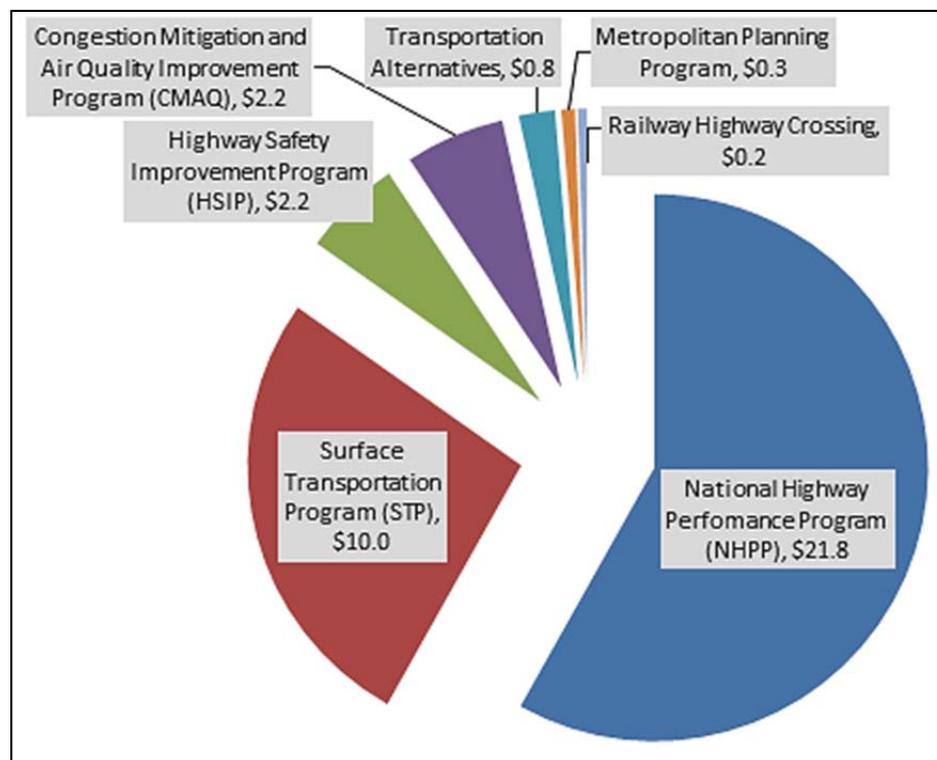


accommodations and freight rail operations. This bill pushed the emphasis of modal choice by including funding for projects outside of the scope of traditional capacity projects. TSM&O projects, although not always termed as such, began to be introduced with an emphasis on all modes.

Once the MAP-21 standard was in place, the formula for apportionments changed significantly. MAP-21 provides a total apportionment for each State and then divides that apportionment amount among five individual apportioned programs:

- National Highway Performance Program (NHPP)
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- Congestion Mitigation and Air Quality Improvement Program (CMAQ)
- Metropolitan Planning Program

Further highlighting the changes that occurred with the introduction to MAP-21, the State apportionment for HSIP projects nearly doubled its apportioned amount under the SAFETEA-LU. Fixed amounts of \$220 million are given to the Railway-Highway Crossing program and a proportionate share of funds for the State's Transportation Alternatives (TA) program. An example of MAP-21's \$37.7 billion annual program funding distribution is shown in Figure 23 from (Federal Highway Administration, 2014A).



**Figure 23 Distribution of Funds across Programs under MAP-21 in Billions**



### **5.2.1 National Highway Performance Program (NHPP)**

The National Highway Performance Program (NHPP) provides support for the condition and performance of the National Highway System (NHS). The NHS is composed of approximately 220,000 miles of rural and urban roads serving major population centers, international border crossings, intermodal transportation facilities and major travel destinations. The program also directs funds to be used for the construction of new facilities on the NHS and to ensure that investments of federal-aid funds are directed to support progress toward the achievement of performance targets established by the state's asset management plan for the NHS.

The NHPP is the highest funded program under MAP-21 and it has received an average of around \$21.8 billion annually (Federal Highway Administration, Office of Policy and Governmental Affairs, 2012). There are two set-asides as part of the program that correspond to the State's Transportation Alternatives (TA) program and State Planning and Research (SPR) program. The opportunity for TSM&O projects under this program are linked to projects on the NHS, which many state roads are. Although relatively unrelated to traditional TSM&O techniques, the program provides the opportunity to streamline procedures of assessing performance measures.

In order to maintain sufficient funding, states are required to develop a risk and performance asset management plan for the NHS. Integrating TSM&O into this plan is critical component of ensuring that this is a viable opportunity for funding. The purpose of the asset management plan is to improve or preserve asset condition and system performance. The plan must be revised every 4 years and failure to update the plan results in a reduction of funds for the state. The secretary is responsible for establishing appropriate performance measures for Interstate and NHS pavements, NHS bridge conditions and Interstate and NHS system performance. MAP-21 also requires a minimum standard of allocated resources to be used to improve conditions for Interstate pavements and NHS bridges. If more than 10% of the total deck area of NHS bridges in a state is structurally deficient, the State must devote a portion of the NHPP funds to improve the condition of these bridges (Federal Highway Administration, Office of Policy and Governmental Affairs, 2012).

### **5.2.2 Surface Transportation Program (STP)**

The Surface Transportation Program (STP) provides funding to be used by states for projects to preserve and improve conditions and performance on any federal-aid highway bridge or tunnel, on any public road, pedestrian and bicycle infrastructure and transit capital projects. The application of modal choice in TSM&O can offer the opportunity for the state to integrate this program with efforts being conducted with TSM&O.

The program under MAP-21 requires three set-asides:

- A proportionate share of funds to the State's Transportation Alternatives (TA) program
- 2% for State Planning and Research (SPR)



- No less than 15% of the state's funding for 2009 Fiscal Year Highway Bridge Program apportionment

After those amounts are set aside, a 50% sub-allocation is distributed among urbanized areas in three different categories, urbanized areas with a population greater than 200,000, transitioning areas with a population between 200,000 and 5,000 and small urban areas with a population less than 5,000. All of the funds are allocated based on the proportion of their population to determine their share of the funds (Federal Highway Administration, Office of Policy and Governmental Affairs, 2012).

### **5.2.3 Congestion Mitigation and Air Quality Improvement Program (CMAQ)**

This program provides funding for projects and programs in air quality which reduce transportation related emissions. Congestion mitigation is one of the benchmarks of TSM&O and “Quality of Life” is a goal that can be achieved with this program. The CMAQ provides a flexible funding source for state transportation projects to meet the requirements of the Clean Air Act. The funding is available to reduce congestion and improve the quality of air in areas that do not meet the National Ambient Air Quality Standards of ozone, carbon monoxide or particulate matter (nonattainment areas) and for former nonattainment areas that are now in compliance (maintenance areas). This is especially important for Florida as the state continues to experience high growth rates, resulting in a significant increase in traffic, congestion and emissions.

MAP-21 stipulates that a state which has an area with a PM 2.5 (fine particulate matter) must use a portion of its funds to address emissions in the area of concern. Highlighted CMAQ eligibilities include transit operating assistance and facilities serving electric or natural gas-fueled vehicles (except where this conflicts with prohibition on rest area commercialization). Similar to other programs MAP-21 has two set-asides in the funding:

- A proportional share of funds or the State's Transportation Alternatives (TA) program
- A 2% for State Planning and Research (SPR)

CMAQ requirements are based on performance-based measures establishing the ability to assess traffic congestion and mobile source emissions. Also, as a funding requirement, each Metropolitan Planning Organization (MPO) with a population of one million or more are required to develop and update a performance plan to reach air quality and congestion reduction targets (Federal Highway Administration, Office of Policy and Governmental Affairs, 2012).

### **5.2.4 Metropolitan Planning Program**

This program institutes a cooperative, continuous and comprehensive framework for making transportation investment decisions in metropolitan areas. Establishing a maintaining Metropolitan Planning Organizations (MPOs) is an important piece of the transportation policy process. It makes the process more localized and accessible than traditional state agencies. It also is driven by local leaders, businesses and industry. Ensuring that TSM&O programs are



implemented starts at the local level, such as an MPO. When MPOs are onboard with TSM&O techniques and strategies, they can be fully integrated from the planning stages. They are also more likely to be considered and tested with the support of the local MPO. While not a direct funding source, this program can influence the course of long range planning and the transportation culture of a region.

The oversight of this program is a joint effort between the FHWA and the Federal Transit Administration (FTA). MAP-21 established a more direct source of funding that is administered under the Highway Account of the Highway Trust Fund and the funds are subject to the overall Federal-aid obligation limitation. It authorizes a lump sum total instead of individual authorizations for each program. In 2013 it funded an amount of \$311 million and in 2014, \$314 million (Federal Highway Administration, 2013A).

The minimum population required for an MPO is 50,000 and those that exceed a population of 200,000 are termed as Transportation Management Areas (TMAs). Other provisions for funding are to update their long range transportation plan every 4 years. The plan must cover a minimum 20-year planning horizon with air quality conformity and fiscal constraint, public involvement, and a congestion management system certified by the Secretary.



## 6. CONCLUSION

### 6.1 Summary of Project Activities

The development of this Primer document has presented a series of concepts that have to do with the implementation of a Transportation Systems Management & Operations (TSM&O) program that suits the needs presented by the Florida Department of Transportation (FDOT). The document stresses the importance of integrating the practice of TSM&O throughout all facets of the organization with the purpose of maximizing the existing infrastructure. Based on a variety of TSM&O theory and best practices, a method of developing a TSM&O program was presented based on goals, performance measures and the full integration of the program into departments and the project cycle.

The work of similar initiatives and programs were examined nationwide to identify the best practices, lessons learned and improvements that were made in a cooperative effort to focus on these strategies. Other FDOT Districts were also included in the study to ensure that the presented material includes considerations that may need to be included to generate a statewide TSM&O program. The document also explores differing funding programs that can benefit TSM&O implementation throughout the state.

Oregon Metro's structure and plan for their TSM&O initiative was a comprehensive document with a series of goals and benchmarks that are regarded as a best practice for TSM&O implementation at this stage. The strategies presented in this Primer suggest that the FDOT establishes goals with functional applications to accomplish these goals.

Supporting the functional applications is a series of performance measures that can be used to assess progress of projects or programs. As a compilation of many agencies and theories, the performance measures list can be further expanded to suit the needs of the FDOT. Guidance is provided on the background and establishment of effective performance measures and what they should represent. These measures should be directly linked to benchmarks that adequately address the purpose of the program or deployment.

The document also provided an exposition of the integration of TSM&O into the project cycle and departments within the agency. Not only the integration of the strategies but the interaction of the staff between the departments as a key to ensuring that the program achieves the highest level of optimization.

The overall goal of the work presented is to provide an exposition of the best practices and a suggested strategy for the FDOT to follow and understand to move forward in implementing their own TSM&O program. By understanding the practices and accomplishments of other organizations, the FDOT can move forward with assessing the needs of their own program. The goal is for TSM&O to be a practice that is a standard within the agency in its everyday operation.



## 6.2 Feedback & Next Steps

With the resulting Primer document, it is suggested that the FDOT distributes the document internally to all applicable parties that could potentially be involved in the promotion of TSM&O activities. Feedback generated from these departments can better serve the FDOT in determining a course of action in the implementation of a TSM&O program. Below is a list of the suggested Departments that this document should be shared with based on the guidance that the FDOT had previously provided:

- ISD/Planning
- Modal Planning
- Work Program
- Design
- Drainage
- Right-of-Way
- Surveying & Mapping
- Emergency Management
- Environmental Management Office (EMO)
- Traffic Operations
- Traffic Operations – ITS
- Traffic Operations – Safety
- Construction
- Maintenance

Input from all departments of the agency are important to consider as the FDOT moves toward a standard practice for TSM&O activities that would be adopted by the entire organization. These employees will be the ones at the forefront of any approved program and their “buy in” is essential to ensure that it is upheld and is put into practice.

Moving forward these employees can provide the FDOT with critical guidance that can be a valuable asset to tailor the program to the challenges present at every level of the organization. With this information, informed final recommendations can be made that will serve the FDOT in developing an acceptable TSM&O program.



## 7. REFERENCES

- AASHTO. (2014A). *Performance Measurement Guidance (Level 1 to Level 2)*. Washington, D.C. Retrieved 2015, from [http://www.aashtotsmoguidance.org/guides/PM\\_L2.pdf](http://www.aashtotsmoguidance.org/guides/PM_L2.pdf)
- AASHTO. (2014B). *Performance Measurement Guidance (Level 3 to Level 4)*. Washington, D.C. Retrieved 2015, from [http://www.aashtotsmoguidance.org/guides/PM\\_L4.pdf](http://www.aashtotsmoguidance.org/guides/PM_L4.pdf)
- Atkinson, J., Bauer, J., Hunt, K., Mullins, K., Myers, M., Rensel, E., Taylor, R. (2013). *Designing for Transportation Management and Operations* (pp. 52). Washington, DC: Science Applications International Corporation.
- Baird, M. E., & Noyes, P. (2014). *Program Planning and Development for Transportation System Management and Operations (TSM&O) in State Departments of Transportation*. Transportation Research Board. Pat Noyes & Associates. Retrieved 2015, from [http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07\(345\)\\_FR.pdf](http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-07(345)_FR.pdf)
- Baker, M. (2014). Woodrow Wilson Bridge Project in Maryland, Virginia, and the District of Columbia: Environmental Stewardship at its Best. *Water, Wetlands, and Wildlife*. Retrieved, from <http://www.environment.fhwa.dot.gov/ecosystems/eei/dc07.asp>, accessed October 1, 2014
- Balke, K. N., & Voight, A. P. (2011). *Operational and Institutional Agreements that Facilitate Regional Traffic Signal Operations* (Vol. 420): Transportation Research Board.
- Birosak, C. (2014). ITS on I-75 in Southwest Florida Nears Completion *TIM Team Times*, 2. Retrieved from: <http://www.swfltim.org/Document%20Archives/CSM/Newsletters/S%20M%20May%202014.pdf>
- Blair, T., Pangborn-Dolde, J., Wyse, J., & Carney, J. (2014, Jun). Engineers+Planners=Success - The World is Better with Engineers and Planners Collaborating. *ITE Journal*. Retrieved 2015, from [http://teamstl.org/doc/ITE\\_Journal\\_Publication\\_6-1-14.pdf](http://teamstl.org/doc/ITE_Journal_Publication_6-1-14.pdf)
- Brennan, A. K. (2015). Bridging the Gaps between Project Phases. *2015 FDOT Design Training Expo*.
- Brownstone, D., Ghosh, A., Golob, T. F., Kazimi, C., & Van Amelsfort, D. (2003). Drivers' willingness-to-pay to reduce travel time: evidence from the San Diego I-15 congestion pricing project. *Transportation Research Part A: Policy and Practice*, 37(4), 373-387. doi: [http://dx.doi.org/10.1016/S0965-8564\(02\)00021-6](http://dx.doi.org/10.1016/S0965-8564(02)00021-6)
- Brownstone, D., & Small, K. A. (2005). Valuing time and reliability: assessing the evidence from road pricing demonstrations. *Transportation Research Part A: Policy and Practice*, 39(4), 279-293. doi: <http://dx.doi.org/10.1016/j.tra.2004.11.001>



- Chandler, C. (Producer). (2012). District Seven Transportation Systems Management and Operations Workshop. Retrieved from <http://www.dot.state.fl.us/trafficoperations/TSMO/documents-workshop/D7-TSMO-Workshop-Sept-2012.pdf>
- Chandra, R. (Producer). (2014). Operation Green Light. Retrieved from [http://www.pcb.its.dot.gov/t3/s070911/Op%20Green%20Light\\_update1.ppt](http://www.pcb.its.dot.gov/t3/s070911/Op%20Green%20Light_update1.ppt)
- Colorado Department of Transportation (CDOT) (2013). *CDOT FY14-15 Performance Plan* (PDF). Denver, CO: CDOT. Retrieved from <https://www.codot.gov/library/AnnualReports/2014-2015-performance-plan/2014-performance-plan.pdf/view>, accessed October 12, 2015.
- Cranson, J. (2011). MDOT team gets national award for making improvements to busy I-94 corridor. Retrieved from [http://michigan.gov/mdot/0,4616,7-151-9620\\_11057-264192--,00.html](http://michigan.gov/mdot/0,4616,7-151-9620_11057-264192--,00.html), accessed September 18, 2014.
- Creating an Effective Program to Advance Transportation System Management and Operations. (2013). 2014, from <http://ops.fhwa.dot.gov/publications/fhwahop12003/background.htm>
- Department of Transportation, Office of Operations (2007). *Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals*. Publication No. FHWA-HOP-07-069. Federal Highway Administration. Retrieved from: <http://ops.fhwa.dot.gov/publications/seitsguide/index.htm>
- Doyle, L. (Producer). (2013, 2014). I-94 Work Zone Performance Measures. Retrieved from <http://www.ops.fhwa.dot.gov/wz/p2p/pmwkshop053013/doyle/doyle.htm>
- Every Day Counts. (2013). Retrieved from <http://www.fhwa.dot.gov/everydaycounts/>, accessed September 6, 2014.
- Federal Highway Administration. (2004). *Getting More by Working Together - Opportunities for Linking Planning and Operations*. U.S. Department of Transportation. Washington, D.C.: US Department of Transportation. Retrieved 2015, from [http://ops.fhwa.dot.gov/publications/lpo\\_ref\\_guide/hop05016.pdf](http://ops.fhwa.dot.gov/publications/lpo_ref_guide/hop05016.pdf)
- Federal Highway Administration. (2013A). Fact Sheets in Metropolitan Planning. Retrieved from <http://www.fhwa.dot.gov/map21/factsheets/mp.cfm>
- Federal Highway Administration. (2013B). *Highway Safety Improvement Program National Summary Report: 2009-2012*. U.S. Department of Transportation, Office of safety, Washington, D.C.
- Federal Highway Administration. (2014A). *Highway Safety Improvement Program 2013 National Summary Report*. U.S Department of Transportation, Office of Safety, Washington, D.C.



- Federal Highway Administration. (2014B). Highway Safety Improvement Reports. Retrieved from <http://safety.fhwa.dot.gov/hsip/reports/>
- Federal Highway Administration. (2014C). Low-Cost Improvements Can Improve Safety At Stop Sign-Controlled Intersections. Retrieved from [http://safety.fhwa.dot.gov/intersection/resources/casestudies/fhwasa09010/stop\\_article.cfm](http://safety.fhwa.dot.gov/intersection/resources/casestudies/fhwasa09010/stop_article.cfm)
- Federal Highway Administration. (n.d.). *Flexibility in Highway Design*. Retrieved 2015, from FHWA - Office of Planning, Environment, & Realty (HEP): <http://www.fhwa.dot.gov/environment/publications/flexibility/ch01.cfm>
- Federal Highway Administration, Office of Legislation and Strategic Planning. (2007). Fact Sheets for Highway Provisions in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). Retrieved from <http://www.fhwa.dot.gov/safetealu/factsheets.htm>
- Federal Highway Administration (FHWA), Office of Operations. (2007). *Chapter 5. Case Studies of Hot Lane Conversion Projects* (Web page). Washington, D.C.: FHWA. [http://ops.fhwa.dot.gov/publications/fhwahop08034/hot5\\_0.htm](http://ops.fhwa.dot.gov/publications/fhwahop08034/hot5_0.htm), accessed October 12, 2015.
- Federal Highway Administration, Office of Policy and Governmental Affairs. (2012). A Summary of Highway Provisions in MAP-21. Retrieved from <http://www.fhwa.dot.gov/map21/summaryinfo.cfm>
- Firman, J. (2012). *Coordinated Work Zone Management Program, I-94, Michigan* (PDF). Washington, D.C.: National Operations Center of Excellence. Retrieved from <http://www.transportationops.org/case-studies/coordinated-work-zone-management-program-i-94-michigan>, accessed October 12, 2015.
- Flanigan, E., & Strasser, J. (2013). Best Practices for TSMO Program and Budget Development *A Framework for Improving Travel Time Reliability*. Cambridge, MA. Retrieved from [http://shrp2archive.org/?attachment\\_id=1053](http://shrp2archive.org/?attachment_id=1053)
- Flanigan, E., & Strasser, J. (2014). *Gap Filling Project 3: Best Practices for TSM&O Program and Budget Development*. Strategic Highway Research Program, Transportation Research Board of the National Academies. Washington D.C.: Cambridge Systematics, Inc. Retrieved 2015, from [http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2\\_L17\\_Gap-Filling\\_Project\\_3\\_BestPracticesFor\\_TSM&O\\_ProgramAndBudgetDevelopment.pdf](http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_L17_Gap-Filling_Project_3_BestPracticesFor_TSM&O_ProgramAndBudgetDevelopment.pdf)



- Florida Department of Transportation (FDOT), District 6. (2013). *95 Express Annual Report, July 1, 2011, through June 30, 2012: Project Status for Urban Partnership Agreement*. Miami, FL: FDOT, District 6. [http://www.sunguide.info/sunguide/images/uploads/tmc\\_reports/95X\\_P1\\_UPA\\_Eval\\_FY\\_12\\_Annual\\_Report\\_4\\_19\\_13\\_FINAL.pdf](http://www.sunguide.info/sunguide/images/uploads/tmc_reports/95X_P1_UPA_Eval_FY_12_Annual_Report_4_19_13_FINAL.pdf), accessed October 12, 2015.
- Furth, P. G., Hemily, B. J., Muller, T. H., & Strathman, J. G. (2003). *Uses of archived AVL-APC data to improve transit performance and management: Review and potential*: Transportation Research Board Washington, DC.
- González, S. (Producer). (2013, 2014). 2013 District 10 Annual Meeting. Retrieved from <http://www.floridasectionite.org/Archives/Annual2013/Session1/TSM%20and%20O.pdf>
- Hammond, P. J. (2012). *2013-2015 Capital Improvement and Preservation Program*. Washington State Department of Transportation. Retrieved from <http://www.wsdot.wa.gov/NR/rdonlyres/5983E100-081C-403C-9CDF-DB28F6DC561E/0/201315WSDOTCAPIMPPRESVPRGRM.pdf>
- Hauswirth, D. B., Hoffman, D. M., Kane, J. F., Ozobu, I. L., Thomas, C. L., and Wong, P. W. (2013). "Collaborative Leadership: Success Stories in Transportation Mega Projects – A "Lessons Learned" Approach to Collaborative Leadership in Mega Project Management". *Progress in Planning* 86:1–43. A Web version of this publication is available at [www.fhwa.dot.gov/ipd/project\\_delivery/lessons\\_learned/success\\_stories\\_big\\_i.aspx](http://www.fhwa.dot.gov/ipd/project_delivery/lessons_learned/success_stories_big_i.aspx), accessed September 21, 2014.
- Houston TranStar. (2015). *About Houston TranStar* (Web page). Houston, TX: Houston TranStar. [http://www.houstontranstar.org/about\\_transtar/](http://www.houstontranstar.org/about_transtar/), accessed October 12, 2015.
- I-15 Express Lanes Fact Sheet. In FasTrak (Ed.). San Diego, CA: San Diego Association of Governments.
- I-24 Multimodal Corridor Study*. (2014). Tennessee: Atkins Retrieved from <http://www.tdot.state.tn.us/i24/docs/I-24FinalReport.pdf>.
- ICF International, URS Corporation, and Marie Venner Consulting. (2010). *Case Study: Woodrow Wilson Bridge in Maryland and Virginia*. (p. 15). Washington, D.C.: National Academy of Sciences.
- Information Communications Technology Innovations Nomination: 511NY. (2010) (pp. 7). Lexington, KY: National Association of State Chief Information Officers.
- Kansas City Scout Traffic Management Center Annual Report. (2007). Kansas City, KS. Retrieved from <http://www.mykcscout.net/downloads/Reports/Annual/KCScoutAnnualReportFY2007.pdf>



- Kansas City Scout, Kansas and Missouri. 2014,  
from [http://www.tsmoinfo.org/project\\_profiles/kansas\\_city\\_scout.aspx](http://www.tsmoinfo.org/project_profiles/kansas_city_scout.aspx)
- Kerlin, M. (Producer). (2013, July 28, 2014). Infrastructure productivity: How to save \$1 trillion a year. Retrieved from [http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga\\_083856.pdf](http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_083856.pdf)
- Lockwood, S. (2013). Institutional Architectures to Improve Transportation Systems Management and Operations (pp. 22). Washington, D.C.: Strategic Highway Research Program.
- Loudon, B. (2009). A Domestic Scan of Congestion Pricing and Managed Lanes (pp. 56). Retrieved from <http://ops.fhwa.dot.gov/publications/fhwahep09044/fhwahep09044.pdf>
- Mahapatra, S., & Wolniak, M. (2013). *Maryland State Highway Mobility Report*. Hanover, Maryland: Maryland State Highway Administration Retrieved from [http://www.roads.maryland.gov/OPPEN/2013\\_Maryland\\_\\_Mobility.pdf](http://www.roads.maryland.gov/OPPEN/2013_Maryland__Mobility.pdf).
- Mahmassani, H. S., Haas, C., Zhou, S., & Peterman, J. (1998). Evaluation of incident detection methodologies. *Work*, 1. Retrieved from [http://www-math.cc.utexas.edu/research/ctr/pdf\\_reports/1795\\_1.pdf](http://www-math.cc.utexas.edu/research/ctr/pdf_reports/1795_1.pdf)
- Maryland Department of Transportation. (2013). *CHART Overview*. Retrieved from Coordinated Highways Action Response Team: <http://www.chart.state.md.us/about/overview.asp>
- Maryland Department of Transportation. (2013). *CHART Subsystems*. Retrieved from Coordinated Highways Action Response Team: <http://www.chart.state.md.us/about/subsystems.asp>
- Mehran, B. (2013). Evaluation of possible directions for improving traffic management system. Paper presented at the Proceedings of the 93rd TRB annual meeting. Washington, DC [CD]. Retrieved from <http://docs.trb.org/prp/13-1073.pdf>
- Mid-America Regional Council (2015). *About OGL* [Operation Green Light] (Web page). Kansas City, MO: Mid-America Regional Council. <http://www.marc.org/Transportation/Commuting/Operation-Green-Light/About-OGL/>, accessed October 12, 2015.
- Minnesota Department of Transportation. (2013). MnPASS. Retrieved from <http://www.mnpass.org>
- Minnesota Department of Transportation. (2015). Maintaining Minnesota's Highways: Highway Systems Operations Plan 2012-2015. Retrieved from <http://www.dot.state.mn.us/maintenance/hsop/>



- Minnesota Department of Transportation. (2015). Minnesota Guidestar. Retrieved from <http://www.dot.state.mn.us/guidestar/>
- Minnesota Department of Transportation. (2015). Minnesota State Highway Investment Plan: 2014-2033. Retrieved from <http://www.dot.state.mn.us/planning/mnship/>
- Moving Washington. (2014). 2014, from <http://www.wsdot.wa.gov/Movingwashington/>
- Navigating the Grey Notebook. (2014). 2014, from <http://www.wsdot.wa.gov/Accountability/GrayNotebook/navigateGNB.htm>
- O'Malley, M., & Brown, A. G. (2012). *2012 Maryland State Highway Mobility Report*. Retrieved from Maryland State Highway Administration: [http://roads.maryland.gov/OOTS/2012\\_Maryland\\_State\\_Highway\\_Mobility\\_Report.pdf](http://roads.maryland.gov/OOTS/2012_Maryland_State_Highway_Mobility_Report.pdf)
- Operation Green Light Strategic Plan: 2013-2016*. (2013). Kansas: Mid-America Regional Council Retrieved from [http://www.marc.org/Transportation/Commuting/OGL-assets/OGL\\_StrategicReport\\_FIN0114.aspx](http://www.marc.org/Transportation/Commuting/OGL-assets/OGL_StrategicReport_FIN0114.aspx).
- Oregon Metro Joint Policy Advisory Committee on Transportation. (2010, June 30). Regional Transportation System Management and Operations 2010-2020 Executive Summary. Portland, Oregon, United States. Retrieved from [http://www.oregonmetro.gov/sites/default/files/062010\\_regional\\_transportation\\_system\\_management\\_operations\\_plan\\_executive\\_summary.pdf](http://www.oregonmetro.gov/sites/default/files/062010_regional_transportation_system_management_operations_plan_executive_summary.pdf)
- Ramp Metering 2011 Evaluation Report. (2012) (pp. 17). Lee's Summit, MO. Retrieved from <http://www.kcscout.net/downloads/RampMetering/2011RampMeteringEvaluationReport.pdf>
- Regional Transportation Systems Management and Operations. 2014, from [http://plan4operations.dot.gov/reg\\_trans\\_sys.htm](http://plan4operations.dot.gov/reg_trans_sys.htm)
- Rice, R. (2013). *Transportation System Management & Operations Reorganization Plan Workshop*. Denver, CO: Colorado Department of Transportation Retrieved from [http://www.coloradodot.info/about/transportation-commission/documents/2013-archive-of-agendas-and-supporting-documents/july-2013/operations-workshop-memo-july.pdf/at\\_download/file](http://www.coloradodot.info/about/transportation-commission/documents/2013-archive-of-agendas-and-supporting-documents/july-2013/operations-workshop-memo-july.pdf/at_download/file).
- Road Ranger Service Patrol Comment Card Report Fiscal Year 2012/2013. (2013) (pp. 8). Retrieved from <http://www.swfltm.org/docs/2013%20Annual%20Survey%20Report.pdf>
- Saito, M., Wright, M., Hernandez, S., Yedlin, M., & Neyssen, J. (2003). *Evaluation of the Effectiveness of Coordinated Ramp Meter Controls*. Provo, UT: Brigham Young University.



- Schrank, D., Lomax, T., & Eisele, B. (2011). 2011 urban mobility report. Texas: Texas A&M University System. Retrieved from <http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-report-2011-wappx.pdf>
- Sims, J., ITS International. *Ramp Metering Delivers - Again*. (2011). Retrieved 2014 from <http://www.itsinternational.com/sections/cost-benefit-analysis/features/ramp-metering-delivers-again/>
- Simmons, T. D. (2001). Traffic Management and Operations for the Interstate 25 and Interstate 40 Interchange Reconstruction Project (pp. 6). Washington, DC: Institute of Transportation Engineers.
- South Florida Interstate 95 Express Project: Lessons Learned*. (2009). Miami, FL: Florida Department of Transportation Retrieved from [http://ops.fhwa.dot.gov/tolling\\_pricing/value\\_pricing/pubs\\_reports/projectreports/sfl\\_95express\\_proj/sfl95explessonslearn.pdf](http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/pubs_reports/projectreports/sfl_95express_proj/sfl95explessonslearn.pdf).
- Southwest Washington Regional Transportation Council. (2011). *Regional Transportation Systems Management and Operations Plan for Southwest Washington*. IBI Group. Retrieved 2015, from <http://www.rtc.wa.gov/programs/vast/docs/tsmoReport2011.pdf>
- Strategic Highway Research Program 2. (2012). *95 Express*. SHRP2 & Transportation Research Board. Kittelson & Associates. Retrieved 2014, from <http://www.transportationops.org/case-studies/95-express-florida>
- Strathman, J. G., Dueker, K. J., Kimpel, T., Gerhart, R. L., Turner, K., Taylor, P., . . . Griffin, D. (2000). Service reliability impacts of computer-aided dispatching and automatic vehicle location technology: A Tri-Met case study. *Transportation Quarterly*, 54(3), 85-102.
- SunGuide ITS Program District Progress Report. (2014) (pp. 19). Tallahassee, FL. Retrieved from <http://www.dot.state.fl.us/trafficoperations/Newsletters/2014/2014-Apr-DPR.pdf>
- Tario, J., Bassett, J., & Barron, K. (2011). Environmental Benefits of a Statewide Traffic Video Network (pp. 31). Fairfax, VA.
- The Braintrust Consulting Group. (2010). The Importance of Stakeholder Management. Retrieved from <http://www.braintrustgroup.com/2010/stakeholder-management/>
- The Florida Senate. (2015). 2015 Florida Statutes. Retrieved from <http://www.flsenate.gov/Laws/Statutes>
- Transportation System Management & Operation (TSM&O) Tier 2 Business Plan. (2011). In *TSMO\_Tier\_2\_Business\_Plan\_03282011.pdf* (Ed.). Florida: Florida Department of Transportation.



- Transportation System Management & Operations Reorganization Plan Workshop*. (2013). Denver, CO: Colorado Department of Transportation Retrieved from [http://www.coloradodot.info/about/transportation-commission/documents/2013-archive-of-agendas-and-supporting-documents/july-2013/operations-workshop-memo-july.pdf/at\\_download/file](http://www.coloradodot.info/about/transportation-commission/documents/2013-archive-of-agendas-and-supporting-documents/july-2013/operations-workshop-memo-july.pdf/at_download/file).
- Travel Time Messaging on Dynamic Message Signs - Houston, TX. (2005). 2014, from [http://ops.fhwa.dot.gov/publications/travel\\_time\\_study/houston/houston\\_ttm.htm](http://ops.fhwa.dot.gov/publications/travel_time_study/houston/houston_ttm.htm)
- TriMet At-a-Glance. (2014). Portland, OR: TriMet. Retrieved from <http://trimet.org/pdfs/publications/TriMet-At-a-Glance-2014.pdf>
- Turnbull, K. F., United States. Federal Highway, A., National Research Council . Transportation Research, B., & United States. Federal Transit, A. (2005). *Performance Measures to Improve Transportation Systems: Summary of the Second National Conference*: National Academy Press.
- U.S. Department of Transportation, Federal Highway Administration. (2007). *Managing Travel for Planned Special Events Handbook: Executive Summary*. Washington, D.C. Retrieved from [http://www.ops.fhwa.dot.gov/publications/fhwahop07108/event\\_impacts.htm](http://www.ops.fhwa.dot.gov/publications/fhwahop07108/event_impacts.htm)
- Unlocking Gridlock. (2010) *Transportation Reboot* (pp. 39). Washington DC: American Association of State Highway and Transportation Officials.
- Vega, P. (Producer). (2012, 2014). *Optimizing Capabilities: District 2*. Retrieved from <http://www.dot.state.fl.us/trafficoperations/TSMO/documents-workshop/D2-TSMO-Presentation.pdf>
- Virginia/Maryland - Woodrow Wilson Bridge. (2014). *Livability in Transportation Guidebook*. Retrieved from [http://www.fhwa.dot.gov/livability/case\\_studies/guidebook/appendix/app14.cfm](http://www.fhwa.dot.gov/livability/case_studies/guidebook/appendix/app14.cfm), accessed October 1, 2014.
- Washington State Commission. (2006). *The Washington Transportation Plan 2007-2026*. Washington Department of Transportation. Retrieved from <http://www.wsdot.wa.gov/NR/rdonlyres/DC0029BD-46DC-4323-BFAE-0186DA1A0B42/0/AWCleavebehindweb85x11627.pdf>
- Washington State Commission. (2010). *Washington Transportation Plan 2030: Connecting Washington Communities For A Prosperous Future*. Retrieved from [http://wstc.wa.gov/WTP/documents/WTP2030\\_Final\\_1210.pdf](http://wstc.wa.gov/WTP/documents/WTP2030_Final_1210.pdf)
- Washington State Commission (2006). *The Washington Transportation Plan 2007-2026*. Washington Department of Transportation. Retrieved from: <http://www.wsdot.wa.gov/NR/rdonlyres/B1E8FB10-D415-4228-817D-9C4BE4569128/0/WTPLinks2.pdf>



- Washington State Department of Transportation. (2015). Intelligent Transportation Systems (ITS) Operations. Retrieved from <http://www.wsdot.wa.gov/Operations/ITS>
- Washington State Department of Transportation. (2015A). Moving Washington. Retrieved from <http://www.wsdot.wa.gov/movingwashington>
- Washington State Department of Transportation. (2015B). Statewide Transportation Improvement Program (STIP). Retrieved from <http://www.wsdot.wa.gov/LocalPrograms/ProgramMgmt/STIPDoc.htm>
- Washington State Department of Transportation. (2015C). Tolling in Washington State. Retrieved from <http://www.wsdot.wa.gov/Tolling>
- Webb, R. (2011). *Operation Greenlight: KC Regional Traffic Signal Coordination*. Retrieved from [http://www.teamconference.org/2011/documents/Breakouts/OGL\\_RayWebb.pdf](http://www.teamconference.org/2011/documents/Breakouts/OGL_RayWebb.pdf)
- Williams, C. A. (Producer). (2012, 2014). District Three TSM&O Perspective. Retrieved from <http://www.dot.state.fl.us/trafficoperations/TSMO/documents-workshop/D3-TSMO-Presentation.pdf>
- Wisconsin Statewide Ramp Control Plan*. (2006). Wilbur Smith Associates Retrieved from [http://www.topslab.wisc.edu/its/rampmetering/WisDOT\\_ramp\\_control\\_plan.pdf](http://www.topslab.wisc.edu/its/rampmetering/WisDOT_ramp_control_plan.pdf).
- Yohanan, D., Truelson, S., Duensing, J., Chenevert, D., Willard, F., & Forgang, M. (2011). Integrating Clarus Data with the 511 New York Traveler Information System (pp. 42). Washington, D.C.