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Integrating transportation systems management and operations into the project life cycle from planning to construction: A synthesis of best practices

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HIGHLIGHTS

- This paper provides detailed guidance on how to apply TSM&O strategies from the planning stages to the construction phase of any general transportation project.
- The developed TSM&O project cycle process provides a detailed structure for the potential interactions between phases of a project and department staff as a key to ensure that the program achieves the highest level of optimization.

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ABSTRACT

Guided by the federal highway administration (FHWA), many states are promoting the implementation of transportation systems management and operations (TSM&O) programs. 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 practice of managing TSM&O can be applied to all units and disciplines, within a transportation entity, for increased efficiency. One main reason of the stagnated integration is the lack of policies which could support the integration of TSM&O strategies within the planning or design stages. This paper 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 and the best practices to create a robust and performance-based program. The developed TSM&O project cycle process provides a detailed structure for the potential interactions between phases of a project and department staff as a key to ensure that the program achieves the highest level of optimization. Continuous evaluation must be undertaken by the agencies to ensure that the

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performance of the system is at an optimal level. Developing performance measures, which accurately describe the objectives of the agency, is critical to ensure the plan to be brought to practice.

1. Introduction

The main purpose of a TSM&O program is to maximize the safety, reliability, and efficiency of all modes of the transportation system. Increasing the benefits of an existing infrastructure can improve operational performance, reduce long term costs, and save 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 multimodal, cross-jurisdictional systems, services, and projects" (FHWA, 2013). Due to limited resources and fiscal constraints for new infrastructure to mitigate congestion, new strategies are needed to obtain the most capacity and efficiency 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 parts of TSM&O and have proven to be quite effective thus far in many categories compared to the traditional capacity improvement projects.

TSM&O is traditionally managed by traffic engineers that focus on optimizing efficiency and operations within a particular corridor utilizing common techniques such as retimings and access modifications. With the emphasis moving towards maximizing current infrastructure, the practice of managing TSM&O can be applied to all units and disciplines to increase efficiency. This should include planning, emergency services, public transportation, environmental management, design, and integration of intelligent transportation systems (ITS) on the roads and railways.

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 (Atkinson et al., 2013). It is still noticeable. However, 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 which could support the integration of TSM&O strategies within the planning or design stages as a routine method of business practice.

This paper 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, which will assist in developing a TSM&O program and best benefit the needs of the agency. Various examples are used to show the effectiveness of TSM&O strategies applying in infrastructure design at the early stages of a project. The application of these strategies allows improvement in regional transportation system efficiency, reliability, and option over a long term of a project's life span.

2. Challenges to an effective TSM&O program

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, it is possible to see major strides are being made to incorporate TSM&O strategies (CDOT, 2013; Chandra, 2014; FDOT, 2013; Hammond, 2012; KCSTMC, 2007; KCS, 2014; MDOT, 2013). Table 1 provides a summary comparison between the different TSM&O programs and practices which were mentioned previously and describes the program goals, strategies implemented and specific applied projects.

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 (AASHTO, 2014a).

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 (AASHTO, 2014b). 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.
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.
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.
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.

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Table 1 – TSM&O programs and practices.

DOT	Goals	Functional areas
California	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
Colorado	Improved accuracy and 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
Florida	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
Missouri	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
Maryland	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
Oregon	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
Tennessee	Plan and implement innovative systems with a focus of improved travel times and congestion reduction throughout the state.	Managed lanes, multi-modal
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 project planning processes and provides transportation program guiding investment principles.	Incident response, managed lanes, its research/planning, system operations, advanced traffic management

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. 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.

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.

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 (2010), an effective TSM&O program has four main goals to achieve as a practice of excellence within an organization. These four goals are reliability, quality of life, safety and security, and traveler information. While many projects accomplish several of the goals, it is important 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.

Reliability is defined as the ability to "provide reliable travel times for people and goods movement". A roadway network that is predictable to give 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

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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. Signaling priorities are given during peak commuting periods to the peak direction of travel. Getting users to establish patterns of travel based on the knowledge of the network performance benefits both of the parties.

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". The environmental factors involved in the transportation network traditionally focus on the reduction of congestion. Modal choice to encourage livable communities is a big player in changing the number of vehicles on the roadway network. 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. Optimizing signals is another major contributor to the reduction in environmental concerns. With less stops, vehicles are not working so 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". 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 usable.

Traveler information is defined as the ability to "provide comprehensive multi-modal travel information to people and businesses". 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. 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. 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. 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 (FHWA, 2007).

Similar projects should also be analyzed so that a base performance measure can be logged to determine the impacts of certain strategies. 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 to evaluate the network condition constantly and make 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 gather 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 which is understandable and able to be discussed by multiple offices within the agencies.

4. TSM&O functional areas

TSM&O in broad scope has generally been divided into four functional areas, which supports the implementation of the program's core areas and supports the established goals. The functional areas are multi-modal 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.

4.1. *Multi-modal traffic management*

The push to make transportation systems more efficient has had an integral part in making multi-modal traffic management for 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. Throughput and delay are the largest impact factors of multi-modal traffic management, and the performance measures are divided as such. The performance measures recommended include multi-modal throughput, travel time as well as recurring and non-recurring delay.

4.2. *Traveler information*

Traveler information is becoming a vital component to drivers in the handheld technology age. Users want instant information to make sound judgment decisions. A fully optimized TSM&O program strives to provide a well-

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integrated network of information tools available to the user. 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.

4.3. *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 responder is a hazard to users on the roadway.

4.4. *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. Fig. 1 provides some of the most common factors when performance measurement is introduced to a system.

4.5. *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 there 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. 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. It is imperative to understand that 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, 2010).

5. 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 judgment and performance measures are the main evaluation tool when it comes to improving an existing facility.

5.1. *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 option.

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.

5.2. *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

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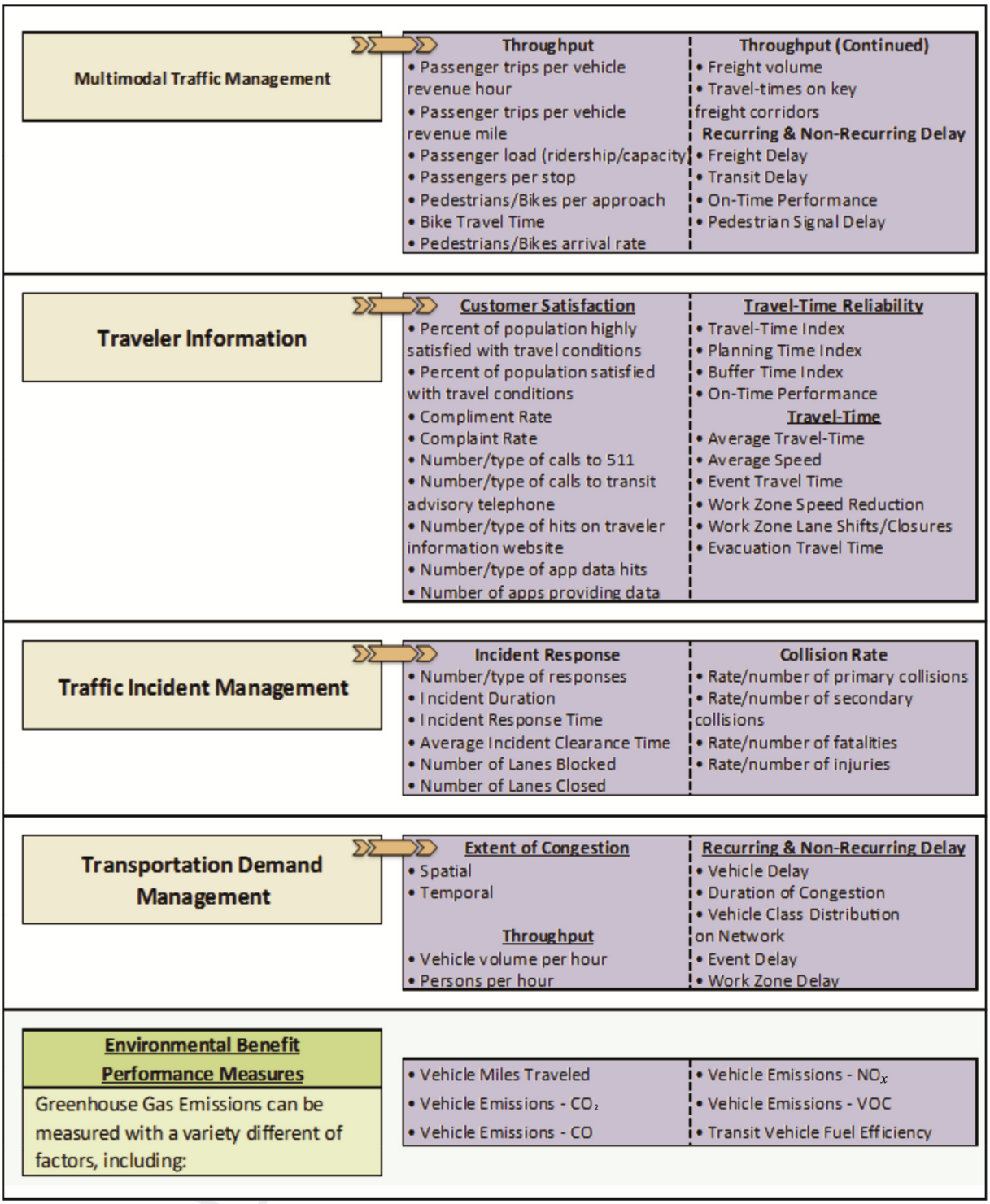

Fig. 1 – TSM&O functional areas with sample performance measures.

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, including.

- Improving travel time reliability;
- Reducing crashes;
- Improving transit on-time arrival;
- Expanding modal choice;
- Reducing travel delay;
- Reducing fuel use;
- Reducing air pollution;
- Reducing greenhouse gas emissions.

With the establishment of the benchmarks that the TSM&O techniques will achieve, the project is then taken

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through the TSM&O project cycle by starting in the project concept & programming phase.

5.3. *Project concept & programming*

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. 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. 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. 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.

5.4. *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 (Braintrust Consulting Group, 2010). The involvement of stakeholders is very important as they can become great assets that can clear organize roadblocks and support projects when needed. 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. 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. 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. Below are a select group of the Braintrust Consulting Group's best practices for managing stakeholder involvement that can be applied to transportation (Braintrust Consulting Group, 2010).

- 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.

5.5. *Planning*

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. 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. 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.

The planning team should identify if the project is small and simple enough to be forwarded directly to design, typically for projects that are standard and simple to implement (Brennan, 2015). 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. 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.

5.6. *Preliminary 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. 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 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.

5.7. *Final plans, final design & specifications*

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

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design related changes and their impact to the overall purpose and need and any assumptions that were made should be final at this point. 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.

5.8. *Construction*

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. 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 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). 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.

5.9. *Operations and maintenance*

The operations and maintenance phase of a project is an indefinite phase of any TSM&O 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. A TSM&O project in this phase is typically always improving and an ever-evolving through the review of system performance measures. The ITS group is especially responsible for ensuring that all communication equipment is operating correctly and generating realistic, usable 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. 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.

6. Applying TSM&O into the project processes

Each TSM&O focused project can produce varying degrees of success depending on multiple factors (Lockwood, 2013). 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.

6.1. *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 (Abou-Senna et al., 2015). 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. Taking the consensus organization model has helped in forming agreements and assuring support/participation in a 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.

6.2. *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.

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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.

6.3. *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. 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 can help tremendously in a project. Risks should be anticipated, understood, and managed accordingly. Items such as ITS contracting can be complex and subject to changes in technology and the market over time.

6.4. *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 project management selection. Many success stories are attributed to 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.

6.5. *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 staffing and communication needs as well as to 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.

6.6. *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.

6.7. *TSM&O project cycle diagrams*

Fig. 2 provides a high level approach to the TSM&O project cycle 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 cycle diagram in Figs. 3 and 4 provides 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 paper.

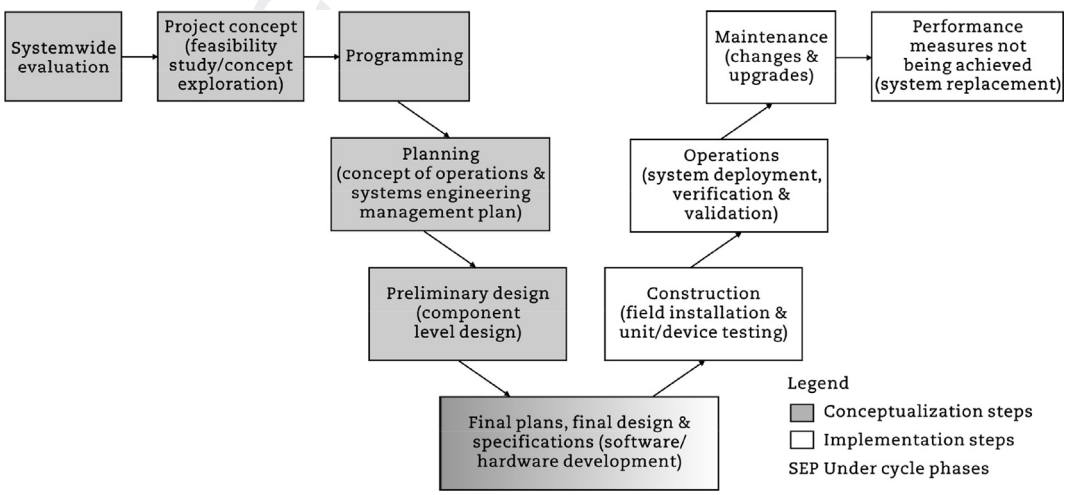

Fig. 2 – TSM&O project cycle diagram–high level diagram with system engineering process (SEP).

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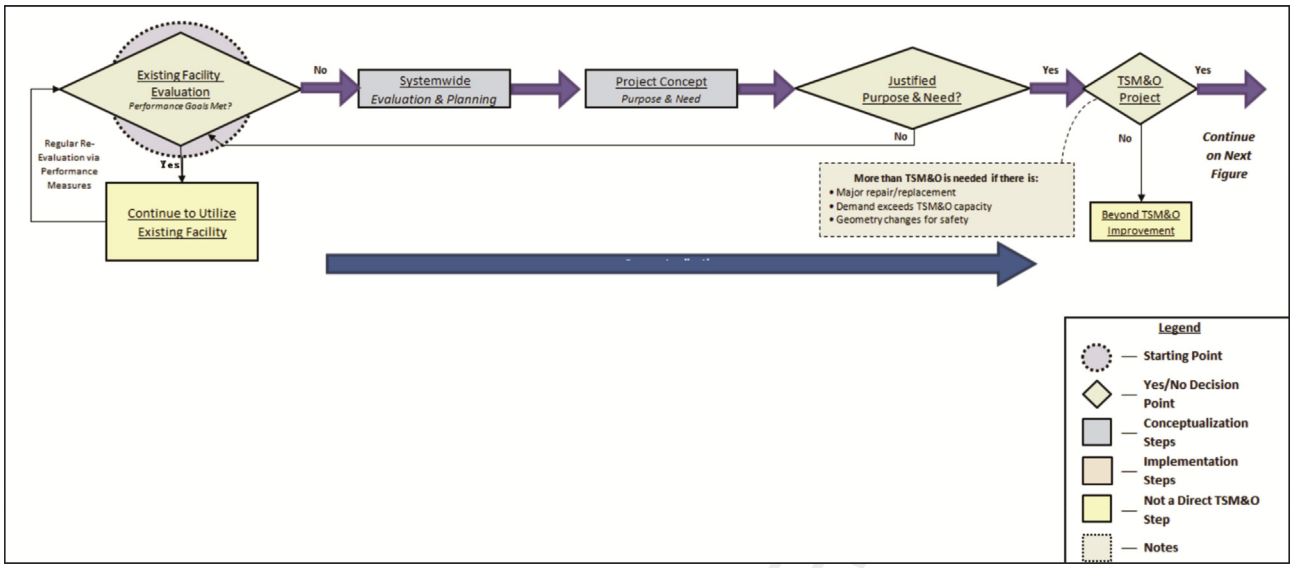

Fig. 3 – TSM&O project cycle diagram-early stages.

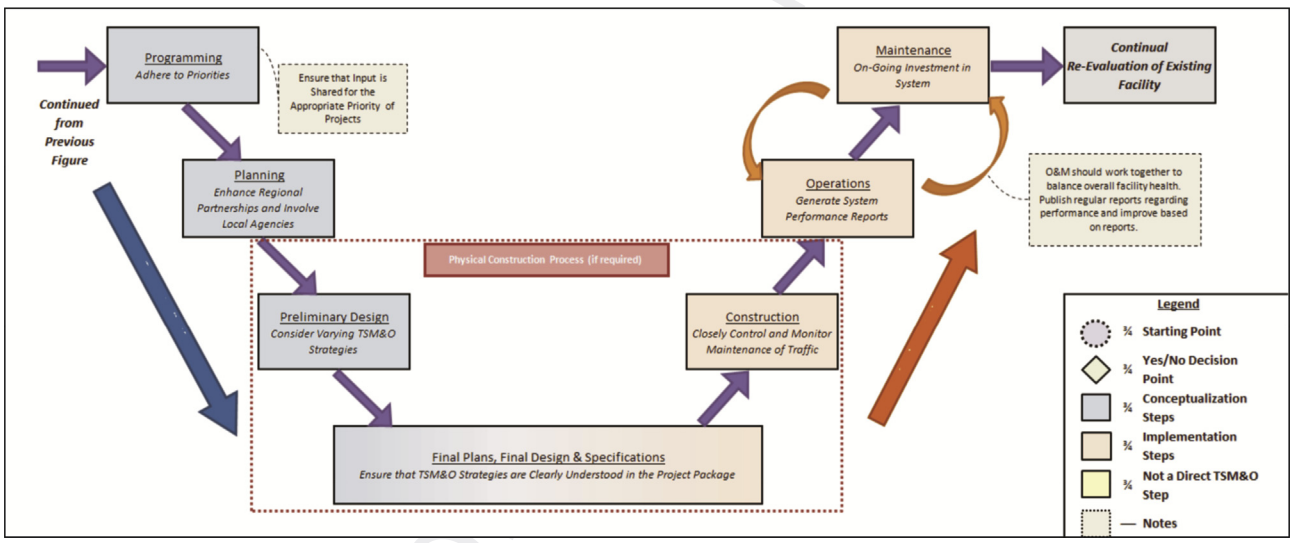

Fig. 4 – TSM&O project cycle diagram-later stages.

7. Conclusions

The development of this paper has presented a series of concepts that have to do with the implementation of a successful transportation systems management & operations (TSM&O) program. 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. 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.

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 an agency. 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 an agency. Not only the integration of the strategies but

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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 an agency to follow and understand to move forward in implementing their own TSM&O program. By understanding the practices and accomplishments of other organizations, an agency 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.

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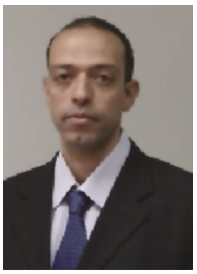

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