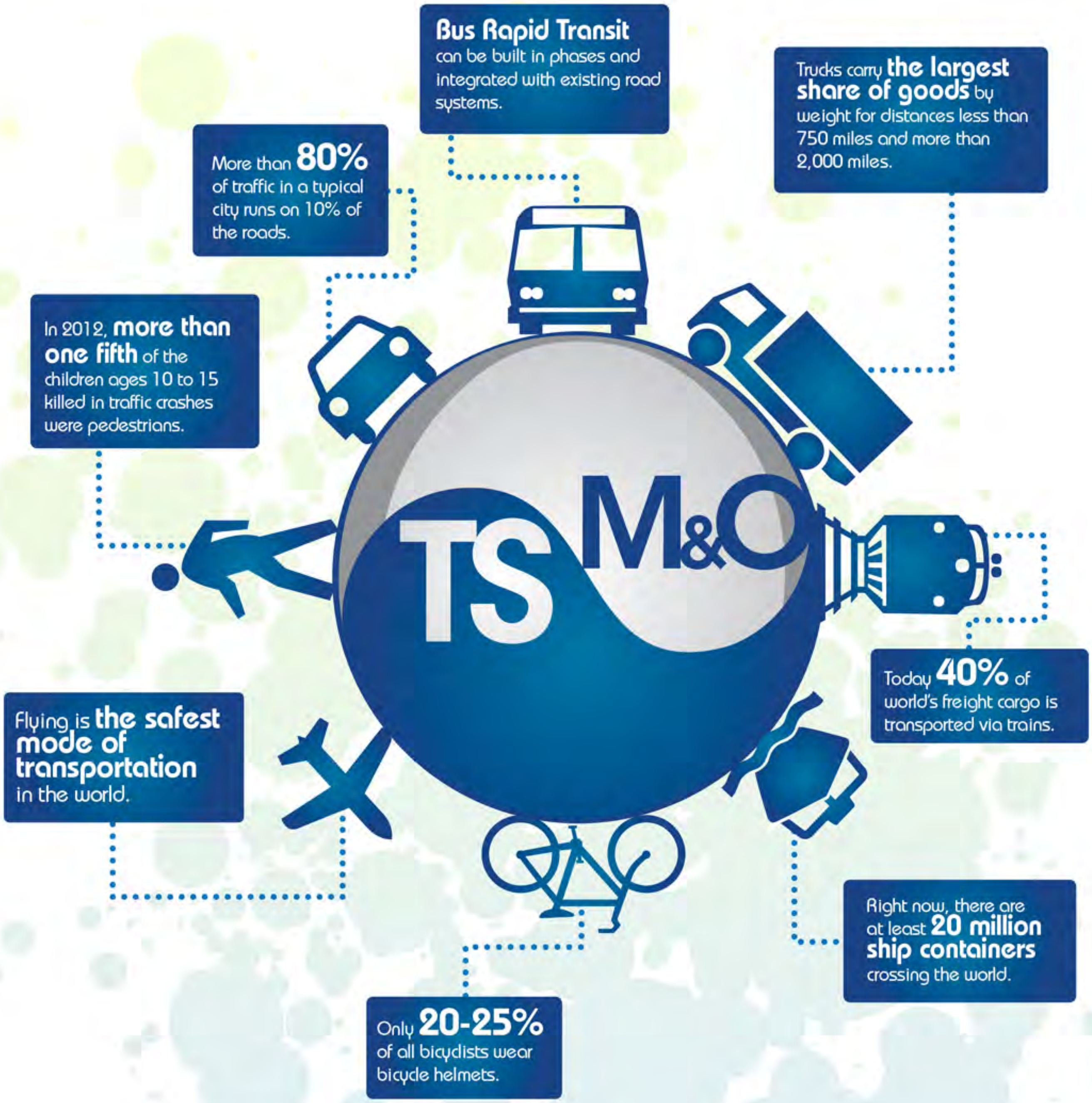

The Planning for TSM&O Guidebook

A comprehensive planning methodology for Transportation Systems Management & Operations.

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Prologue

Transportation professionals have long realized the common adage, "we cannot build our way out of congestion." Inevitably, capacity-based projects lead to increased travel demands and traffic resulting in increased congestion, delay, and lack of reliability. The Transportation Systems Management and Operations (TSM&O) Program provides alternative transportation strategies that are multi-modal, cost-efficient, and sensitive to livability and sustainability goals. Beyond congestion, solutions can enhance safety, improve travel time reliability, and reduce environmental impacts by minimizing congested travel for all modes. TSM&O in the context of transportation planning can be defined as a program to produce strategies that improve the safety, congestion, and reliability of the transportation network.

Through programs like the Strategic Highway Research Program (SHRP2), the U.S. Department of Transportation's Federal Highway Administration (FHWA) has made these solutions a top priority of local, state and federal agencies. This program is supporting the development of this Guidebook to provide transportation practitioners around the country comprehensive guidance on TSM&O. SHRP2 has also produced research projects to develop solutions to improve the way transportation professionals manage the existing transportation infrastructure, as well as strategically plan for the future.[1] Additional information is available on the FHWA Planning for Operations website describing how the FHWA and the Federal Transit Administration (FTA) are promoting the use of TSM&O as a way to integrate planning and programming with operations.[2] The American Association of State Highway and Transportation Officials (AASHTO) has also provided guidance in support of agencies developing the capabilities within their organizations to support TSM&O programs.[3]

TSM&O Program Goals

- Improve safety
- Reduce congestion
- Improve reliability

The TSM&O program provides transportation agencies with alternative, innovative, and cost-effective solutions to address the increasing demands on transportation infrastructure at the project level, throughout all phases of the project development process (e.g. transportation planning, design, right-of-way, construction, and maintenance and operations). Perhaps more importantly, TSM&O seeks to both improve the reliability of existing transportation systems and to enhance capacity-related projects to extend the life of major capital investments. Finally, with continual budget and funding restrictions, TSM&O provides solutions that can often be implemented at a lower cost or impact, and can often enhance the natural, social, physical, and cultural environment. These solutions achieve more with less and often complement stated goals of state and federal transportation programs related to funding, safety, congestion and environmental elements such as Congestion Mitigation and Air Quality Improvement (CMAQ) programs.

In order to develop a functional, long-lasting TSM&O program, transportation agencies may first seek to adopt TSM&O practices at the project level, or on a specific project-by-project-basis; however, for the practice of TSM&O to be truly successful, transportation agencies should consider adopting a TSM&O program, which is, in part, the aim of this document – namely to provide a rational process and best practices. To date, many publications have been developed to identify specific functional areas of the TSM&O practice, yet little to no literature exists that affords the practitioner with a comprehensive document that fully explores the various considerations that start at the planning level and can be applied universally to all types of projects.

The TSM&O Guidebook will provide a programmatic approach to TSM&O from transportation planning through operations and maintenance.

The goal of the TSM&O Guidebook is to provide a comprehensive description of the programmatic approach of TSM&O from transportation planning through construction. To be truly effective and implement the goals stated above, TSM&O must leverage all units or departments within an agency to provide a broad scope that incorporates input and considerations from those focused on budgeting/programming, transportation planning, traffic operations, preliminary and final design, environmental/permitting, right-of-way, construction and operations and maintenance. This is due, in part, to the various elements that comprise a TSM&O program which can generally be categorized in three major areas: planning, implementation, and monitoring. By following the recommended processes and procedures outlined in this TSM&O Guidebook, transportation professionals will

1 FHWA, SHRP2 Solutions, http://www.fhwa.dot.gov/goshrp2/
2 FHWA, Planning for Operations, http://www.ops.fhwa.dot.gov/plan4ops/focus_areas/planning_prog.htm
3 AASHTO, TSM&O Guidance, http://www.aashtotsmoguidance.org/

be able to effectively implement improvements and strategies and develop a long-term program. The TSM&O program adopted by an agency, if carried out properly and with input from various disciplines, will provide a nexus for alternative improvement strategies that can improve the overall system performance including, but not limited to: incident management; infrastructure upgrades to optimize system operations (signs, signals, and communications); programs to promote alternative modes of transportation such as walking, biking, transit use, and carpooling; and the delivery of traveler information. Ultimately, the TSM&O Guidebook provides a comprehensive methodology to identify the appropriate strategy and advance the project through a collaborative approach from planning, to operations and into construction.

The TSM&O program will provide a nexus for alternative improvement strategies to improve system performance, including:

- Incident management
- Infrastructure upgrades
- Programs to promote alternate modes
- Delivery of traveler information

Programmatic Approach to TSM&O

As stated above, any TSM&O program a transportation agency adopts should be viewed as a comprehensive program with a range of methodologies that allow improvements to be integrated into the existing planning and project development process. In some cases, with the early evaluation of system-wide infrastructure, professionals will be able to effectively identify the appropriate mitigating strategy and efficiently prioritize the improvements. As a result, professionals - through a collaborative process - may reduce, or even eliminate, the need for lengthy and expensive infrastructure improvements. Part of this process, illustrated in **Figure 1**, will be to ensure that operational and safety solutions are also considered and included in long-term complex solutions, with the goal of maximizing the operational benefits of any improvement strategy.

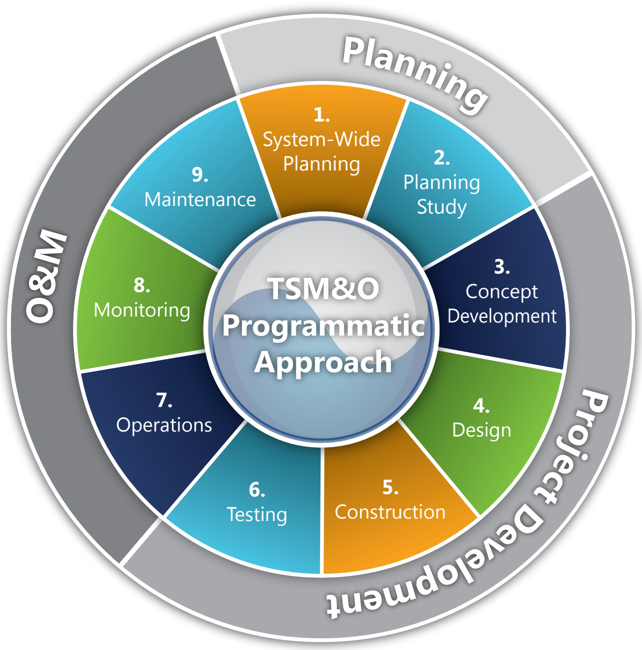

Figure 1: TSM&O Programmatic Approach

Capability Maturity Framework (CMF):

- Program self-assessment exercise
- Across all functional units
- Assign levels of maturity 1-4, 4 being fully integrated and functioning
- Results in goals to advance maturity and task action items

One of the problems is that, historically, transportation professionals have provided Maintenance and Operations (M&O) services, leading to the perception that the industry has been practicing TSM&O all along. However, the key distinguishing factor is that professionals have rarely followed a holistic TSM&O approach that brings all transportation practitioners to the table and keeps them at the table through the project development process and beyond. This TSM&O Guidebook provides clarity on technical gaps that have been longstanding in the transportation industry between planners, engineers and other transportation practitioners. This document clarifies the roles and responsibilities, introduces and expands upon existing frameworks, while emphasizing and providing practical suggestions for coordination between disciplines throughout the project development process.

The TSM&O Guidebook is a result of the recognized gap of information, policies and procedures for integrating all units into a programmatic TSM&O process and program. In order to understand the context of this Guidebook, it is important to understand the relationship between previously mentioned FHWA activities and the Capability and Maturity Framework (CMF) as outlined in the *Creating an Effective Program to Advance Transportation System Management and Operations Primer.*[4] The word "maturity" in CMF could easily be replaced by "status" and is generally a self-assessment tool, developed and recommended by FHWA, to assist agencies in developing or evaluating existing TSM&O programs by identifying maturity levels, program maturity goals, and what the appropriate steps are to accomplish those goals. The CMF consists of six key dimensions that contribute to a successful TSM&O Program. It is important to understand that while all the elements are equally important, the CMF self-assessment will emphasize areas that respective agencies should focus on in various scenarios. The CMF dimensions are shown in **Figure 2** and described below.

Business Process – including formal scoping, planning, programming, and budgeting

Systems & Technology – including systems architecture, standards, interoperability, and standardization and documentation

Performance Measurement – including measures of success definition, data acquisition, analysis, and utilization

Culture – including technical understanding, leadership, policy commitment, outreach, and program authority

Organization & Workforce – including organizational structure, staff capacity, development, and retention

4 FHWA, Office of Operations, Creating an Effective Program to Advance Transportation Systems Management and Operations Primer, http://www.ops.fhwa.dot.gov/publications/fhwahop12003/background.htm. Accessed on May 25, 2016

Collaboration – including relationships with public safety agencies, local governments, MPOs, and the private sector.

Figure 2: TSM&O Program Dimensions

How does the CMF and its six dimensions relate to the TSM&O Guidebook? Fundamentally, all six dimensions are needed to support the methodology that will be described in this Guidebook. Business Processes will support not only programming, planning, and budgeting, but also how agencies utilizing the TSM&O program will do business, in other words, the project development process. In order to promote the management and operations of the transportation systems, it is important to know when and how technology can be leveraged to support the TSM&O program goals. Continued Performance Measurement will be critical for the program to identify system deficiencies, prioritize needs, and determine the return on investment of improvement strategies.

One of the more difficult dimensions to define is Culture. This dimension addresses the need for leadership to be committed to the goals of the TSM&O program, and to support those goals with policy and program authority. Next, Organization & Workforce is detailed in the Guidebook to assist in the defining of roles and responsibilities, and what skill sets are needed for what functions within the program.

Finally, the Collaboration dimension, which will be an ongoing theme in this Guidebook, outlines the need for communication and buy-in between different public agencies, the private sector supporting those agencies, the public, and different disciplines, or units within an agency. This will be addressed later by topic of discipline and will include planning, design, right-of-way, construction, operations, and maintenance. The levels of involvement at different stages of the project development process, and important points

Fundamentally, all six dimensions are needed to support the methodology that will be described in this Guidebook.

Business Process
Project development process

Systems & Technology
How and when to leverage technology

Performance Measurement
Prioritize needs and deficiencies

Culture
TSM&O program vs. ribbon-cutting

Organization & Workforce
TSM&O roles and responsibilities

Collaboration
Communication between disciplines from planning to construction

Guidebook Contents

at which communication and collaboration are key issues and will be described throughout the Guidebook.

Using this Guidebook

Historically, there has not been a clearly defined TSM&O process or programmatic approach to provide transportation practitioners a resource for how to properly implement the TSM&O program. This Guidebook will outline a systematic methodology for developing the TSM&O program beginning at the planning stage of project development and continuing through the lifecycle of a project.

The TSM&O Guidebook is recommended for all professionals that could be involved in implementing or advancing a TSM&O program. As a result, the desired outcome is for practitioners to understand the needs of all components of a successful TSM&O program. The TSM&O program should be collaborative in nature within agencies and with partnering agencies; therefore, this Guidebook has been prepared for State Departments of Transportation (DOT), Metropolitan Planning Organizations (MPO) / Transportation Planning Organizations (TPO), local governments, communities, transit agencies and private transportation in general.

The practitioner should take away the following concepts from this Guidebook:

- Clearly defined roles for individuals involved in a TSM&O Program
- Fundamentals needed for a TSM&O Program and related methodologies
- Integration of the TSM&O Program into the existing project development process

The significant modification to the TSM&O program is the clarification and understanding of the various roles of transportation practitioners. Typically, project identification is coordinated early in the planning stage as part of a comprehensive plan or area-wide transportation study. From this large-scale planning document, specific projects are identified and advanced in the project development process for agencies. This is the area where the TSM&O program can provide the most significant benefit. Identifying the right solution for the appropriate congestion or safety project requires close coordination between multiple units or departments. A critical evolving element facing transportation practitioners is the understanding and development of strategies that provide:

- Context-Sensitive Solutions
- Improvement in Community Livability
- Consideration for Complete Streets
- Multi-modal Solutions

In order to integrate these elements into the TSM&O program, it is important to describe the details and references associated with the potential development strategies. These planning concepts may be considered tools a transportation planner may utilize for system improvements which seek to incorporate strategies that support social views, environmental issues, economic development, and social justice. These tools may still be utilized in the TSM&O program in an effort to develop and provide solutions to the transportation network that address specific needs of the system and surrounding community. These concepts are described in more detail in **Appendix A.**

The TSM&O Guidebook describes a detailed comprehensive approach to a previously vague process that impacts transportation practitioners throughout the country. This document was prepared with the intent to provide transportation professionals a clear methodology for integrating the full lifecycle approach to TSM&O from planning through construction into each unit or department.

Guidebook Audience:

- State DOT
- MPO/TPO
- Local Government
- Transit Agencies
- Private Transportation Industry

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1

1.0 What's the Problem?

The problem currently facing the transportation industry is how do we improve and maintain the safety and reliability of our transportation network while making informed funding allocation decisions based on need.

When faced with the challenge of increasing demand on an aging and deteriorating infrastructure, innovative and efficient solutions to meet the demand on the system are necessary. Making the most out of existing roadway infrastructure is key to addressing congestion, safety, and reliability goals given the current state of funding in the United States. The 2013 American Society of Civil Engineers (ASCE) infrastructure report card[5] notes that the current level of investment (about $90 billion annually) is insufficient to accommodate existing and projected transportation needs and would result in a decline in travel characteristics and system performance over the long term. Currently, the FHWA estimates that $170 billion annually in capital investment would be needed to significantly improve conditions and performance. These figures present a significant gap between current financial infrastructure investment and FHWA's estimates on where we need to be. How do we bridge this gap?

When faced with the challenge of increasing demand on an aging and deteriorating infrastructure, innovative and efficient solutions to meet the demand on the system are necessary.

One step to bridging this gap is to provide more effective planning for operations. This need is supported by several key factors:

1. There is a demand for a more clearly defined process to establish a TSM&O program.

5 http://www.infrastructurereportcard.org/a/#p/overview/executive-summary

2. There is a lack of guidance on the role of planning in the project development process for operational improvements.
3. Project priority lists are not always based on need.
4. Operation improvements are often reactive as opposed to proactive.
5. Systems are not monitored in a consistent way to determine whether performance measures are being met.
6. Return on investment for improvement strategies are not being consistently catalogued and monitored.

The second challenge is how to implement TSM&O. This Guidebook will address that problem by providing:

- The project development process in the TSM&O Program (Business Process).
- An outline for different strategies and resources available (Systems & Technology).
- Information on system-level planning and applying performance monitoring to set goals and objectives (Performance Measurement and Business Process).
- Understanding of the importance and impact of operational vs. traditional capacity improvements, or TSM&O vs. Ribbon Cutting (Culture).
- Definition of different units within the TSM&O project development process (Organization and Workforce).
- The critical checkpoints within the process from system-level planning to construction to system maintenance, during which collaboration between units or agency partners is key (Collaboration).

The TSM&O program is NOT
- A project
- ITS only
- Operations and maintenance only
- Vehicle only

The TSM&O program is
- An integrated program
- Performance-based
- From planning to construction
- Multi-modal

1.1 What is TSM&O?

FHWA defines Transportation Systems Management and Operations (TSM&O) as "an integrated program to optimize the performance of existing multi-modal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of our transportation system."

Simply stated, TSM&O is a program that promotes the management and operations of the transportation system through which strategies are developed by transportation professionals to address increasing congestion, safety-related challenges, and travel-time reliability. TSM&O is a broad topic that encompasses projects at both the system-level and facility-specific level, as illustrated in **Figure 3**. The TSM&O program provides the framework for planners to conduct both area-wide and corridor-specific analysis, while closely coordinating with engineers to advance various projects through the project development lifecycle process.

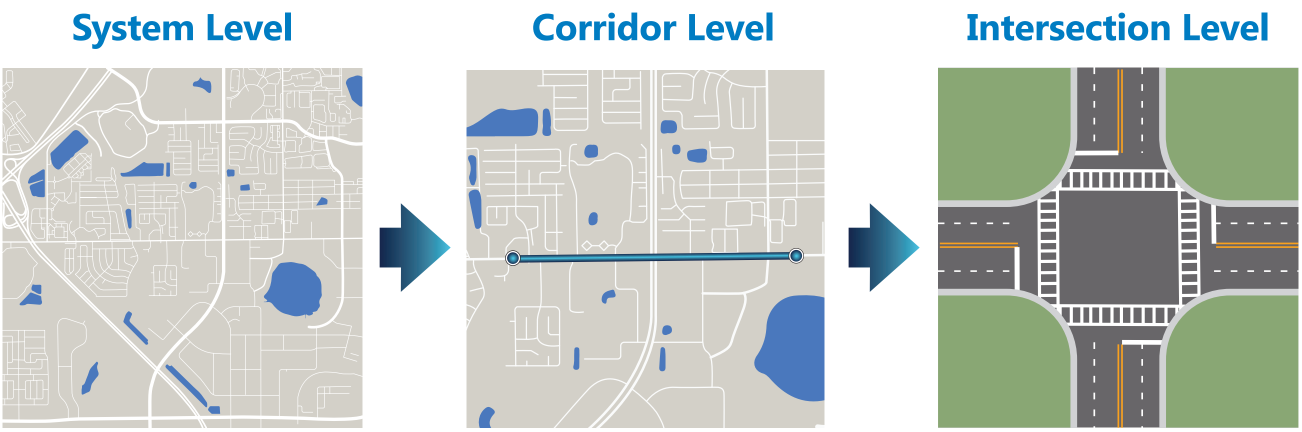

Figure 3: TSM&O Program Focus Levels

There are many misconceptions and misunderstandings associated with the TSM&O program. Many transportation professionals contend that TSM&O has been in practice for decades; or that TSM&O is synonymous with Intelligent Transportation Systems (ITS). It is true that ITS projects have included piecemeal elements of TSM&O with the management and operations (M&O) practice, including the development of the Concept of Operations (ConOps) and System Engineering Management Plan (SEMP). What differentiates the TSM&O program from the traditional M&O practice is the holistic evaluation of the transportation system, and the integration of performance measures into the process of partnering with transportation planners and operations engineers.

At its core, the TSM&O program is a cyclical, iterative process, as illustrated in **Figure 4,** that begins with an evaluation of the system, identifying needs based on deficiencies, implementing solutions, and re-evaluating the system based on a combination of evaluation criteria and performance measures. The tools and strategies used to accomplish a successful TSM&O program go beyond ITS projects, or the re-timing of signals to improve traffic flow. TSM&O is about increasing the efficiency of the existing transportation systems, with the consideration of all opportunities to relieve congestion, address safety concerns and enhance the reliability of travel conditions. In short, TSM&O is about doing more with less and documenting system benefits. M&O and ITS still play an important role as a sub-component in the TSM&O program and will be expanded upon in this document. The TSM&O programmatic graphic identified in **Figure 4** systematically evaluates all facilities and ensures that projects consider operational improvements prior to the traditional widening of infrastructure.

What is different about the TSM&O process?

1. The transportation system must be managed as a SYSTEM; and needs and priorities are based on quantified data. This will require collaboration and buy-in from all local agencies that determine any kind of project priority list. This corresponds to the first box of the diagram in **Figure 4**.

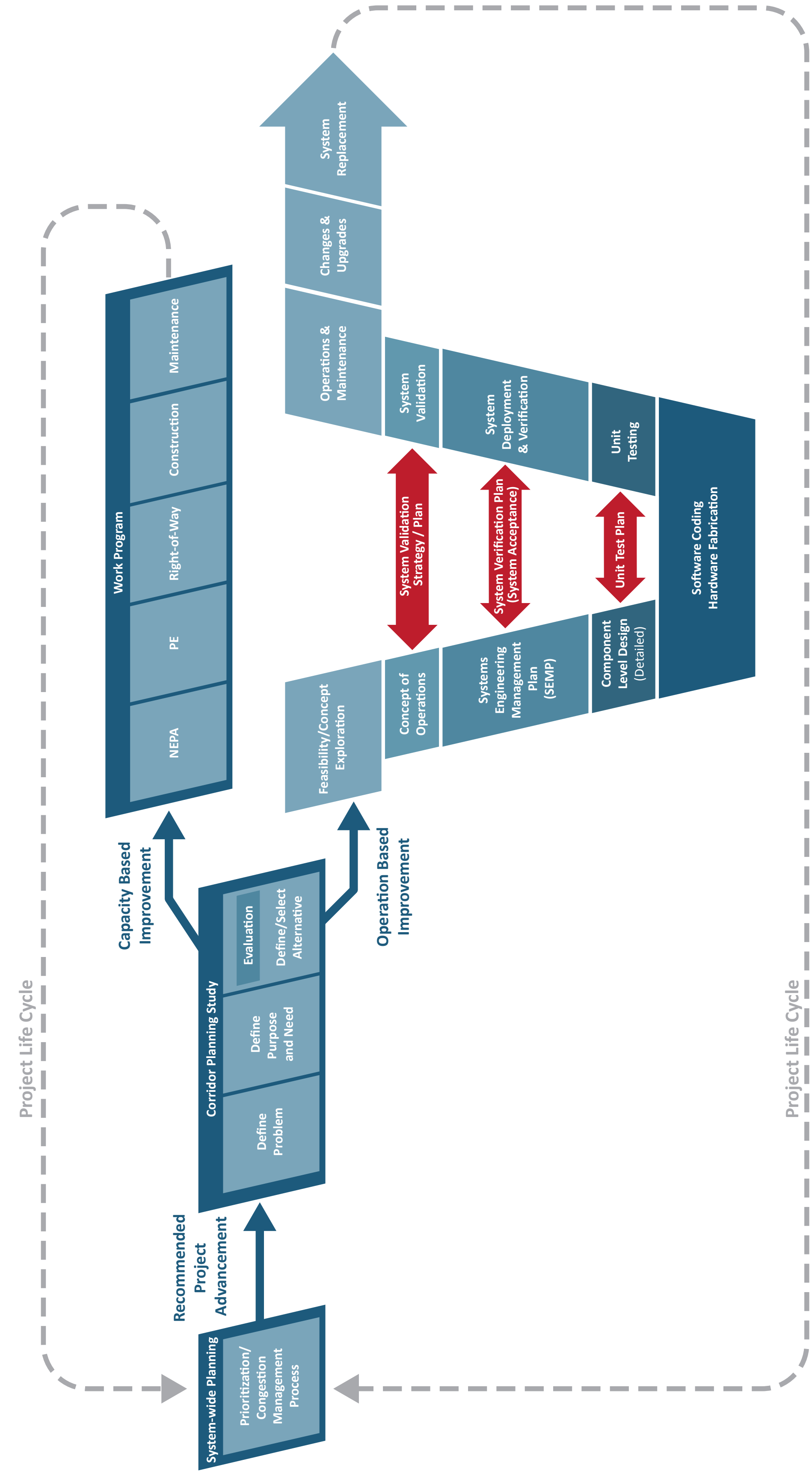

Figure 4: The TSM&O Planning and Project Development Lifecycle

2. Transportation practitioners will be asked to collaborate and provide input into stages of the project development, a process that was previously conducted independently from other groups. For instance, operations engineers will be new to the planning process, and planners will be new to the systems engineering process utilized for operational improvements.
3. The TSM&O program project development process is a cycle. Projects are not constructed and forgotten about, improvement strategies will be monitored post-construction to determine if the goals and objectives are being met, if the purpose and need is being fulfilled, and what the return on investment is for that strategy.
4. The program requires continued performance monitoring of the system and yearly (or more frequent) evaluations of priority project lists based on need.

1.2 Why Practice TSM&O?

TSM&O solutions are designed to address three major areas of concern in transportation: congestion, safety, and travel-time reliability. Funding at the national, regional, and local levels is currently being pipelined to address the aging infrastructure as needs are increasing faster than the funds can accommodate. Therefore, the appropriate expenditure of funds towards the applicable projects is more critical than ever. TSM&O confirms that projects advancing forward in the project development process have considered alternative strategies prior to implementing major capital improvements. The safety challenges presented by the increasing demand on the system, the growth in congestion, and the demand for more reliable networks, all present the need for a program specifically designed to address network safety, operations, and mobility of all modes of transportation.

The TSM&O program will address:

- Congestion
- Safety
- Travel-time reliability

Congestion

The U.S. Chamber of Commerce estimates that $78 billion is lost annually to delay and fuel due to the deteriorating transportation system.[6] Specific to freight movement, it was estimated that congestion added approximately $49 billion in operating costs to the trucking industry in 2014.[7] Congestion occurs when transportation demands exceed the available capacity of a facility for the various modes of travel including roadway, rail line,

The Cost of Congestion:
The U.S. Chamber of Commerce estimates that *$78 billion* is lost annually to delay and fuel due to the deteriorating transportation system.[6]

6 Transportation & Infrastructure, U.S. Chamber of Commerce, https://www.uschamber.com/issue-brief/transportation-101-series-0 Accessed April 26, 2016

7 Trucking Industry Congestion Costs Top $49.6 Billion in 2014, American Transportation Research Institute, http://atri-online.org/2016/04/19/trucking-industry-congestion-costs-top-49-6-billion-in-2014/ Accessed December 05, 2016

transit system, and bike and pedestrian facilities. Each mode of travel can contribute to the development of congestion in the overall trip process. As different types of congestion have different causes, it is imperative to understand the contributing factors to best manage the transportation system or network.

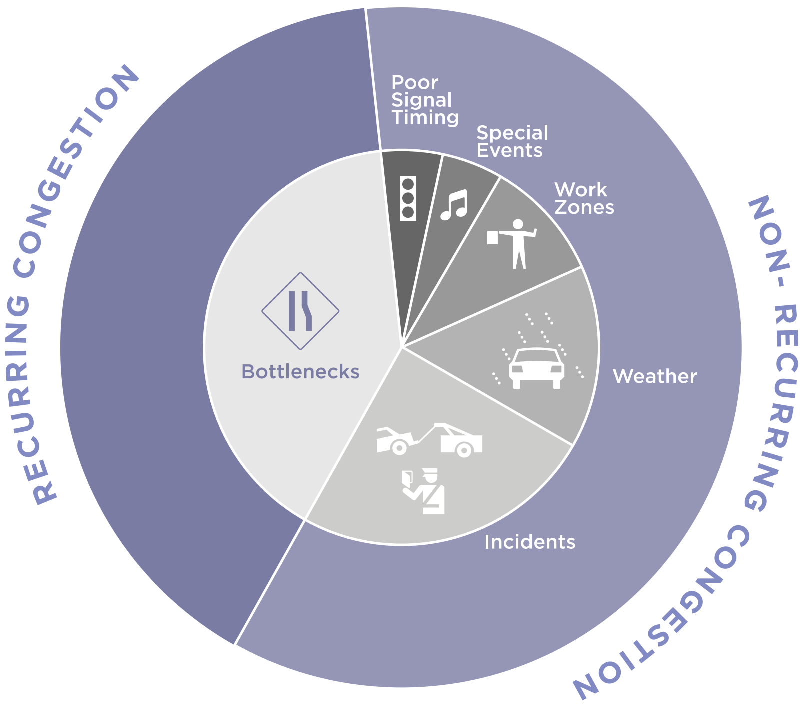

Figure 5: FHWA Causes of Highway Congestion[8]

Transportation congestion is defined as "recurring" or "non-recurring" congestion based on the root cause and the frequency by which it occurs. **Figure 5** illustrates the causes of congestion as identified by FHWA. Congestion is related to safety and travel-time reliability, described in detail below.

Recurring Congestion
- Bottlenecks
- Rush hour traffic
- Choke points on a roadway

Recurring Congestion - Recurring congestion is typically associated with common "bottlenecks" or locations where a decrease in roadway capacity causes delays on a recurring basis (for example, congestion identified on the same segment between 4:00 PM and 6:00 PM every typical weekday). Bottlenecks can occur at freeway lane drops, intersections, ramps, weaving segments, and at other places where capacity is reduced due to normal, day-to-day traffic operations.

Non-Recurring Congestion
- Weather delays
- Special Events
- Incidents
- Work Zones

Non-Recurring Congestion - Non-recurring congestion is caused by atypical events which result in demand exceeding capacity for temporary or ongoing conditions. These conditions may be related to demand spikes during special events, incidents which block roadway lanes, or unexpected weather events which reduce capacity, and temporarily cause a change in normal traffic patterns.

8 Traffic Congestion and Reliability, FHWA Office of Operations http://www.ops.fhwa.dot.gov/publications/fhwahop11034/ch1.htm. Accessed on April 21, 2016

The TSM&O program will focus on identifying areas of congestion, evaluating the cause, and developing solutions to address congestion. These solutions may be operational or capital improvements, or potentially a combination of both.

Safety

Enhancing the safety and performance of the roadway network is at the forefront of the national discussion on transportation. The need to eliminate the 30,000+ annual fatalities occurring on U.S. roads and highways is embodied by the FHWA's *Toward Zero Deaths*[9] program.

Some strategies, as a result of the TSM&O program's goal to address the safety conditions, are specifically designed to reduce the potential for crashes or to lessen the severity of these potential crashes. It is imperative for practitioners to collaborate on safety improvements and to consider the indirect impacts that create additional safety concerns.

9 *Toward Zero Deaths*, FHWA Office of Safety Programs. http://safety.fhwa.dot.gov/tzd/. Accessed on April 21, 2016

Travel-Time Reliability

Travel-time reliability is defined as the consistency or dependability in travel times, as measured from day-to-day and/or across different times of the day.[10] This reliability is not only important for the mobility of the traveling public on a daily basis; this is an important factor for freight, for those who manage supply chains, and for the trucking and shipping industry that depend on the reliability of the network. In other words, it is related to the degree of consistency at which the transportation system performs. In the last decade, emphasis has shifted from reporting "static" travel-time metrics, such as volume-to-capacity ratios or Level of Service (LOS), to focus on the reliability of travel-times over a long period of time. Travel-time reliability can be an important component of the LOS offered to motorists and transit riders. It is impacted by both recurring and non-recurring congestion. Through the TSM&O program, transportation practitioners can develop solutions that limit, and perhaps eliminate, the impact of these events on travel-times for recurring congestion.

The distinction between the TSM&O process and the existing project development process is the clarification and understanding of the transportation practitioner's role throughout the process.

1.3 How do we apply TSM&O?

Typically, project identification is coordinated early in the system-wide evaluation, as part of the planning process in the comprehensive plan or area-wide transportation evaluation. From this large-scale planning effort, specific projects are identified and advanced in the project development process for agencies. This is where the TSM&O program can provide the most significant benefit to the transportation project development process. Identifying the right solution for the appropriate congestion or safety project requires close coordination between multiple units and departments.

The remaining sections of this Guidebook provide guidance on "planning for operations" and how to integrate the TSM&O program into the transportation planning and project development process for transportation practitioners. The approach presented is general in nature and intended to be adapted and refined to meet the range of problems, needs, and goals and objectives of a regional transportation network. The intention of this Guidebook is to present practitioners with the information necessary to incorporate a TSM&O program into the overall process from system-wide planning evaluation, through the programming stage, and into the project development process.

10 Travel Time Reliability: Making It There On Time, All the Time, FHWA Office of Operations http://www.ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm. Accessed on June 14, 2016

2.0 Fundamentals of TSM&O

The overarching goal of TSM&O as defined by FHWA is "to optimize the performance of existing multi-modal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of our transportation system." This cannot be achieved by practicing TSM&O in a vacuum. As outlined through the remainder of this Guidebook, a TSM&O program must be integrated into all of an agency's existing processes.

2.1 Goals and Objectives

TSM&O spans from planning to operations.

As the Guidebook has identified the procedural challenges for the TSM&O program, it is important to determine goals, objectives and measures of success for each of the overarching factors (congestion, safety and travel-time reliability). Through collaborative discussions between the transportation planners, traffic engineers, and agency partners, a set of regional evaluation characteristics to identify the appropriate strategies should be developed. **Table 1** provides an example of what these could entail.

Reduce Congestion – Reducing vehicular demand and "taking back" the capacity lost to system inefficiencies or delay. Providing the public with mode choice through a complete and integrated multi-modal system can encourage shifts away from automobile travel. Effectively preserving capacity by reducing inefficiencies can improve mobility for users of the transportation system.

Improve Safety - Reducing the number and severity of conflicts between all modes of transportation, including vehicle, pedestrian, bicycle, transit, and freight. This includes providing adequate multi-modal facilities that enable the safe movement of people and goods.

Improve Travel-Time Reliability – Reducing the temporary effects of non-recurring congestion such as traffic incidents, work zones, weather, and special events. These non-recurring causes account for approximately half of congestion.

Table 1: Example TSM&O Program Goals & Objectives

PLANNING CONCEPT	OBJECTIVE	REFERENCE
Reduce Congestion	Identify priority of congested facilities within 12 months	Prioritized project list
	Reduce number of congested facilities by 10% in five (5) years	Reduce delay
		Provide mode choice
		Increase person throughput
Improve Safety	Reduce the number of crashes by 15% in five (5) years	Reduce conflicts
		Reduce severity of conflicts
	Create an Incident Management Program within 12 months	Development of traveler assistance programs
		Reduce clearance times
		Reduction of secondary crashes
Improve Travel-Time Reliability	Reduce delay by 5% in five (5) years	Consistent travel times
		Consistent average speeds on facilities

Beyond setting up the framework for achieving their individual goals and objectives, transportation agencies are also bound by legislation to establish and track performance measures that align with national performance goals for the Federal-aid highway program.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) of 2012 first established national goals, and has since been readopted as part of the Fixing America's Surface Transportation (FAST) Act of 2015.

These national goals are presented in **Table 2**, and are intended to result in more efficient investment of Federal transportation funds. They will also increase the accountability and transparency of the Federal-aid highway program and contribute to more informed decision-making. More details on performance monitoring and how it can be used to track progress toward these and other goals are included in section 2.4.3.

Table 2: MAP-21/FAST ACT National Goals

GOAL AREA	NATIONAL GOAL
Safety	To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
Infrastructure condition	To maintain the highway infrastructure asset system in a state of good repair
Congestion reduction	To achieve a significant reduction in congestion on the National Highway System
System reliability	To improve the efficiency of the surface transportation system
Freight movement and economic vitality	To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
Environmental sustainability	To enhance the performance of the transportation system while protecting and enhancing the natural environment
Reduced project delivery delays	To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices

Source: MAP-21 [§1203; 23 USC 150(b)], continued under the FAST Act, https://www.fhwa.dot.gov/map21/factsheets/pm.cfm

2.2 Solutions and Strategies

A TSM&O program should be developed to provide a systematic approach to providing solutions for area-wide or corridor-specific challenges. Strategies developed through the TSM&O program should be aligned to meet the goals and objectives identified by the practitioners that consider system improvements or corridor-facility improvements. While these strategies can be categorized by systems or corridor-facility improvements, the intent is to provide sustainable results that produce near-term solutions, without compromising the ability to meet future needs. The following defines the two main types of strategies that are illustrated in **Figure 6**:

System Improvements – Improvements that generally provide regional congestion or safety benefits to multiple roadways and/or intersections within a region or area. System improvements may include system-wide transit improvements, increased

The practice of TSM&O requires collaboration between transportation-related disciplines continuously throughout the process, where experts work together, not just to keep each other informed, but to create new value for system users.

system-wide ITS communications for incident management, or the introduction of traveler information systems.

Facility Improvements – Improvements that are applicable at the facility level to relieve congestion or improve safety conditions. These improvements can consider multi-modal improvements along identified corridors or intersections in order to address congestion, safety or travel time reliability issues. Corridor or facility improvements may include ITS-related enhancements, bicycle/pedestrian improvements, access management, or capacity improvements.

Figure 6: System-wide vs Facility-Specific Strategies

2.3 Roles and Responsibilities

Multidisciplinary collaboration is key to the success of a TSM&O program. As with most transportation programs, different parties are primarily responsible for different deliverables at various stages of a project. This section of the Guidebook provides an overview of the roles and responsibilities of various disciplines throughout the stages of a TSM&O program. As can be expected, the level of involvement of each discipline fluctuates over time; in one stage a certain discipline may be leading, and in another stage it may only provide support. Nevertheless, an effective TSM&O program maintains representatives from each discipline throughout the duration of the program. To better visualize the fluctuations in the involvement of each discipline, the Guidebook relies on a timeline graphic, depicted in **Figure 7**. Annotations on the graphic highlight specific steps, how they relate to larger efforts, and how it is envisioned that different experts would collaborate. The steps are categorized as follows:

Planning Phase: During the planning phase, important elements that will define potential strategies and alternatives are defined. These include developing system-wide goals and objectives, prioritizing projects, and refining purpose and need.

Project Development Phase: The project development phase follows the planning phase. It encompasses concept development, environmental documentation, design, construction, and testing.

Performance Monitoring Phase: After the completion of a project, it is recommended that performance monitoring be carried out to 1) assess whether the completed project's purpose and need have been fulfilled, and 2) to feed information into the next cycle of the TSM&O program.

As part of the discussion on roles and responsibilities, the Guidebook identifies three levels of involvement for the standard disciplines within transportation. These levels of involvement are based on the current phasing in the project lifecycle.

Lead: Under this level of involvement, the discipline(s) will be responsible for moving the project forward under the appropriate phases. The Lead discipline(s) are the experts and authority for their respective phase(s). The Lead is also responsible for the inclusion of other disciplines during this phase, when appropriate. For example, the Maintenance unit is responsible for leading a project that has entered the maintenance phase.

Contributor: For this level of involvement, the discipline(s) will play an active role in shaping the project during specific phases. While they are not leading the effort, they should play a key supporting role, either because of their prior experience or knowledge in another phase of the project, or because they will soon be the Lead in an upcoming phase. For example, Traffic Operations should be consulted during the planning phases of a project to both provide data and performance measures to the Planning unit and to express any concerns with alternatives or strategies under development by the Planning unit.

Engaged: Discipline(s) under this level of involvement should be periodically consulted during specific phases to ensure the project will not impede or adversely affect their own effort. While the involvement of Engaged disciplines is not required to see the completion of a given phase, consulting with these disciplines will likely lead to improved results over the project lifecycle, potentially even identifying fatal flaws early in the project lifecycle before it reaches them in a later phase. Engaged does not mean no involvement; rather, Engaged implies that the discipline does not need to actively contribute to the details of a project, but should still play a role in determining the approach and direction of a project. For example, the Design unit should still be engaged during the planning phase of a project because they can identify fatal flaws in the alternatives or strategies developed by the planning unit.

The rest of this section provides additional detail on the typical scope of each role, as well as clear action items that experts from these disciplines can take to enhance collaboration over the course of a TSM&O program.

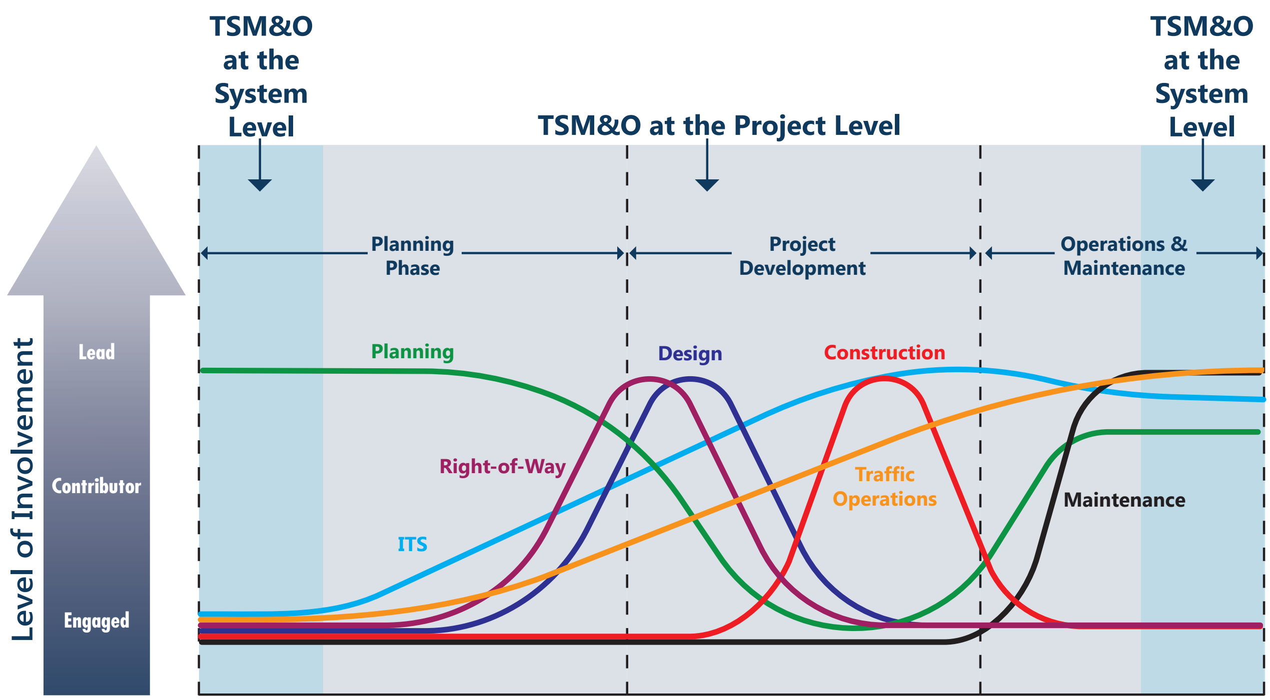

Figure 7: TSM&O Program Roles and Responsibilities at the System & Project Levels

Planning

The transportation planner is involved at both the system and project levels. Planning at the system level is usually led by an MPO or TPO, with input from local municipal planning departments, and support from the state planning agency. Systems-level planning involves the development of system-wide evaluations, long range plans, and congestion management plans. Planners also fulfill key roles at the project level by supporting planning-level traffic studies, concept development, ConOps, Systems Engineering Management Plans, ITS Master Plans, and the development of the performance metrics for monitoring purposes. The chart below shows the typical tasks of the planning role through the TSM&O lifecycle. Transportation planners are key to the success of the TSM&O program. They play important roles in the system planning, project development, and operations and maintenance stages.

Table 3: Planning Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	**System-Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Typical Tasks	Define goals and objectives Evaluate options Prioritize	Define the problem and evaluate alternatives		Coordinate with experts and maintain continuity			Validate performance measures	Evaluate strategy effectiveness	
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Incorporate technical expertise into the planning phase
- Base prioritization decisions on agreed-upon goals and objectives, expected outcomes, and known constraints
- Provide continuity throughout the TSM&O lifecycle by making data and communication available to all experts
- Monitor performance beyond the end of the TSM&O lifecycle to estimate project- and systems-level payoffs

DON'Ts

- Prioritize projects based solely on stakeholder pressure or anecdotal evidence
- Forget about the project after the planning-led efforts are complete
- Skip performance monitoring at the end of a project
- Forget to consider performance measures to incorporate real-time and long-term operational and safety goals

Traffic Operations

The TSM&O program requires involvement and coordination from traffic operations in the planning phase. During the planning phase, traffic operations professionals can provide input as a stakeholder and technical advisor. At the system-level, traffic operations staff can provide valuable access to data, provide technical assistance on system-wide improvements, and assist in the establishment of performance measures to be carried forward in the TSM&O lifecycle. In the project development process, traffic operations professionals can coordinate with transportation planners on the assumptions of the project prior to the design and implementation process. Similar to the planning phase, traffic operations professionals can work with transportation planners to monitor performance after a project is implemented. The chart below shows the typical tasks of the traffic operations role through the TSM&O lifecycle. Traffic operations provide technical expertise and valuable data to inform decision-making at the system and project levels.

Table 4: Traffic Operations Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	System-Wide Planning	Planning Study	Concept Development	Design	Construction	Testing	Operations	Monitoring	Maintenance
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Typical Tasks	Participate in the planning process and provide expert input	Collect / analyze data and communicate expected outcomes for each alternative	Work with planners to develop a feasibility assessment or ConOps		Maintain awareness		Actively monitor performance and operations of the system	Provide data and technical support for performance monitoring	
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Be engaged in the systems- and project-level planning efforts
- Use data analysis skills to compute and communicate performance measures that can inform the selection of alternatives
- Participate in operations and maintenance activities after projects are implemented

DON'Ts

- Wait for projects to be handed down from planning—by which time input would be less likely to be considered
- Neglect to consider a wide range of future scenarios when calculating performance measures
- Discard operational data—it can be valuable in future studies

ITS Engineering

The TSM&O program considers projects of different types and varying levels of complexity. For projects that incorporate ITS elements, the involvement of ITS engineers early in the process will help to identify implementable alternatives that are consistent with the Regional ITS Architecture (RITSA). During the early system planning stage, ITS engineers can also provide valuable access to data, lend their expertise on technology, and assist in the establishment of performance measures to be carried forward in the TSM&O lifecycle. In the project development process, ITS engineers can work with planners to develop feasibility assessments and ConOps reports. Finally, ITS engineers can work with transportation planners on the system verification and validation process that follows the completion of a project. The chart below shows the typical tasks of the ITS engineering role through the TSM&O lifecycle. ITS engineers can use their unique expertise to help identify and evaluate ITS alternatives at the system and project levels.

Table 5: ITS Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	**System-Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Typical Tasks	Participate in the planning process Provide expert input	Collect and analyze data Communicate expected outcomes for each alternative	Provide additional detail on the operational performance of different concepts		Maintain awareness		Monitor ITS deployments and assist in data collection	Provide data and technical support for performance monitoring	
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Be engaged in the system- and project-level planning efforts
- Provide timely and clear input on the advantages and disadvantages of different ITS technologies
- Encourage the use of the systems engineering approach to develop a management plan for the project
- Incorporate data quality control and assurance as part of ITS deployments
- Share data with other units

DON'Ts

- Wait for projects to be handed down from planning—by which time input would be less likely to be considered
- Let sporadic errors in the data prevent data sharing—simply document and caveat the inconsistencies
- Confuse data ownership with data integration—data can be stored in a central location yet the owner can maintain control over it

Right-of-Way (ROW)

ROW staff do not typically provide input at the systems level. However, ROW staff will typically be involved at the project level during the conceptual plan development as well as the project development phase. During conceptual plan development, ROW staff are consulted to determine the potential risk of various alternatives. In addition, ROW staff are significantly engaged during design for more detailed assessment of the ROW cost and acquisition implications. The chart below shows the typical tasks of the ROW role through the TSM&O lifecycle.

ROW staff can help planners and engineers avoid costly errors by providing early input on ROW constraints and cost estimates.

Table 6: ROW Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	**System-Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Typical Tasks	Maintain awareness of system-wide planning	Provide early input on ROW impacts of alternatives being evaluated	Perform detailed analysis of ROW impacts of the selected alternative		Maintain Awareness				
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Provide early input to planners and engineers to help estimate the ROW costs of different alternatives
- Perform ROW analyses at different levels of detail and accuracy to match the needs of different stages of the TSM&O lifecycle

DON'Ts

- Wait until the alternative selection process is complete to evaluate ROW impacts
- Forget about the project once the ROW-led parts are complete

Design

Design professionals play a key role in the project development process. As such, they are an important part of any TSM&O program. However the involvement of design professionals should go beyond the design stage; their expertise is hugely beneficial at the system-wide and concept planning stages. Design professionals can provide valuable input at the planning stages, and then proceed to lead the design of the selected alternative(s).

Similarly, design professionals can continue to contribute to a TSM&O program beyond the completion of final design plans. Providing support to the construction and maintenance roles can make their jobs easier—and can result in valuable feedback on the actual performance of a design. The chart below shows the typical tasks of the design role through the TSM&O lifecycle:

Table 7: Design Role in TSM&O

	PLANNING		**PROJECT DEVELOPMENT**				**O&M**		
Role	**System-Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Typical Tasks	Maintain awareness of system wide planning	Provide early input on ROW impacts of alternatives being evaluated	Perform detailed analysis of ROW impacts of the selected alternative		Maintain Awareness				
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Be engaged in the systems- and project-level planning efforts
- Understand the purpose and need on a system and project level
- Provide technical support during the construction and performance monitoring stages
- Design multimodal facilities
- Coordinate with functional experts, i.e. drainage, ITS, signal design, maintenance, or construction

DON'Ts

- Design in a silo—right-of-way and construction experts can offer valuable input
- Disconnect design goals from project objectives
- Forget about the project after final design is complete

Construction

The construction professional should be involved in a minor role as a stakeholder during early planning and concept development. It is important on critical projects for construction engineers to review project concepts for constructability concerns. Construction takes center stage during the build and implementation phase of the TSM&O lifecycle. The construction role is primarily responsible for implementing the design plans and/or the Systems Engineering Management Plan.

Note that the construction role is not limited to the construction of roadway infrastructure but may include the installation of ITS equipment, the development of ITS software applications, or signal re-timing. This role includes testing or inspecting the newly-built project to ensure that it performs as expected. The chart below shows the typical tasks of the construction role through the TSM&O lifecycle.

Table 8: Construction Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	**System Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Typical Tasks	Maintain awareness of planning efforts		Aid planners and designers in gauging the constructability and cost of alternatives		Carry out the design plans and Implement the Systems Engineering Management Plan (if any)	Unit test to catch bugs and deficiencies and verify that the work meets the intended purposes	Maintain awareness		
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead

DO's

- Maintain base technical knowledge of different functional specialties, e.g. drainage, ITS, signal design, maintenance, or roadway design
- Share hands-on expertise with planners and traffic operations/design engineers early on
- Review the work done in the feasibility and concept exploration stages
- Adhere to principles of Systems Engineering: performing decomposition and definition first, and integration and verification afterwards

DON'Ts

- Wait until the final design plans arrive to provide constructability advice
- Wait until the work is fully finished to start testing: unit testing can catch errors when they are still easy to address

Maintenance

The maintenance role is critical in both the system and project levels of the TSM&O program. As a stakeholder at the system level, maintenance staff can provide valuable information on the state of the physical system. Maintenance staff can contribute during all stages of the TSM&O program by providing asset management and data expertise. They are primarily responsible for maintenance and upkeep needs after a project is complete.

At the project level, it is critical to engage maintenance staff in the planning phase to understand maintenance and regional architecture from a condition and asset management perspective. The maintenance role then takes the lead in keeping the newly built facilities in optimal conditions. Lessons learned by maintenance staff can also be valuable to future decision-makers as they seek to select the most cost-effective alternatives over a project's lifecycle. The chart below shows the typical tasks of the maintenance role through the TSM&O lifecycle.

Table 9: Maintenance Role in TSM&O

	PLANNING		PROJECT DEVELOPMENT				O&M		
Role	**System Wide Planning**	**Planning Study**	**Concept Development**	**Design**	**Construction**	**Testing**	**Operations**	**Monitoring**	**Maintenance**
Planning	Lead	Lead	Lead	Engaged	Engaged	Engaged	Contributor	Lead	Engaged
Traffic Operations	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
ITS	Contributor	Contributor	Contributor	Contributor	Engaged	Contributor	Lead	Contributor	Engaged
Right-of-Way	Engaged	Contributor	Contributor	Contributor	Engaged	Engaged	Engaged	Engaged	Engaged
Design	Engaged	Contributor	Contributor	Lead	Contributor	Contributor	Engaged	Engaged	Engaged
Construction	Engaged	Engaged	Engaged	Engaged	Lead	Lead	Engaged	Engaged	Engaged
Maintenance	Engaged	Engaged	Engaged	Engaged	Engaged	Engaged	Contributor	Contributor	Lead
Typical Tasks	Maintain awareness of planning efforts, contribute asset management expertise, and provide operational data			Maintain awareness			Coordination and support on maintenance duties		Perform maintenance duties

DO's

- Provide input on maintenance costs during the alternative analysis and feasibility stages
- Use asset management knowledge to improve understanding of existing conditions

DON'Ts

- Discard maintenance data—it can be valuable in future studies
- Let sporadic errors in the data prevent data sharing—simply document and caveat the inconsistencies
- Confuse data ownership with data integration—data can be stored in a central location yet the owner can maintain control over it

Key Concepts
- Stakeholder coordination
- Economic analysis
- Performance

Identify stakeholders that may include
- Internal DOT units
- Public safety agencies
- Local governments
- TPOs and MPOs
- General public
- Private sector

2.4 Key Concepts

The TSM&O program provides a programmatic approach to developing system-wide and corridor-/facility-specific strategies. In order to achieve a successful TSM&O program, the approach must incorporate stakeholder input, consider the economic return on investment, and determine a mechanism to monitor the success or impact of the strategies.

Stakeholder Coordination

The planning for TSM&O program is a stakeholder-driven process, with engagement being a critical part in every stage of the process. Stakeholder coordination is emphasized as one of the six dimensions of the CMF. The CMF's Collaboration dimension encourages maintaining effective communication with public safety agencies, local governments, MPOs/TPOs, and the private sector. For the sake of simplicity, all these organizations are referred to as stakeholders in this Guidebook. Before attempting to create a foundation for stakeholder coordination, a number of TSM&O myths and misconceptions must first be addressed with potential stakeholders:

Myth 1 **TSM&O is just ITS -** For various reasons, TSM&O programs in many jurisdictions have gravitated toward autocentric ITS deployments. FHWA's definition of TSM&O, and the guidance contained herein, encourages multimodal systems, services, and projects.

Myth 2 **TSM&O is not "ribbon cutting" material -** Related to the point above, misconceptions about TSM&O result in many decision-makers viewing it as "back of house," highly technical operations. In reality, strategies developed by TSM&O include high-profile and multimodal systems, services, and projects - such as new premium transit options, bicycle and pedestrian infrastructure, or traveler information services.

Myth 3 **TSM&O benefits are smaller than automobile capacity expansion -** Although the benefits of a single TSM&O-generated project may pale in comparison to benefits from a multi-billion dollar capacity expansion project, a multi-billion dollar package or suite of TSM&O projects may be more beneficial than a similarly priced capacity expansion project.

Once these concerns have been addressed, a foundation for successful stakeholder coordination is more likely to take root. Building this foundation must be part of any TSM&O program. This may be done by creating forums for effective communication, including email mailing lists, committees, workshop series, websites, or other digital and physical communication channels. A well-defined stakeholder coordination plan can support system plans and project-level studies from their very beginnings. They can also serve to facilitate collaboration with stakeholders to assess outcomes and quantify the return on investment once the projects have been implemented.

Another important goal of a stakeholder coordination program is to help the project team build and document consensus among stakeholders at major milestones. Given the complexity and long timelines of certain transportation projects, it is essential that "checkpoints" be established along the way. The checkpoints can help safeguard work in progress by maintaining proof of buy-in. However, for these checkpoints to be valid, meaningful engagement of all stakeholders—other functional units, relevant agencies and organizations, elected officials, the public, etc.—is critical. Public involvement guidance and tools are available to help TSM&O practitioners maintain meaningful engagement. The following section describes and references these resources.

Public Involvement

The FHWA Office of Planning, Environment, & Realty offers guidance and techniques for effective public involvement for transportation decision-making. Some of the public involvement guidance presented by FHWA overlaps with the stakeholder coordination needs of a TSM&O program:

- Outreach to all potential participants from transportation agencies and public groups leads to representation from broad segments of the communities that the project would serve
- Coordination must begin with clearly-defined goals that focus on the specific issues to be addressed, the types of input needed, and the sectors of the public that need to be involved
- Most importantly, understanding and accommodating the various ways people interact with each other is the major element of working together toward common goals

This guidance does not constitute a separate or new public involvement process, as most agencies already have established policies and procedures. The emphasis for the TSM&O program is that it is critical that the correct stakeholders are identified for each phase of the process. For example, a system-wide congestion management plan (CMP) has a process which involves the appropriate planning organization committees (e.g., Technical Advisory Committee, Citizen Advisory Committee, MPO Board, or additional public committees). Furthermore, the public or stakeholder involvement process during the project development process should be consistent with the maintaining agency's protocol.

Economic Analysis

Economic analysis is a critical tool for understanding the lifecycle benefits and costs of proposed projects and strategies. The primary tool for economic analysis is benefit-cost analysis, in which market values are used to identify tradeoffs between measures such as cost, travel-time reliability, safety, and environmental effects. As benefits and costs are measured in fixed units (dollars), benefit-cost analysis is a scalable performance measure that can provide an "apples-to-apples" comparison across projects of all sizes, from small maintenance efforts to system-wide baskets of projects.

Benefit-Cost Analysis

Benefit-cost analysis can be performed to prioritize strategies or project alternatives by evaluating the project's benefits—measured using metrics that capture the objective(s) of the project as well as potential peripheral benefits (or negative impacts)—against the project's cost. A project's cost typically includes capital, operational, and maintenance costs over the life of the project. A benefit-cost analysis of different alternatives to reduce congestion on a busy corridor may result in a table such as the one shown in **Table 10**.

Table 10: Illustrative Example of a Benefit-Cost Analysis

ALTERNATIVE	BENEFITS[1]	COSTS[2]	B/C[3]	NPV[4]
Do Nothing (Base case)	None	None	N/A	N/A
Widen Roadway (Alternative 1)	$$$$	$$$$	~1.0	-
Install Coordinated, Adaptive Signals (Alternative 2)	$$$	$$	~3.0	$$
Improve Transit Service (Alternative 3)	$$	$	~2.0	$

1 User and non-user benefits over the course of the analysis' lifecycle. Travel-time savings typically account for a majority of user benefits. Other benefits—e.g., travel-time reliability, health, and car ownership benefits—should be included, although they may be difficult to price accurately.

2 User and non-user costs over the course of the analysis' lifecycle. Some costs—especially environmental costs—are difficult to quantify.

3 Benefit/Cost Ratio, a normalized measure of an alternative's effectiveness.

4 Net Present Value, an absolute measure of an alternative's impact.

Benefit-cost analysis is well-documented, and a variety of resources and software tools are available to assist in crafting approaches. Some available resources for benefit-cost analysis are described in Appendix A.

Incorporation of Lifecycle Costs - O&M Considerations

A comprehensive economic analysis should also include lifecycle impacts with respect to both capital and O&M costs. As an example, a shortsighted benefit-cost analysis may include the costs of construction, but not the costs of operation and maintenance through the project's lifecycle. In addition, oftentimes the analysis may not include the effort needed to retire a solution at the end of its useful life. Similarly, the benefits experienced by various parties should be monetized over the life of the project. A common tool used to visualize lifecycle benefits and cost is the cash flow diagram, shown in **Figure 8** as it applies to a hypothetical TSM&O strategy. In this example, the cost is illustrated for the initial cost of the improvement, as well as the ongoing maintenance cost. Furthermore, the cash flow analysis should incorporate the revenues generated over the lifecycle, as well as the salvage value of the improvement.

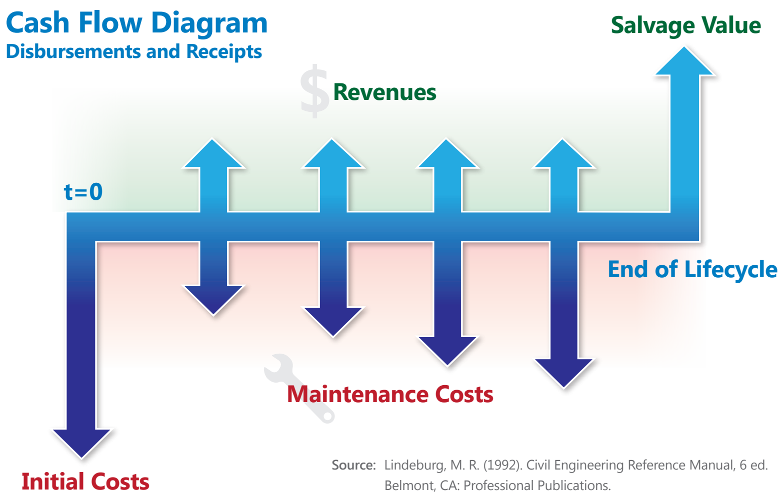

Figure 8: Sample Cash Flow Diagram

A funding source may vary at different stages of a project's lifecycle, it is important to differentiate between capital, operational, and maintenance costs when a net present value is computed. Quantifying the magnitude of the operational and maintenance costs at the onset of a project—and allocating sufficient budget to cover them—can help in funding critical maintenance efforts years down the road.

It is common for large infrastructure projects to have a separate funding source for its capital costs (e.g. Federal or state) and another funding source for its operation and maintenance (e.g., local sources). A lifecycle benefit-cost analysis can help quantify how much funding would be needed from each source throughout the project's life.

Figure 9 illustrates a fictional project's lifecycle investment, showing both capital and O&M costs. In this example, the FY 2017 construction cost of $1M is funded using Federal or state funds, but subsequent O&M costs must be covered by the municipality in which the project is located. It can also be noted that O&M costs increase over the lifecycle of a project. This typically results from a combination of inflation and higher maintenance needs due to the aging of infrastructure. Further down the project's lifecycle, higher-than-normal expenses may be incurred if rehabilitation is needed. A TSM&O program should encourage the accurate estimation of both magnitude and timing of O&M costs, with the intent of making "apples-to-apples" comparisons of net present values and benefit-cost ratios across multiple project alternatives.

Regular O&M costs include the costs associated with operating and maintaining an asset.

Replacement O&M costs consist of the cost of replacing an old or out of use asset.

Figure 9: Example Work Program Funding by Year

O&M costs vary significantly

When comparing different TSM&O strategies, it is important to keep in mind that O&M costs can vary significantly as shown in **Table 11**.

Table 11: Example O&M Cost Thresholds

COSTS	LOW	MEDIUM	HIGH
Operational	Roundabouts	Ramp Metering	Congestion Pricing
Maintenance	Park and Ride	Arterial Geometric Modifications	Managed Lanes

Lifecycle varies significantly

When comparing different TSM&O strategies, it is important to keep in mind that lifecycle thresholds can vary significantly as shown in **Table 12**.

Table 12: Example Lifecycle Thresholds

SHORT (1-3 YEARS)	MEDIUM (3-15 YEARS)	LONG (15+ YEARS)
Work zone management Special event management Traffic signal re-timing	Bus rapid transit Variable speed limits/ speed harmonization Hard shoulder running	Heavy rail transit (e.g., subways) Roundabouts Arterial geometric modifications

Performance Monitoring

Relevant data sources may include:

- Crash History
- Sensor Data
- Vehicle Probe Data
- Statewide Roadway Characteristic Inventory

The importance of incorporating system performance into the planning process continues to grow as federal and state funding becomes more connected to performance. MAP-21 first established the performance-based planning requirements in 2012, including setting state targets and reporting back system performance to federal agencies. The FAST Act (2015) continues this emphasis on performance measures. Overall, the FAST Act largely maintains MAP-21's program structures and funding shares between highways and transit. The law makes changes and reforms to many federal transportation programs, including streamlining the approval processes for new transportation projects, providing new safety tools, and establishing new programs to advance critical freight projects.[11]

11 FHWA, Fixing America's Surface Transportation Act. https://www.transportation.gov/fastact/, accessed on April 14, 2016.

Performance measures are quantifiable or qualitative indicators used to assess progress towards achieving desired goals and objectives. Performance measures provide an efficient way to provide information to decision-makers by translating the technical analyses—using tools and data—into a consistent and understandable format.

Performance measures are applied at every stage of the decision-making process from planning to programming to project development and construction. These are directly related to the goals and objectives characterized by the measures of success, such as the example given in **Table 1** (page 18). By monitoring the performance of the system, prior to, during, and after improvement alternatives are implemented, practitioners are able to verify that the goals and objectives were achieved and to determine the benefit of the improvement.

As mentioned earlier, the engagement of experts and stakeholders throughout the TSM&O program is vital to its success. This notion is embodied by the concept of data sharing and data management. Smart data management enables a multitude of opportunities, including public outreach, asset management, and better decisions based on information from complementary sources. Other benefits of data management are summarized in Chapter 4 of the FHWA's Data Integration Primer.[12] The rest of this FHWA reference document provides valuable advice on why data management is important and how to integrate and maintain data.

Risk Assessment

Similar to the traditional project development process, risk is monitored for awareness on the project level and program level. Risk identified within the project development lifecycle process is important to understand and document in the ConOps and SEMP reports. In order to identify these risks early in the process, it is essential for transportation planners and traffic operations engineers to collaborate during the Planning Stage. Projects with identified risk at the Planning Stage can provide an awareness of the issues and challenges in order to make early decisions on the advancement of the system or corridor-specific project. In addition to the risks identified within the project development lifecycle process, there are also risks associated with the TSM&O framework.

Each of the six dimensions have potential risk association, and the following highlights several key aspects of risk associated with the Capability Maturity Framework model.

Business Process – Minimizing risk with thorough scoping and budgeting of projects. By defining and adopting the business model for the TSM&O program, transportation

MAP-21 and FAST Act Performance Measures

- Travel time reliability
- Peak hour travel time
- Annual hours of excessive delay per capita
- Percent of mileage uncongested
- 2 and 4-year total emission reductions
- Crash frequency, severity, and rates
- Percentage of pavement and bridges in good and poor condition

Source: National Performance **Management Measures:** Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program, April 2016 (https://www.regulations.gov/document?D=FHWA-2013-0054-0092)

12 Data Integration Primer, FHWA Asset Management (August 2010). https://www.fhwa.dot.gov/asset/dataintegration/if10019/dip00.cfm. Accessed on April 14, 2016

professionals would have a clear understanding of roles, responsibilities and procedural protocol for the advancement of project development.

Systems & Technology – Risk is highly increased within this dimension when systems and standards are not well-defined. The TSM&O program attempts to minimize risk associated with systems through pre-established and interoperable technology. In addition, to minimize this dimension, professionals must simultaneously focus on the collaboration dimension as interagency collaboration is often a key component of technology standards alignment.

Performance Measurement – Through the use of data acquisition and technical analysis, transportation professionals can identify system-wide and corridor-specific risk. The continued or lifecycle monitoring of performance measures provides a mechanism to identify and minimize risk opportunities on future project development opportunities.

Culture – The Culture dimension is an obvious, but extremely critical, area to minimize risk. It is imperative for all levels within an agency to have a foundational understanding of the TSM&O program and more importantly have a commitment to advance the program. With the need for "buy-in" from internal staff and external agencies, the early commitment from leadership will reduce the associated risk.

Organization & Workforce – As in the Culture dimension, to identify and minimize the organizational friction, the TSM&O program should be clearly defined to explain how the program is integrated into the existing structure. With the clear identification of how the TSM&O program is ingrained into the structure, the desire is to increase the stability of staff retention by minimizing the inefficiency of staff responsibility.

Collaboration – Risk is increased when projects are developed in silos. Therefore, the TSM&O program embraces the fostering of relationships between all public safety agencies, local governments, MPOs, and the private sector.

2.5 The Importance of a TSM&O Champion

It is hard to overstate the importance of a "project champion" in the success of a project. The project champion is an individual who takes on the responsibility of engaging key stakeholders, building consensus, and keeping the project moving through completion.

An ideal project champion is someone who is passionate but level-headed, who is open to feedback but decisive when decisions must be made, and who is familiar with all technical aspects of the project but can step back and expertly manage the project. Due to their involvement in early project stages, planning and traffic operations professionals—

particularly senior-level individuals—are in excellent positions to take on the role of project champion.

Figure 10: TSM&O Champion Role

What is the tie that binds the key concepts of a TSM&O program?

- A TSM&O Champion!

2.6 What's Next?

This chapter covered the fundamentals of the TSM&O program, including answers to basic questions about such a program:

- Why? - Goals and Objectives
- What? - Solutions and Strategies
- Who? - Roles and Responsibilities

The next two chapters cover the "How": the mechanics of applying the key concepts to make TSM&O work at both the system level (Chapter 3) and the project level (Chapter 4).

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3

3.0 TSM&O in the System-Planning Process

This chapter provides guidance on incorporating TSM&O into existing system-planning processes. Existing system-planning processes are being performed by agencies across the country and include Congestion Management Processes (CMP), Long Range Transportation Plans (LRTP), Work Program Development, State of the System reviews, and others. Over the past few decades, federal transportation laws have evolved to require performance-based planning and programming (PBPP) in the development of these system plans. Agencies are encouraged to engage in PBPP activities with the support of a robust and mature TSM&O program.

As illustrated in **Figure 11**, the system-planning process is the first step of a comprehensive TSM&O program. The purpose of a system-planning evaluation is to identify locations experiencing congestion, safety, or reliability issues. By benchmarking system conditions against agreed-upon performance measures, a system can be classified by its ability to meet desired performance targets.

Furthermore, transportation professionals have the ability to leverage system-wide data to help make informed decisions on which projects to advance to the next stage of the TSM&O program. In addition, system-wide results can be used to estimate needs at a more granular level—such as a bus stop, an intersection, or a corridor.

The purpose of a system-planning evaluation is to identify locations experiencing congestion, safety, or reliability issues.

The rest of this section discusses how TSM&O considerations can be part of these performance-based system-planning activities.

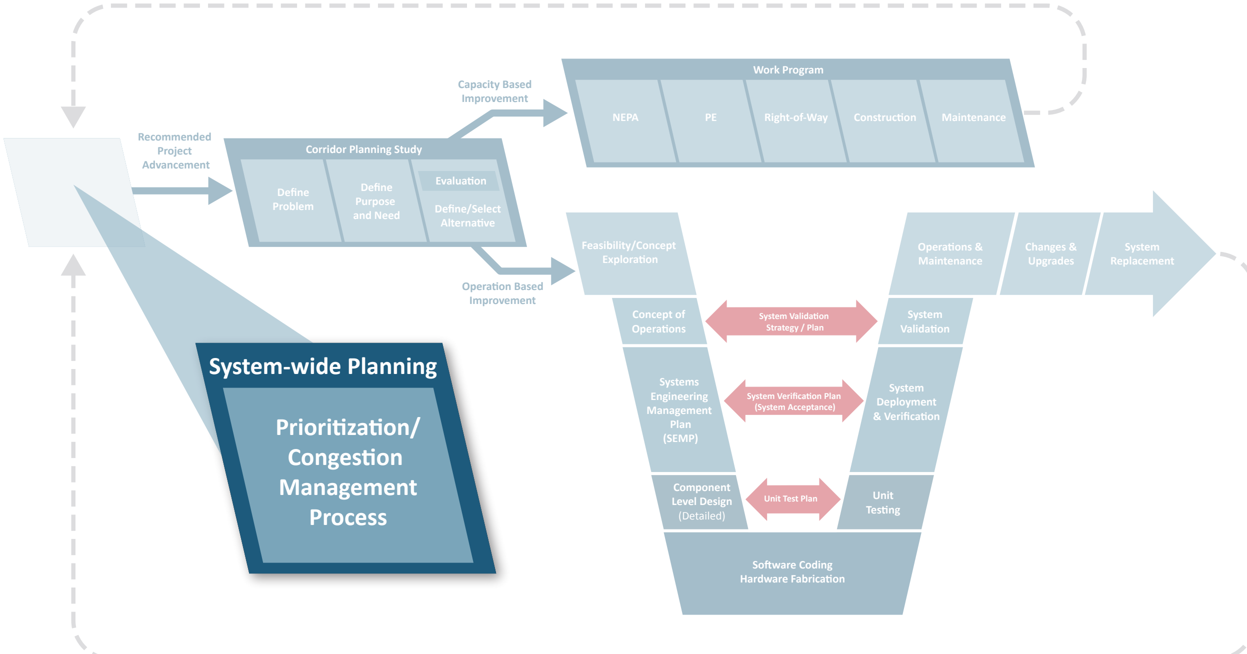

Figure 11: TSM&O at the System Level

3.1 Background on System Planning

System planning can take different forms depending on the purpose of the organization doing the planning, its legislative mandates, and its goals and objectives. Examples of system plans include:

- Congestion Management Process (CMP)
- Freight Mobility Plans
- Long Range Transportation Plan (LRTP) (also known as Regional Transportation Plan [RTP])
- Transportation Improvement Program (TIP)
- Transit System Plans and Transit Development Plans
- Bicycle and Pedestrian Master Plans
- Vision Zero Plans
- Community Transportation Coordination

More detailed information on establishing a Congestion Management Program can be found in FHWA's Congestion Management Process: A Guidebook FHWA-HEP-11-011.

Despite the different types and complexities of system plans, they all share certain characteristics, including:

- Creating consensus on system goals and objectives
- Selecting performance measures which can track progress toward those goals and objectives

- Identifying and assessing potential strategies to achieve stated goals and objectives
- Prioritizing the implementation of those strategies using robust data, expected outcomes, and known constraints

The following sections illustrate how the TSM&O program can be strategically leveraged to improve system planning. By understanding how the TSM&O program fits within system plans, transportation agencies can have a better grasp of their system, effectively prioritize projects, and implement strategies that go beyond capacity expansion and include operations, ITS, or demand management.

Interdisciplinary collaboration is a key part of incorporating TSM&O into system planning. Since system planning is conducted at the beginning of the process, input from traffic operations, design, construction, and maintenance professionals can be considered and acted upon without disruptions to a project development schedule. The transportation planner is in an ideal position to lead the system-planning process and solicit input from these experts, as well as from a broader set of community stakeholders. As illustrated in **Figure 12**, the planner's role typically decreases through the design and construction phases of an individual project. The planner usually reclaims the lead role when evaluating the project's performance at the end of the TSM&O lifecycle.

A system-planning process that does not consider TSM&O strategies at critical decision points will be heavily weighted towards capacity expansion, missing out on or under-valuing strategies which may be more cost-effective and adhere better to stated goals and objectives.

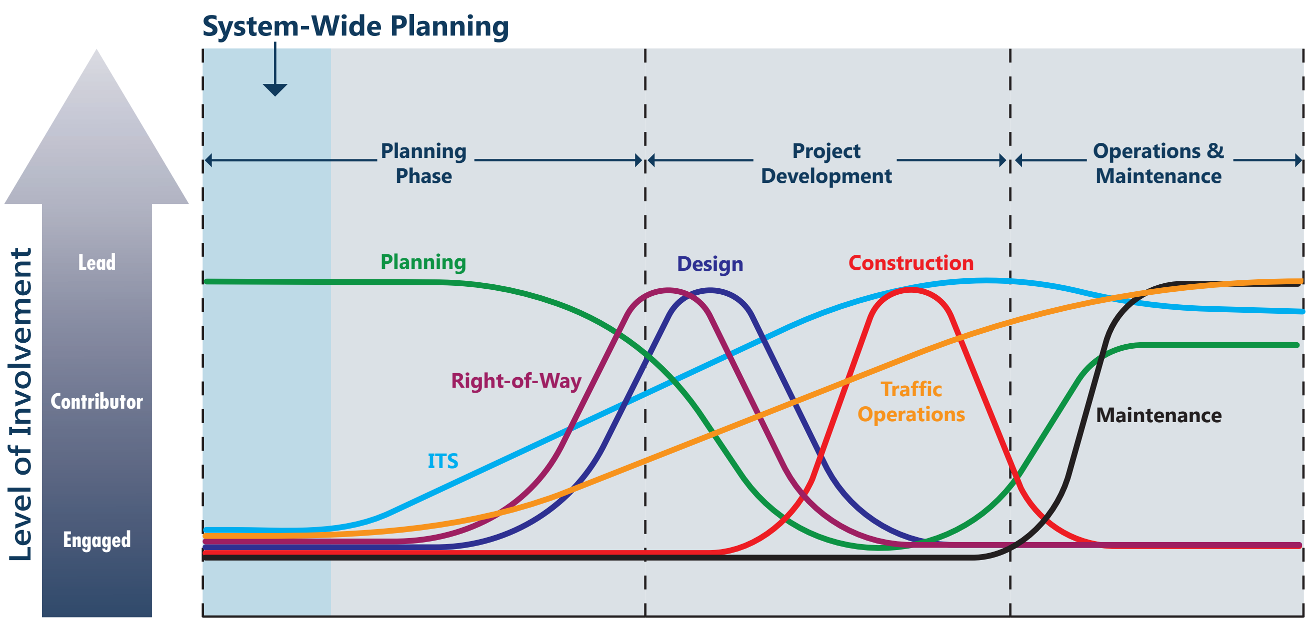

Figure 12: Discipline Roles in the TSM&O Process

3.2 Goals and Objectives

Compared to general policy statements or principles, outcome-oriented goals are encouraged to set strategic direction, answering questions like:

"What do we want our area to look like?"

"What do we want to achieve?"

Ask yourself:

"Do your goals communicate the region's vision for congestion, safety, and reliability?"

"Do your goals address multiple modes?"

"Are your goals outcome-oriented?"

In order to successfully incorporate the TSM&O program, agencies need to implement effective performance-based planning practices, starting at the system-level. System planning is based upon goals and objectives established by a region to represent its desired outcomes. Goals set strategic priorities about what is important to a region and serve as a basis for developing more detailed objectives, corresponding performance measures, and targets. Since goals reflect agreed-upon system-wide priorities, stakeholder collaboration and coordination is essential in the process of establishing goals, objectives, and performance measures.

Goals developed in this manner form the basis for selecting investments, policies, or activities to help support the attainment of a region's desired outcomes. Federal law requires the use of a performance-based approach to support seven national goals for the transportation system. These goals serve as an important basis for developing goals for any transportation planning agency.

National Goals for the Federal-aid Highway Program (23 USC Section 150(b))

1. **Safety** - To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
2. **Infrastructure Condition** - To maintain the highway infrastructure asset system in a state of good repair
3. **Congestion Reduction** - To achieve a significant reduction in congestion on the National Highway System
4. **System Reliability** - To improve the efficiency of the surface transportation system
5. **Freight Movement and Economic Vitality** - To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development
6. **Environmental Sustainability** - To enhance the performance of the transportation system while protecting and enhancing the natural environment
7. **Reduced Project Delivery Delays** - To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices

Table 13: Example goals from Mississippi DOT's MUTLIPLAN 2035

GOAL	DESCRIPTION
Accessibility and Mobility	Improve Accessibility and Mobility for Mississippi's People, Commerce, and Industry
Safety	Ensure High Standards of Safety in the Transportation System
Maintenance and Preservation	Maintain and Preserve Mississippi's Transportation System
Environmental Stewardship	Ensure that Transportation System Development is sensitive to Human and Natural Environmental Concerns
Economic Development	Provide a Transportation System that Encourages and Supports Mississippi's Economic Development
Awareness, Education, and Cooperative Process	Create Effective Transportation Partnerships and Cooperative Processes that Enhance Awareness of the Needs and Benefits of an Intermodal System
Finance	Provide a Sound Financial Basis for the Transportation System

Distinguished from a goal, an objective is a specific, measurable statement or tactic that supports the achievement of a goal. Example goals are listed in **Table 13**. The process of establishing objectives may start out general (e.g., improve system reliability) and evolve over time to be more specific, measurable, and bound to time (e.g., reduce the person hours of total delay on highways and major arterials associated with traffic incidents by X percent over Y years). Ideally, objectives should have "SMART" characteristics as defined below:

"SMART"
- **S**pecific
- **M**easurable
- **A**greed
- **R**ealistic
- **T** ime-Bound

Specific - Objective provides specificity to guide formulation of viable approaches to achieve the objective without dictating the approach

Measurable - Objective facilitates quantitative evaluation. Tracking progress against objectives enables an assessment of effectiveness of actions

Agreed - Planners, operators, and relevant planning partners come to consensus

Realistic - Objective can reasonably be accomplished within limitations of resources. Factors such as population growth, economic development, and land use may have an impact on the feasibility of the objective. Based on system performance data and analysis, the objective may need to be adjusted to be achievable.

Time-bound - Objective identifies a timeframe within which it will be achieved (e.g., "by 2025")

Meaningful objectives are linked to performance measure targets and supported with data collection in order to measure progress over time.

Objectives may also have different hierarchies and may be outcome-, output-, or activity-based. Multiple types of objectives may be useful depending on the planning activity. All activity-oriented objectives should support outcome-oriented objectives, providing a simple check to make sure that they support a system performance outcome. Again, and most importantly, the SMART objectives should be developed through close collaboration between transportation planners and traffic operations engineers. This early collaboration on what the system- or facility-desired outcomes should be can minimize future risks and increase the overall efficiency of project development. Descriptions of outcome-, output-, and activity-based objectives are listed in **Table 14.**

Table 14: Example Objectives Based on Outcome, Output, and Activity

OBJECTIVE	DESCRIPTION	EXAMPLE
Outcome	Reflect concerns of the public, customers, or stakeholders; these objectives are often the most meaningful to the public and relate most directly to system goals; however, they may be influenced by the range of factors beyond the control of transportation agencies.	Reduce hours of incident-based delay experienced by travelers
Output	Reflect quantity of activities that affect outcomes, and may be more directly influenced by a transportation agency (although they also may not be entirely in the control of the agency).	Reduce the clearance time for traffic incidents (For incident clearance the transportation agency would need to work with law enforcement, etc.)
Activity	Reflect actions that are taken by transportation agencies. These are less directly tied to the outcome, and often directly relate to a strategy being implemented.	Increase the number of cameras tracking system conditions

Source: FHWA-HEP-13-041, "Performance Based Planning and Programming Guidebook." 2013

Ask yourself:

"Are your objectives outcome-oriented?"

"Do your objectives support the achievement of your goals?"

"Do your objectives lead to or establish relevant performance measures?"

Other dimensions that may be considered in developing objectives include:

- Types of travel affected (e.g., passenger, freight)
- Mode (e.g., highway, transit, bicycle, pedestrian, intermodal)
- Geography (e.g., metropolitan area, rural area)

Like regional goals, SMART objectives should be developed through close collaboration with all stakeholders. This early collaboration can minimize future risks and increase the overall efficiency of project selection, project development, and performance monitoring through the lifecycle of a project. Example SMART objectives are provided in **Table 15**.

The incorporation of goals and objectives that are consistent with the TSM&O program will open up more opportunities to pursue cost-effective solutions or strategies that can be implemented more quickly.

Table 15: SMART Objectives

MOBILITY	
Vehicle Miles Traveled	Reduce vehicle miles traveled per capita by X percent by year Y
Trip Connectivity	Reduce door-to-door trip time by X percent by year Y
SAFETY	
Pedestrian Fatalities	Reduce pedestrian fatalities by X percent by year Y
Intersection Crashes	Reduce serious (fatal/incapacitating injury) intersection crashes by X percent by year Y
RELIABILITY	
Non-Recurring Delay	Reduce total person hours of delay (or travel-time delay per capita) by time period (peak, off-peak) caused by: (Option 1) scheduled events, work zones, or system maintenance by X hours in Y years (Option 2) unscheduled disruptions to travel by X hours in Y years. (Option 3) all transient events such as traffic incidents, special events, and work zones by X hours in Y years
Travel Time	Reduce the average of the 90th (or 95th) percentile travel times for (a group of specific travel routes or trips in the region) by X minutes in Y years.
Transit On-Time Performance	Improve average on-time performance for specified transit routes/facilities by X percent within Y years.

Note: Adapted from FHWA's Performance Based Planning and Programming Guidebook, FHWA-HEP-13-041 and FHWA's Incorporating Travel-Time Reliability into the Congestion Management Process (CMP): A Primer (FHWA-HOP-14-034)

When selecting performance measures to address your region's congestion concerns, the four factors of congestion should be considered:

1. **Intensity -** Severity of congestion
2. **Duration -** Amount of time the congested conditions persist
3. **Extent -** Number of users impacted by congestion
4. **Variability -** Different timeframes of congestion

3.3 Update/Select Multimodal Performance Measures

Performance measures are used to assess progress toward meeting the stated objectives and goals. Performance measures are key to implementing the TSM&O program as the stated, desired outcome will drive the types of projects or strategies that advance into the project development process.

Performance measures are also used as a reference for target-setting (refer to previous section on objectives) and should be used to assess the effectiveness of the return on investment for projects and strategies post-implementation. If possible, the selected performance measures should be consistent with those established on a larger agency-wide level for the purposes of assessing facilities on a platform consistent with other areas within the region.

As travel-time reliability becomes a higher priority, it is essential for system-planning efforts to incorporate reliability into goals, objectives, and performance measures. Reliability performance measures are quantitative indices used to measure progress towards the planning objectives for reliability. Several candidate performance measures identified in FHWA's *Incorporating Travel-Time Reliability into the Congestion Management Process: A Primer (FHWA-HOP-14-034)* are included in **Table 16,** and additional performance measures related to reliability are included in Chapter 36 (Volume 4) of the Highway Capacity Manual (HCM).

Table 16: Example Reliability Performance Measures

PERFORMANCE MEASURE	POTENTIAL UNITS OF MEASUREMENT
85th Percentile Travel Time Index (TTI)	The ratio of the 85th-percentile highest vehicle-hours traveled (VHT) on the CMP system divided by the VHT that would have been expended if the same trips could have been completed at their free-flow speed. (unitless)
Planning Time Index	95th Percentile TTI. The ratio of the 95th-percentile highest vehicle-hours traveled (VHT) on the CMP system divided by the VHT that would have been expended if the same trips could have been completed at their free-flow speed. (unitless)
Reliability Rating	Percentage of trips experiencing TTI less than 1.33 for freeways or 2.50 for urban streets. (These thresholds are generally at the speed where level of service (LOS) deteriorates from LOS "E" uncongested to LOS "F" congested). (unitless)
Failure Measure	Similar to Reliability Rating, but using agency-set minimum acceptable threshold speeds for the facilities rather than those specified by the HCM and its definition of levels of service. (unitless)

Note: Percentile TTI is the ranking from lowest to highest of a collection of travel time indices measured over the course of a year. The 95th percentile highest TTI, is the value that 95 percent of the observations fall below.

The TSM&O program should also incorporate safety into the planning process. In 2016, federal regulations established data-driven performance measures to support the Highway Safety Improvement Program (HSIP). With the availability of safety-related data, it is viable to include safety in both system-wide evaluations and in corridor- or facility-specific project assessments.

Special attention should be given to ongoing federal rule-making regarding the use of specific performance measurements to be applied by State DOTs and MPOs/TPOs. The performance measures identified as part of MAP-21 and FAST Act legislation are summarized in **Table 17**.

Table 17: MAP-21 / FAST ACT Performance Measures

PERFORMANCE MEASURE	DEFINITION	POTENTIAL UNITS OF MEASUREMENT
Annual Hours of Excessive Delay per Capita	Reflects the total amount of time during the year when highway users have experienced excessive delay (<35 MPH freeways or expressways, < 15 MPH other NHS)	Vehicle-hours per person
Total Tons of Reduced Emissions	Reflects the reductions in particular pollutants resulting from the delivery of CMAQ funded projects per fiscal year in non-attainment and maintenance areas.	Tons per year
Interstate System Providing for Reliable Truck Travel Time	Percent of the interstate system mileage meeting reliable truck travel time criteria	Percentage
Uncongested Interstate System	Percent of the interstate system mileage meeting uncongested criteria	Percentage
Interstate System Providing for Reliable Travel	Percent of the interstate system meeting reliable travel criteria for non-truck users	Percentage
Peak Hour Travel Time Expectations (Interstate)	Percent of the interstate system where peak-hour travel times meet expectations	Percentage
Non-Interstate NHS Providing for Reliable Travel	Percent of the non-interstate system meeting reliable travel criteria for non-truck users	Percentage
Peak Hour Travel Time Expectations (Non-Interstate NHS)	Percent of the non-interstate NHS where peak-hour travel times meet expectations	Percentage
Number of Fatalities	Five-year rolling average of number of fatalities resulting from traffic incidents	Fatalities
Fatality Rate	Five-year rolling average rate of number of fatalities resulting from incidents divided by total vehicle-miles traveled (VMT)	Fatalities per 100 Million VMT
Number of Serious Injuries	Five-year rolling average of number of serious injuries resulting from traffic incidents	Serious Injuries

PERFORMANCE MEASURE	DEFINITION	POTENTIAL UNITS OF MEASUREMENT
Serious Injury Rate	Five-year rolling average rate of number of serious injuries resulting from incidents divided by total vehicle-miles traveled	Serious Injuries per 100 Million VMT
Number of Combined Non-Motorized Fatalities and Non-Motorized Serious Injuries	Five-year rolling average of combined number of non-motorized fatalities and serious injuries resulting from traffic incidents	Non-motorized Fatalities and Serious Injuries

3.4 Identify and Assess Strategies

Improvement strategies should correlate to identified deficiencies and link back to the region's goals and objectives. Once the system-wide infrastructure needs, priorities, and the order of magnitude of the impacts are identified, the next stage in the TSM&O program is determining the appropriate strategy for the corridor or facility. Most agencies at this decision point have historically advanced the construction of additional lanes of travel. However, working with stakeholders can expand the "toolbox" of typical improvement strategies that should be considered beyond traditional capacity-adding projects. A list of sample alternative strategies to address capacity and reliability deficiencies is presented in **Table 18**. In addition to the strategies listed in Table 18, the TSM&O 2017 Strategic Plan, still in development by the Florida Department of Transportation (FDOT), provides a strategy toolbox in its Appendix A, which describes over 50 TSM&O strategies.

Table 18: Example Strategies in the TSM&O Program

STRATEGY AREAS	EXAMPLE STRATEGIES
Demand Management Measures	• Programs that encourage transit use, ridesharing, telecommuting, and flexible work schedules • Guaranteed ride home • Car sharing and bike sharing • Pedestrian and bikeway improvements • Roadway congestion pricing • Parking management and pricing • Freight rail and port improvements to reduce truck travel on highways • Growth management (mixed use, transit-oriented developments, and higher intensity developments)
Operational Improvements	• Metering, reversible lanes, access management, temporary shoulder use • Signal optimization, geometric improvements, transit signal priority, traffic calming • Traffic incident management (more patrol cars, protocol for directing traffic, • Pullout areas • Work zone rules (lane closures occur during periods of least demand, minimize the number of lane closures, provide walking and biking access where feasible) • Special event traffic plans • Snow or debris removal plans (response times, ensure clearance of roadways, bikeways and sidewalks, appropriately-sized equipment) • Traveler information • Freight management, including delivery window restrictions • Detection • Cameras • Changeable message signs • Active traffic management
Public Transportation Improvements	• More frequent service to address crowding • Service expansion in congested areas • Operational improvements (transit signal priority, bus bulb-outs, queue jump lanes) • Bus stop consolidation • Operational control strategies (i.e., changes to normal route operation in response to delay-causing events) • Fleet maintenance strategies (e.g., preventative maintenance, vehicle replacement)

Source: Adapted from Congestion Management Process: A Guidebook, Federal Highway Administration, FHWA-HEP-11-011.

Road Capacity Improvements	• New HOV/HOT lanes • New mixed-flow lanes • Intersection widening • Interchange reconfiguration • Truck climbing lanes • Freeway widening at bottlenecks

Source: Adapted from Congestion Management Process: A Guidebook, Federal Highway Administration, FHWA-HEP-11-011.

The use of a strategy tree may help identify strategies that correlate to specific planning goals and objectives at the system-level. An example strategy tree for improving system reliability is illustrated in Appendix A. An evaluation of strategies is needed to estimate the expected benefits of the strategies compared to expected capital and operating costs over the project lifecycle. The analysis may be quantitative or qualitative depending on the nature of the strategies and the resources available to the agency. Evaluation criteria used in the analysis should link to the stated goals, objectives, and multimodal performance measures. In addition to expected performance, the evaluation will involve identifying the range of capital, staffing, technology, training, and maintenance requirements of operations deployments.

Table 19 presents the general range of benefits and cost-benefit ratios that can be expected for typical operations strategies. The Tool for Operations Benefit Cost Analysis (TOPS-BC) and other tools for evaluating a range of TSM&O strategies are available at FHWA's Office of Operations website: http://www.ops.fhwa.dot.gov/plan4ops/topsbctool/index.htm.

Table 19: Systems Operations Benefits

STRATEGY	BENEFITS AND BENEFIT-COST RATIOS	SAFETY IMPACT	MOBILITY IMPACT	ENERGY/ ENVIRONMENTAL IMPACT
Traffic incident management	Incident duration reduced 30-50 percent	High	High	High
Safety service patrols	2:1 to 42:1	High	High	High
Surveillance and detection	8:1	High	High	High
Road weather information systems	2:1 to 10:1; crash rates reduced 7 to 80 percent	High	High	High
Traveler information dynamic message signs	3 percent decrease in crashes; 5 to 15 percent improvement in on-time performance	Low	High	Low
Work zone management	2:1 to 40:1; system delays reduced up to 50 percent	High	Medium	Medium
Active traffic management	Throughput increased by 3 to 7 percent; decrease of incidents by 3 to 30 percent	High	High	Medium

Source: Adapted FHWA's Incorporating Travel-Time Reliability into the Congestion Management Process (CMP): A Primer (FHWA-HOP-14-034)

System-wide evaluations are likely to yield a number of possible courses of action. The identification of focus areas is a critical part of the TSM&O program. Many times, focus areas will be of a geographical nature—an intersection or a roadway segment that is identified as a "hotspot." Identifying focus areas at the system level can leverage the Pareto principle (the "80-20 Rule," or approximately 80% of network problems can oftentimes be traced to 20% of the network as the source) to focus the identification of project needs or problem areas. As with various aspects of business, science, and society, many transportation problems are concentrated on a small percentage of causes. To provide context for this discussion, **Table 20** presents examples of focus areas at both the system and spot levels.

Table 20: Examples of Focus Areas

STRATEGY AREA	SYSTEMS	SPOT
Congestion	High daily VMT per capita suggests that certain sections of a city could benefit from alternative land use or transportation modes.	A certain section of a freeway is identified as a congestion hotspot: it is the bottleneck point for recurrent commuting congestion.
Safety	A high share of angle crashes due to failure to obey traffic controls suggests that a city-wide red light running camera program may be beneficial.	A certain intersection is identified as having significantly more pedestrian crashes than neighboring intersections.
Reliability	Most transit routes are found to have poor on-time performance, leading to low reliability for users. This may point to an evaluation of new transit technology and transit-only lanes.	A work zone is found to have a large impact on the reliability of a freeway, particularly during peak hours. A review of the maintenance of traffic plan may be considered.

Although a comprehensive discussion of system-wide data analysis is outside the scope of this Guidebook, a few concepts should be kept in mind to produce objective, accurate, and repeatable focus area analyses.

Data and metadata - There are a multitude of data sources available to analysts, all at different stages of readiness and pre-processing. To be able to turn system-wide data into actionable information, the analyst must first understand what the data mean. A metadata document describes the dataset, documenting the meaning, source, and limitations for each field in the dataset. It is important to recognize that data specificity varies between stakeholders. As an example, hourly data may be acceptable to transportation planners. However, traffic operations engineers may require data every five seconds.

Time - The temporal coverage of a dataset is one of the first considerations that must be made at the onset of a system-wide analysis. For rare events—like crashes—multiple years of data are needed to inform a robust analysis. For congestion events, peak periods during representative times of the year are typically sufficient. The extent and resolution of the data must be sufficient to address the objective of the analysis.

Space - Similar to the time considerations, the space considerations include both extent and resolution. Analyses that are intended to identify spot focus areas (e.g., intersections, freeway segments, etc.) must use data and analysis techniques that capture patterns at that scale.

Absolute vs. Relative - Performance measures can typically be categorized as either absolute or relative. Absolute measures include vehicle-miles traveled, total number of crashes, vehicle-hours of delay, and more. Relative measures normalize the absolute measures by a control variable (e.g., vehicle-miles per capita, crashes per vehicle-miles traveled, etc.). Based on the regional goals, the evaluation of both absolute and relative metrics may be required.

Methodology - The methodology of transportation analyses varies widely, even within analyses aimed at the same problem (e.g., congestion, safety, reliability). It is therefore important to carefully collaborate with affected agency partners, in addition to the transportation planners and traffic operations engineers.

The TSM&O program incorporates an evaluation of both operational- and capacity-related projects. With more cost-effective operational improvements being considered as an embedded process, intuitively more infrastructure needs will be considered.

3.5 Programmatic Prioritization

System planning culminates with a list of projects and strategies identified to address the needs of a region in a way that accomplishes its stated goals and objectives. Long range plans typically span a 25- to 30-year horizon period, with the ultimate purpose of programming the long range projects and strategies into a shorter list of prioritized projects to advance as part of a TIP.

Ideally, the project selection criteria for the TIP should reflect those used to evaluate the needs in the long range plan. Strategies that move forward from the system-planning process to the project-level process will have been vetted through an objectives-driven, performance-based approach. The application of PBPP, as summarized in this chapter (with more detail in FHWA's Performance Based Planning and Programming Guidebook, FHWA-HEP-13-041), will provide a strong technical basis for the advancement of improvement strategies from long range plans to prioritized project lists. Therefore, from a programmatic approach, the TSM&O program incorporates an evaluation of both operational and capacity-related projects during the system-planning process. Using the performance-based planning process, system planning establishes the basis for advancing project-specific corridors for consideration of operational- or capacity- based improvements. Section 4.0 describes the process for evaluating the project-level improvements and requirements.

4

4.0 TSM&O at the Project Level

This chapter summarizes and presents best practices for incorporating aspects of the TSM&O program into the project-level planning process. It provides guidance by building upon the work done at the systems level.

In many cases, the transition from systems-level planning to project-level planning is disconnected. For various reasons, analyses and recommendations made at the systems level do not always result in the programming of project-specific studies to carry out those recommendations. Three primary barriers are noted:

1. Insufficient collaboration between planners at the systems-level and planners at the project-level
2. Lack of prioritization tools to inform the decision-makers on the order of importance
3. Funding structures that are disconnected from systems-level studies

Collaboration between transportation planners involved in systems planning and project planning is essential, whether it be across organizations (MPOs/TPOs, State DOTs, or local planning divisions) or between various agency units within a single organization.

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For the reasons described above, project-level planning is a key part of the TSM&O program. As shown in **Figure 13**, the corridor planning study is a "fork in the road." Its outcomes will likely determine which project development path will ensue. In some cases, the project planning process will find that a *capacity* improvement is necessary. This is shown by the upper path in **Figure 13**, which includes items such as environmental documents, preliminary engineering, right-of-way acquisition, and others. Alternatively, in other cases the project planning process will recommend *operational* improvements. This is illustrated by the traditional "V-diagram" portion of **Figure 13**, which shows the decomposition (e.g., planning, design) and integration (e.g., testing, validation) stages that are typical in systems engineering projects. Some projects may include both capacity and operational improvements. In those instances, they will have to follow the capacity-based project cycle as primary, and the operational-based cycle as secondary. An important aspect of the TSM&O program is the decision point or consideration of both paths (capacity and operational). While this seems logical, it is common industry practice to advance capacity-related projects when roadways are over capacity when, in fact, there may be an operational improvement or strategy that can ameliorate the identified issue. Therefore, a project should not advance in the process unless it has been vetted to determine if an operational improvement could be implemented.

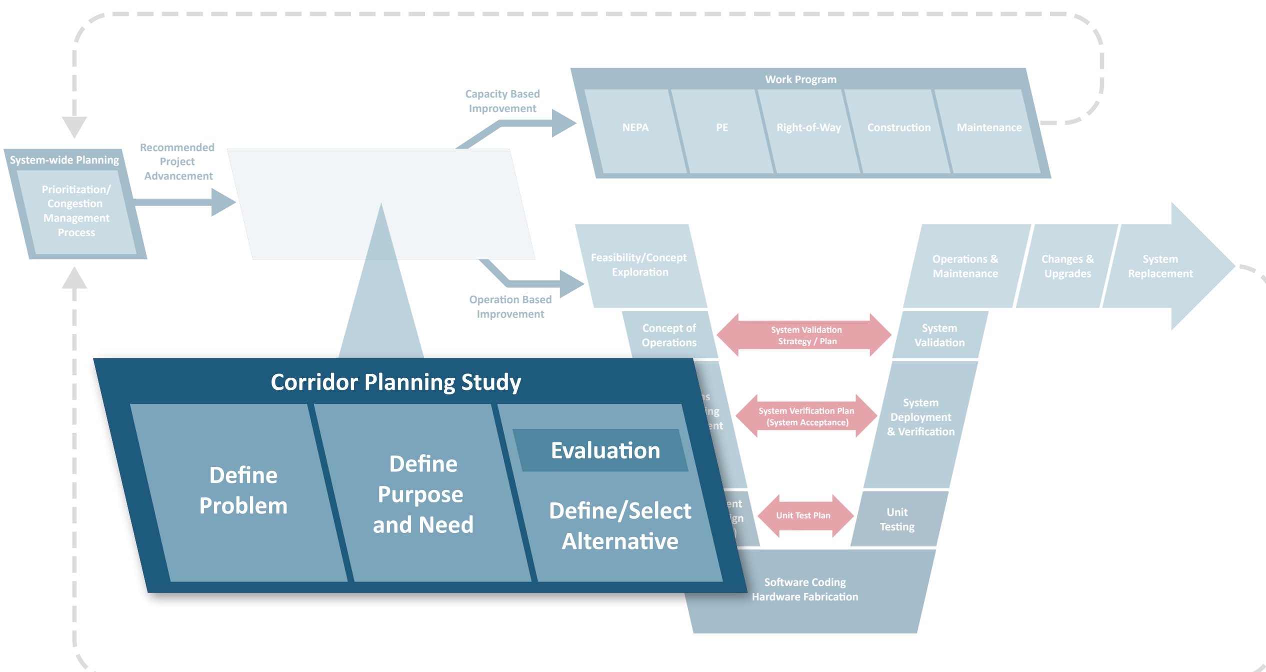

Figure 13: Project-Level Planning in the TSM&O Program Process

4.1 Problem Identification and Determination of Risk

Traditionally, transportation planners have been primarily responsible for identifying systems-level and project-level deficiencies and developing the purpose and need of a project. This Guidebook, and specifically the following sections, recommends engaging a group of experts from other roles (e.g., traffic operations, design, construction, maintenance, etc.) early in the project. These experts can provide a different perspective relative to their area(s) of expertise that may have expanded considerations (e.g. safety implications, design impacts, or constructability reviews).

Projects are seldom performed in isolation. Chances are high that a given project is just one of several projects in the system being evaluated, designed, or constructed. The planner is in an ideal position to organize and categorize projects to make it easy for project implementers to know what is going on around them.

It is especially important to obtain and maintain information about other projects in the same geographical or jurisdictional area. Beyond this, it also makes sense to coordinate across jurisdictions and specialties to present a unified approach to planning within a TSM&O program. A unified approach considers the interaction between different potential projects, putting emphasis on meeting systems-level goals through the implementation of projects that support those goals.

Figure 14 shows how the problem definition stage fits within the larger project lifecycle. It also shows that at this point, the planning role has started to exchange more knowledge and responsibility with other roles.

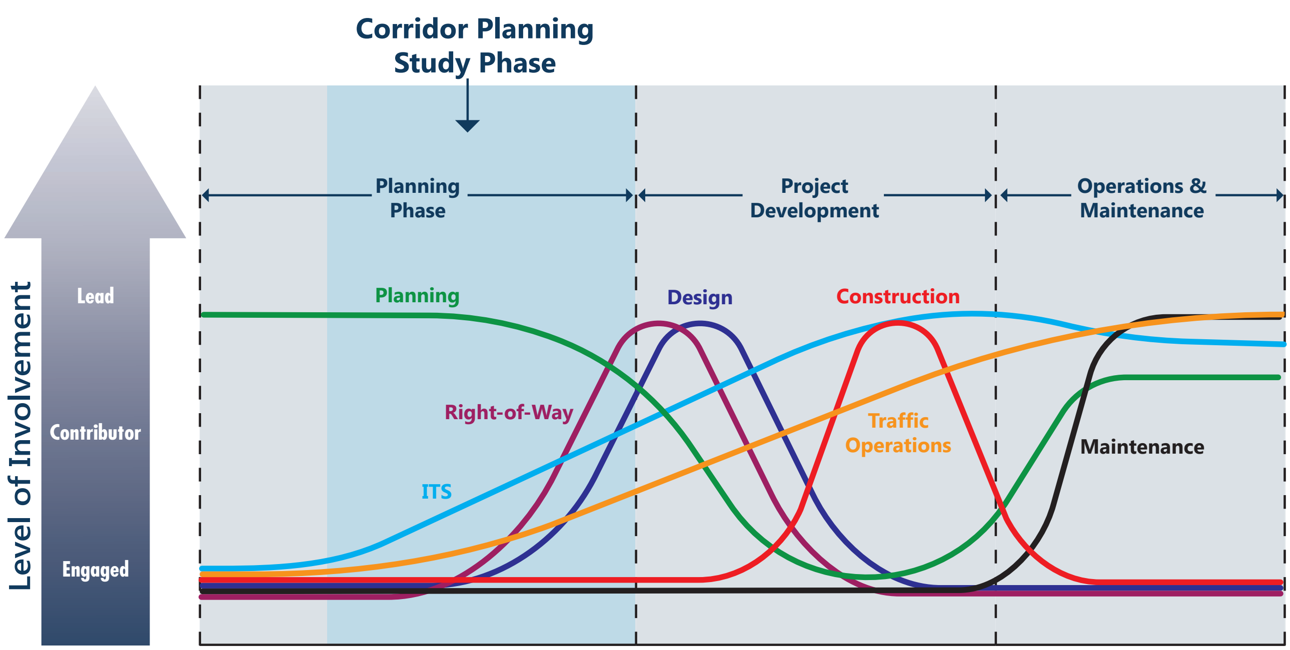

Figure 14: Repartition of Roles in a Project's Lifecycle

Risk is inherent in any project; however, risk can be quantified, managed, and mitigated. At the very minimum, a TSM&O practitioner should perform an objective assessment of a project's risk and develop suitable mitigation strategies. **Table 21** provides a template for organizing and presenting the key elements of a risk assessment.

Risk - Uncertainty which can impact a project's ability to meet defined goals and objectives. Risk can come in many forms, including budgetary, contractual, scheduling, legal, and more.

Issue - Specific reason(s) that contributed to the materialization of risk(s)

Mitigation - Proactive activity or set of activities that can prevent or address the potential issue(s)

Table 21: Risk Assessment Template

ELEMENT	ISSUE	MITIGATION STRATEGY
Description of the Risk	**Specific Issue(s)**	**Description of potential mitigation(s)**
Example: Facility does not work for buses	Example: Turning radii too small	Example: Perform truck design checks for all geometric modifications, with special attention at facilities with existing or proposed bus routes
	Lane width too narrow	Use a lane width which can accommodate the existing and future bus fleets
	Route too circuitous	Take into account existing or proposed bus routes when discussing changes to traffic patterns

The identification, tracking, and management of risk should be ongoing activities through the project-planning lifecycle. If done right, the adverse impact of risk can be controlled, minimized, or even eliminated. FHWA offers additional guidance on their Innovative Program Delivery Office,[13] including two Strategic Highway Research Program 2 (SHRP2) products available for reference; the SHRP2 R09: Managing Risk in Rapid Renewal Projects and SHRP2 R10: Project Management Strategies for Complex Projects.

Project-level goals and objectives should support long-range planning goals and objectives. However, they are more specific and require significant stakeholder coordination.

4.2 Goals and Objectives

Goals and objectives identified at the project level differ from those identified at the system level. While project-level goals and objectives should support those of long-range planning, project-level goals and objectives are more specific and, therefore, require additional coordination with stakeholders. As with traditional planning, these are identified in the project planning process, illustrated in **Figure 13**. Project-level goals and objectives will guide the development of performance measures that are monitored through the project

13 FHWA, Innovative Program Delivery, http://www.fhwa.dot.gov/ipd/project_delivery/resources/risk_management/. Accessed on May 9, 2016

development process in the TSM&O program. Furthermore, in the TSM&O program, these goals and objectives will be utilized to:

- Determine performance metrics for the project
- Verify improvements strategy and validate after construction and testing
- Set the framework to determine return on investment

Beyond the initial planning study and determination of specific performance measures, during the incorporation or update of the regional ITS architecture (RITSA), these goals and objectives will determine if the system, or improvement strategy, is incorporated into the Concept of Operations.

Potential improvement strategies identified by the planning phase may include any combination of the following:
- No-Build
- Capacity
- Operational
- Other

4.3 Identify Strategies

As a result of the initial planning stage illustrated in **Figure 13**, one or multiple potential strategies are identified. At this phase in the TSM&O program, a decision point occurs, determining what strategies will follow the appropriate path. In order to determine that, it is important to understand the differences between capacity-based and operations-based strategies. Within each of these general categories lie varying degrees of involvement or technical knowledge, which will be discussed later in this chapter when improvement strategies are prioritized and evaluated for advancement.

Capacity-Focused Projects in the TSM&O Program

Although the TSM&O project planning stage encourages the consideration of lower cost, shorter time-frame operational projects, sometimes the process results in a recommendation to move forward with a capacity expansion project. Capacity projects follow a different project development timeline, which typically includes items such as environmental documents, preliminary engineering, right-of-way acquisition, and others. This branch is highlighted in **Figure 15** as part of the overall TSM&O program.

The TSM&O program addresses ALL modes:
- Vehicle
- Freight
- Pedestrian
- Bicycle
- Transit

Operational-Focused Projects in the TSM&O Program

The TSM&O program considers operational-focused projects that should typically adhere to a systems engineering process. This section provides an overview of the systems engineering process and introduces how transportation planners interact throughout the various components of the operational "V-diagram." Additional information on the Systems engineering process is available in FHWA's "Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals."[14]

14 http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf

Federal regulations first required the use of systems engineering processes in Intelligent Transportation Systems (ITS) projects in FHWA Rule 940.11 and FTA Policy Section VI. From the International Council of Systems Engineering (INCOSE), the definition of *Systems Engineering* includes:

- An interdisciplinary approach and means to enable the realization of successful systems
- Focus on defining customer needs and required functionality early, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem
- Integration of all disciplines and specialty groups to proceed from concept to production to operation in an organized manner
- Consideration of both business and technical needs of all customers to provide a quality product that meets the user needs

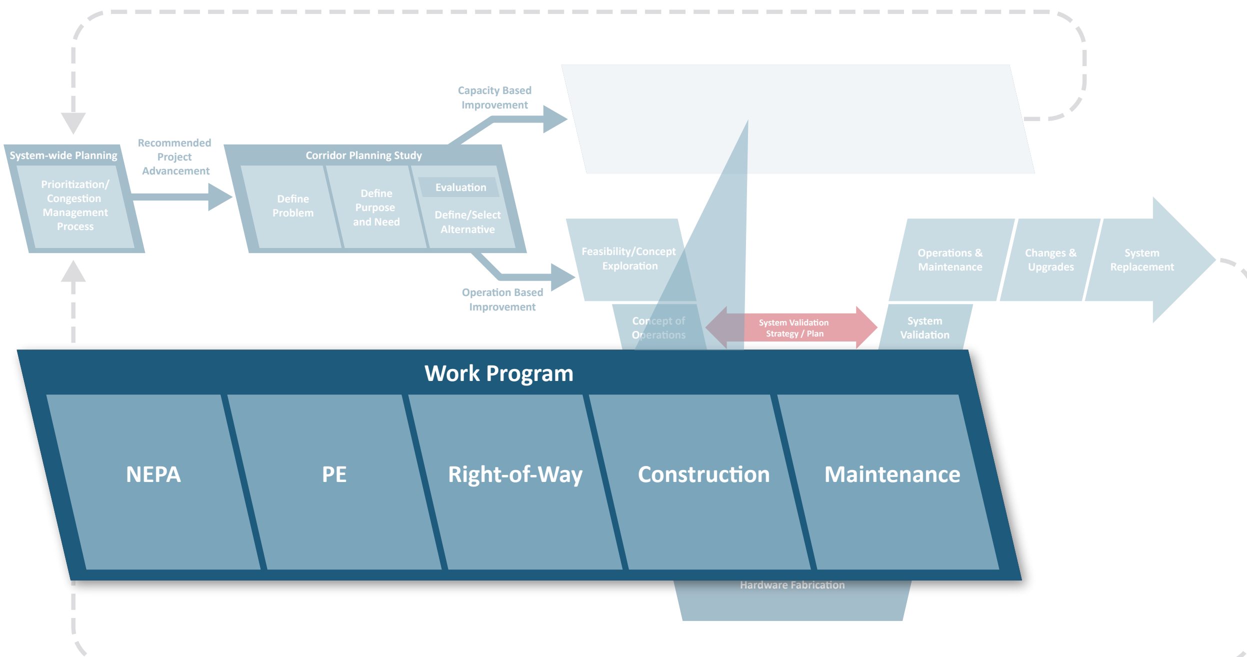

Figure 15: Capacity-Focused Project Branch

The systems engineering process can be understood through the "V-diagram" model illustrated in **Figure 16**. The "V-diagram" model represents the full lifecycle of activities related to the systems engineering process, beginning with high-level and more detailed planning processes, then proceeding with design, implementation (construction), system verification and validation, and operations and maintenance.

Feasibility / Concept Exploration

The first planning-level activity in the project development lifecycle is the feasibility and concept exploration phase. At this point in the overall project development lifecycle, the problem, the purpose and need, and the goals and objectives of the corridor and/or facility have been identified and agreed upon by the stakeholders.

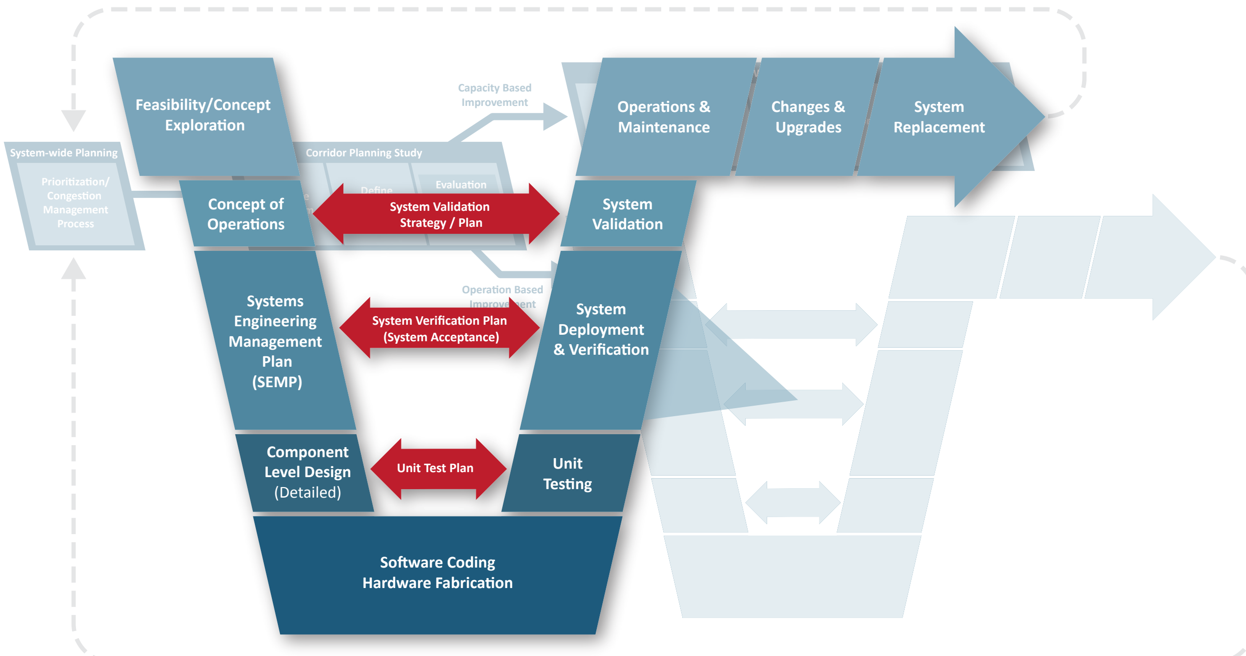

Figure 16: Systems Engineering Process for Operational Focused Projects

The feasibility and concept exploration phase will explore what types of operational improvements will address the purpose and need in order to align with meeting the goals and objectives for the assessment of the corridor or facility. Stakeholders will once again be engaged to discuss the impacts and benefits of different operational improvement solutions. In this activity, the purpose and need, and goals and objectives of the operational improvement alternatives will be defined and compared.

The feasibility and concept exploration phase will explore what types of operational improvements will address the purpose and need in order to align with meeting the goals and objectives for the assessment of the corridor or facility.

Operational improvements take many forms. In addition to traditional operational enhancements, ITS-related improvement strategies that result from the feasibility and concept exploration phase may require a RITSA. The FHWA defines the RITSA as the ITS architecture within a defined region, that regional stakeholders wish to realize or implement over a given timeframe. The purpose of a RITSA is not only to identify existing regional architecture and stakeholder needs; it may also identify opportunities for cost-effective investments through inter-agency coordination during the planning stage.

This report will provide information for MPOs and TPOs to update their LRTP, the Transportation Improvement Program (TIP), and other capital project plans. It will also serve as a reference for the systems engineering process and will provide valuable information for the development of a ConOps and SEMP, as well as requirements, and high-level design and test planning for ITS projects.

Potential Stakeholders:

- MPO/TPO
- MPO/TPO – DOT Liaisons
- Transportation Planners
- Operations / ITS Engineers
- Transit Agencies
- DOT Design
- Environmental Management Office
- DOT Project Management
- DOT Directors and Managers
- DOT Maintenance
- County and City Representatives

Concept of Operations

The ConOps is a non-technical description of HOW a system will be used. This provides a connection between the project needs identified in the planning process and the specific technical requirements. In the context of the TSM&O program, the ConOps should be a planning-level document relevant to high-level decision-makers, as well as, system managers and operators.

The ConOps answers the following questions:

1. Who are the stakeholders involved with the system?
2. What are the known elements and high-level capabilities of the system?
3. When is the time sequence of activities that will be performed?
4. What are the geographical and physical extents of the system?
5. Why are the improvements needed?
6. How will this be designed, built, or retrofitted to the system?

The ConOps is written from the perspective of the system operator and should be developed as a joint venture between the planners and traffic operations / ITS engineers. The primary audience for the document is composed of stakeholders or agencies who will share the operation of the system or be directly affected by it. The stakeholders or agencies are tasked with describing their needs and objectives succinctly enough to determine what functions the proposed system must be capable of fulfilling.

An example of a ConOps template is provided in **Appendix C**.

Table 22: Elements of a ConOps Document

ELEMENT	DESCRIPTION
Introduction	Should include the document outline, the purpose & need of the project, goals & objectives, and boundaries of the system.
Reference Documentation	Any supporting documentation to be included in Appendix C, such as: business planning documents, related system ConOps & requirements, studies identifying operational needs, meeting minutes.
Operational Description	An overview of HOW the improvements will be implemented; user activities, operational process, and organizational / personnel structures required.
Operational Needs	An outline of what is necessary for the agency / region to implement the system and/or complement / improve the existing system.
System Overview	High-level description of the key system components and the interrelationships among the elements (e.g. system capabilities, goals and objectives of the system).
Operational Support	Description of the overall system needs; this does not include the design details such as vendor hardware.
Operational Scenarios	The system's impact under general conditions such as, normal, peak hour or stress, maintenance mode, failure events, and how it handles anomalies.

Systems Engineering Management Plan (SEMP)

The SEMP may be required for specific alternatives to detail the project plan. When applicable, the SEMP focuses on the management plan of the project and the systems engineering processes required for successful completion of the project. The purpose is to define and assign responsibility for those engineering tasks, and to provide detailed information on the steps of the process. The engineering tasks, from requirements through design implementation, integration, and verification, are new to many transportation planners and will require input from engineers. The elements of a SEMP are included in **Table 23**.

Table 23: Elements of a SEMP

ELEMENT	DESCRIPTION
Introduction	Project background and up-to-date coordination.
Need for a SEMP	This section will address the purpose and need of the project, the relationship to the existing system network, and any applicable documents that will be references, such as the ConOps, previous study-related documents, or manual.
Systems Engineering Processes	General overview of the systems engineering process. This section will be applicable to all SEMPs.
• High-level Functional Requirements	This is a high-level discussion on the requirements of the system, which will be identified by the ConOps.
• Risk Identification, Assessment, and Mitigation	This section contains the identified risks such as cost and system failures or requirements; it will assess the likelihood and severity of the risks, and provide mitigation for those risks, such as responsible parties.
• Requirements for a Verification Matrix	The plan will document how requirements will be checked. It will list what performance measures will be monitored, and develop a validation plan to match the needs of the system to the needs of the project, and the creation of performance measures to evaluate if the system is meeting the goals and objectives of the project.
• Technical Review Plan	A process to review documents and address reviewer comments will be established.
Project Management & Control	This section will outline the responsible parties for various activities of the project, from planning to system retirement.
• Organizational Structure	This will define the responsible parties for each aspect of the systems engineering process including planning, design, implementation, and maintenance of the system.
• Quality Management Plan	Each agency or group associated with the project will be required to follow the Quality Assurance/Quality Control process outlined in this section.
• Systems Acceptance	This section assigns responsibility for the system once installation and testing is complete.
Operations and Maintenance, Upgrade, and Retirement	This section assigns responsibility for the maintenance, upgrade, and retirement of the system. It will specify support roles to assist in this, such as data collection and management, and operation activities.

The SEMP is intended to be a dynamic or "living" document that will require modification and updates throughout the project development process. Similar to the ConOps, the SEMP is intended to be drafted by the transportation planners, through collaboration with the traffic operations / ITS engineers. The SEMP document, as described, is an evolving document in the overall lifecycle of the project development process. Transportation Planners should remain involved in the advancement of the SEMP to ensure what was originally described in the project need during the Planning Stage is verified through the performance measures once implemented by the traffic operations / ITS engineers.

System Verification and Validation

Validation - Is the solution solving the transportation problem?

Verification - Did we build what we said we were going to build?

ConOps vs. SEMP

It is necessary for the planner to understand the distinction between a ConOps and a SEMP, and the importance of both documents in the project development process of the TSM&O program. The planner is responsible for the creation and management of both documents, when applicable. The ConOps is a document presenting HOW a specific alternative will operate. It will explain how that strategy will fulfill the previously identified purpose and need, and how it will meet the goals and objectives of the project. A high-level discussion of the alternative, how it works with the existing system, and the risks involved, is included. A planning-level discussion on how the system will work and/or fit into the existing network is also included in a ConOps. A SEMP should be developed after the ConOps, with input from the ConOps, transportation planners and traffic operations / ITS engineers. This document consists of a planning-level discussion on WHAT and WHO. While the ConOps is strategy-based, the SEMP will identify the specific system or brand of the strategy, who is responsible for the different aspects of the implementation, and management of the system.

Roles and Responsibilities

Remember: Planning has a role in the systems engineering process!

Although the division of responsibility in operational-focused projects is similar to the one presented earlier for capacity-focused projects, there are certain aspects unique to the systems engineering process that requires a higher level of involvement from the transportation planner.

In a systems engineering process such as the one illustrated in **Figure 16**, the transportation planner's role is heavier in the beginning, where purpose and need are defined and a preferred alternative is selected (Feasibility Study / Concept of Exploration). The transportation planner plays an active role in the ConOps, SEMP Requirements, and High-Level Design stages, at which point the lead role transitions to the traffic operations / ITS engineer or designer. The transportation planner takes on an active role again in the System Verification and System Validation stages, ensuring the deployed system successfully meets the needs of the users. **Figure 17** shows the roles and responsibilities shift throughout the project development phase and how they are associated with the products of the systems engineering process.

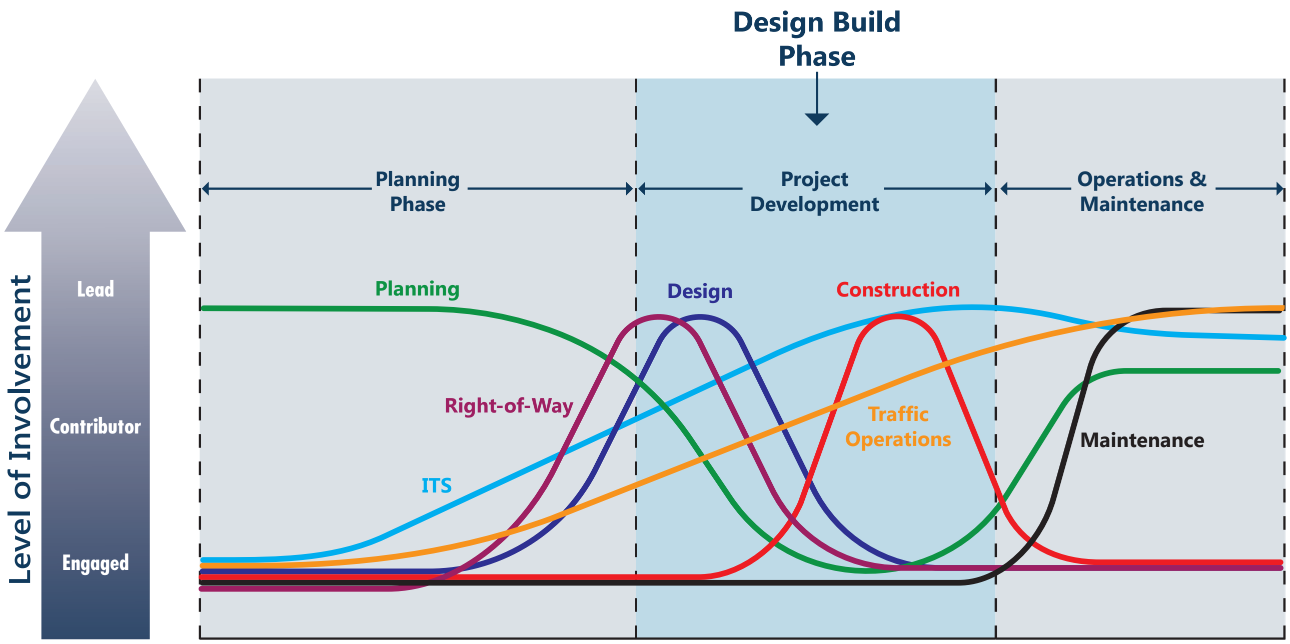

Figure 17: Roles and Responsibilities in the Project Development Phase

4.4 Assess Strategies

The process of assessing strategies at the project level is a refined version of its equivalent in the system planning process (see Section 3.4). It is critical to consider all the improvement categories, including Safety, Operations, and Capacity when prioritizing or selecting a preferred or recommended alternative.

Figure 18: Improvement Categories

Although the key concepts discussed in Section 2.4 still apply, a higher level of detail is afforded, and analyses of strategies at the project level tend to be more thorough. The key concepts of a TSM&O program can be extended to this more detailed analysis.

Stakeholder Coordination

All relevant stakeholders should be included in a collaborative discussion about potential alternatives. The number of stakeholders would likely vary depending on the complexity of the project.

Performance Monitoring

The evaluation criteria used in assessing strategies should link to the stated goals and objectives of the project. The performance evaluation may be qualitative or quantitative, depending on the resources available to the agency. Ideally, the performance measurements used would link to those identified in the region's system-wide performance monitoring plan.

Safety

Safety should be a priority to every agency and considered in every transportation project. For improvement strategies to address safety issues (i.e. signalization, pedestrian facility enhancements, and roadway or intersection geometry enhancements), performance measures listed below should be evaluated in addition to stakeholder input and cost-benefit analysis:

- Reduction in number of crashes
- Reduction in bike / pedestrian crashes
- Reduction in property damage
- Reduction of crashes with resulting injury

Operations

Operational strategies may include, but are not limited to, adaptive signal systems, progression analysis, or retiming. With these strategies the following example performance measures may be considered:

- Reduction in delay
- Increased person throughput
- Reduction in volume to capacity

Tools have been developed to assess operations strategies, such as FHWA's TOPS-BC, available at: http://www.ops.fhwa.dot.gov/plan4ops/. These assessment tools continue to be developed and refined as part of ongoing programs, including FHWA's SHRP2.

Capacity

The TSM&O program will still address capacity improvements; however, the difference is there will be a requirement to include safety and operational improvements in conjunction with this. As a step to ensure that these other performance measures are included and analyzed, the Colorado Department of Transportation (CDOT) has developed a checklist that every project must incorporate during the planning phase of the project development lifecycle. The **CDOT checklist** is included in **Appendix E** for guidance on the types of issues and measures that should be considered with the following traditional performance measures:

- Volume/capacity
- Level of Service

Economic Analysis

The determination of benefit-cost ratios or net present values is made easier by the availability of project-specific data. Project costs should account for the range of capital, staffing, technology, training, and maintenance requirements. Accurate estimates of these important measures can help select viable alternatives with high B/C ratios (see **Figure 19**). Strategies that move forward into funded plans should indicate strong performance through an objectives-driven, performance-based approach.

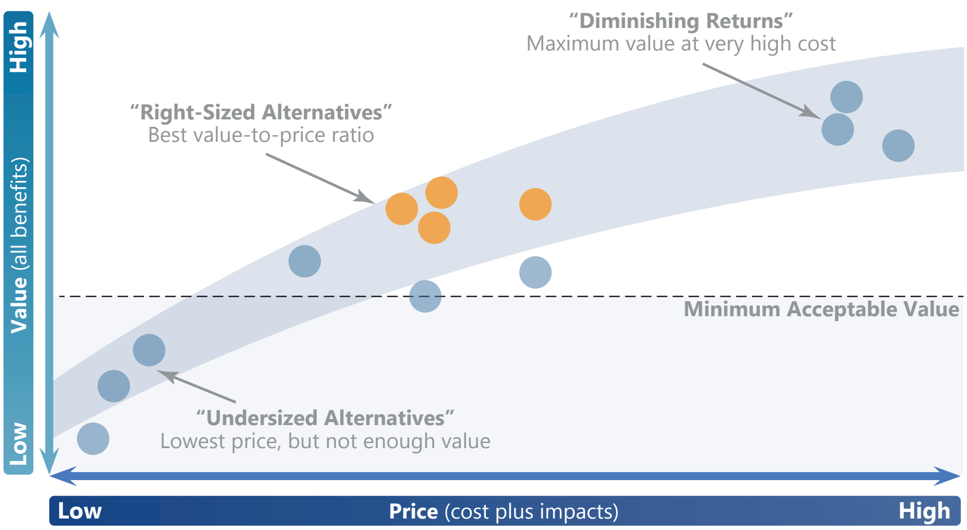

Figure 19: Assessing the Benefits and Costs of Alternatives

The purpose of **Figure 19** is to illustrate the comparison between performance measures and benefit-cost or return on investment. Often when selecting a range of improvement strategies for advancement, outcomes must be weighed with community needs, and no single solution or set of solutions will meet every object.

Benefit-Cost Analysis:

Do the benefits outweigh the cost?

By how much do the benefits justify the cost?

Can total expected cost be compared to total expected benefit of each strategy?

Risk Assessment

Risk is inherent in any project and can arise in a number of areas, including budgetary, contractual, scheduling, legal, and more. However, risk can be quantified, managed, and mitigated. When selecting among project alternatives, a TSM&O practitioner should perform an objective assessment of the alternatives' risk and develop potential mitigation strategies.

4.5 Strategy Prioritization

The practitioner can use the different project development paths available in the TSM&O program, to determine what proposed alternatives or improvement strategies are advanced into project development or the appropriate next phase. The next phase is determined by the level of engineering and environmental analyses necessary to proceed with a selected alternative. For instance, an intersection modification involving minor geometric changes would not require extensive documentation. For relatively simple strategies such as these, where little to no impact is expected and no obvious public controversy is anticipated, a scaled-back analysis could easily be developed through collaboration of the TSM&O programmatic team. To illustrate this point, **Figure 20** plots representative examples of improvement strategies (see Appendix A for a more complete list) in the context of complexity and planner involvement.

Key concepts to assess strategies

- Stakeholder Coordination
- Performance Monitoring
- Purpose and Need
- Economic Analysis
- Risk Assessment

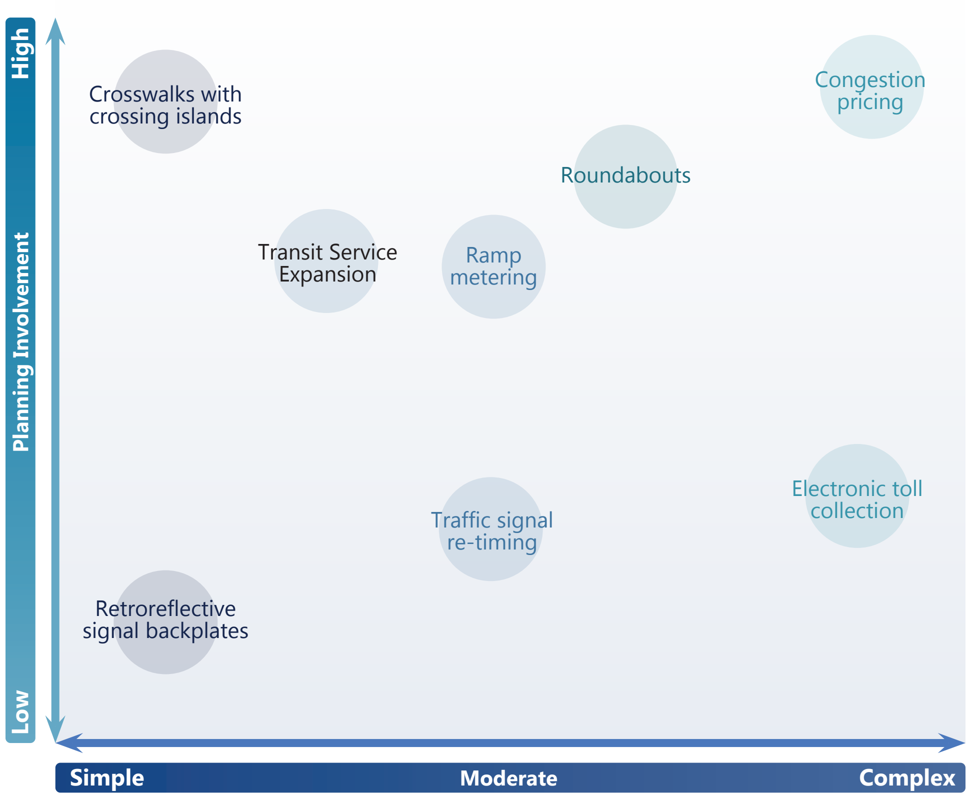

Figure 20: Project Complexity vs. Planning Involvement

However, for more complex strategies that involve many experts, larger community impacts, or greater controversy, a more comprehensive project development path might be needed. Oftentimes, complexity in transportation projects may be gauged by the level of preparation and coordination needed to move the project from planning to construction. These complex projects may go through environmental studies and/or a systems engineering process before being designed and constructed. In some cases, property impacts may require the purchase of right-of-way.

While the complexity of a project cannot be categorized into clearly defined categories, it is helpful to think of projects as being on a spectrum of simple to moderate to complex. Since complexity is about many parts that interact with many other parts, the planner's level of involvement will vary for projects of different complexity levels.

Thinking about the complexity of the project at the planning phase can set the stage for its project development path. As can be expected, complex projects have longer development timelines, involve more experts, and require more formal buy-in from stakeholders and regulators. **Figure 21** shows how simple, moderate, and complex projects typically advance through different project development paths. Additional guidance for completing the steps in the complex project branch can be found in the sections below.

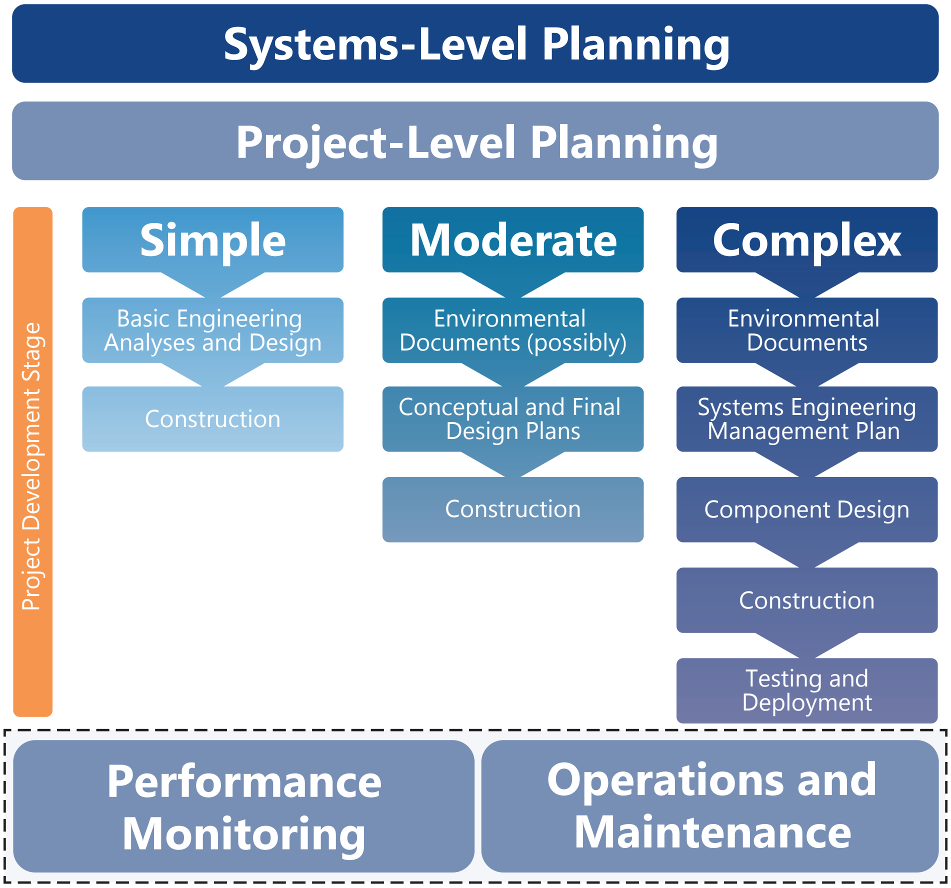

Figure 21: Project Development Branches

Note how projects ranging from simple to complex are shown to follow systems-level and project-level planning stages. These stages, described in detail earlier, provide a foundation for a successful project that efficiently addresses an identified problem, have support from stakeholders and decision-makers, and contribute toward meeting system goals and objectives. On the back end, projects of all types are followed by performance monitoring and operations and maintenance stages. Performance monitoring is useful in assessing the effectiveness of the project in meeting (or continuing to meet) its specific objectives, as well as informing future decisions of a similar nature. The performance monitoring stage ultimately feeds back into the systems-level planning process. Proactive operations and maintenance can maximize the effectiveness and extend the life of the project by keeping its components up to date with changing conditions.

4.6 Performance Monitoring

The TSM&O program is about streamlining the decision-making process, optimizing infrastructure, and increasing the overall effectiveness of the transportation system. It has been noted throughout the process that identifying the purpose and need during the Planning Stage is the basis for determining which process a project should take during the project development phase. An integral part of the TSM&O program is the monitoring of the system throughout the lifecycle of the project. As such, it is imperative to continually evaluate the project during the Testing and Operations Phase.

Oftentimes, once the project is implemented, transportation professionals "check the box" and deem the project completed. However, how do we determine the success of a project? Transportation professionals should verify the concluding benefits against the purpose and need, performance measures, ConOps and SEMP. It is noted that isolating the exact benefits of a particular project may be difficult, particularly over a long period of time. Often, changes in travel demand and other infrastructure projects can offset or compound benefits from the project that is being evaluated. Nevertheless, the verification process is critical in order to validate that the stakeholders and agency representatives follow through with the targeted performance measures. The monitoring of project effectiveness is the role of both the transportation planners and the traffic operations / ITS engineers.

Epilogue

TSM&O has long been considered interchangeable with ITS. Although TSM&O may sometimes result in ITS deployments and projects, it is much more than ITS and operations. TSM&O is a program that will produce strategies that improve safety, reduce congestion, and increase the reliability of the transportation system. When this broader definition is considered, planning for TSM&O is not significantly different from planning for multi-modal systems, services, and projects. The key differences between a TSM&O program and the traditional planning process can be summarized as follows:

- A cradle-to-grave approach which starts at the system level and continues through project-level planning and implementation, maintenance, and performance monitoring
- Strategic collaboration between experts from multiple disciplines—ranging from planning to design to construction

REMEMBER!

TSM&O is...

- An integrated program
- A collaborative effort
- From planning to maintenance
- Performance-based
- Multi-modal

- Performance-based decision-making at multiple stages of the program, including during alternatives analyses and after a system, project, or service is implemented

This Guidebook has provided the fundamentals of integrating a TSM&O program into the planning process, described roles and responsibilities, and outlined the project development lifecycle within the program. How can transportation professionals at state DOTs, MPOs/TPOs, and local agencies apply these fundamentals? Here are some ideas:

Unveil Myths

Review your agency's current program

There is a chance that a transportation agency already has a TSM&O program. The first step should be to perform a thorough review of it. Does the program embody the definition of TSM&O or is it a mechanism to purchase and install ITS equipment? If the current program is too limited in its scope, an overhaul may be necessary. Although each agency will have its own preferences and procedures, these overhauls typically involve education, staffing, and consultation of outside experts.

Gather a Team

Identify the correct group of experts

A successful TSM&O program needs a committed group of experts from different disciplines. These experts must work together at all stages of the TSM&O program—although naturally some will be more involved in phases that more closely relate to their expertise. Note that the collaboration needs to go beyond keeping each other informed. A committed, diverse group of experts will bring different perspectives in a timely manner, and will create better outcomes for the systems, services, and projects considered through the TSM&O program.

Listen to Data

Understand the importance and value of data

One of the core elements of the TSM&O program is its reliance on performance-based planning. To make this happen, system-wide data must first be collected and published. For a comprehensive TSM&O program, multi-modal high-resolution data, relating to topics such as travel time and safety, should be made readily accessible to the TSM&O team. Performance measures which are robust, reproducible, and easy to understand should be developed utilizing these data sets and monitored on a regular basis.

The ultimate purpose of performance measures is to inform decisions based on the need and the anticipated effect of proposed systems, services, or projects on the transportation network. Nevertheless, the data and resulting performance measures should be viewed through the lens of agreed-upon system goals and objectives. It is important to know the numbers and expected outcomes, but sometimes other factors (for example, the distribution of benefits and costs or adherence to an overall vision) can lead to different, and sometimes better decisions.

Act Now

Unlike traditional long-range planning, a TSM&O program is not on a five-year schedule, is not constrained to only a few agencies, and is not solely focused on conditions 20 years down the road. A TSM&O program can focus on solving the problems of today and not just the problems of tomorrow.

A TSM&O program can focus on solving the problems of today, and not just the problems of tomorrow!

Unlike planning studies on a project development path, a TSM&O program does not depend on "upstream" work, is not tied to a limited set of alternatives, and is not on a defined schedule. A TSM&O program enjoys wide flexibility to advance systems, services, and projects that can improve the security, safety, and reliability of the transportation system in the short-term and the long-term.

Any agency can utilize this Guidebook to start or revive a TSM&O program today. The foundational knowledge contained in this Guidebook can help your agency plan for TSM&O. The list of TSM&O strategies presented in **Appendix B** and the TSM&O checklist presented in **Appendix E** will provide a roadmap to the development of a successful TSM&O program.

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TSM&O Guidebook Appendices

Appendix A: TSM&O Key Concept References

Appendix B: TSM&O System Level

Appendix C: Systems Engineering References

Appendix D: FDOT TSM&O 2017 Strategic Plan

Appendix E: CDOT TSM&O Evaluation Checklist

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Appendix A: TSM&O Key Concept References

Table A-1: Planning Concepts

Table A-2: Benefit Cost Analysis References

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Table A-1: Planning Concepts

PLANNING CONCEPT		REFERENCE
Context Sensitive Solutions	Context-sensitive solutions (CSS) are categorized as a process and a product, and are relevant to TSM&O because of the emphasis on creating solutions for the whole transportation network, not just the roadway. In other words, to maximize the existing transportation network, all modes of transportation, community needs, and available, relevant data sources should be considered.	http://contextsensitivesolutions.org/
Livability	The Livability Initiative supported by FHWA is a concept based on the principle that the transportation network can promote the livability of a community by providing access to jobs, goods and services, housing, schools, and safe transportation facilities. This is directly applicable to the TSM&O program with the goal of providing safe and efficient transportation to the traveling public, which includes mode choice and reliability.	http://www.fhwa.dot.gov/livability/
Complete Streets	The Complete Streets initiative adopted by transportation agencies around the country, supports the goal of improving safety and mobility for all modes of travel, users of all ages and all mobility levels. This is accomplished by utilizing the entire right-of-way for design elements to enhance safety, mobility, and operations.	http://www.smartgrowthamerica.org/complete-streets
Multi-modal Solutions	Multi-modal solutions provide safe and logical access to the transportation network for all modes of travel, including vehicles, pedestrians, bicycles, freight, and transit. This concept requires connectivity between transportation facilities, pedestrian and bicycle, and transit facilities. There is an important land use connection in addition to the transportation element when planning these facilities.	

Table A-2: Benefit Cost Analysis References

REFERENCE	PUBLISHER	REFERENCE
Operations Benefit/Cost Analysis Desk Reference	FHWA	http://ops.fhwa.dot.gov/publications/fhwahop12028/index.htm
Life-Cycle Cost Analysis Primer	FHWA	https://www.fhwa.dot.gov/asset/lcca/010621.pdf
User and Non-User Benefit Analysis for Highways	AASHTO	https://bookstore.transportation.org/item_details.aspx?id=1590
Economic Analysis Primer	USDOT	http://www.webpages.uidaho.edu/~mlowry/Teaching/EngineeringEconomy/Supplemental/USDOT_Economic_Analysis_Primer.pdf
SHRP2 C11	SHRP2	http://shrp2archive.org/?page_id=44

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Appendix B: TSM&O System Level

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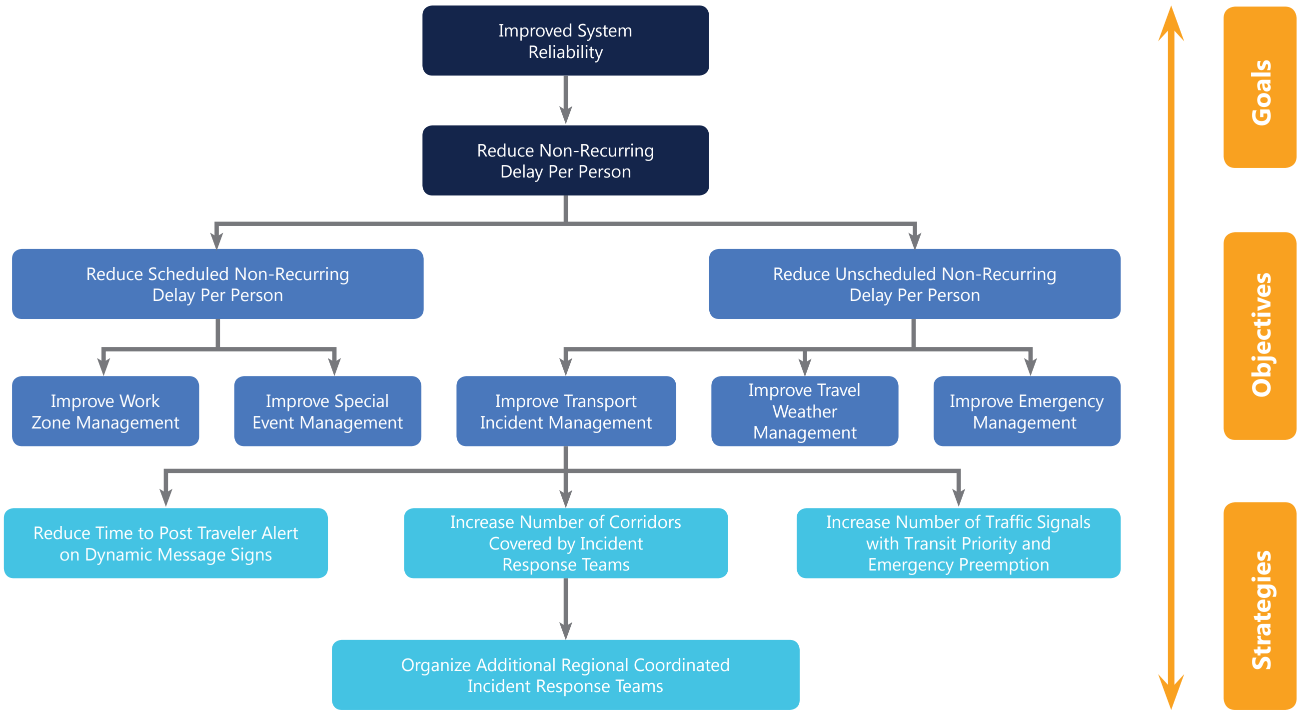


Figure B-1: Decision Tree

Table B-1: Transit Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Fixed route bus transit	X			Fixed-route services include any bus service in which vehicles run along an established path at preset times.	LYNX (Central Florida)	TCRP Synthesis 10: Bus Route Evaluation Standards TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System

Table B-1: Transit Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
On-Demand Transit	X			On-demand transit is a form of public transportation characterized by flexible routing and scheduling. As opposed to a fixed route and traditional bus, small and medium sized vehicles provide a shared ride for multiple passengers with similar pick-up and drop-locations.	UberPool, Bridj	Dynamic Ridesharing Technologies: Opportunities for the MBTA's The RIDE Paratransit Services Rundin Center for Transportation Policy & Management: Intelligent Paratransit
Transit Signal Priority (TSP)			X	Transit Signal Priority (TSP) is an operational strategy to facilitate the movement of transit vehicles through signalized intersections. It is done by giving transit vehicles an extended green or reduced red at signalized intersections under certain pre-defined conditions (e.g., passenger load).	DDOT	FTA Transit Signal Priority Research Tools NCHRP Report 812 Signal Timing Manual 2nd Edition
Bus Rapid Transit (BRT)	X			Bus rapid transit (BRT) is typically characterized as a bus route with dedicated bus lanes. Other key features includes off-board ticketing and at-level boarding. BRT combines the speed, convenience, and capacity of a light rail system with the flexibility of bus transit, and increases the quality of service provided to transit riders.	Cleveland HealthLine	TCRP Report 118: Bus Rapid Transit Practitioner's Guide TCRP Report 117: Design, Operation, and Safety of At-Grade Crossings of Exclusive Busways
Light Rail Transit	X			Light rail transit is a form of public transportation using rolling stock similar to a tramway, but operating at a higher capacity, and often on an exclusive right-of-way. LRT is designed to accommodate a variety of environments, including streets, freeway medians, and railroad rights-of-way (operating or abandoned).	Portland Streetcar	TCRP Report 17: Integration of Light Rail Transit into City Streets TCRP Report 69: Light Rail Pedestrian and Vehicular Safety

Table B-1: Transit Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Heavy Rail Transit	X			A heavy rail system is as an electric railway with the capacity to handle a heavy volume of traffic. It is characterized by high-speed, passenger rail cars running in separate rights-of-way from which all other vehicular and foot traffic are excluded.	New York City Subway	APTA: Rail Transit to Focus on Improving, Expanding Rail Infrastructure TCRP Report 13: Rail Transit Capacity
Park and Ride	X			Electronic Toll Collection (ETC) systems charge a toll to an established customer account without requiring any action by the driver as a car or truck passes through. The system electronically debits the accounts of registered car owners or identifies the license plate for later billing without requiring vehicles to stop.	BART parking lots, San Francisco, CA	TCRP Report 95: Park-and-Ride/Pool Texas A&M Transportation Institute: Park-and-Ride Lots

Table B-2: Bicycle and Pedestrian Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Enhance or provide bicycle infrastructure		X		Bicycle-specific projects can include re-striping a roadway during regular maintenance to include bicycle lanes, and cities are increasingly adding bicycle share programs and building lanes with physical barriers for bicyclists, known as cycle tracks.	Portland Bureau of Transportation 20's Bikeway Project	AASHTO Task Force on Geometric Design: ASSHTO Guide for the Development of Bicycle Facilities NACTO: Urban Bikeway Design Guide

Table B-2: Bicycle and Pedestrian Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Bikesharing	X			Bikeshare is a service in which bicycles are made available for shared use to individuals on a short term basis. Users can rent a bike at one station and return the bike to any other station in the network, allowing users to get from point "A" to point "B."	Capital Bikeshare (Washington, D.C.); BikeTown (Portland, OR)	NACTO: Bike Share Station Siting Guide Bike-Share Systems: Accessibility and Availability
Enhance or provide pedestrian infrastructure		X		Some of the most effective investments in pedestrian facilities in recent years include sidewalk construction for closing gaps in pedestrian networks, audible countdown pedestrian signals at crosswalks, and flashing overhead beacons for crossing streets in the middle of a long block.	Tilikum Crossing (Portland, OR)	ACCESS MINNEAPOLIS: Design Guidelines for Streets & Sidewalks - Chapter 10: Pedestrian and Facility Design Sacramento Transportation & Air Quality Collaborative: Best Practices for Pedestrian Master Planning and Design
Pedestrian Hybrid Beacon (HAWK)		X		The pedestrian hybrid beacon (or HAWK) is a pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings. The beacon head consists of two red lenses above a single yellow lens. The beacon head is "dark" until the pedestrian desires to cross the street. At this point, the pedestrian will push an easy-to-reach button that activates the beacon. After displaying brief flashing and steady yellow intervals, the device displays a steady red indication to drivers and a "WALK" indication to pedestrians, allowing them to cross a major roadway while traffic is stopped.	Tucson, AZ, provided the research team for the study, "Safety Effectiveness of the HAWK Pedestrian Crossing Treatment" with a list of all HAWKs that were planned or installed in their city	FHWA: Pedestrian Hybrid Beacon Guide, Recommendations and Case Study FHWA: Safety Effectiveness of the HAWK Pedestrian Crossing Treatment

Table B-2: Bicycle and Pedestrian Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Crosswalks with Crossing Islands		X		Pedestrian crossing islands (or refuge areas)—also known as center islands, refuge islands, pedestrian islands, or median slow points—are raised islands placed on a street at intersections or midblock locations to separate crossing pedestrians from motor vehicles.	School Zone Traffic Calming (Portland, OR)	Pedsafe: Crossing Islands FHWA: Medians and Pedestrian Crossing Islands in Urban and Suburban Areas

Table B-3: Arterials Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Arterial Traffic Signal Coordination	X		X	This strategy involves the coordination of traffic signal timing patterns and algorithms to smooth traffic flows – reducing stops and delays and improving travel times. This strategy can be implemented on a small corridor, a limited grid, or regionwide in aggressive deployments. The sophistication of the timing coordination can also vary from simple preset timing programs to more advanced traffic actuated corridor systems, to fully centrally controlled applications.	Lake Forest Drive - Cañada to I-5, El Toro Road - Muirlands Blvd. to I-5, Bake Parkway - Town Centre Drive to Jeronimo Road (Trabuco Road, Cromwell/ Calle Entrada, Toledo Way & Jeronimo Road are Irvine-maintained) (Lake Forest, CA)	USDOT: Traffic Signal Timing & Operations Strategies USDOT: Real-Time Arterial Traffic Signal Performance Measures

Table B-3: Arterials Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Adaptive Signal Control	X			Adaptive traffic control is a traffic management strategy in which traffic signal timing changes, or adapts, based on actual traffic demand. This is accomplished using an adaptive traffic control system consisting of both hardware and software.	Portland I-84 Corridor	NCHRP 403: Adaptive Traffic Control Systems USDOT: Adaptive Signal Control Technologies
Roundabouts		X		A roundabout is a type of circular intersection in which road traffic flows almost continuously in one direction around a central island. Vehicles yield on entry to the circulating traffic.	Gaines Street roundabout (Tallahassee, FL)	NHCRP 672: Roundabouts: An Informational Guide - Second Edition NACTO: Roundabouts - An informational Guide
Road Widenings	X		X	Widening a freeway or street has been a traditional strategy for mitigating congestion along a corridor. Widening or adding a freeway or street is a major project that requires careful planning, comprehensive public engagement, and ample financial support.	Widening road to increase capacity and/ or to expand surfaces to improve quality of road material for safety	ROADEX: Road Widening - Literature Review and Questionaire Responses Victoria Transport Policy Institute: Generated Traffic and Induced Travel

Table B-3: Arterials Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Arterial Access Management	X	X		Access management is a set of techniques that State and local governments use to control access to highways, major arterials, and other roadways. The benefits of access management include improved movement of traffic, reduced crashes, and fewer vehicle conflicts. Access management principles are applicable to roadways of all types, ranging from fully access-controlled facilities, such as freeways, to those with little or no access control, such as local streets. Successful access management, managed by change in access density, seeks to simultaneously enhance safety, preserve capacity, and provide for pedestrian and bicycle needs.	Washtenaw County Access Management Plan (Michigan)	Iowa DOT: Access Management Guidebook for Major Arterial Intersections NACTO: Chapter 2 - Standards for Access, Non-Motorized, and Transit
Retroreflective Signal Backplates		X		Backplates are added to traffic signal indication in order to improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background. The improved visibility of a signal head with a backplate is then made more conspicuous by framing the backplate with a retroreflective border. Taken together, a signal head equipped with a backplate with retroreflective border is made more visible and conspicuous in both daytime and nighttime conditions, which is intended to reduce unintentional red-light running crashes.	South Carolina DOT: Sumter Highway (US 378) with Lower Richland Boulevard (S-37), I-26 Westbound (WB) with Piney Grove Road (S-1280), Piney Grove Road (S-1280) with Jamil Road (S-1791)	FHWA: Backplates with Retroreflective Boarders FHWA: Retroreflective Boarders on Traffic Signal Backplates - A South Carolina Success Story

Table B-3: Arterials Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Arterial Geometric Modifications		X		The most common strategies include removing elements that hinder sight distance, making drivers aware that they are approaching an intersection, and improving bicycle or pedestrian facilities at the intersection	Tensleep-Buffalo Highway (U.S. 16) (Buffalo, WY)	FHWA: Mitigation Strategies for Design Exceptions City of San Jose DOT: Geometric Design Guidelines
Traffic Signal Re-Timing	X		X	Signal improvements are among the most common, readily available, and cost effective strategies to alleviate congestion. Signal timing improvements increase travel speed, reduce stop-and-go traffic, and increase intersection capacity.	The City of San Antonio, Texas, has been conducting a city-wide signal system upgrade since 2008, including signal retiming for most major roadway corridors.	ITE Journal: The Benefits of Retiming Traffic Signals NCHRP Synthesis 409:Traffic Signal Retiming Practices in the United States
Traffic Management Center	X		X	Traffic management centers (TMCs) serve as the mission control for an urban area's major street and highway network. This one location monitors traffic signals, intersections, and roads and proactively deploys traffic management strategies to reduce congestion and coordinate state and local authorities during special events, emergencies, or daily stop-and-go traffic.	Florida Department of Transportation District Five (FDOT D5) Regional Traffic Management Center in Orlando, Florida.	Texas A&M Transportation Institute: Traffic Management Centers FHWA: Transportation Management Centers, Emergency Operations Centers, and Fusion Centers

Table B-4: Freeways Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Ramp Metering	X	X	X	Ramp meters are traffic signals installed on freeway on-ramps to control the frequency at which vehicles enter the flow of traffic on the freeway. Ramp metering reduces overall freeway congestion by managing the amount of traffic entering the freeway and by breaking up platoons that make it difficult to merge onto the freeway.	Minneapolis-St. Paul	University of California, Berkeley: Coordination of Freeway Ramp Meters and Arterial Traffic Signals Field Operational Test USDOT: Ramp Metering - A Proven, Cost-Effective Operational Strategy--A Primer
Traffic Incident Management	X	X	X	These strategies are often divided into several substrategies that may be combined to create a coordinated system. The benefits of these systems include a reduction in incident related delay (and associated fuel use and emissions impacts), and can include safety benefits by allowing for faster dispatch and response of emergency personnel and assets to injury accidents.	City of Tallahassee and Leon County Public Safety Complex	FHWA: Best Practices in Traffic Incident Management FHWA: Traffic Incident Management: Cost Management and Cost Recovery Primer
Traveler Information				These strategies may provide a variety of information (e.g., travel times, mode change opportunities, construction work zone information, incident warnings, and alternative route recommendations) to travelers already using the system, allowing the travelers to make more informed decisions on travel route and mode choice.	FHWA - 511: America's Traveler Information Telephone Number	FHWA: America's Travel Information Number - Implementation and Operational Guidelines for 511 Services FHWA: Real-Time System Management Information Program

Table B-4: Freeways Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Variable Speed Limits/Speed Harmonization		X	X	Involves the implementation of variable speed limits and the communication of those limits through roadside signs. The speed limits are modified according to congestion levels to lessen stop-and-go conditions and lower the speed of vehicles as they approach downstream bottlenecks. The primary benefit of these emerging systems is improved safety.	IH 40 (eastbound) in Albuquerque, New Mexico	Center for Transportation Research: Speed Harmonization and Peak-period Shoulder Use to Manage Urban Freeway Congestion Colorado DOT: Guide to Variable Speed Limits on the I-70 Mountain Corridor
Work Zone Management		X	X	Involves the coordinated implementation and use of pre-trip (e.g., 511 web-based applications) and en-route (e.g., DMS and HAR) traveler information, along with construction traffic management and alternative construction work hours planning to mitigate the congestion related to construction work zones.	IH 96, South and west of Lansing, Michigan [16] VSL in work zones	FHWA: Work Zone Traffic Management FHWA: Appendix B - Work Zone Management Strategies Matrix
Managed Lanes	X		X	Allows SOVs to pay a toll to use underutilized HOV lane capacity. These systems most often utilize an in-vehicle transponder to determine lane usage and assess tolls. The tolls charged may vary according to time-of-day schedules, or may be dynamically assessed in response to traffic conditions and available HOV lane capacity.	I-4 Ultimate in Orlando, Florida	Florida Public Transit Association: Managed Lane Action Plan FHWA: Priced Managed Lane Guide

Table B-4: Freeways Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Queue Warning System			X	Queue warning's basic principle is to inform travelers of the presence of downstream stop-and-go traffic (based on real-time traffic detection) using warning signs and flashing lights.	IH 610, Houston	Texas A&M Transportation Institude: Queue Warnings Journal of Transportation Technologies: Test a Queue Detection System for Special Events in Nevada
Weigh-In-Motion	X		X	Weigh-in-motion or weighing in motion (WIM) devices are designed to capture and record axle weights and gross vehicle weights as vehicles drive over a measurement site.	Installation of weight sensors such as bending plate sensors, load cell sensors, piezoelectric sensors, piezoceramic sensors, piezopolymer sensors, piezo quartz sensors, fiber-optic sensors	Virginia Tech Transportation Institute: Final Report of ITS Center Project - Weigh-in-motion evaluation FHWA: LTBP Program's Literature Review on Weigh-in-Motion Systems
Electronic Toll Collection	X	X	X	Electronic Toll Collection (ETC) systems charge a toll to an established customer account without requiring any action by the driver as a car or truck passes through. The system electronically debits the accounts of registered car owners or identifies the license plate for later billing without requiring vehicles to stop.	Successful conversion to all electronic tolling by the North Texas Tollway Authority.	Texas A&M Transportation Institute: Electronic Toll Collection Systems AASHTO: Managing the NEPA Process for Toll Lanes and Toll Roads

Table B-4: Freeways Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Hard Shoulder Running	X			Involves allowing vehicles to travel on the shoulder facilities of roadways often for isolated sections of roadway or limited times of operation. The availability of the shoulder for use is often communicated through the use of overhead gantries or roadside DMS.	Minneapolis, Minnesota Ð Dynamic Shoulder Lane	FHWA: Use of Freeway Shoulders for Travel Texas A&M Transportation Institute: Temporary Shoulder Use
Longitudinal Side Rumble Strips		X		Longitudinal rumble strips are milled or raised elements on the pavement intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane.	Maryland DOT State Highway Administration	SHA: Guidelines for Application of Rumble Strips and Rumble Stripes FHWA: Longitudinal Rumble Strips and Stripes on Two-Lane Roads
Reversible Lanes	X			Reversible traffic lanes add capacity to a road and decrease congestion by borrowing capacity from the other (off-peak) direction.	Golden Gate Bridge in San Francisco, CA	Texas A&M Transportation Institute: Reversible Traffic Lanes Miami-Dade MPO: Executive Summary - Reversible Lanes

Table B-5: Planning Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Traveler Information				These strategies may provide a variety of information (e.g., travel times, mode change opportunities, construction work zone information, incident warnings, and alternative route recommendations) to travelers already using the system, allowing the travelers to make more informed decisions on travel route and mode choice.		

Table B-5: Planning Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Congestion Pricing	X	X	X	Cordon area congestion pricing is a fee or tax paid by users to enter a restricted area, usually within a city center, as part of a demand management strategy to relieve traffic congestion within that area.	London, UK Congestion Charge Singapore Congestion Charge	FHWA: Congestion Pricing - A Primer: Overview Victoria Transport Policy Institute: London Congestion Pricing - Implications for Other Cities
Encourage Carpooling	X			Carpooling programs are designed to promote ridesharing by identifying riders with similar origins and destinations. Using a database of interested riders, employers, or regional agencies can promote this for an entire region.	Carpooling.com, Zimride	FHWA: Casual Carpooling Focus Group Study Texas A&M Transportation Institute: Carpooling
Encourage Telecommuting	X			Telecommuting offers flexibility to employees who can perform work tasks remotely. Advancement in technology has allowed most office functions to occur remotely, eliminating the requirement to be physically present in an office.	In Minneapolis, 75 percent of Best Buy's 4,500 corporate employees participate in a Results-Only Work Environment (ROWE) program. The program allows employees to work at alternative locations and times.	Texas A&M Transportation Institute: Telecommuting TRB: Does Telecommuting Reduce Vehicle-Miles Traveled? An Aggregate Time Series Analysis for the U.S.
Encourage Flexible Work Schedules	X			Flexible work hour programs (or Flextime) allow employees to work within a specific time range during the day, often avoiding peak traffic periods, though all employees work a core period of the day.	Establishment of programs such as flextime, compressed workweek, staggered shifts	Texas A&M Transportation Institute: Flexible Work Hours Victoria Transport Policy Institute: Alternative Work Schedules

Table B-5: Planning Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Encourage Carsharing	X			Carsharing is a model of car rental where people rent cars for short periods of time, often by the hour. They are attractive to customers who make only occasional use of a vehicle, as well as others who would like occasional access to a vehicle of a different type than they use day-to-day.	Zipcar, Hertz 24/7	TCRP Report 108: Car-Sharing - Where and How It Succeeds Victoria Transport Policy Institute: Evaluating Carsharing Benefits
Encourage Ridebooking	X			Transportation Network Companies (TNCs) connect paying passengers with drivers who provide the transportation on their own non-commercial vehicles. All parties connect to the service via website and mobile apps.	City of Altamonte Springs, FL partnership with Uber	National Association of Insurance Commissioners: Transportation Network Company Insurance Principles for Legislators and Regulators NACTO: Ride-Hailing Services - Opportunities & Challenges for Cities
Parking Pricing	X			Cities see parking as a commodity and are deploying new parking technology with flexible pricing methods to better utilize the available parking inventory.	SF Park, San Francisco, CA	TCRP Report 95: Parking Pricing and Fees National Center for Transit Research: Washington, DC - How Free Parking Affects Transportation Choices
Road Diets		X		A road diet, or lane elimination, is a technique where the number of travel lanes and/or effective width of the travel lanes is reduced in order to incorporate other improvements such as bike lanes or on-street parking.	Nebraska Avenue (Tampa, FL)	FDOT Statewide Lane Elimination Guidance FHWA: Road Diet - Information Guide

Table B-5: Planning Strategies Matrix Continued...

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Special Event Traffic Management Plan	X	X		Special events (sporting events, concerts, fairs, conventions, etc.) cause high traffic congestion as attendees overload local street and highway networks adjacent to the venue. Unlike unplanned events, mitigation can easily be planned and coordinated to minimize its effects on normal traffic operation.	The University of Florida partners with the City of Gainesville to manage gameday traffic.	Texas A&M Transportation Institute: Special Event Management FHWA: Planned Special Events Traffic Management
Road Safety Audits		X		A Road Safety Audit (RSA) is the formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.	Conducting design quality control or standard compliance checks also known as "safety reviews of design," Traffic impact or safety impact studies	FHWA: Road Safety Audits (RSA) FHWA: Priority, Market-Ready Technologies and Innovations
Safety Project Prioritization		X		This systemic safety planning process involves identifying the problem, screening and prioritizing candidate locations, selecting countermeasures, and prioritizing projects. The premise that makes systemic safety planning different from traditional network screening techniques is that it looks for similar issues across the roadway system rather than focusing on select locations with high crash histories or densities.	MnDOT's Application of the Systemic Safety Planning Process: Identify Focus Crash Types and Risk Factors – Select Focus Facilities	FHWA: Systemic Safety Project Selection Tool FHA: MPO Guidebook for Using Safety as a Project Prioritization Factor

Table B-6: Freight & Other Strategies Matrix

STRATEGY	CONGESTION	SAFETY	RELIABILITY	DESCRIPTION	SAMPLE PROJECTS	RESOURCES
Dynamic Freight Routing and Scheduling	X		X	Dynamic truck restrictions constrain trucks to certain lanes or routes that give at least one lane exclusively to passenger traffic and may be adjusted based on traffic flow or time of day considerations.	The Netherlands began testing dynamic truck restrictions after successful implementations of restrictions based on time-of-day.	USDOT: Dynamic Mobility Applications (DMA) Program University of Maryland National Transportation Center: State of the Art in Freight Reliability Analysis and Modeling
Vehicle Collision Avoidance		X	X	A collision avoidance system is an automobile safety system designed to reduce the severity of a collision. It uses radar (all-weather) and sometimes laser and camera (both sensor types are ineffective during bad weather) to detect an imminent crash. Once the detection is done, these systems either provide a warning to the driver when there is an imminent collision or take action autonomously without any driver input (by braking or steering or both)	In March of 2016, the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety announced the manufacturers of 99% of U.S. automobiles had agreed to include automatic emergency braking systems as a standard feature on virtually all new cars sold in the U.S. by 2022.	FHWA: Crash Data Analysis for Vehicle-to-Infrastructure Communications for Safety Applications FHWA: Update on Intelligent Vehicles and Intersections

Appendix C: Systems Engineering References

Table C-1: Systems Engineering Document Templates

Table C-1: Systems Engineering Document Templates

REFERENCE	PUBLISHER	FILE NAME OR URL
ConOps Guide and Template	VDOT	http://www.vdot-itsarch.com/docsandfiles.html
FDOT ConOps Template	FDOT	http://www.fdot.gov/traffic/ITS/Projects_Deploy/SEMP.shtm
FDOT SEMP Template	FDOT	http://www.fdot.gov/traffic/ITS/Projects_Deploy/SEMP.shtm

Concept of Operations Guidance Document and Template

June 2009

Northern Region Operations

TABLE OF CONTENTS

1 INTRODUCTION

The Virginia Department of Transportation's (VDOT) Northern Region developed this document to provide guidance to transportation professionals as they seek to develop and use Concepts of Operation to define Northern Region Operations (NRO) ITS projects. This document is closely based on Federal Highway Administration's (FHWA) primer on *'Developing and Using a Concept of Operations in Transportation Management Systems'*.

1.1 Objective

The Concept of Operations Guidance Document is designed to provide the reader with insight into VDOT NRO's recommended requirements for an operations-focused Concept of Operations document. As such, it offers:

- *Guidance on developing the Concept of Operations*, including what information to include, how to begin the development process, stakeholder identification and involvement in the process, and identifying resources that will facilitate the development process.
- *Guidance on using Concepts of Operations*, including highlights of the entire systems engineering process.
- *Specific examples of good practice*, including examples *from* past VDOT NRO Concept of Operations.

1.2 Audience

This document is written for transportation professionals involved in the VDOT NRO project planning and development of ITS projects within the VDOT NRO footprint. However, the document is relevant to a wide audience and is intended to communicate essential information about Concepts of Operation to a variety of transportation professionals.

The following audiences will find the guidance document useful for the following reasons:

- *State and Local DOT Management* – Transportation managerial professionals will find that this document reiterates the necessity of system stakeholder communication. A Concept of Operations is a critical foundation for such communication.
- *State and Local DOT Technical Staff* – Technical staff working on operations projects that deal with all aspects of the system's operation, including but not limited to design engineers, integration and test engineers, operators of the various system functions, and maintenance staff, will find that this document demonstrates how a Concept of Operations helps to clarify agency goals and objectives and keep all involved personnel on the same page.
- *Transportation Consultants* – Transportation consultants that are working within or in conjunction with VDOT NRO, performing work that includes repairs and maintenance, system support services, etc., will find that this document shows how a Concept of Operations assures that the 'client' has communicated, at the highest possible level, what they want the system to be – adding clarity and helping to avoid scope creep for all parties.

This document is also written for non-technical community leaders, local officials, and others who have an interest in transportation issues and who may influence resource allocation decisions. Such individuals may have as much input, if not more, in some cases, into transportation system development decisions as transportation professionals themselves.

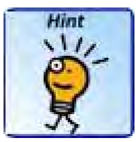
Information presented in this document is presented with the understanding that not all of the individuals or groups reviewing this document will be at the same point operationally or developmentally. As such, consideration will be given to those organizations, agencies and individuals who:

- Are new to a Concept of Operations.
- Have limited experience with developing a Concept of Operations for VDOT NRO.
- Are seeking to develop and use a Concept of Operations for an existing system.

1.3 About the Icons

Icons are used to highlight pertinent information throughout this document.

This *"Reference / Tools"* icon identifies resources that offer additional information related to systems engineering, including books, reports, presentations, and other documents. It also identifies references and/or tools may that support some aspect of the development of the Concept of Operations.



This *"Hint"* icon identifies suggestions that may improve the systems engineering analysis or the quality of the systems engineering products that are created. Usually based on actual experience, these are ideas that have worked in the past.

This *"Outreach"* icon identifies steps in the Concept of Operations development where VDOT NRO staff or regional stakeholders need to be included in the process. Meetings, conference calls, and other means should be used to solicit input from stakeholders.

This "*Example*" icon identifies real-world examples from existing VDOT NRO Concept of Operations. These examples are intended to assist the reader with understanding the expected content that should be included in a Concept of Operations prepared for VDOT NRO.

This *"Caution"* icon flags warnings. In contrast to tips, these are problems that have been encountered that you should avoid. Also frequently based on actual experience, these are ideas that have NOT worked in the past.

2 WHAT IS A CONCEPT OF OPERATIONS?

The Concept of Operations is a user-oriented document that describes characteristics of a to-be-delivered system from the user's viewpoint. The Concept of Operations is used to identify and communicate overall quantitative and qualitative characteristics of systems to the user, developer, maintainer, and other affected parties.

The Concept of Operations should be a document available, and relevant, to all stakeholders in the system, no matter what their background or role within the system. It should be as readable and relevant to high-level decision makers as it is to the project manager and the system operator. The Concept of Operations answers the who, what, when, where, why, and how for the new or existing system:

- *What* – What are the known elements and the high-level capabilities of the system?
- *Where* – What are the geographical and physical extents of the system?
- *When* – What is the time sequence of activities that will be performed?
- *How* – What resources do we need to design, build, or retrofit the system?
- *Who* – Who are the stakeholders involved with the system?
- *Why* – What does your organization lack that the system will provide?

Figure 1 provides a conceptual representation of a Concept of Operations. This includes information about the system itself as well as the operational environment (i.e., facility, personnel, hours of operation) and the support environment (i.e., how will the system be maintained).

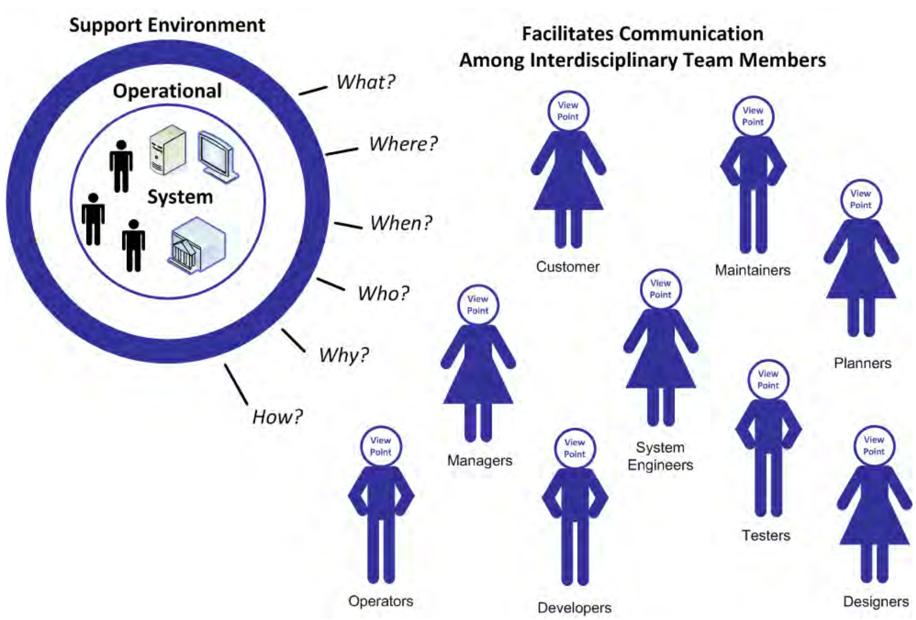


Figure 1. Concept of Operations Conceptual Representation (Graphic adapted from ANSI/AIAA's "Guide for the Preparation of Operational Concept Documents" ANSI/AIAA G-043-1992).

This information is gathered through facilitated communication among interdisciplinary team members including various regional stakeholders. This includes planners, system engineers, developers, operators, maintainers, customers, and other stakeholders that interact with the system. Development of a Concept of Operations should be led by a facilitator that can engage communication between these stakeholders, has an understanding of regional stakeholder roles and responsibilities, and has knowledge of existing and future systems. The Concept of Operations documents agreement on:

- Goals, objectives, and expectations.
- Project Scope.
- Stakeholder responsibilities.
- How the system will operate.
- Operational and support environment.

The Concept of Operations is not a "wish list" generated by users that engineers focus on briefly prior to beginning the hard work of figuring out what the system is actually going to do. This perspective has several faults: a good Concept of Operations for a complex problem should be jointly developed by stakeholders and describe something that is "doable" in the engineering sense. The result of applying the faulty "wish list" perspective is often a development effort that rapidly devolves into cycles of reduced expectations and cost overruns.

2.1 Why Develop a Concept of Operations?

There are a variety of benefits that can accrue to an organization or group of organizations from developing a Concept of Operations. When planning, designing, deploying, operating, and maintaining a project, defining a shared set of expectations is of critical importance. The Concept of Operations supports the development and documentation of these expectations to serve as the essential foundation for the project. The Concept of Operations provides structured, comprehensive guidance by:

- Identifying, and serving as a tool to engage the diverse array of stakeholders who will be impacted by the project.
- Identifying the users of the proposed system so that a description of user needs can be developed.
- Developing goals and objectives based on identified user needs and agreed upon vision for the project.
- Revealing institutional barriers to collaboration and suggesting ways to surmount the obstacles.
- Describing the current infrastructure and institutional framework.
- Providing a comprehensive view of how the proposed system will function under expected conditions (scenarios).
- Describing current operations within the region and describing how this will be affected by the proposed project.
- Differentiating between those functions and services that would provide greater benefit if approached at the regional level and those that should continue to be performed at the local level.
- Identifying the resources necessary to build, operate, and maintain the new system or service created by the project.

- Detailing the number and types of agreements needed to implement the proposed project.
- Defining the roles and responsibilities of the various agencies that will build, operate, and maintain the proposed system.

An additional benefit from stakeholder consensus is a *decreased risk of project failure*. The experiences of transportation professionals have shown that developing a Concept of Operations significantly increases the chance for success on the project. The stakeholder consensus integral to the Concept of Operations development process not only builds a unified vision and understanding of a new system, but also contributes to reductions in cost overruns, a more accurate definition of the system earlier in the development stage, and a decrease in the likelihood that stakeholder dissatisfaction will terminate the project. One transportation professional said of the Concept of Operations for a Transportation Management System that it is "not a silver bullet [i.e., not a cure-all to the problems of developing and maintaining a TMS], but it does decrease the likelihood of failure for a project." The benefit of a Concept of Operations can best be described using an example:

EXAMPLE #1 – WHY DEVELOP A CONCEPT OF OPERATIONS?

A local transportation agency (i.e., a County Department of Transportation) is planning to take a more proactive approach toward operating its roadways and decided to move forward with a closed circuit television (CCTV) project on the 'County Parkway'. The project originated from the need for the agency to monitor traffic on its roadways and so the agency could update its traffic signal timing plans during major incidents/events. The project seemed straightforward, simply deploy CCTV cameras in the field and tie them into the County's new Advanced Traffic Management System (ATMS).

As the County began moving forward with its CCTV project, they were approached by the County Police Department asking if they could get access to the video images once the project was complete. The Police Department wanted to be able to monitor the roadway during incidents and emergencies. Understanding the Police Department's need the County decided to include a fiber connection between its Transportation Operations Center (TOC) and the Police Dispatch Building.

A few weeks later, the County learned that VDOT was also thinking about putting CCTV cameras on the 'County Parkway' and asked the County if they could have a direct feed to the cameras instead of installing their own cameras on the same road to assist with incident management. The media also expressed a need for the cameras to allow them to show traffic conditions on the news. The County soon recognized that the cameras could serve multiple regional needs, but they did not have funding to install and maintain fiber between each agency's facilities. It also seemed like an opportunity for the region to leverage various funding sources for a larger more comprehensive project.

Rather than moving forward with what seemed like a "stove-piped" project, the County decided to develop a Concept of Operations to identify all stakeholder needs and to leverage various funding sources between the County and VDOT. A series of stakeholder outreach meetings were scheduled to solicit input for the new project. During these meetings the County learned that in addition to the County Police, VDOT, the media, and Virginia Department of Emergency Management, and Metropolitan Area Transportation Operations Coordination facilitator and a few additional regional stakeholders also wanted to be able to view the cameras. The County also learned that VDOT had an existing 'Video Sharing Clearinghouse' that allowed video images to be shared with agencies over the web where County can leverage VDOT's contract to join the network.

A Concept of Operations was developed and it was stakeholder consensus determined that rather than having fiber connections between each agency it would be best to leverage VDOT's 'Video Sharing Clearinghouse'. This would result in a significant cost savings to the County and promoting regional coordination.

2.2 Role within the Systems Engineering Process

The International Council of Systems Engineering (INCOSE) defines systems engineering as following:

> *"Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem.*
>
> *Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs."*

Since it was first developed in the 1980s, the "V" model has been refined and applied in many different industries. Wings have been recently added to the "V" as part of its adaptation for ITS to show how project development fits within the broader ITS project life cycle. The left wing shows the regional ITS architecture, feasibility studies, and concept exploration that support initial identification and scoping of an ITS project based on regional needs. A gap follows the regional architecture(s) step because the regional architecture is a broader product of the planning process that covers all ITS projects in the region. The following steps in the "V" are for a specific ITS project. The central core of the "V" shows the project definition, implementation, and verification processes. The right wing shows the operations and maintenance, changes and upgrades, and ultimate retirement or replacement of the system. The wings are a key addition to the model since it is important to consider the entire life cycle during project development.

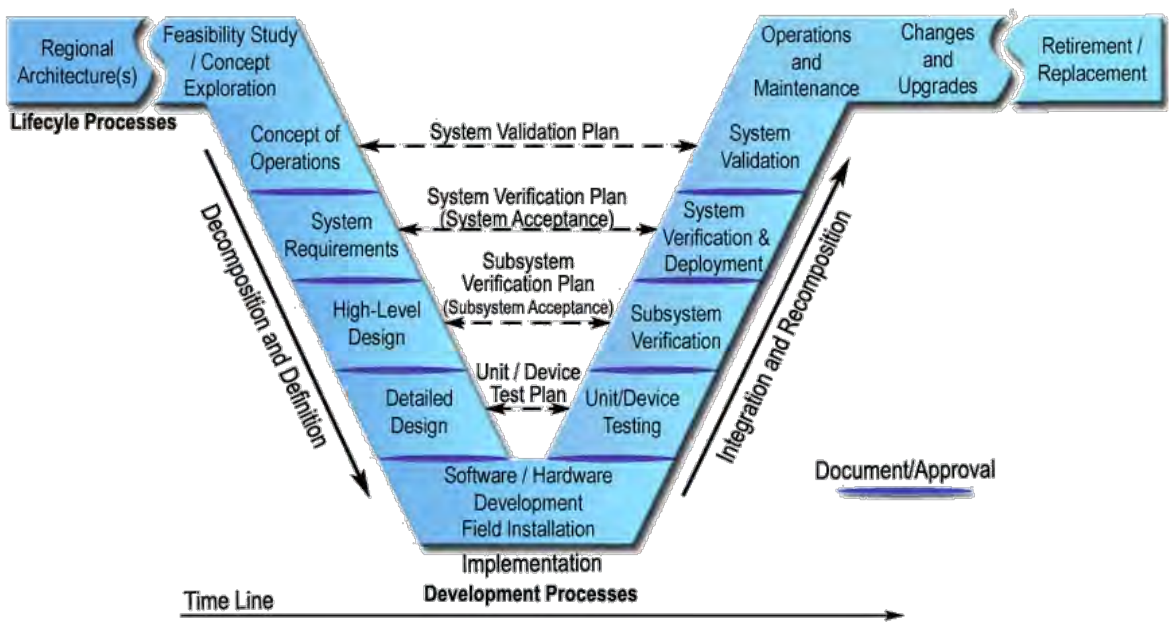


Figure 2. The Systems Engineering "Vee Diagram".

As shown in the "V", the systems engineering approach defines project requirements before technology choices are made and the system is implemented. On the left side of the "V", the system definition progresses from a general user view of the system to a detailed specification of the system design. The system is decomposed into subsystems, and the subsystems are decomposed into components – a large system may be broken into smaller and smaller pieces through many layers of decomposition. As the system is decomposed, the requirements are also decomposed into more specific requirements that are allocated to the system components.

VDOT's Northern Virginia ITS Architecture was expanded in 2009 to become a truly regional architecture (no longer VDOT-centric) to cover the entire NRO boundary. It is available at www.vdot-itsarch.com. VDOT NRO's project proposal template and Feasibility Review Process prior to funding consideration are normally complete prior a project establishment and Concept of Operations development. They can be accessed from the architecture website.

As development progresses, a series of documented baselines are established that support the steps that follow. For example, a consensus Concept of Operations supports system requirements development. A baseline set of system requirements then supports system design. The hardware and software are implemented at the bottom of the "V", and the components of the system are then integrated and verified in iterative fashion on the right. Ultimately, the completed system is validated to measure how well it meets the user's needs.

3 ELEMENTS OF A CONCEPT OF OPERATIONS

This section identifies the core elements of VDOT NRO's Concept of Operations template. The template leverages input from two recommended ITS Standards for developing a Concept of Operations. These standards include the ANSI / AIAA standard (G-043-1992) and the IEEE standard (P1362 V3.2). These Concept of Operations standards contain similar information, but are packaged in a different manner.

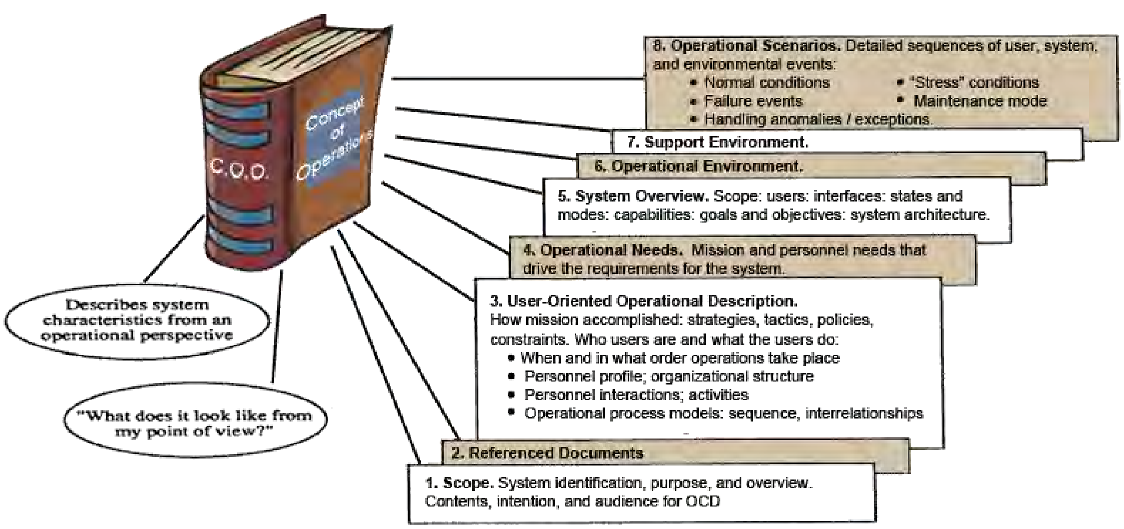


Figure 3. The Core Elements of a Concept of Operations (Graphic adapted from ANSI/AIAA's "Guide for the Preparation of Operational Concept Documents" ANSI/AIAA G-043-1992).

Figure 3 depicts the eight recommended components of VDOT NRO's Concept of Operations: (1) Scope, (2) Reference Documents, (3) Existing Conditions, (4) Operational Needs, (5) System Overview, (6) Operational Environment, (7) Support Environment, and (8) Operational Scenarios. A description of each section is discussed in more detail below. Additionally, examples from previous VDOT NRO Concepts of Operation are provided as references.

3.1 Section 1 – Scope

Scope is the first section of the Concept of Operations and presents an overview of the document. It includes the following components:

- *Introduction, System Overview, and Purpose*. The Concept of Operations should start with an introduction of the proposed system, including a brief overview of the system and its intended purpose. This overview should be done at a high-level and should be independent of specific technologies or vendors. The introduction should also define the contents of the document, the intention of the Concept of Operations, and its intended audience.
- *Project Limits*. Where applicable, this section should define the project limits – including both a written description and a map of the geographic boundaries. An example of a project limit description is provided in Example 2. The description and map should clearly define the geographic boundaries, setting the stage for the remainder of the document.
- *System Vision, Goals, and Objectives*. This section defines the vision, goals, and objectives of the proposed system. Goals and objectives are statements that describe what the system will accomplish, or the business value the system will achieve. The goals and objectives will serve as guiding principles providing the framework, helping stakeholders define system needs and components.

Reference VDOT NRO's 2008 Strategic Plan when defining the system's goals and objectives. The strategic plan identifies VDOT NRO's plan make roadway travel safe, efficient, and reliable. All VDOT NRO projects should map back to this Strategic Plan which can be downloaded from www.vdot-itsarch.com.

- *Role of the Concept of Operations within the Systems Engineering Process*. *Section 1 – Scope* should also briefly define the Role of the Concept of Operations within the Systems Engineering Process. This section should provide an introduction to the Systems Engineering Process for the audience that is unfamiliar with the process. The Systems Engineering "V Diagram" should be discussed and the role of the Concept of Operations should be included in the discussion.

This VDOT NRO Guidance Document is an excellent reference for defining the role of the Concept of Operations in the Systems Engineering Process. Leverage text from Chapters 2 and 6 of this guidance document.

EXAMPLE #2 – PROJECT LIMITS

(from VDOT NRO's I-66 Spot Improvement Concept of Operations)

The Virginia Department of Transportation (VDOT) is proposing a series of spot improvements along westbound I-66 in Arlington and Fairfax Counties to help improve mobility and safety of the corridor. These spot improvements will also help facilitate evacuations from Washington, D.C. in the case of an emergency. The I-66 Spot Improvements consists of three construction segments which will extend the auxiliary lane in the following segments, described below:

- *Segment 1 – between Fairfax Drive and Sycamore Street;*
- *Segment 2 – between Washington Boulevard and the Dulles Connector; and*
- *Segment 3 – between Lee Highway / Spout Run Parkway and Glebe Road.*

The I-66 Spot Improvements are scheduled to begin in Fall 2008 and would be completed by approximately 2010, depending on the procurement approach and staging. Design-build procurement is being considered by VDOT, and construction schedule depends on funding availability. It is possible all 3 segments or just individual segments may be constructed during a specific time frame.

This project area is one of the original routes operated and managed by the VDOT's ITS / Operations Program. Existing ITS components along this corridor include traffic detection, closed circuit television (CCTV) cameras, dynamic message signs (DMS), ramp metering, and Safety Service Patrols. These components are currently being operated by VDOT's Northern Region Traffic Management Center (TMC) located in Arlington, Virginia (moved in late 2008 to Fairfax). Although there have been some recent upgrades – notably modernized dome-type CCTV cameras, non-intrusive detection in lieu of the older loop detection, and replacement of the original coaxial communications with fiber optics – many devices found in the project area are in dire need of upgrades.

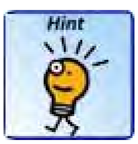
3.2 Section 2 – Referenced Documents

In this section, developers of the Concept of Operations list the resources used when developing the document. This clarifies the sources of information that went into the document and provides the reader with guidance to find additional information. Types of reference documents that are typically listed include:

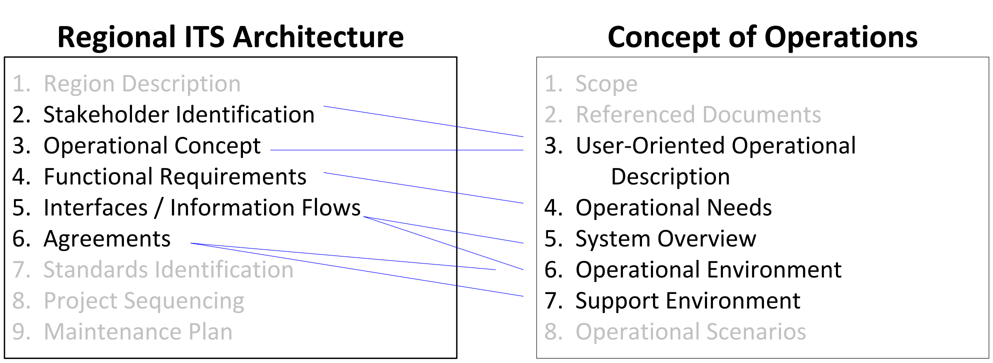
- Business Planning Documents.
- Concepts of Operation for related systems.
- Requirements for related systems.
- Studies that Identify Operational Needs.
- Stakeholder Outreach Meeting Minutes.

VDOT NRO has several existing documents that can be utilized when developing a Concept of Operations. These documents include:

- *VDOT NRO's Strategic Go-Forward Plan (2005).*
- *VDOT NRO Strategic Plan (2008).*
- *VDOT NRO ITS Architecture (http://www.vdot-itsarch.com/Default.htm).*
- *VDOT NRO ATMS (OpenTMS) Concept of Operations (2007).*
- *VDOT NRO Standard Operating Procedures (SOP) (2007).*
- *VDOT NRO ITS Master Plans (currently DMS, CCTV, and Detection, 2008).*
- *Other Concepts of Operation developed for VDOT NRO.*



A well-defined regional ITS architecture provides a good starting point for developing a Concept of Operations for an ITS project. The components of the regional ITS architecture provide a high-level description of the ITS systems in the region, which can often be directly incorporated into a project Concept of Operations. Several of the regional ITS architecture components can be used. The following figure maps the architecture to various sections of the Concept of Operations. One may leverage VDOT Northern Virginia ITS Architecture in the following identified areas for the development of Concept of Operations.



3.3 Section 3 – Operational Description

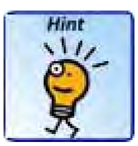
Section 3 – Operational Description is used to describe the system from the user's vantage point. Its purpose is to outline the strategies, tactics, policies, and constraints within which the system will operate and how the goals and objectives in *Section 1 – Scope* will be met by the system implementation. Information that should be highlighted in this section includes:

- Stakeholder Roles and Responsibilities.
- Locations of Existing ITS Infrastructure.
- Operational procedures and sequences of events.

The section should begin with a description of regional stakeholder roles and responsibilities. This early documentation of "who does what" grabs the stakeholders' attention and supports development of the new system. Typically, roles and responsibilities are documented as a list or in tabular form. This early documentation of "who does what" supports development of system requirements and operational agreements and procedures in future steps.

This section also needs to identify the location of existing ITS infrastructure within the project limits and brief description of the state of the existing infrastructure (e.g. approaching end of life cycle). The infrastructure may include ITS devices (i.e., DMS, CTV cameras, etc.), coverage areas of safety service patrols or police officers for incident management, location of fiber, or any other infrastructure that may be pertinent to the coverage area.

Finally, the operational procedures that the organization follows, including sequences of events, to address common conditions or events should be documented from the perspective of how the system will operate or how the procedures need to change given the capabilities of the system installed. The functionally, as it pertains to the new system, should be discussed.



VDOT NRO's ITS Architecture (http://www.vdot-itsarch.com/Default.htm) includes a list of regional stakeholders and description. Additionally, interconnects and information flows identified in the architecture can be used to develop draft stakeholder roles and responsibilities. The Architecture can also be used to identify existing systems that the new system may interact with. VDOT NRO also has GIS layers with existing ITS Device locations. These GIS layers can be used to develop maps of existing DMS, CCTV cameras, detection, lane control signals, truck rollover warning systems, fiber communications, and other ITS devices. Contact VDOT NRO Planning and Programming for access to the GIS files.

The Concept of Operations developer should hold a stakeholder outreach meeting with appropriate stakeholders to gather input and verify stakeholder roles and responsibilities, and identify existing systems, device locations, and processes. This outreach meeting should be included in the Scope of Work.

EXAMPLE #3 – EXISTING CONDITIONS

(from VDOT NRO'S Dulles Rail TMP Concept of Operations)

Stakeholder Roles and Responsibilities

VDOT's Northern Regional Operations (NRO) is the primary stakeholder that owns, operates, and maintains the freeway and arterial ITS/Operations components within the project area. Although VDOT is the primary stakeholder, operations in the project area require the skills and expertise of a diverse group of stakeholders. This group includes (1) Dulles Corridor Metrorail Project, (2) other VDOT mega projects, (3) law enforcement, (4) fire and rescue, (5) emergency medical services, (6) transportation agencies, (7) towing and recovery service providers, (8) media, and (9) information service providers. The roles and responsibilities of these stakeholders are defined below.

Law Enforcement. Law enforcement agencies from the state and county levels are responsible for incident management in the project area. This includes the Virginia State Police, MWAA Police, and Fairfax County Police. In general, participation from these agencies is dictated by the jurisdiction in which the incident occurs. State Police agencies are responsible for incident management on the interstate highways (I-495 and I-66), MWAA Police are responsible for incidents on the DTR and DIAAH, and Fairfax Country police are responsible for arterials such as Routes 7 and 123. Overall, incident management roles and responsibilities assumed by law enforcement agencies include:

- *Assist in incident detection*
- *Secure the incident scene*
- *Assist disabled motorists*
- *Provide emergency medical aid until help arrives*
- *Coordinate with the TMC for incident response and management*
- *Direct traffic at the incident scene*
- *Conduct accident investigations*
- *Supervise scene clearance*

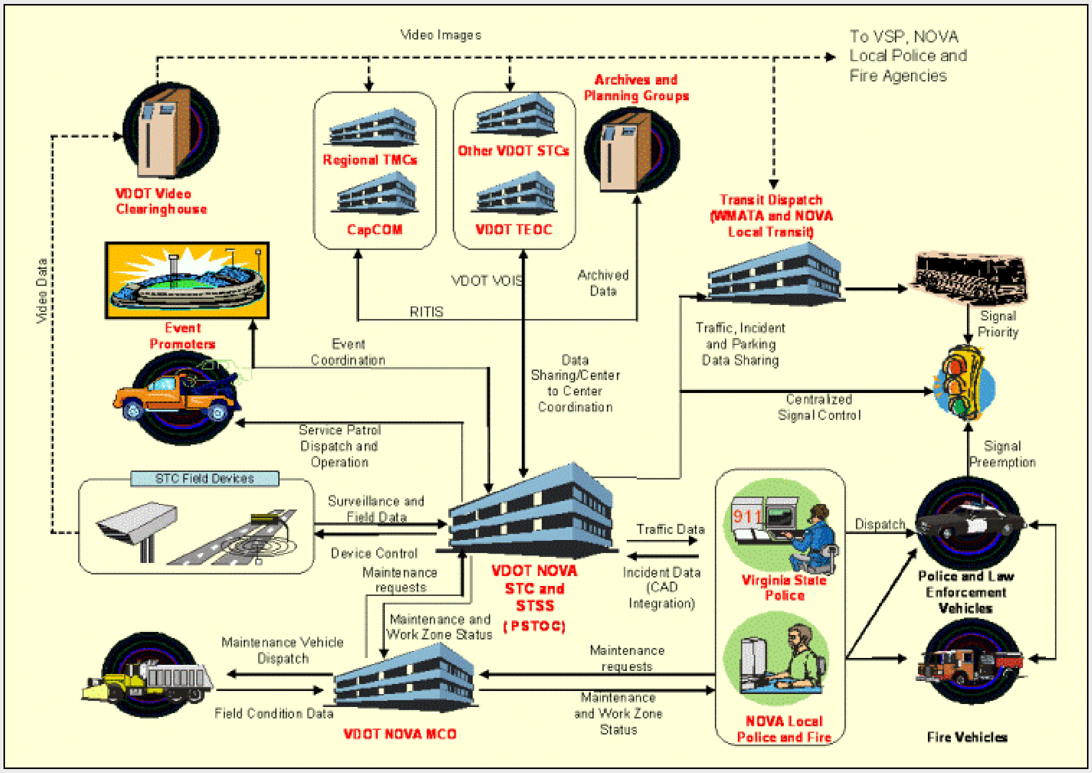
Fire and Rescue. Fire and rescue services are provided by local fire departments. Fairfax County Fire and Rescue is responsible for the Tysons Corner Project area. Roles and responsibilities assumed by the fire departments include:

- *Provide traffic control until police or DOT arrival*
- *Provide emergency medical care*
- *Provide initial HAZMAT response and containment*
- *Fire suppression*
- *Rescue crash victims from wrecked vehicles*
- *Rescue crash victims from contaminated environments*
- *Assist in incident clearance*

Description of Existing Systems

The existing ITS information network is depicted in the figure below. This diagram illustrates the various ITS components involved and the different entities with which they communicate throughout the ITS network.

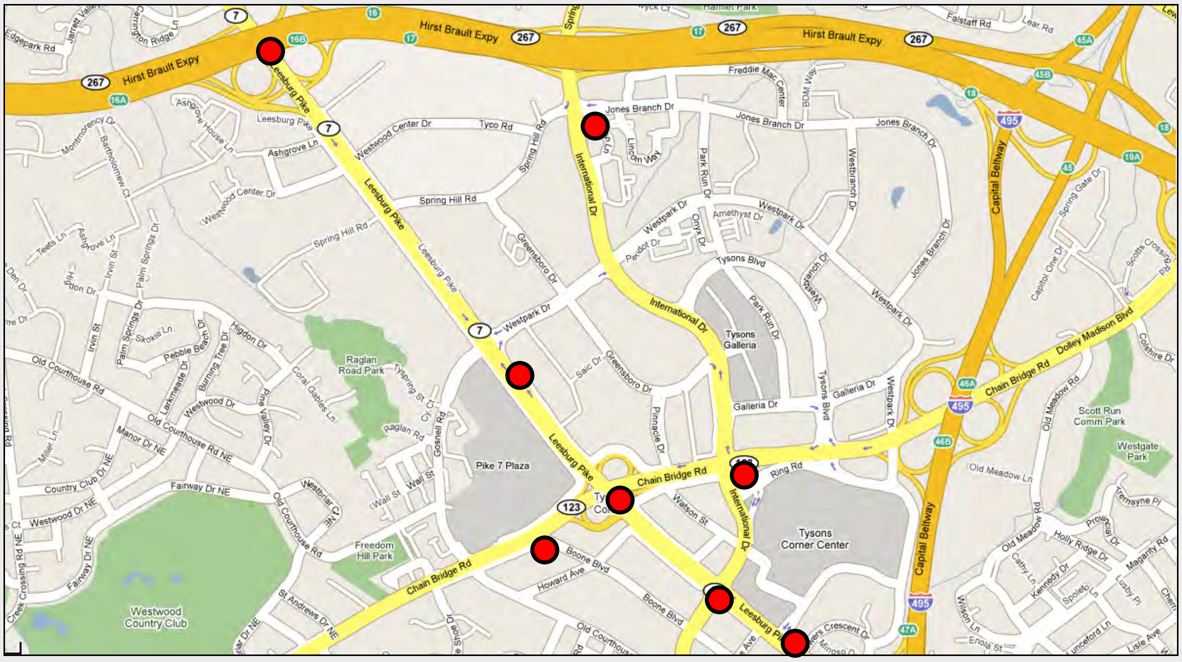
At the center of ITS operations in this region is the VDOT NRO Traffic Management Center (TMC) in Arlington, Virginia (moved to Fairfax in late 2008). This facility serves as the hub through which nearly all ITS information passes and therefore provides management and coordination of the various ITS components throughout the region.



Existing ITS Infrastructure

The closed circuit television subsystem is a collection of cameras owned, operated and maintained by VDOT. These cameras provide live video feeds of traffic conditions to personnel at the TMC. Currently in the project area, VDOT has eight operational cameras. Full construction area coverage is not provided by these cameras; for example there is currently no CCTV coverage of the DTR and I-495. The identification number and location of each camera can be found in the following list and figure. Note that one of these cameras is mounted to a building rooftop; the others are pole mounted.

- CCTV @ Route 7 – Leesburg Pike & SAIC Drive (SAIC rooftop)
- CCTV @ Route 7 – Leesburg Pike & Route 267 – Dulles Toll Road
- CCTV @ Spring Hill Road & Jones Branch Road
- CCTV @ Route 123 – Chain Bridge Road & International Drive
- CCTV @ Route 7 – Leesburg Pike & Route 123 – Chain Bridge Road
- CCTV @ Route 123 – Chain Bridge Road & Boone Boulevard
- CCTV @ Route 7 – Leesburg Pike & Fashion Boulevard
- CCTV @ Route 7 – Leesburg Pike & International Drive



3.4 Section 4 – Operational Needs

This section should identify needs expressing the underlying objectives of stakeholders in terms of what they are trying to accomplish as it relates to the new system but are not currently satisfied with the existing systems or environment. Operational Needs are not requirements. The needs identified in the Concept of Operations should be deliberately high-level and focus on outcomes rather than methods.

Following the structure of the template, this section builds on the previous section of the Concept of Operations outline. *Section 1 – Scope* identifies the vision, goals, and objectives for the proposed system. And *Section 3 – Operational Description* identifies the stakeholder roles and responsibilities, locations of existing ITS infrastructure, and existing operational procedures and sequences of events under which the new system will operate and how the system will aid in meeting the goals and objectives of the stakeholders. The needs should represent the capabilities, resources, and functionality not currently met by existing systems in pursuit of the stakeholder goals and objectives.

There is a temptation at this point to make assumptions about system design. The Concept of Operations should address what is to be done, but not how it will be implemented. That will be determined later during design.

Operational needs should be developed independent of technological solutions. Their intent is to define "what" is needed, not "how" it will be done. This allows several technological solutions to be evaluated. For example, operational needs should state that "volume, speed, and occupancy data is needed on a 5 minute basis." This allows several different technologies (i.e., radar detection) to be evaluated instead of stating that "RTMS detectors" are needed.

This section should be organized in a structured manner to be leveraged in the future when high-level requirements and a validation plan is developed. It is recommended that the Operational Needs are included in a matrix that will allow designers to trace high-level requirements back to the needs via a traceability matrix.

Operational Needs should be identified through a series of stakeholder outreach meetings. The meetings should group similar stakeholders together to allow for focused discussion. Outreach meetings should be included in the Scope of Work. The exact number of meetings will vary based on the complexity of the Concept of Operations and the size of the project.

EXAMPLE #4 – OPERATIONAL NEEDS
(from VDOT NRO'S CCTV Master Concept of Operations)

Freeway Operations staff use the CCTV system to detect and verify freeway incidents such as accidents, breakdowns, and debris on the roadway as well as to monitor planned and unplanned events such as lane closures for road work. Freeway Operations staff need to be able to verify the performance of other ITS systems using the CCTV system. The Freeway Operations staff need the system to help increase operator efficiency through a Video Incident Detection (VID) expert system to notify operators of road condition changes in a camera's feed while another feed is being viewed.

System objectives based on Freeway Operations user needs are presented in the following traceability matrices.

Objective	User Need
4.1.1.1 Corridor Management	a. Monitor freeways and arterials with limited gaps b. Ability to monitor and compare parallel arterials that can support diversion during an incident and report on congestion c. Monitor regular lanes as well as express and reversible lanes
4.1.1.2 Condition Monitoring	a. Provide camera coverage of full mainline laneage in both directions b. Ability to monitor interchanges: merge areas, diverge areas, and weave areas c. Avoid visual obstructions such as vegetation, ramps, overpasses, buildings, and signs d. Ability to view images in low light conditions e. Ability to view images in fog, rain, snow conditions f. Ability to view steady, clear image g. Cameras programmed to return to preset angle, zoom, and focus when not under active operator control.
4.1.1.3 Inform Public and Media	a. Create low bandwidth copy of TMC video feed and make available to general public via internet sites such as VDOT 511 webpage b. Create low bandwidth copy of TMC video and provide to media and ISPs through a media feed c. Disable public feeds during emergencies, security events, or other events of a sensitive nature (i.e., fatalities)
4.1.1.4 Regional Coordination	a. Share video images with regional stakeholders (state and local DOTs, Police, Fire & Rescue) b. Share video images via Video Clearinghouse c. Share video images via RITIS

3.5 Section 5 – System Overview

Section 5 – System Overview includes a brief overview of the proposed system, relationships and interfaces with other systems / stakeholders, proposed high-level locations of infrastructure, and discussion of software and communication requirements, and key considerations for its design. Included in this section is a Project Architecture. Note that the Project Architecture is not a design document [that will be done later]. Instead it provides a structure for describing the operations, in terms of where the operations will be carried out, and what the lines of communication will be.

This section is the "meat" of the Concept of Operations, describing the proposed system based on Operational Needs. The components of this section will depend on the complexity of the proposed system. However, it is anticipated that the following items should be addressed in the Concept of Operations:

- System (or Subsystem) Overview.
    - Description of the System / Subsystem.
    - Proposed Content / Functionality (if necessary).
    - Proposed Device Locations (if necessary) – including descriptions and maps.
    - Software Implications (if necessary).
    - Communication Requirements (if necessary) – including descriptions and maps.
- Project Architecture.
    - Interconnect Diagram.
    - Information Flow Diagrams.
    - Stakeholder / Element Descriptions.

In many cases, the proposed system may be comprised of several subsystems. For example, a Concept of Operations for a roadway construction project may consist of DMS, CCTV camera, and detection subsystems. In this case, each subsystem should be discussed independently in regards to its proposed content / functionality, proposed device locations, software implications, and communications requirements.

A major component of *Section 5 – System Overview* is the project architecture. The project architecture provides a framework that identifies the institutional agreement and technical integration necessary to interface a major ITS project with other ITS projects and systems. The project architecture addresses application of the proposed system with a focus on integration and operation of the system(s). The project architecture should be limited to the proposed architecture and integrated into the regional ITS architecture at a later date. Components of the project architecture include a description of the stakeholders and elements, interconnect diagrams, and information flow diagrams.

The Turbo file for VDOT NRO ITS Architecture can be downloaded from the ITS Architecture website (http://www.vdot-itsarch.com/Default.htm). Project Architectures should be created in Turbo Architecture and should be based on the stakeholders and elements in the existing regional architecture. If the proposed project architecture is not fully agreeable with the regional architecture, one should notify VDOT NRO via the architecture website feedback page.

EXAMPLE #5 – SYSTEM OVERVIEW

(primarily from VDOT NRO's DMS Travel Time Pilot Project Concept of Operations)

This DMS Travel Time Project is intended to be a "demonstration project" or "pilot project" for VDOT's Statewide Travel Time Program. VDOT NRO will work closely with VDOT Central Office to deploy a travel time system that is consistent with the Department's statewide vision, standards and guidelines. Additionally, the Pilot Project is expected to support the development efforts currently being conducted by the Department to implement a Statewide Travel Time Program.

Planning and design of the Pilot Project will adhere to all Systems Engineering principals and processes as required by FHWA 23 CFR 940. The System's Engineering process will provide an optimal framework for ensuring successful implementation of the project. The NRO Pilot Project will last for a period of two (2) years or until the end of the I-95 Corridor Coalition's Probe Data project contract, whichever comes first.

Travel Time Data

A primary goal of the Pilot Project is to leverage and integrate existing resources in order to facilitate a rapid deployment of the pilot project. While the INRIX data remains available for free of charge for another two years under the I-95 Corridor Coalition Probe Data Project, it was determined that NRO should take advantage of this resource while available.

It is expected that this Pilot Project will simply utilize INRIX data for travel time information. As VDOT NRO's DMS Travel Time Program matures, the travel time module is expected to aggregate data from various future data sources including private sector data feeds, detector data, and toll tag data. When these data sources are available, the travel time module is expected to aggregate data from various sources and to fuse the data.

INRIX travel time data will be transmitted through an XML stream between the I-95 Corridor Coalition's Probe Data Project's data clearinghouse and VDOT. The data will include:

- *Speed,*
- *Travel Time,*
- *Confidence level ratings (10, 20, 30)*
- *Expected Speed,*
- *Free Flow Speed,*
- *Road Segments (TMC location codes)*
- *Update Rate / Latency (Agencies access every 2 minutes)*

OpenTMS Software Module

A new travel time software application will be required in order to aggregate INRIX travel time data, automatically calculate and disseminate travel times, and provide a command and control platform for the operations and management of the travel time system. In order to meet this requirement, it was determined to develop a new travel time module as an integrated feature with the new OpenTMS software application recently deployed by NRO. The travel time algorithm being developed for this Pilot Project will provide for a fully automated system, including:

- *Travel time calculations,*
- *Message selection,*
- *Message derivation,*
- *Message dissemination,*
- *Data quality assessment,*
- *Verification and validation features, and*
- *Information quality assessment.*

The travel time module will also provide a command and control graphical user interface (GUI) for operator system management including the ability to configure or override travel time messages and the travel time system by those authorized to do so.

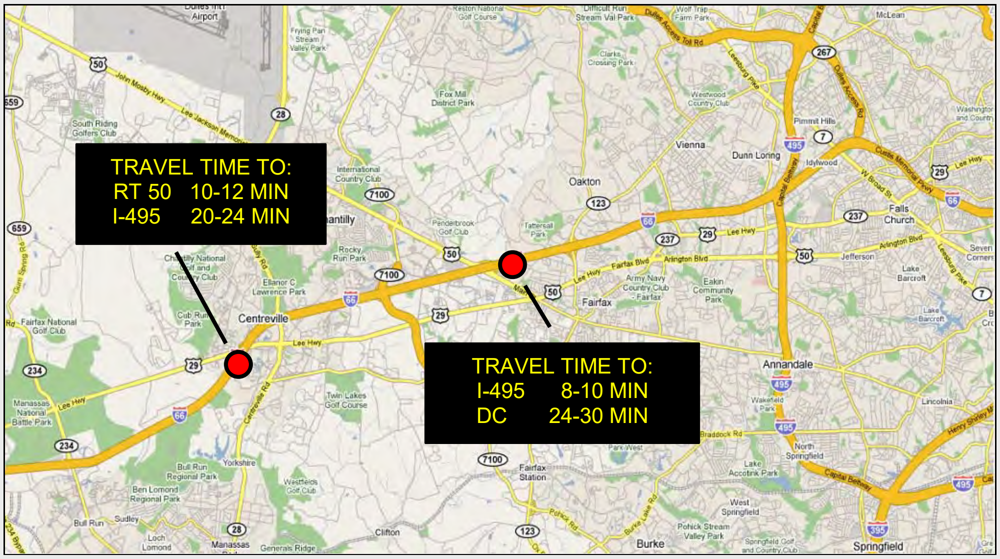
Dynamic Message Signs

One of the first planning tasks in framing the new DMS travel time system was identification of potential DMS ideal for posting travel time messages. Identification of candidate sign locations and evaluation and selection of potential sites were based on preliminary citing criteria including:

- *DMS availability*
- *DMS size and configuration*
- *Provision of travel times for general purpose lanes (only)*
- *Potential for diversion routing*
- *Potential for messaging references to well known landmarks, and*
- *Reliable, existing infrastructure*

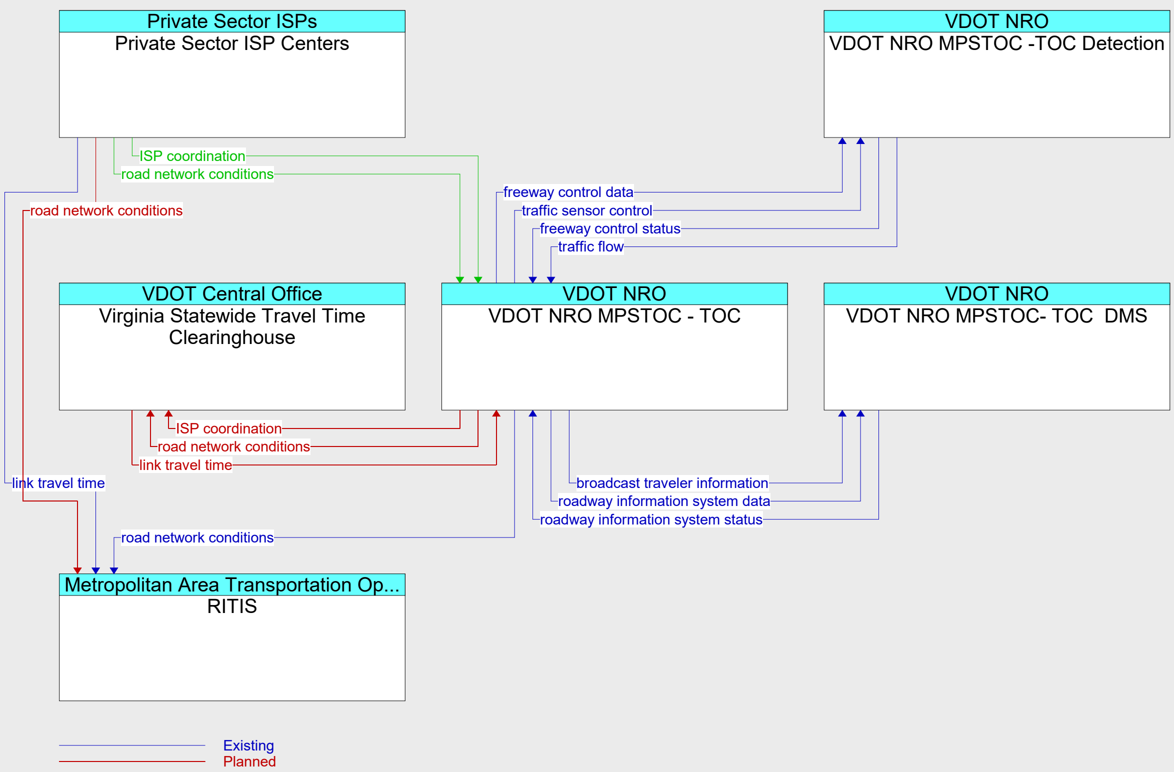
The project test sites (DMS locations) were selected through a multiple-stage evaluation process. A report was generated from OpenTMS detailing all existing regional DMS that meet the minimum operating and configuration criteria for the project. The report and GIS mapping were used to conduct a preliminary in-house evaluation of candidate signs. Following the preliminary in-house evaluation, a comprehensive field review was conducted to confirm test site locations.

Candidate DMS Travel Time maps (Figure x) are also included in this report. These maps depict the location of the DMS as well as potential travel time messages.



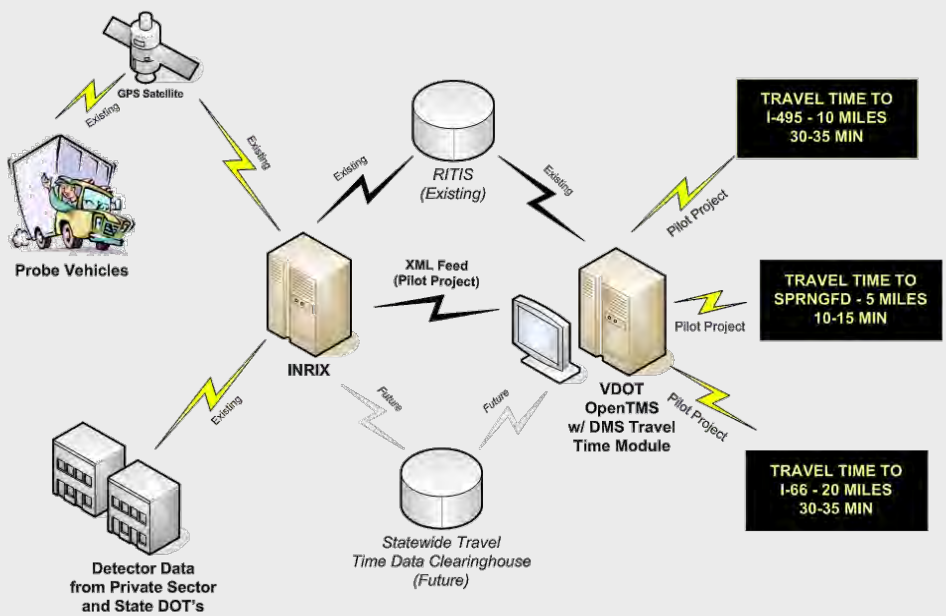
Project Architecture

The following information flow diagram illustrates the elements of the Northern Virginia ITS Architecture that will be implemented with the project. Further details regarding the individual elements of the diagram can be found at the ITS Architecture website.



System Architecture

Travel times will be generated by a new travel time software module, to be integrated with VDOT NRO's existing ATMS – OpenTMS. The module will autonomously aggregate travel time data and information (generated by INRIX, Inc. for the I-95 Corridor Coalition project), calculate travel times and automatically generate messages and disseminate travel time messages as default message on selected DMS signs in NRO without operator's action. The following graphic provides a high-level overview of the Pilot System Architecture.



3.6 Section 6 – Operational and Support Environment

Although the ANSI/AIAA standard describes two sections, there is considerable overlap between them. Therefore, it is recommended that the sections be combined to provide information about the general operational environment for operation of the new system (or created by the change in the current system). This section includes the following environmental characteristics:

- Facilities.
- Equipment.
- Hardware.
- Software.
- Personnel.
- Operational Procedures.
- Support Necessary to Operate the Deployed System.

This section describes the physical operational environment in terms of facilities, equipment, computing hardware, software, personnel, operational procedures and support necessary to operate the deployed system. For example, it will describe the personnel in terms of their expected experience, skills and training, typical work hours, and other activities that must be or may be performed concurrently.

It is important to include operations and maintenance staff in Concept of Operations discussions. Often times, personnel and maintenance needs are overlooked. This would result in systems being built that cannot be operated or maintained by current staffing levels or tools.

EXAMPLE #6 – OPERATIONAL AND SUPPORT ENVIRONMENT

(from VDOT NRO's Detection Master Concept of Operations)

This document identifies the need for several new applications for detectors, many of which require additional man-hours of effort, new hardware and/or software, and new operating procedures. This section addresses each of these operational support areas.

Personnel

For the real-time applications, TMC Operators may have additional responsibilities. For instance, applying traffic-responsive ramp metering will require additional monitoring to ensure the system is functioning properly. However, at the same time, an improved congestion map and more reliable detection of anomalies in traffic patterns could reduce operator load and offset these additional responsibilities. In addition, the new ATMS software should be able to automate many of the procedures that are currently performed manually. This will need to be evaluated on an ongoing basis.

VDOT should consider whether a new operator position should be identified—one with specialized expertise in active traffic management. Or, depending on workload, VDOT should provide specialized training for TMC Operations Supervisors should traffic-responsive metering or other active traffic management applications be employed.

VDOT should also consider a new position or an ongoing contract with a university for data reduction and analysis for performance measurement. In order to take the raw data from the TMC and translate it into meaningful information that can be used to truly assess VDOT's operational performance, regular effort is required. This can never be truly automated because it requires different data sets to be merged, e.g., traffic data and incident reports. Further, the relative contribution of incidents to congestion requires some judgment from an inspection of the data.

However, this is a vitally important measure because it reflects on how well VDOT is responding to incidents and helping to manage them.

Facilities

No new facilities are envisioned for future detector expansion and upgrades.

Hardware and Software

All new functionality can be integrated with NRO's new ATMS software. Depending on the complexity of the desired application, a short or lengthy period of development and testing will be required.

Operating Procedures

Operating procedures would need to be revised for the following sections of the Northern Virginia Smart Traffic Center Standard Operating Procedures document.

- *Reversible Lane Operations – Procedures would need to be written to define the criteria under which reversible lanes should be reversed, based on an analysis of historical traffic patterns.*
- *Ramp Meter Operations – Instead of detecting queue spillback onto adjacent arterials through "CCTV or citizen calls," the detection system would notify the operator and/or modify the metering rate automatically. In addition, operators would need to be able to modify ramp metering hours in response to congestion, or monitor a traffic-responsive system that makes such decisions automatically.*
- *DMS – Operators will be introduced to a new system where messages will have priorities and each DMS will have a message queue at any given time. Travel time messages will have a lower priority than incident-related messages, for instance. Operators will need to be able to assign priorities to messages relative to the base travel time message. New operating procedures would be needed for new applications such as variable speed limits, mainline queue detection, park and ride occupancy monitoring, and warning systems.*

Maintenance

Maintenance will be conducted as for all other field devices. Opportunities to effectively apply capital dollars to maintenance in the form of purchasing data from the private sector should be considered whenever evaluating the relative merits of agency-owned infrastructure compared with outsourcing.

A key consideration for maintenance is tracking inventory, particularly to ensure availability of spares. For this purpose, NRO is planning to implement a barcode tracking system for its Inventory and Maintenance Management System (IMMS). The barcode requirements for detectors and other devices are given in Appendix B.

When deploying system detectors throughout the region, a percentage of the capital construction project should be effectively added to the annual maintenance funding in support of the personnel and equipment needed to maintain an expanded system. A common rule of thumb is that maintenance will cost 10% of the one-time capital cost annually. A typical cost for a detection station is $25,000 per site assuming available power and communications. The annual maintenance cost would then be approximately $2,500 per year. It must be noted, however, that this depends on the maintainability of the design, remote troubleshooting and reset capabilities of the device. If fiber or other fixed line communications is not available, cellular communications is available at an approximately monthly recurring cost of $75 or $900 per year.

3.7 Section 7 – Operational Scenarios

In this section of the Concept of Operations, the developers place themselves in the users' position and detail how the new system would impact their activities under various conditions ranging from normal to stress and failure conditions. Each scenario describes a sequence of events, activities carried out by the user, the system, and the environment. It specifies what triggers the sequence, who or what performs each step, when communications occur and to whom or what [e.g., a log file], and what information is being communicated. The scenarios will need to cover all normal conditions, stress conditions, failure events, maintenance, and anomalies and exceptions.

There are many ways for presenting scenarios, but the important thing is that each stakeholder can clearly see what his expected role is to be. Two examples of Operational Scenarios are provided below.

The first is a narrative taken from *FHWA's Systems Engineering for Intelligent Transportation Systems Handbook.*

EXAMPLE #7 – OPERATIONAL SCENARIO

Marcel, a StarTran bus operator, usually begins his work shift with administrative activities. After receiving supervisory direction, he boards the bus and prepares the AVL system. He begins by logging into the system.

The system then prompts Marcel for the route to be followed. He enters the planned route number, and the AVL system retrieves the appropriate route and schedule information from the AVL server. The bus' AVL system then asks Marcel to verify the appropriate route and schedule information were properly retrieved.

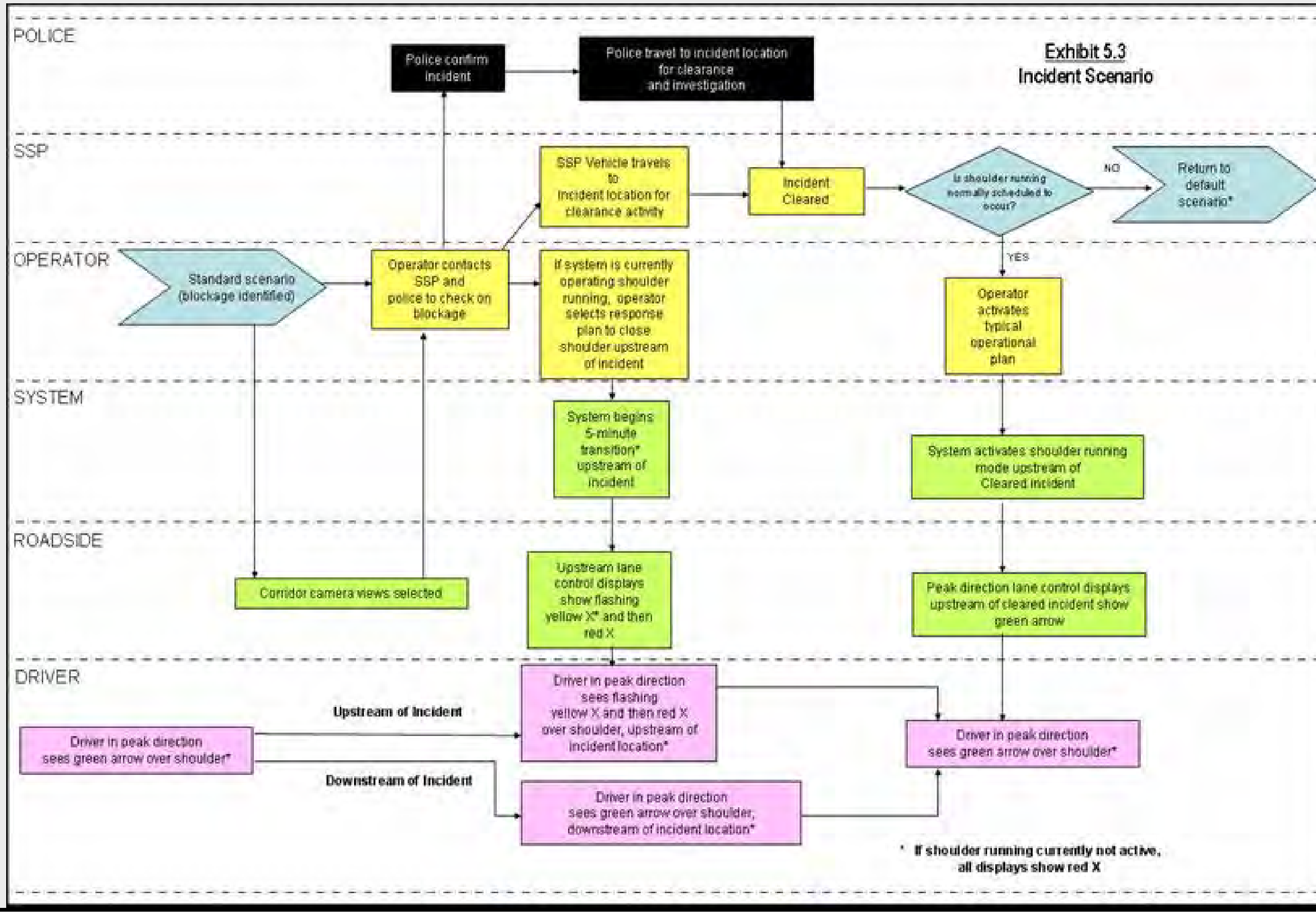
Once he provides verification, the bus' head sign is automatically updated to reflect the appropriate route information. The fare payment schedule is automatically adjusted to reflect the verified rout, modified as necessary by the system clock to reflect any applicable time-differential rates.

The system then loads the appropriate bus stop announcements for the chosen route. These pre-recorded announcements are consistent regardless whether Marcel or another bus operator is driving the route, and have been verified as ADA compliant. These announcements are then broadcast at the appropriate bus stop throughout the route.

The second Operational Scenario example is a transaction diagram. Instead of providing a narrative it includes a time-based transaction diagram that shows stakeholder roles and responsibilities. The following example is taken from *VDOT NRO's I-66 Shoulder Lane Control System (SLCS) Concept of Operations*.

EXAMPLE #8 – OPERATIONAL SCENARIO

Example



3.8 Section 8 – Next Steps

Section 8 – Next Steps identifies the next steps for the project following completion of the Concept of Operations. These steps should be consistent with the Systems Engineering Process and should be in compliance with FHWA Rule 940. Each step identifies 'what' needs to be done and by 'whom'. These steps include:

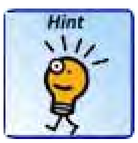
- *High-level and Detailed Requirements* – In this step, stakeholder needs identified in the Concept of Operations are reviewed, analyzed, and transformed into verifiable requirements that define *what* the system will do but not *how* the system will do it. Working closely with stakeholders, the requirements are elicited, analyzed, validated, documented, and baselined.
- *System Design* – In this step, a system design is created based on the system requirements including a high-level design that defines the overall framework for the system. Subsystems of the system are identified and decomposed further into components. Requirements are allocated to the system components, and interfaces are specified in detail. Detailed specifications are created for the hardware and software components to be developed, and final product selections are made for off-the-shelf components.
- *Software / Hardware Development Field Installation* – In this step, hardware and software solutions are created for the components identified in the system design. Part of the solution may require custom hardware and/or software development, and part may be implemented with off-the-shelf items, modified as needed to meet the design specifications. The components are tested and delivered ready for integration and installation.
- *Integration and Verification* – In this step, the software and hardware components are individually verified and then integrated to produce higher-level assemblies or subsystems. These assemblies are also individually verified before being integrated with others to produce yet larger assemblies, until the complete system has been integrated and verified.
- *System Validation* – In this step, after the ITS system has passed system verification and is installed in the operational environment, the system owner/operator, whether the state DOT, a regional agency, or another entity, runs its own set of tests to make sure that the deployed system meets the original needs identified in the Concept of Operations.
- *Operations & Maintenance* – In this step, once the customer has accepted the ITS system, the system operates in its typical steady state. System maintenance is routinely performed and performance measures are monitored. As issues, suggested improvements, and technology upgrades are identified, they are documented, considered for addition to the system baseline, and incorporated as funds become available. An abbreviated version of the systems engineering process is used to evaluate and implement each change. This occurs for each change or upgrade until the ITS system reaches the end of its operational life.

4 DEVELOPING A CONCEPT OF OPERATIONS

Although there is no single recipe for developing a Concept of Operations, successful efforts will include a few key activities:

- *Identify the stakeholders associated with the system/project* – Systems engineering in general, and this effort in particular, require broad participation from the project's stakeholders. One of the first steps in developing a Concept of Operations is to make sure that all the stakeholders involved in or impacted by the project – owners, operators, maintainers, users, and so forth – are identified and involved. You can start with the stakeholder list from the regional ITS architecture and then expand it to identify the more specific organizations – divisions and departments – that should be involved.

- *Define the core group responsible for creating the Concept of Operations* – Although broad involvement is critical, you can't have 20 people on your writing team. Select a few individuals who are responsible for capturing and documenting the vision of the broader group. Depending on the size of the project and staff capabilities, this team might include a consultant or staff members with knowledge of the project and requisite writing and communications skills.

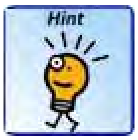
  The best person to write the Concept of Operations may not be the foremost technical expert on the proposed system. A person skilled with organizing and facilitating stakeholder outreach, consensus building, and the ability to understand and clearly document the larger picture are key credentials for the Concept of Operations developer.

  The stakeholders are the foremost experts on their needs and must be materially involved in the Concept of Operations development. The consultant can provide technical expertise on what should be in a Concept of Operations, facilitate the meetings and outreach activities, prepare the document, and coordinate the review, but the stakeholders' concept should be documented in the end. The stakeholders should consider the Concept of Operations *their* document, not the consultant's document.

- *Define stakeholder needs* – This is a key purpose of the Concept of Operations – to capture a clear definition of the stakeholders' needs and constraints that will support system requirements development in the next step. Interviews, workshops, and surveys are some of the techniques that are used to perform this activity. The Concept of Operations is a great tool for defining needs since it forces the stakeholders to think about the way the system will behave and how it will interact with users and other systems. The operational scenarios in the Concept of Operations are among the best tools for discovering needs. The list of needs that is generated should be prioritized by the stakeholders. Once they start to compare and rank the needs, they will discover that some of their "needs" are really "wants" or "nice-to-haves".

- *Develop the initial Concept of Operations, review it with the broader group of stakeholders, and iterate* – Incrementally create the Concept of Operations, review relevant portions with stakeholders, and adjust the concept as necessary to get buy-in. All stakeholders do not have to agree on every aspect of the project, but all must feel that they are achieving their major goals for the project.

Portions of the Concept of Operations can often be created from existing documents. For example, the regional ITS architecture identifies stakeholder roles and responsibilities that can be used. A feasibility study, project study report, or other preliminary study documentation may provide even more relevant information. A project application form used to support project fiscal programming will normally include goals, objectives, and other information that should be reflected in the Concept of Operations for continuity.



Operational scenarios are an excellent way to work with the stakeholders to define a Concept of Operations. Scenarios associated with a major incident, a work zone, or another project-specific situation provide a vivid context for a discussion of the system's operation. It is common practice to define several scenarios that cover normal system operation (the "sunny day" scenario) as well as various fault-and-failure scenarios.

- *Create a System Validation Plan* – A Validation Plan provides a guide for evaluating a deployed ITS system to determine if it has met its goals. The Validation plan should list criteria for judging whether or not the ITS system meets the user needs and objectives defined in the Concept of Operations. Typically, a *Traceability Matrix* is developed to map user needs to requirements. This helps ensure that the user needs are carried forward into design. An example of a *Traceability Matrix* is provided in the example below.

EXAMPLE #7 – TRACEABILITY MATRIX

(from VDOT NRO's CCTV Master Concept of Operations)

Example

User Need	ConOps Section	High-Level Requirement Number and Title	High-Level Requirement
		1.0 - Functional Requirements	
Ability to monitor and compare parallel arterials that can support diversion during an incident and report on congestion	4.1.1.1.b	1.1 – Video Wall & Monitors	Operators should have the ability to select and view single or multiple CCTV locations on either their computer monitor or the PSTOC video wall.
		1.2 – Corridor Bundle Camera Groups	ATMS should support device groupings for parallel routes in support of incident management diversion corridors.
Create low bandwidth copy of TMC video feed and make available to general public via internet sites such as VDOT 511 webpage	4.1.1.3.a	1.3 – Low Quality Video	CCTV encoders and/or software shall be capable of producing a lower quality/lower bandwidth copy of each camera feed.
		4.1 – Equipment Compatibility With Other Agencies	Defined in High Level Requirement 4.1 - Equipment Compatibility With Other Agencies.
Disable public feeds during emergencies, security events, or other events of a sensitive nature (i.e., fatalities)	4.1.1.3.c	1.4 – Cutting Video Feeds	Operators should have the ability to disable selected low bandwidth video feeds to designated agencies, public, or media during justified events. The feed(s) should remain disabled until the operator reactivates the feed(s). Primary video feeds for ATMS operators should remain active at all times.
Visually verify incident reports from other detection means such as Virginia State Police Computer Aided Dispatch (VSP CAD), Traveler Calls, and the SSP	4.1.2.1.d	1.5 – Pan/Tilt/Zoom Controls	Cameras shall be able to pan/tilt/zoom. Operators will be able to control the cameras from the PSTOC, or the backup TMC.
		2.1 – Freeway Spacing	Defined in High Level Requirements 2.1 – Freeway Spacing.
		2.2 – Arterial Spacing	Defined in High Level Requirements 2.2 – Arterial Spacing.
		4.3 – ATMS Software Compatibility	Defined in High Level Requirements 4.3 – ATMS Software Compatibility.
Ability to select displayed camera feed	4.1.2.1.f	1.1 – Video Wall & Monitors	Previously defined.
Potential for automatic notification of incidents: VID	4.1.2.1.g	1.6 – Video Incident Detection	ATMS shall have the ability (where specified by design plans), through predefined algorithms, to detect a possible event from CCTV video feeds and notify the appropriate operator. These events include, but are not limited to accidents, stalled vehicles, unusual congestion and wrong-way vehicles.
Ability to monitor planned events entailing lane or interchange closures or route diversion, such as long-term construction, parades and festivals, and the Marine Corps Marathon	4.1.2.2.a	1.2 – Corridor Bundle Camera Groups	Previously defined.
		2.1 – Freeway Spacing	Defined in High Level Requirements 2.1 – Freeway Spacing.
		2.2 – Arterial Spacing	Defined in High Level Requirements 2.2 – Arterial Spacing.
Operator ability to detect and monitor traffic conditions due to unplanned events such as early school closures	4.1.2.3.a	1.7 – User Defined Camera Set	Operator shall have the ability to define a set of cameras as a group to monitor during an unplanned event. This group can easily be recalled through the ATMS for a user defined timeframe.

5 REFERENCES

1. ANSI/AIAA, *Guide for the Preparation of Operational Concept Documents*, ANSI/AIAA G-043-1992.

2. FHWA Rule 940/FTA Policy, http://www.ops.fhwa.dot.gov/its_arch_imp/policy.htm

3. International Council on Systems Engineering (INCOSE), *INCOSE Systems Engineering Handbook*, http://www.incose.org

4. TMC Pooled-Fund Study, *Developing and Using a Concept of Operations in Transportation Management Systems*, , http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=38&new=0

5. United Stated Department of Transportation (USDOT), *Systems Engineering for Intelligent Transportation Systems, January 2007*. http://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm

6. United States Department of Transportation (USDOT), *Regional ITS Architecture Use and Maintenance Workshop*, Charlottesville, VA. April 2009.

7. Virginia Department of Transportation (VDOT), *Systems Engineering and Architecture Compliance (Rule 940) Checklist for Use in Northern Virginia,* http://www.vdot-itsarch.com/Default.htm

APPENDIX – CONCEPT OF OPERATIONS TEMPLATE

<Insert Project Title> Concept of Operations

1. SCOPE

1.1 Introduction, System Overview, and Purpose

1.2 Project Limits

1.3 System Vision, Goals, and Objectives

1.4 Role of the Concept of Operations in the Systems Engineering Process

2. REFERENCED DOCUMENTS

3. OPERATIONAL DESCRIPTION

3.1 Stakeholders Roles and Responsibilities

3.2 Locations of Existing ITS Infrastructure

3.3 Operational Procedures and Sequences of Events

4. OPERATIONAL NEEDS

4.1 Operational Need Category 1

4.2 Operational Need Category 2

4.3 Operation Need Category X

5. SYSTEM OVERVIEW

5.1 Description of the System(s)
- Proposed Content / Functionality
- Proposed Locations
- Software Implications
- Communication Requirements

5.2 Project Architecture
- Stakeholder / Element Descriptions
- Interconnect Diagram(s)
- Information Flow Diagram(s)

6. OPERATIONAL AND SUPPORT ENVIRONMENT

6.1 Facilities

6.2 Equipment

6.3 Hardware

6.4 Software

6.5 Personnel

6.6 Changes to Operational Procedures

7. OPERATIONAL SCENARIOS

7.1 Scenario #1

7.2 Scenario #2

7.3 Scenario X

8. NEXT STEPS

8.1 High-level and Detailed Requirements

8.2 System Design

8.3 Software / Hardware Development & Field Installation

8.4 Integration and Verification

8.5 System Validation

8.6 Operations & Maintenance

Northern Region Operations

June 2009

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TSM&O

Transportation Systems Management & Operations

Managing and Operating for an Efficient Transportation System

Concept of Operations for: ***insert project name***

Version : *insert version number*

Approval date : *insert approval date*

FDOT

Form FM-SE-01 Concept of Operations Template. Effective 11/12/2015

DOCUMENT CONTROL PANEL		
File Name:		
File Location:		
Version Number:		
	Name	**Date**
Created By:		
Reviewed By:		
Modified By:		
Approved By:		

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List of Acronyms and Abbreviations

ConOps .... Concept of Operations
FDOT .... Florida Department of Transportation
ITS.. Intelligent Transportation Systems

1. Overview

The first section of the Concept of Operations (ConOps) document provides four elements: system identification, an overview of the document, a high-level overview of the proposed system, and a brief description of the scope of effort required to take the system from the current state to the final future state of deployment that will be achieved at the conclusion of the proposed deployment. These elements are described in the following sections.

1.1 Identification

This section contains the proper title, identification number, and abbreviation, if applicable, of the system or subsystem that the ConOps applies to. If a system's related ConOps documentation has been developed in a hierarchical manner, the position of this document relative to other ConOps documentation should be described.

1.2 Document Overview

This section summarizes and expands on the purpose for the ConOps document. The intended audience for the document should also be described. The audience can be a variety of people from multiple parties with various levels of technical knowledge. Therefore, it is important that the document be clearly written to clearly define technical terms, and utilize layman English for the majority of the text. This section of the ConOps also outlines the remaining parts of the document. The purposes of a ConOps document will, in most cases, be:

- To communicate user needs and the proposed system expectations
- To communicate the system developer's understanding of the user needs and how the system will meet those needs

The ConOps document might also serve other purposes, such as building consensus among several user groups or developers, or the document may be summarized for a press release or information brochure.

1.3 System Overview

This section briefly states the purpose of the proposed system or subsystem to which the ConOps applies. It describes the general nature of the system, and identifies the project sponsors, user agencies or departments; system developers; maintenance and support entities; evaluation and certification entities; and the operating centers or sites that will run the system. It also identifies other documentation that is relevant to the present or proposed system.

A high-level graphical overview of the system is strongly recommended. This can be in the form of a physical layout diagram, a top-level functional block diagram, or some other type of diagram that depicts the system and its environment. Documentation that might be cited includes, but is not limited to, project authorizations, relevant technical documentation, significant correspondence, documentation concerning related projects, risk analysis reports, and feasibility studies.

2. Referenced Documentation

This section lists the publisher, document identification number, title, revision, and date of all documentation referenced in the ConOps document. This section should also identify a contact for all documents not available through normal channels.

3. Current System Situation

This section of the ConOps describes the problem to be solved, and the system or situation as it currently exists. This section basically answers the following questions.

- What is the system?
- What is the system supposed to do?
- Who owns, operates, and maintains the system?
- How well does the system perform?
- What is the system's geographic coverage?
- When is the system used?
- How does the system operate?
- What other systems does it talk to?

The current system could be an older technology-based system or one where manual processes are in place. If there is no current system, this section will describe the reasons and motivations for developing the system. In addition, this section will introduce the problems, needs, issues, and objectives that need to be addressed by the proposed system. This enables the reader to better understand the reasons for the desired changes and improvements. Specific elements that may be documented in this section are outlined in the sections below.

3.1 Background, Objectives, and Scope

This section should provide an overview of the current system or situation, including the background, mission, objectives, and scope of the current system, as applicable.

3.2 Operational Constraints

This section should include a description of limitations on the operational characteristics of the system. This could include limits on hours of operation, hardware limitations, or resource limitations.

3.3 Description of the Current System or Situation

This section should provide a thorough description of the current system, including operational characteristics; major system components; component interconnections; external system interfaces; current system functions; diagrams illustrating inputs, outputs, and data flows, such as intelligent transportation systems (ITS) architecture market package diagrams; system costs; and performance statistics. Include a brief description of user classes and other people who interact with the system. A user class is distinguished by the way users interact with the system, and is classified according to common responsibilities, skill levels, work activities, and the ways they interact with the system.

3.4 User Profiles

This section should include a description of how the users interact with the system and the scenarios that occur when they interact with the system. The section should also discuss how the users interact with each other. For example, a supervisor user class may have certain capabilities that an operator class may not have with the system, and the ConOps should describe when, why, and how such an interaction takes place to achieve a system objective or function.

3.5 Support Environment

This section should describe how the system is supported and maintained, including the maintaining department or agency; facilities; equipment; support software or hardware; and repair or replacement criteria. The section should also identify whether the District will maintain the system or a vendor will be contracted to maintain the system according to a level of service agreement.

4. Justification and Nature of the Changes

This section describes the shortcomings of the current system or situation that motivate development of a new system or modification of an existing system, and also describes the nature of the desired changes assumptions for the proposed system. This section provides a transition from the third section of a ConOps, which describes the current system or situation, to the fifth section, which describes the proposed system. If there is no current system on which to base changes, this section should so indicate and provide justification for the features of the new system. Specifically, this section should include the information detailed in the following sections.

4.1 Justification for Changes

This section should include the reasons for developing the proposed system, including:

- New or modified user needs, missions, or objectives
- Dependencies or limitations of the current system

4.2 Description of the Desired Changes

This section should include a summary of the new or modified capabilities, functions, processes, interfaces, and other changes needed to respond to the justifications previously identified. This shall include:

- Capability changes (i.e., functions and features to be added, deleted, or modified);

- System processing changes (i.e., changes in the process or processes of transforming data that will result in new output with the same data, the same output with new data, or both)
- Interface changes (i.e., changes in the system that will cause changes in the interfaces and changes in the interfaces that will cause changes in the system)
- Personnel changes (i.e., changes in personnel caused by new requirements)
- Environmental changes (i.e., changes in the operational environment)
- Operational changes (i.e., changes to the user's operational policies, procedures, or methods)
- Support changes (i.e., changes in the support or maintenance requirements)
- Other changes (i.e., a description of other changes that will impact the users)

4.3 Change Priorities

This section should include any prioritization or ranking regarding the proposed changes. The section should define what features are essential, what features are desirable, and what features are optional.

4.4 Changes Considered but Not Included

This section should include significant changes or features that were assessed but not included in the proposed system description. This information is included to assist others in knowing what other options were considered and why they were not included.

4.5 Assumptions and Constraints

This section describes assumptions or constraints applicable to the changes and new features identified in this section. This should include all assumptions and constraints that will affect users during development and operation of the new or modified system.

5. Concepts for the Proposed System

This section describes the proposed system that results from the desired changes specified in the fourth section of the ConOps document. The format follows the format of the third section to make it easy to understand the role of the proposed system in solving the problem stated in the beginning of the document. This includes a high-level description of the proposed system that indicates the operational features to be provided without specifying design details. Methods of description to be used and the level of detail in the description will depend on the situation. The level of detail should be sufficient to fully explain how the proposed system is envisioned to operate in fulfilling user needs and requirements.

In some cases, it may be necessary to provide some level of design detail in the ConOps. The ConOps should not contain design specifications, but it may contain some examples of typical design strategies for the purpose of clarifying the proposed system's operational details. In the event that actual design constraints need to be included in the description of the proposed system, they shall be explicitly identified as requirements to avoid possible misunderstandings.[1]

Specifically, the fifth section should include information on the:

- Proposed system's background, objectives, and scope
- Operational polices or constraints imposed on the proposed system
- Description of the proposed system
- Modes of operation
- User involvement and interaction
- Support environment

5.1 Background, Objectives, and Scope

An overview of the new or modified system, including the background, mission, objectives, and scope, should be provided, as applicable. In addition to providing the proposed system's background, a brief summary of the system's motivation should be provided. The goals for the new or modified system should also be defined, as well as the strategies, solutions, tactics, methods, and techniques proposed to achieve those goals.

5.2 Operational Policies and Constraints

The operational policies and constraints that apply to the proposed system should be described. This includes, but is not limited to, such elements as hours of operation, staffing constraints, space constraints, and hardware constraints.

5.3 Description of the Proposed System

A thorough description of the proposed system should be provided that includes:

- Operational environment and its characteristics
- Major system components and the interconnections among these components
- Interfaces to external systems or procedures
- Capabilities or functions of the proposed system
- Relationship to other systems
- Conformity and compatibility to the statewide ITS architecture and regional ITS architectures
- Charts and accompanying descriptions that depict inputs; outputs; data flows; and manual and automated processes so the proposed system or situation is sufficiently understood from the user's point of view

[1] If some of the proposed system's features are the same as the original system's features, then a comment indicating that there is no change should be included for that element.

- Cost of system operations
- Deployment and operational risk factors
- Performance characteristics
- Quality attributes, such as reliability, accuracy, availability, expandability, flexibility, interoperability, maintainability, portability, reusability, supportability, survivability, and usability
- Provisions for safety, security, privacy, integrity, and continuity of operations in emergencies

Since the purpose of this section is to describe the proposed system and how it should operate, it is important that the description of the system be simple and clear enough that all intended readers can fully understand it. It is important to keep in mind that the ConOps should be written in the user's language. Graphics and pictorial tools should be used wherever possible. Useful graphical tools include, but are not limited to, the contract work breakdown structure; sequence or activity charts; functional block diagrams; and relationship diagrams.

The description of the operational environment should identify the facilities, equipment, computing hardware, software, personnel, and operational procedures needed to operate the proposed system. This description should be as detailed as necessary to give the readers an understanding of the numbers, versions, capacity, etc., of the operational equipment to be used.

The author(s) of a ConOps should organize the information in this section as appropriate to the proposed system, as long as a clear description of the proposed system is achieved. If parts of the description are voluminous, they can be included in an appendix or incorporated by reference. An example of material that might be included in an appendix would be a data dictionary. An example of material to be included by reference might be a detailed operations or policy manual.

5.4 Modes of Operation

This section should describe the proposed system's various modes of operation. Examples of modes of operation include standard, after-hours, maintenance, emergency, training, or backup.

5.5 User Involvement and Interaction

The users and the way they interact with the system should be described. This section should include the identification of the users, organizational structure, skill levels, roles, work activities, methods of interacting with the system, and system interaction scenarios. In addition, the interactions among users should be identified and defined.

5.6 Support Environment

The support and maintenance concepts and environment for the proposed system should be documented. This section should include the support agency or agencies; facilities; equipment;

support software; repair or replacement criteria; maintenance levels and cycles; and storage, distribution, and supply methods.

6. Operational Scenarios

A scenario is a step-by-step description of how the proposed system should operate and interact with its users and its external interfaces under a given set of circumstances. Scenarios are written in layman's language and should be nontechnical as much as possible. Scenarios should be described in a manner that will allow readers to walk through them and gain an understanding of how all the various parts of the proposed system function and interact. The scenarios tie together all parts of the system, users, and other entities by describing how they interact. Scenarios may also be used to describe what the system should not do.

Scenarios should be structured so that each describes a specific operational sequence that illustrates the role of the system, and its interactions with users and other systems. Operational scenarios should be described for all operational modes of the proposed system. Each scenario should include events, actions, inputs, information, and interactions as appropriate to provide a comprehensive understanding of the operational aspects of the proposed system.

It may be necessary to develop several variations of each scenario, including one for normal operation, one for exception handling, one for degraded mode operation, etc.

Scenarios play several important roles. The first is to bind together all of the individual parts of a system into a comprehensible whole. Scenarios help the readers of a ConOps document understand how all the pieces interact to provide operational capabilities. The second role of scenarios is to provide readers with operational details for the proposed system; this enables them to understand user roles, how the system should operate, and the various operational features to be provided.

In addition, scenarios can serve as the basis for the first draft of a users' manual and as the basis for developing acceptance test plans. The scenarios are also useful for the Florida Department of Transportation (FDOT) and the developer to use when verifying that the system design will satisfy user needs and expectations.

Creative writing and graphics should be employed to make the scenarios interesting and easy to read. A good ConOps will have a story line that features different characters that relate to the situation and environment where the proposed system is being contemplated. The story line will have a common thread that weaves through all the characters as they interact with the system. Story lines should be selected that highlight key system features based on the initial understanding of the problem to be solved and the user needs so that readers can understand the consequences of their needs when they are translated to a system that meets those needs.

Scenarios are an important component of a ConOps and, therefore, should receive substantial emphasis. The number of scenarios and level of detail specified will be proportional to the complexity and criticality of the project.

7. Summary of Impacts

This section describes and summarizes the operational impacts of the proposed system from the users' perspective. This section can also include a description of the temporary impacts that can be realized during the development, installation, or training periods. This information is provided to allow all affected departments to prepare for the changes that will be brought about by the new system, and to allow the FDOT divisions/departments or other agencies to plan for the impacts. Impacts can be characterized into several areas, including operational impacts, organizational impacts, and developmental impacts

8. Analysis of the Proposed System

This section provides a summary of the benefits, limitations, advantages, disadvantages, alternatives, and trade-offs considered for the proposed system. Improvements to the system should be documented. This includes a qualitative and quantitative summary of the benefits to be provided by the proposed system, and can include new capabilities, enhanced capabilities, deleted capabilities, and improved performance. In addition, any disadvantages or limitations should also be provided.

The major alternatives considered, the trade-offs among them, and the rationale for the decisions reached should be summarized in this section. In the context of a ConOps document, alternatives are operational alternatives and not design alternatives, except to the extent that design alternatives may be limited by the operational capabilities desired in the new system. This information can be useful in determining, now and later, whether a given approach was analyzed and evaluated, or why a particular approach or solution was rejected.

This section should describe the proposed system's rough order of magnitude cost based on assumptions that are clearly listed. An approximate schedule for the development based on months after contract award should also be included.

9. Notes

This section should contain any additional information that will aid in understanding the ConOps document. If there are no notes, this section should still be included with the notation that there are no notes at this time. Subsequent revisions of the ConOps usually require that notes be added.

10. Appendices

To facilitate the ConOps' ease of use and maintenance, some information may be placed in appendices to the document. Each appendix should be referenced in the main body of the document where that information would normally have been provided. Appendices may be bound as separate documents for easier handling.

11. **Glossary**

The inclusion of a clear and concise compilation of the definitions and terms used in the ConOps document that may be unfamiliar to readers is important. A glossary should be maintained and updated during the ConOps' concept analysis and development processes. To avoid unnecessary work due to misinterpretations, all definitions should be reviewed and agreed upon by all involved parties.

DOCUMENT REVISION HISTORY			
Version Number	**Approved Date**	**Description of Change(s)**	**Created/ Modified By**

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TSM&O

Transportation Systems Management & Operations

Managing and Operating for an Efficient Transportation System

Project Systems Engineering Management Plan for: ***insert project name***

Version : *insert version number*

Approval date : *insert approval date*

FDOT

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List of Acronyms and Abbreviations

CEI	Construction, Engineering, and Inspection
CFP	Cost Feasible Plan
ConOps	Concept of Operations
CPM	Critical Path Method
FDOT	Florida Department of Transportation
ITS	Intelligent Transportation System
MOE	Measure of Effectiveness
MOP	Measure of Performance
MTR	Minimum Technical Requirement
O&M	Operations and Maintenance
PERT	Project Evaluation and Review Technique
PITSA	Project Intelligent Transportation System (ITS) Architecture
PSEMP	Project Systems Engineering Management Plan
QA	Quality Assurance
QC	Quality Control
QM	Quality Management
RITSA	Regional Intelligent Transportation System (ITS) Architecture
RTVM	Requirements Traceability Verification Matrix
SEMP	(Florida's Statewide) Systems Engineering Management Plan
SEP	Systems Engineering Process
SITSA	Statewide Intelligent Transportation System (ITS) Architecture
TSP	Technical Special Provision

DEVELOPING A PROJECT SYSTEMS ENGINEERING MANAGEMENT PLAN

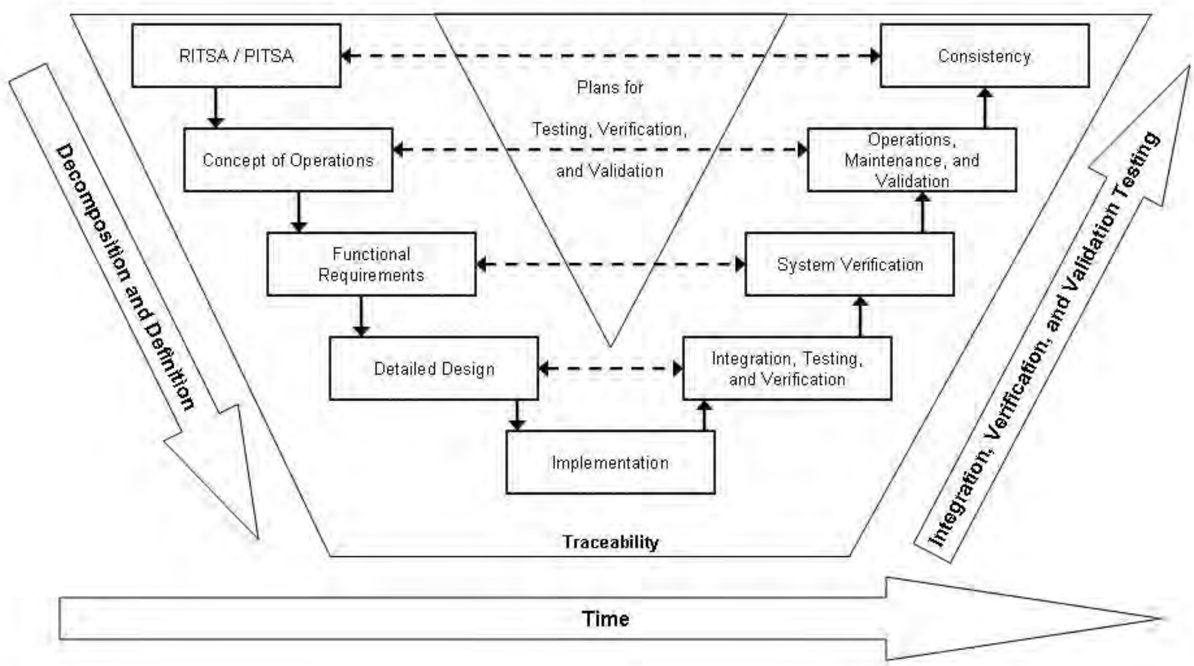
Introduction

This document is both a tutorial and a template for your project systems engineering management plan (PSEMP). If you remove the entire introduction section, you will have the correctly numbered outline for your PSEMP starting with Section 1.1 – Document Overview. **Tutorial text is in italics or underlined *italics.* Boilerplate text is presented in normal text and can be used as is.**

Consultants and suppliers in the service/product development process will do the majority of the systems engineering work for Florida Department of Transportation intelligent transportation systems (ITS) projects. Systems engineering processes (SEP) vary depending on the nature of the project. For software development projects and complicated product development projects, SEPs are very extensive. But for projects where existing products are procured and installed based on user-defined requirements, SEPs are not that extensive. Florida's Statewide Systems Engineering Management Plan (SEMP), referred to herein as Florida's Statewide SEMP, provides an extensive description of SEPs and management control that can be used in software/hardware development projects to design/build or procure/install projects. Hence, Florida's Statewide SEMP is used as a general reference while embarking on a new ITS project. It is available on-line at: http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/SEMP.shtm.

This document is an extraction from Florida's Statewide SEMP in that it documents some basic SEPs that should be followed in all ITS projects that primarily deal with procurement and installation of equipment. The PSEMP will enable the Overall Project Manager to manage a project using systems engineering principles and methods. Systems engineering is a discipline that organizes work in a systematic way. By doing so, it eliminates the need to correct errors during later stages of the project. Figure 1.1 shows a simplified approach that systems engineering adheres to. This diagram is also known as the "V" diagram.

Figure 0.1 – Simplified Systems Engineering Approach – the "V" Diagram



Following SEPs maximizes the quality of the system being implemented while minimizing the budget and time required for its completion. Hence it is the responsibility of the Overall Project Manager to instruct his/her staff as well as consultants and suppliers to adhere to pertinent SEPs as described in Florida's Statewide SEMP or this document, as the case may be.

Although the PSEMP has been created to satisfy a Federal Highway Administration requirement, the main purpose of the document is to guide the Overall Project Manager from project conception to the operations and maintenance phases in a systematic way following systems engineering principles. The PSEMP is a living document in that it is updated continuously as various project steps are completed. The document revision history panel located at the end of the template should be used to document all approved versions.

The template to use for your ITS project starts immediately below. Delete all above text including this entire line.

1.1 Document Overview

This document is the Project Systems Engineering Management Plan (PSEMP) for the *insert project name*. A PSEMP is a plan that helps manage and control a project utilizing systems engineering processes (SEP). The PSEMP identifies what items are to be developed, delivered, integrated, installed, verified, and supported.
The document is organized as follows:

- Section 1.2 – Need for a PSEMP
- Section 1.3 – Applicable Documents
- Section 1.4 – Systems Engineering Processes
- Section 1.5 – Project Management and Control

1.2 Need for a Project Systems Engineering Management Plan

The Florida Department of Transportation (FDOT) requires high-risk intelligent transportation systems (ITS) projects using federal funds to use a SEP.[1] The PSEMP documents how systems engineering will be used for ITS project management.

Florida's Statewide Systems Engineering Management Plan (SEMP) is used as a reference guide in the creation of this PSEMP.

1.2.1 Project Identification

Project Name: *Insert the official project name*.

Financial Project Identification: *Insert the financial project identification code*.

Federal Aid Project Number: *Insert the federal aid project number*.

1.2.2 Purpose and Scope

This document serves as the PSEMP for the *insert project name* of FDOT District *insert District number, if appropriate, or delete the word "District."* It provides planning guidance for the technical management, procurement, installation, and acceptance of the project, which includes *provide a general description of the project scope, such as install and maintain roadway surveillance and roadway information dissemination devices, etc*.

[1] FDOT Procedure titled Systems Engineering and ITS Architecture (Topic No 750-040-003). Available online at http://www.dot.state.fl.us/proceduraldocuments/procedures.shtm.

Further details of the project can be obtained by reviewing other documents, such as the project concept of operations (ConOps), quality assurance (QA) plan, operations and maintenance (O&M) plan, etc.

1.2.3 Technical Project Summary Schedule

Provide an overview of the project's schedule. For example:

- *Advertisement .... February 2006*
- *Letting / Notice to Proceed .... March 2006*
- *Construction .... July 2006 to January 2007*
- *Fiber / Conduit Install .... July 2006 to October 2006*
- *Poles / Cameras Install .... October 2006 to January 2007*
- *Pole / Remote Traffic Microwave Sensor Install .... October 2006 to January 2007*
- *Dynamic Message Sign Structure Install .... October 2006 to January 2007*
- *Unit / Subsystem Tests .... July 2007 to October 2006*
- *System Acceptance Tests .... January 2007 to March 2007*

Avoid providing a detailed schedule in this section – just an overview of the major events to give a general time perspective for the project should be included. The detailed schedule will be available once the project evaluation and review technique (PERT) chart is prepared as described in Section 1.5.2.

1.2.4 Relationship to Other Plans

Describe where this project fits into the funding organization's strategic plan in this section. At a minimum, refer to the FDOT Ten-Year ITS Cost Feasible Plan (CFP) if the project is identified in that document. Another reference plan includes the regional ITS architecture (RITSA). Specifically identify what part of the RITSA is being implemented. It is desirable, at this stage, that you mention what other project-specific plans, such as the quality assurance (QA) plan, the O&M plan, etc., are being prepared for this project.

1.2.4.1 Relationship to Florida's *Ten-Year ITS Cost Feasible Plan*

The Ten-Year ITS Cost Feasible Plan (CFP) is a ten-year program and resource plan that identifies ITS projects in the overall context of Florida's ITS Corridor Implementation Plans.[2] It represents a commitment of state- and District-managed ITS funds to provide a coordinated statewide program to develop ITS infrastructure on Florida's major intrastate highways. The *insert project name* project is included in the Ten-Year ITS CFP.

[2] The FDOT's ITS Corridor Implementation Plans are available online at http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/CFP/CFP_Legacy.shtm .

The FDOT's current Ten-Year ITS CFP is available online at http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/Ten-Year_CFP.shtm.

1.2.4.2 Relationship to Florida's *Statewide ITS Architecture*

The *insert project name* project is included in the District *insert District number (if applicable)* regional ITS architecture (RITSA), which was developed as part of the Statewide ITS Architecture (SITSA). More information on the current SITSA is available online at http://www.consystec.com/florida/default.htm.

1.2.4.3 Relationship to Other "On-project" Plans

Describe other "on-project" plans in this section, such as the project QA plan, O&M plan, etc., that this PSEMP relates to.

1.3 ***Applicable Documents***

The following documents, of the exact issue shown, form a part of this document to the extent specified herein. In the event of a conflict between the contents of the documents referenced herein and the contents of this document, this document shall be considered the superseding document.

Document #1, including the title, version, and date published	*Provide the name of the publisher or organization that controls document distribution and contact information so a copy can be obtained.*
Document #2, including the title, version, and date published	*Provide the name of the publisher or organization that controls document distribution and contact information so a copy can be obtained.*
Et cetera	*Et cetera*

1.4 ***Systems Engineering Processes***

Describe the SEPs that are typically followed in ITS projects in this section of the PSEMP. All processes may not be required for every project. Conversely, other processes may be required, depending on the nature of each project. Tailor each PSEMP accordingly. Refer to Chapter 3 of Florida's Statewide SEMP for more details on SEPs.

1.4.1 Developing the Project Intelligent Transportation System Architecture

Each project will most likely be identified in the RITSA. If that is the case, mention the service packages selected from the RITSA to develop the PITSA in this section.

If for some reason a project architecture is not identified in the RITSA, a Turbo Architecture needs to be created for the project. Define the process used to create that architecture. Verify that all interfaces are defined and that interface control documents exist for all interfaces. If the interface control documents do not exist, create those documents separately and refer to them here.

1.4.2 Creating High-Level Functional Requirements

The concept of operations (ConOps) document describes high-level project requirements from a customer and stakeholder perspective. This document is a must for all projects. A feasibility study or something similar that was done prior to the project kick-off may exist. The project ConOps is created as a separate document at this stage and referred to here.

For most ITS projects, the ConOps can serve as high-level functional requirements for the system; however, for complicated ITS projects, another stage of functional requirements — the system/subsystem requirements — needs to be developed based on the ConOps.

1.4.3 Creating Detailed Requirements

For 30 or 60 percent design/build projects, detailed requirements are referred to as minimum technical requirements (MTR). MTRs are developed based on high-level requirements as mentioned in Section 1.4.2 herein during the normal design/build process. The Design/Build Consultant develops detailed specifications based on the MTRs. Mention the MTR document that was created.

For low-bid projects, the detailed requirements are referred to as the specifications and/or technical special provisions (TSP). Specifications and/or TSPs are developed based on high-level requirements as mentioned in Section 1.4.2 herein for low-bid projects. Mention the specifications and/or the TSP document that has been created

1.4.4 Performing Trade-off Studies, Gap Analyses, or Technology Assessments

As a formal decision analysis method, trade-off studies are used in situations where more than one alternative exists for a given product, system, or technology. For example, there are multiple detection units available to detect vehicle presence and measure traffic parameters. Choosing the best detector in a given situation will require a trade-off study. Trade-off studies can be done at several levels and at different times during the project.

A gap analysis focuses on determining the gap that exists between existing system capabilities and the desired system to be implemented.

When the same product or system can be built using different technologies, a technology assessment is completed to determine the right technology to use to build the product in the given situation.

If the trade-off study, gap analysis, or technology assessment processes are very involved, create a separate document and refer to that document here; however, if the processes are simple, document the information in this section itself.

Some of these studies may have been completed prior to the project kick-off date. If that is the case, mention those documents here.

1.4.5 Performing Technical Reviews

A SEP requires several reviews to properly accomplish the various work items that are to be completed in a project. Section 4.6.1.1 of Florida's Statewide SEMP describes various reviews that can be performed for a project. Not all reviews are needed for all projects. Depending on the scope of the project, only a few reviews may be necessary. The Overall Project Manager should follow the District's design review process for design/build and low-bid projects. System engineers attend these reviews and document changes, which could be applicable to requirements and schedules. A requirement change that modifies stakeholder requirements is reported to the Overall Project Manager for a decision. Schedule changes are reported at the monthly project status review meetings as described in Section 1.5.7 herein.

Document planned project reviews in this section.

1.4.6 Identifying, Assessing and Mitigating Risk

Describe how various project risks will be identified and document them in this section. Risks are assessed as low, medium, or high. Begin with high-risk items and describe the measures that can be taken to mitigate the risks. Completion of these tasks will yield a risk matrix. Risks are evaluated throughout a project's life cycle, as risks may change during the course of the project. The following areas are specifically considered for risk identification:

- *Known problems in the existing system,*
- *Operational danger,*
- *Current technology,*
- *Critical path tasks in the project schedule, etc.*

1.4.7 Creating the Requirements Traceability Verification Matrix

Once stakeholder needs and requirements have been defined, create the requirements traceability verification matrix (RTVM). Among other items, the matrix references all *stakeholder needs typically identified in a ConOps document (and any other potential requirements sources). System requirements are then referenced in the matrix. Such requirements specify what the system will do; they are derived from and are directly traceable to stakeholder needs. Depending on project-type (for example, design/build, low-bid), system requirements may include minimum technical requirements, specifications, or technical special provisions.*

System requirements must be verifiable and a method to verify compliancy to each requirement is also referenced in the RTVM in addition to compliancy results. The purpose of this early assignment of a verification method, long before the system requirements will actually be verified, is to make sure there is thought given to how the requirement will be verified from the very start.

Subsystem requirements and high-level design components may also be referenced in the RTVM, depending on project needs.

The matrix will provide backward and forward traceability, at a minimum, between stakeholder needs, system requirements, and verification test cases. The matrix can be maintained directly in a database or spreadsheet for small projects or generated and maintained with a requirements management tool for more complex projects. The Test Manager will use the RTVM to ensure that each requirement is properly tested. The organization that defines the detailed requirements also creates the RTVM.

1.4.8 Creating Performance Measure Metrics

The systems engineering team must define system effectiveness measures that reflect overall stakeholder expectations and satisfactions. Relate the measures to project stakeholder goals and objectives.

The performance measures can be categorized as follows:

- *Safety measures*
- *Protection of public investment measures*
- *Interconnected transportation measures*
- *Travel choice measures*

There are two ways to evaluate how well a system design meets its requirements. One is by defining MOEs and the other is by defining MOPs.

Customers or stakeholders will use MOEs to measure satisfaction with products produced by the technical effort.

The MOPs are the engineering performance measures that provide the design requirements needed to satisfy the MOEs. There could be several MOPs, which are sometimes referred to as technical performance measures, for each MOE.

After functional system requirements are defined and low-level requirements are allocated by the Systems Engineer to the subsystems, components, and elements of the system, the Systems Engineer will select or specify the requirements that are testable. Testable requirements are MOPs that can be traced to stakeholder requirements and their MOEs.

The RTVM prepared in the previous section will already include some of the MOPs, depending on the depth of requirement included.

Describe the MOEs and MOPs that will be used during the project in this section, or create a separate document and refer to it here. The Test Manager will use these during system acceptance.

For construction projects, a separate set of performance parameters are developed as described in Section 13.1 of the Construction Project Administration Manual (Topic Number 700-000-000), online at http://www.dot.state.fl.us/proceduraldocuments/formsandprocedures.shtm.

1.4.9 Conducting System Testing, Integration, Verification, Validation, and Acceptance Planning

Describe the system test and evaluation methodology in this section. Also, include the system integration testing methodology here. It is recommended that a phased integration approach be used. Refer to Section 3.3.10.3 of Florida's Statewide SEMP for details on this subject.

Describe the process that will be used for FDOT to accept the system. If FDOT is the Systems Integrator, then describe how FDOT will accept the subsystems.

Typically, this section includes the following:

- *Test approach*
- *Test schedules*
- *Test tools*
- *Test facility*
- *In-process test plans*
- *System integration test plan*
- *System verification and validation plan*
- *System acceptance criteria*
- *Integration and testing organizational responsibilities*

The Construction Consultant will provide the test plan. The Construction, Engineering, and Inspection (CEI) Consultant will use the RTVM and test plan to determine if a test should be accepted or rejected based on results.

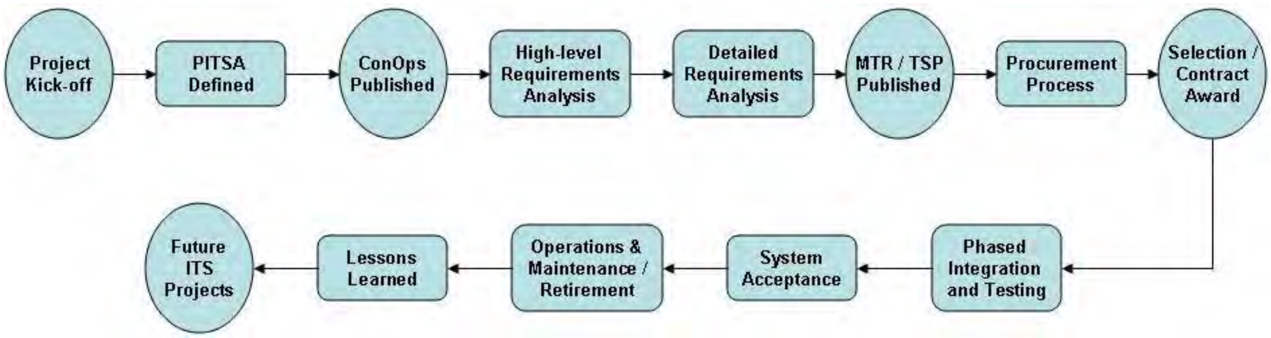
1.5 Project Management and Control

Describe the project management and control needed to successfully complete the project in this section. Also, identify the tasks that need to be performed to achieve these goals and define the organizational responsibilities required for accountability in the project.

The successful completion of SEPs described in Section 1.4 herein form the backbone for project success. The Overall Project Manager's responsibility is to ensure that tasks are completed on schedule and at cost. Hence, the Overall Project Manager's responsibility is to put proper controls in place that help achieve this goal.

Figure 1.2 shows stages for an ITS project. The Overall Project Manager's responsibility starts with project kick off and ends with O&M. There will be various people and organizations that help throughout this process. The Systems Engineer will typically select the RITSA service packages to define the PITSA. The Consultant will typically perform duties including, but not limited to, the high-level requirements analysis for publication of the MTRs/TSPs. The District office will be responsible for the procurement process, and selection and award of the contract. A Consultant will perform construction/installation, which will be supervised by the Construction Project Manager on behalf of the Overall Project Manager. System acceptance will be supervised by the District office or an independent verification and validation team. The maintenance department will take over after the system has been accepted.

Figure 0.2 – Intelligent Transportation System Project Stages



The following areas will be covered in this section:

- Organization structure
- Managing the schedule with a project evaluation and review technique (PERT) chart, and the critical path method (CPM)
- Procurement management
- Risk management
- Subcontractor management
- Engineering specialty integration
- Monthly project status reviews
- Change management
- Quality management (QM)

- Systems acceptance
- O&M / upgrade / retirement
- Lessons learned

1.5.1 Organization Structure

Describe project organization and responsibilities as they relate to the specific tasks to be performed in this section. List the names of functional managers and delineate their responsibilities in this section. Provide a description and diagram of the interaction between functional organizations, including the structure of the systems engineering organization and the responsibilities of all organizations. The Overall Project Manager is in charge of the entire project, and may designate other people from time to time to manage certain aspects of the project on his behalf, but the responsibility still lies with the Overall Project Manager.

Describe the organizational structure of the project here and clearly define responsibilities. Include items such as:

- *Who will get environmental permits*
- *Who will perform surveying and geotechnical investigation*
- *Who will get roadway permits, etc.*

1.5.2 Managing the Schedule with the Project Evaluation and Review Technique and the Critical Path Method

The PERT/CPM is one of the most efficient methods available for managing a project schedule. Before a schedule can be prepared, high-level task items or product elements are broken down into smaller manageable units in a hierarchical fashion. Breaking down tasks in this fashion is sometimes called the work breakdown structure.

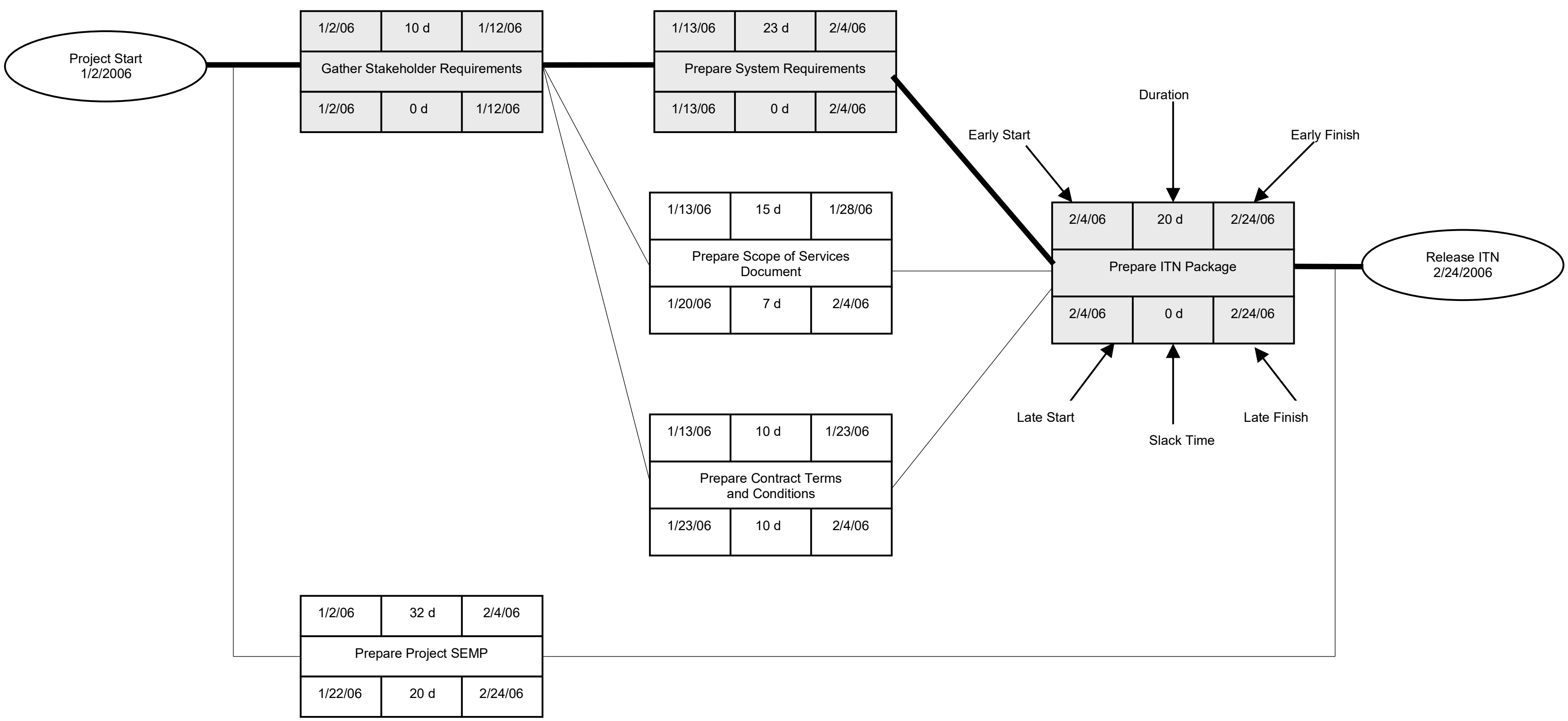
Prepare a PERT chart that shows all project tasks and task dependencies. It is critical that these dependencies are identified accurately and that no task is left open ended. It is the Overall Project Manager's responsibility to prepare this chart after receiving task details (either in the form of a segment of the PERT chart, or as start and end dates for individual tasks, staffing requirements, and task dependencies) from each responsible member of the project team, including consultants and contractors. The Overall Project Manager may delegate the creation of the PERT chart to the District Scheduling Engineer or a Consultant. Figure 1.3 shows a sample PERT chart. Further details on how to create a PERT chart are provided in Section 4.6.1.2.1 of Florida's Statewide SEMP.

The way a project schedule is managed is referred to as the CPM. A critical path is the longest path in the PERT chart from start to finish. It is called the critical path because any delay in the activities on this path pushes forward the project completion date. The tasks on the critical path have no slacks. This means that their early/late start dates are the same and so are the early/late finish dates. In Figure 1.3, this path is indicated by bold lines and shadowed task boxes. All tasks are reviewed in the project review process and any date changes are entered in the PERT chart.

Any time there is a delay in any task on the critical path, a flag is raised indicating this issue needs to be addressed immediately because this signals a delay in the project completion date. For this reason, the tasks on the critical path are reviewed more frequently than other tasks that have slacks — in other words, tasks that are not on the critical path.

Create your project PERT chart as soon as possible. Refer to the document where this chart can be found or attach the chart to this document if it is not very elaborate.

Figure 0.3 – Sample Project Evaluation and Review Technique Chart



1.5.3 Procurement Management

FDOT does not perform software/hardware development or construction. For most projects, FDOT will procure products or services from outside vendors and consultants. Therefore, the procurement process is very critical to overall project success. Section 4.4 of Florida's Statewide SEMP describes this procurement process in detail. The process varies depending on the nature of the products/services to be procured.

Describe the planned management process for procurement of systems, products, and services in this section.

1.5.4 Risk Management

The preliminary risk identification, assessment, and mitigation strategies have been completed by the Systems Engineer as described in Section 1.4.6 herein. The Overall Project Manager reviews the matrix created by the Systems Engineer, and adds some project-level or external risks that he may think are important. This provides a new risk matrix. The new risk matrix is evaluated by the Overall Project Manager and the Systems Engineer on a regular basis, especially during or after major reviews.

Document the project's risk matrix in this section.

1.5.5 Subcontractor Management

Describe how the Overall Project Manager will manage the Subcontractor's technical work to ensure product control in this section. In most instances, a Prime Consultant or a Systems Integrator, and not FDOT, will manage Subcontractor activities. The Systems Integrator or Prime Consultant assigns appropriate people to coordinate with the Subcontractor working teams. These people will oversee design reviews, system testing, etc. The Overall Project Manager requests PERT charts for the major tasks to be completed, either from the Prime Consultant or the Systems Integrator, and uses them to better oversee the processes.

Document who will manage the project's Subcontractor activities in this section, as well as the scheduled reviews and how often the reviews are planned.

1.5.6 Engineering Specialty Integration

Engineering specialties are the highly specialized engineering disciplines needed in projects because the Overall Project Manager may not be an expert in all disciplines of a project or in successfully maintaining the system throughout its life cycle. The idea is to get members from different specialties involved in the project at an early stage and make them aware of their project responsibilities. There are various specialty engineering disciplines that may be required, depending on the complexity and nature of the project. Section 6.1 of Florida's Statewide SEMP details these specialties. Most of the specialties described in Section 6.1 are needed in system/product/process development phases, so they are the responsibility of the Systems Integrator or Consultant. Only one essential specialty is described here. If a project requires the involvement of more disciplines, more information is available in Section 6.1 of Florida's Statewide SEMP.

1.5.6.1 Integrated Logistics Support and Maintenance Engineering

This engineering specialty is responsible for determining the total support required for a system to ensure operational readiness and sustainability throughout its life cycle.

This specialty provides the following project input:

- Defines support requirements – for example, the mean time to repair
- Supports considerations that influence requirements and design
- Provides the necessary support package
- Provides operational support at a minimum cost

Mention the engineering specialties that will be used by a project in this section.

1.5.7 Monthly Project Status Reviews

The Overall Project Manager assesses project health, based on technical progress, budget, and schedule performances as well as risk status, at monthly project status reviews. Information from Systems Engineers, Systems Integrators, and/or Consultants is gathered, depending on the nature of a project. Various issues may be discussed at these meetings, but the following items must be discussed in detail:

- *Action item reviews and resolution*
- *Critical path item status reviews*
- *Major risk item reviews*

After each review, the schedule should be updated to reflect the project's latest status. Keep minutes from the reviews and the PERT chart in a separate document.

Describe how monthly reviews are conducted in this section. Refer to the document containing the review minutes and the PERT chart.

1.5.8 Change Management

The Overall Project Manager addresses changes in schedule and the subsequent impacts by adjusting the PERT chart and cost metrics. Sometimes changes in task durations give rise to a new critical path for the project, which must be monitored as the project proceeds.

Changes in some basic requirements need careful review. The Overall Project Manager informs stakeholders of changes to basic requirements and the subsequent outcomes. The Overall Project Manager decides if design changes will be accepted and the Construction Project Manager generally makes a decision regarding construction changes. If there are substantial construction changes, the Overall Project Manager, the CEI Consultant, and the Construction Project Manager generally make a decision regarding acceptance.

When dealing with a software project or other standard-related issues that will have statewide impact, the Overall Project Manager presents the issue to the Change Management Board for resolution.

Follow the normal change order process for all changes on construction projects.

1.5.9 Quality Management

The Overall Project Manager must establish a quality management (QM) plan not only for internal project processes, but also for quality systems from vendors and consultants. A QM plan should contain both a plan to implement quality control (QC), and a plan to monitor and verify that quality standards are being achieved. QC is the process whereby quality is engineered into the products being deployed using inspection, testing, and audits of documentation. QA is the process of verifying that the product meets the quality standards established by the QM plan.

Describe the project's QM plan in this section. For construction projects, follow the statewide and District-specific QC/QA process that has already been established.

1.5.10 Systems Acceptance

The systems acceptance process is critical because this is where FDOT becomes responsible for the continued maintenance and management of the systems, products, and processes delivered.

The Overall Project Manager must assign a Test Manager right after the requirements have been written. For construction projects, the Test Manager is part of the CEI team. The Test Manager uses the plans described in Section 1.4.9; the RTVM created in Section 1.4.7; and the MOEs and MOPs discussed in Section 1.4.8 to supervise the entire testing process. The Test Manager provides the status of all tests in report form to the Overall Project Manager, who carefully reviews the reports and decides on the final system acceptance.

Document the process included in the project for FDOT to accept the system in this section. Describe in detail where the system developer or supplier obligation ends, and the system transitions to maintenance mode by FDOT.

1.5.11 Operations and Maintenance, Upgrade, and Retirement

Once a system has been through the acceptance testing process and has been accepted, it moves into the O&M phase. In this phase, system problems could be resolved in one of many ways. An FDOT employee trained on the system could repair it. The manufacturer's warranty could be used to get it fixed. In some cases, FDOT could contract with an outside agency to maintain the system. In any case an O&M plan should be written to spell out the details of how the system will be maintained and operated.

Once a system has been in operation for some years, it may be upgraded. The need for upgrade could be due to the availability of new technology that makes the existing system function better and extends its life. Refer to Section 7.2.5 of Florida's Statewide SEMP for more details on this subject.

Finally, there comes a time when the system is no longer able to function as it was intended to. This could be caused by normal wear and tear on the system; system maintenance has become too costly; and technological obsolescence due to better and cheaper systems have become available, or because the equipment is no longer supported by the manufacturer. The time has come for the system to be retired. There are expenses involved in retiring a system that need to be considered during the project planning stage. Refer to Section 7.2.6 of Florida's Statewide SEMP for more details on this subject.

Mention the O&M plan that has been created for the project to support system operations, maintenance, upgrade, and retirement here.

1.5.12 Lessons Learned

In every project, there are lessons to be learned. Document the lessons learned for future guidance. Sometimes, it is feasible to have lessons learned from the project applied to the same project, but, usually, lessons learned during a project will be valuable guidance for future projects.

Mention the lessons learned depository that has been created for the project.

2. User Definitions

DOCUMENT REVISION HISTORY			
Version Number	**Approved Date**	**Description of Change(s)**	**Created/ Modified By**

Appendix D: FDOT TSM&O 2017 Strategic Plan

In Development by the Florida Department of Transportation

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Appendix E: CDOT TSM&O Evaluation Checklist

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Level 2 Operations Analysis - Table of Contents

Included (check)	Level 2 Operations Analysis Categories
	Data and Modeling
	Traffic issues from Form 463
	Detailed review of existing and future project traffic volumes from OTIS, COGNOS, INRIX
	Further analysis of queuing, delay, and LOS
	Other
	Operational, Geometric, and Road User Conditions
	Improvements to Lane Geometry
	Signing and Striping to improve positive guidance
	Improvements to accommodate unique users
	Improvements specific to bicycles and pedestrians
	Lane utilization and merge/diverge points
	Project tie-ins
	Transit improvements
	Railroad crossings and facilities
	Roadside and maintenance features (turnaround points, staging areas, debris flow, etc.)
	Work zone safety and mobility
	Other
	Operational Strategies
	Traffic Signal Optimization
	Auxiliary Lanes
	Intersection Channelization
	Reduce Bike/Bed/Vehicle Conflicts
	Lane Assignment
	Road Diet
	Shoulder Widening
	Truck Enhancement
	Intersection Control Type Changes
	Shoulder/Lane Narrowing
	Railroad Crossing Improvements
	Traffic Signal Detection
	Access Modifications
	Sight Distance Improvement
	Ramp Metering Strategies
	Signing Improvements
	Transit Improvements
	Pavement Markings
	Bike Facility Enhancements
	Active Traffic Management
	On-Street Parking Modifications
	Other
	Other Operational Strategies
	Bottleneck Mitigation
	Peak Period Shoulder Lane
	Access Management
	Managed Access Lanes
	Continuous Flow Metering
	Alternative Intersection Treatments
	RoadX Initiative

	Other
	Coordination and Collaboration
	Additional input from internal CDOT stakeholders
	Additional input from external stakeholders
	IGA related coordination
	Other

SAFETY ANALYSIS - General Information

Name of RTR filling out this form:	
Form start date:	

Level 1 Safety Analysis

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box if Level 2 Analysis is necessary
The following seven questions are standard recommendations that are found in all safety assessments. Please answer these questions based on your review of the corridor. If you answer yes to any of the questions, add detail in recommendations column.							
Does the roadway need to be resurfaced to maintain good skid resistance and drainage of the roadway surface?	○ Yes ○ No ○ N/A						
Does the existing guardrail need to be adjusted, repaired, or upgraded to meet current standards?	○ Yes ○ No ○ N/A						
Does a safety edge need to be applied to eliminate pavement edge drop-offs?	○ Yes ○ No ○ N/A						
Does the super-elevation or crown need to be corrected?	○ Yes ○ No ○ N/A						
Do existing pavement markings, signing, and delineation need to be replaced or improved?	○ Yes ○ No ○ N/A						
Do advance warning signs for curves need to be installed?	○ Yes ○ No ○ N/A						
Do the button reflectors and guardrail reflectors need to be replaced to ensure good nighttime and inclement weather (fog, snow, rain, etc.) delineation?	○ Yes ○ No ○ N/A						
Did you pull crash data from Vision Zero? Remember to save the Vision Zero report in the project folder.	○ Yes ○ No ○ N/A						
Did you recognize any patterns in the data that you can solve in the Level 1 safety review?	○ Yes ○ No ○ N/A						
List patterns in **comments** column (use + to add rows) and recommendations for improvement in the **recommendations** column (use + to add rows or - to remove extra rows).							
Is Level 2 Safety Analysis necessary? If so, please describe specific items you would like studied in the **comments** column.							

Level 2 Safety Analysis	Begin MP	End MP	Ramp	Comments	Recommendations	
Add the recommendations from the Level 2 Safety Analysis in the **recommendations** column. Use + to add rows for each recommendation.						

OPERATIONS ANALYSIS - General Information

Name of RTR filling out this form:	
Form start date:	

Level 1 Operations Analysis

Purpose: A statewide quality assurance process to promote opportunities to use TSM&O strategies to improve operational performance in terms of capacity, safety, mobility, and maintenance.
Each project shall be evaluated to ensure that context-relevant operational improvements are being considered as part of the project. The reviewer shall consider the following when assessing projects for the Level 1 Operations Analysis portion of the TSM&O Evaluation. In addition to this form, consider the results of the Level 1 Safety, and Level 1 ITS Analyses.

Data and Modeling

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Are there any count stations in the area that highlight specific peak traffic times?	Yes No N/A						
Were any traffic design issues that may impact operations identified in Form 463?	Yes No						☐
If Yes, list here and identify if they were addressed (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							
Review existing and future projected traffic data using OTIS,[i] COGNOS, and INRIX[ii]. Are there:							☐
Identifiable bottlenecks in the project area?	Yes No N/A						
Recurring, daily congestion patterns?	Yes No N/A						
Recurring, seasonal congestion patterns?	Yes No N/A						
Non-recurring or special event congestion?	Yes No N/A						
Operational issues related to heavy vehicles (e.g. turning path conflicts)?	Yes No N/A						
Issues with specific turning movements?	Yes No N/A						
Directional peak hour traffic volumes that reciprocate one another?	Yes No N/A						
Significant Bicycle and Pedestrian users present or known issues?	Yes No N/A						
Planning Time Index values higher than expected compared to similar facilities?	Yes No N/A						
Travel Time Index values higher than expected compared to similar facilities?	Yes No N/A						
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							
Does the scope and complexity of the project warrant further analysis of traffic, queuing, delay, and LOS with any of the following tools?	Yes No (selected) N/A						☐
If so, indicate here:							
Traffic Analysis (Synchro, Tru-Traffic, HCM)	Yes No N/A						
Microsimulation (VISSIM, CORSIM, SimTraffic)	Yes No N/A						
Travel demand data (origin-destination data)	Yes No N/A (selected)						
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.	Yes No N/A						☐
Have any of these tools been initiated? If so, which ones?	Yes No N/A						

Operational, Geometric, and Road User Conditions

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Can improvements to lane geometry be made to better serve existing and future traffic demand?	Yes No N/A						☐
Can the current project incorporate signing and striping improvements to improve positive guidance (See CDOT Signing and Striping Standards[iii])?	Yes No N/A						☐
Can intersection or roadway geometry and cross-section elements be enhanced to better accommodate unique users (frequent large trucks, trailers, recreational vehicles)?	Yes No N/A						☐
Can improvements to the roadway specific to Bicycles and Pedestrians[iv] be included within the scope of the project?	Yes No N/A						☐
Can improvements to how the roadway connects/integrates into the existing roadway, i.e., lane utilization/demand and lane merge/diverge with existing upstream and downstream traffic be incorporated into the project?	Yes No N/A						☐
Has appropriate consideration been given to the tie-ins at each end of the project?	Yes No N/A						☐
Is there an opportunity to incorporate transit improvements (bus pullouts, concrete pads) with the project?	Yes No N/A						☐
Are there opportunities to improve or modify railroad crossings or facilities within the project boundaries?	Yes No N/A						☐
Are there opportunities to provide or improve the following features: Turn Around points, Staging areas, Debris Flow areas, Avalanche Safety zones, and Slopes for vegetation maintenance?	Yes No N/A						☐
Are there elements of the project that warrant consideration of the CDOT Work Zone Safety and Mobility[v] procedures as part of the scoping efforts?	Yes No N/A						☐
If yes, please explain and describe if they were addressed?							

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							☐

Operational Strategies (Refer to Strategies List)

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Please review the following list of operational improvement types, which includes example projects and strategies that could potentially be initiated as a part of the project. The following strategies may require additional study that may not be possible to complete until later in the scoping process.							
If applicable to the current project, or if they would apply to a future project, should the following strategies be considered? ***Click the green button to see more strategies or the gray button to remove rows.***							
Traffic Signal Optimization	Yes No N/A						☐
Auxiliary Lanes	Yes No N/A						☐
Intersection Channelization	Yes No N/A						☐
Reduce Ped/Bike/Vehicle Conflicts	Yes No N/A						☐
Lane Assignment	Yes No N/A						☐
Road Diets	Yes No N/A						☐
Shoulder Widening	Yes No N/A						☐
Truck Enhancements	Yes No N/A						☐
Intersection Control Type Changes	Yes No N/A						☐
Shoulder/Lane Narrowing	Yes No N/A						☐
Railroad Crossing Improvements	Yes No N/A						☐
Traffic Signal Detection	Yes No N/A						☐
Access Modifications	Yes No N/A						☐
Sight Distance Improvements	Yes No N/A						☐
Ramp Metering Strategies	Yes No N/A						☐
Signing Improvements	Yes No N/A						☐
Transit Improvements	Yes No N/A						☐
Pavement Markings	Yes No N/A						☐
Bike Facility Enhancements	Yes No N/A						☐
Active Traffic Management	Yes No N/A						☐
On-Street parking modifications	Yes No N/A						☐
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							☐
Are there other operational strategies and/or improvements that should be studied as part of the project, such as?							
Bottleneck Mitigation	Yes No N/A						☐
Peak Period Shoulder Lane	Yes No N/A						☐
Access Management	Yes No N/A						☐
Managed Access Lanes	Yes No N/A						☐
Continuous Flow Metering[vii]	Yes No N/A						☐
Alternative Intersection Treatments	Yes No N/A						☐
RoadX Initiative[ix]	Yes No N/A						☐
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							☐

Coordination/Collaboration

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Has input from applicable internal CDOT stakeholders related to capacity, safety, mobility, and maintenance on the project corridor been requested and documented?							☐
Incident Manager in Project Area	Yes No N/A						
Corridor/Area Operations Manager	Yes No N/A						
Region Access Manager	Yes No N/A						
CTMC (or other operations centers, if applicable)	Yes No N/A						
Maintenance Supervisor	Yes No N/A						
Public Information Offices	Yes No N/A						
Project Managers of Adjacent Projects	Yes No N/A						
Special Events	Yes No N/A						
Venues	Yes No N/A						

		Begin MP	End MP	Ramp	Comments	Recommendations	Check box to include in Level 2 analysis
Region Bike & Pedestrian Representatives[x]	Yes No N/A						
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							☐
Considering the scope and complexity of the project, has input from applicable external stakeholders been requested and documented?							☐
City and County Agencies	Yes No N/A						
Transit Agencies	Yes No N/A						
MPO and TPR	Yes No N/A						
School Districts	Yes No N/A						
Law Enforcement	Yes No N/A						
Local Businesses	Yes No N/A						
Special Events	Yes No N/A						
Venues	Yes No N/A						
Other (describe in comments column and/or add recommendations in recommendations column). Use + to add rows or - to remove extra rows.							☐
Is there a current IGA for maintenance responsibilities in the project area?	Yes No N/A						
Is a new or modified IGA required to address maintenance responsibilities following project completion?	Yes No N/A						☐
Have any of the following FHWA processes been completed? If not, describe if they are necessary in the Recommendations column.							
Design Variance	Yes No N/A						
Interchange Access Request	Yes No N/A						
Minor Interchange Modification Report	Yes No N/A						
Level 2 Operations Analysis		Begin MP	End MP	Ramp	Comments	Recommendations	
Add the recommendations from the Level 2 Operations Analysis to the recommendations column. Use + to add rows for each recommendation.							

Links

[i] http://dtdapps.coloradodot.info/otis
[ii] https://inrix.ritis.org/analytics/
[iii] https://www.codot.gov/library/traffic/traffic-manuals-guidelines/fed-state-co-traffic-manuals
[iv] https://www.codot.gov/business/designsupport/bulletins_manuals/roadway-design-guide/dg05-ch-14/view
[v] https://www.codot.gov/library/traffic/lane-close-work-zone-safety/work-zone-safety-mobility-program/WZSM_Procedures.pdf/view
[vi] http://safety.fhwa.dot.gov/road_diets/info_guide/
[vii] https://www.codot.gov/business/designsupport/other-specifications/its/project-special-details/Ramp%20Metering%20Standard.dgn/view
[viii] https://www.codot.gov/travel/i-70-continuous-flow-metering-at-the-eisenhower-tunnel/video-tunnel-metering-vs-continuous-flow-metering.html
[ix] https://www.codot.gov/programs/roadx
[x] https://www.codot.gov/programs/bikeped/design-policy.html

ITS ANALYSIS - General Information							
Name of RTR filling out this form:							
Form start date:							
Level 1 ITS Analysis							
		Begin MP	End MP	Ramp	Comments	**Recommendations**	Check box to included in Level 2 analysis
The following information has been pre-filled based on the TSM&O Evaluation Request. Please update and add details as necessary.							
Are there existing ITS infrastructure/devices (including traffic signals or ramp meters) within the project limits? If so, Level 2 ITS review is required	0						☐
If yes or unknown, begin Project Information Sheet in Sharepoint for Level 2 ITS Review							
Is the project implementing or replacing new ITS infrastructure/devices (including traffic signals or ramp meters)? If so, Level 2 ITS review is required.	0						☐
If yes or unknown, begin Project Information Sheet in Sharepoint for Level 2 ITS Review							
List existing or new ITS devices in **comments** column (Use + to add rows or - to remove extra rows)					0		
THE FOLLOWING SECTION IS FOR ITS TO FILL OUT							
Are there existing ITS infrastructure/devices (including traffic signals or ramp meters) within the project limits?	○ Yes ○ No						
List the existing ITS devices in the comments column (Use + to add rows or - to remove extra rows)							
Are there any ITS infrastructure/devices that are being recommended (including traffic signals or ramp meters)?	○ Yes ○ No						
List the recommended infrastructure/devices in the recommendations column (Use + to add rows or- to remove extra rows)							
Level 2 ITS Analysis		Begin MP	End MP	Ramp	Comments	**Recommendations**	
Add the recommendations from the Level 2 ITS Analysis in the **recommendations** column. Use + to add rows for each recommendation.							