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of Transportation

Federal Highway  
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# Developing and Using a Concept of Operations in Transportation Management Systems

## Final Report

August 2005

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# CHAPTER 1 – Introduction

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## Chapter Purpose

This chapter provides an introduction, overview, and summary of the document. It introduces key concepts on how to develop and use a Concept of Operations in transportation management systems (TMSs). Finally, the chapter provides the reader with information about how to best use the guidance document.

## Chapter Objectives

The key objectives of this chapter are:

- *To introduce the reader to the Concept of Operations and its role in a TMS.*
- *To provide a brief background on key topics that serve as a foundation for the guidance document.*
- *To define the challenges and state-of-the-practice in Concept of Operations development and use in TMSs.*
- *To provide information on how to use the guidance document.*

## Chapter Sections

Each section of this chapter is briefly described below.

### 1.1 Why Use This Document?

This section provides an introduction to the information contained in the document, and describes the benefits that a Concept of Operations provides to a TMS.

### 1.2 Systems Engineering and Transportation Management Systems

This section highlights the need for, and benefits of, using the systems engineering process to develop and operate a TMS. The systems engineering life cycle will be introduced and the important role of the Concept of Operations within the life cycle will be discussed.

### 1.3 What is a Concept of Operations and Why is it Important?

Before developing and using a Concept of Operations, one must have a clear understanding of the purpose behind generating such a document, as well as how it should be structured. This section briefly provides an overview of the main goals and objectives for a Concept of Operations, and it highlights the core elements necessary to include in the document. This section also highlights the motivating principles behind the generation and use of a Concept of Operations.

#### **1.4 What is the Challenge?**

This section will address the state-of-the-practice in TMS Concept of Operations and describe the challenges involved in changing practice in the TMS community in order to better exploit the benefits of a Concept of Operations.

#### **1.5 How to Use This Document**

This section is intended to help users with different needs and degrees of experience determine how to best use the guidance document. In addition, it identifies key supporting resources to supplement this document.

#### **1.6 Guiding Principles**

This section provides a brief summary of the key information contained in this chapter.

## 1.1 Why Use This Document?

The objective of this document is to provide guidance to transportation professionals as they seek to develop and use a Concept of Operations throughout the life cycle of a TMS. It is written for transportation professionals involved in the planning, development, design, operation, and maintenance of TMSs. The guidance document is relevant to a wide audience – ranging from technical personnel to individuals with relatively little TMS experience. This is consistent with the Concept of Operation's mandate to document and communicate essential information about a TMS to a varied array of intended users.

To provide more detail, the usefulness of the guidance document for typical “classes” of TMS professionals is outlined below:

- *Management* – Transportation managers working with a TMS will find this useful as it clearly describes the necessity for system stakeholder communication. A Concept of Operations is a critical foundation for such communication.
- *Technical staff* – Professionals working within a TMS who 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 this document useful as it demonstrates how a Concept of Operations helps to clarify agency and system goals and objectives – providing essential context for their activities.
- *Support engineering firms* – Any members of a contracted firm who work within or in conjunction with the TMS, including repair and maintenance personnel, system support personnel, etc., will find this document useful as it shows how a Concept of Operations assures that the ‘client’ communicates, at the highest possible level, what they want the system to be – adding clarity and helping to avoid scope creep for all parties.

### 1.1.1 This Document’s Development Methodology

This document was developed based on significant involvement of transportation professionals using the following methods:

- *Analysis of standards* – Several systems engineering standards on how to develop and use a Concept of Operations were identified and examined. The ANSI/AIAA standard G-043-1992 was chosen as the chief reference on Concept of Operations development for this handbook. It was selected because it was written in a simple fashion, yet the method was rich enough to effectively capture the considerations necessary in developing a Concept of Operations.
- *Survey* – An Internet survey was conducted to obtain experiences and guidance from transportation professionals that are, or have been, involved in the development of a Concept of Operations. This served as an important source of expert information for this document.
- *Analysis of transportation documents* – Examples of Concept of Operations documents were gathered from TMSs throughout the country. These documents provided the examples given in this handbook of the different approaches to Concept of Operations development and use from real-world TMS professionals.
- *Interviews with transportation professionals* – The Internet survey described above gathered mostly general information. These were followed-up with one-on-one interviews to acquire more detailed

testimonials for guidance on specific components of a Concept of Operations. Interviews were conducted with professionals in conjunction with the example documents so that the guidance given from the professional and results of the development process from that system would be consistent.

### 1.1.2 Practical Guidance within this Document

This document helps transportation professionals develop and use a Concept of Operations for TMS. Specifically, the document offers:

- *How to develop a Concept of Operations* – The handbook will provide guidance on all aspects of Concept of Operations development, 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. Examples of the content of developed and developing Concept of Operations will be provided for support.
- *How to use a Concepts of Operations* – This document will provide guidance from transportation professionals concerning how their systems use the Concept of Operations. Usage of Concept of Operations documents will be highlighted in the entire systems life cycle from a variety of stakeholder vantage points.
- *Specific examples of best practices from transportation agencies* – Throughout the document, testimonials, experiences and guidance from transportation professionals, as well as direct excerpts from their Concept of Operations documents, are used to the greatest extent possible to make this handbook useable and applicable to a TMS setting.
- *That there are no “Cookbooks” for developing/using Concepts of Operations* – This document does not present highly detailed multi-step processes for developing the perfect Concept of Operations. The situation for each TMS will be different, and as you will see later in the document, there is no way to create a ‘cookie cutter’ process for the development of a Concept of Operations for all TMSs. Tailoring the Concept of Operations to your specific system is necessary for a successful development process. Experiences among the TMSs described here will identify possible pitfalls and give strategies that are successful in the development process.

## 1.2 Systems Engineering and Transportation Management Systems (TMS)

A TMS is any system focused on improving the efficiency, safety, and predictability of travel. For the latter half of the 20th century, and the beginning of the 21st, TMSs have been deployed to fulfill the ever-increasing transportation needs of society. Modern TMSs are very complex systems, combining field equipment, operations personnel, communications, and advanced information technology to meet their mission. Examples of frequently developed and utilized TMSs are:

- *Freeway management system* – Such a TMS focuses on the management of freeway traffic using a variety of technologies and personnel. Its geographic scope may range from one interstate through an urban area, to several interstates throughout an urban area, to one interstate throughout the length of a State. An example of a TMS – freeway management system is the Virginia Department of Transportation's Northern Virginia Smart Traffic Center that manages traffic flow on the Interstates in Virginia within metropolitan Washington, DC. The center includes the use of: Closed Circuit Television – to monitor traffic flow and to verify incidents; service patrols – to monitor traffic flow and to facilitate incident resolution; loop detectors – to monitor traffic flow and detect incidents; Variable Message Signs – to communicate with the general automotive traffic; and coordination and communication with Public Safety Agencies and the Media.
- *Traffic signal control system* – This class of system manages traffic flow on arterials. Most major metropolitan cities include some form of an integrated signal control system to improve traffic flow on their roadway networks.

As stated above, contemporary TMSs are extremely complex systems. Indeed, they have become a system of systems; in particular, the level of complexity of information technology included in the systems is high. As such, it is no longer feasible to proceed with the development and maintenance of these systems in the classic “construction” approach, where there is an initial creation of detailed design specifications, the search for low-cost bidders, and then construction.

Such complex systems rely on a step-wise, iterative process that requires a full life cycle vision for the system in question. This is the systems engineering life cycle process. This process takes the developer and operator through a series of iterative steps that have been refined to help engineers manage large and complex system development. At its heart, the steps include:

- The development of the *Concept of Operations*, where the goals, objectives, system components, and stakeholders are identified;
- The development of the *System Requirements*, where the functions of the overall system are detailed;
- The development of the *System Design*, where the make-up of low-level sub-systems are detailed;
- The *Implementation* of the system, where components are built and moved into place;
- The *Integration and Testing* of the system, where components are linked and tested;
- *System Acceptance*, where the system is evaluated to see if it meets the goals and objectives outlined in the beginning;
- *System Operation and Maintenance*, where the system performs its on-going role until it is modified, replaced, or retired.

The systems engineering process outlined above is typically encapsulated into what is referred to as the systems engineering "Vee:" Figure 1.1 provides an illustration of the "Vee." This form places the steps in a step-wise, temporally relevant (with time moving left to right), shape that can clearly be seen in once glance.

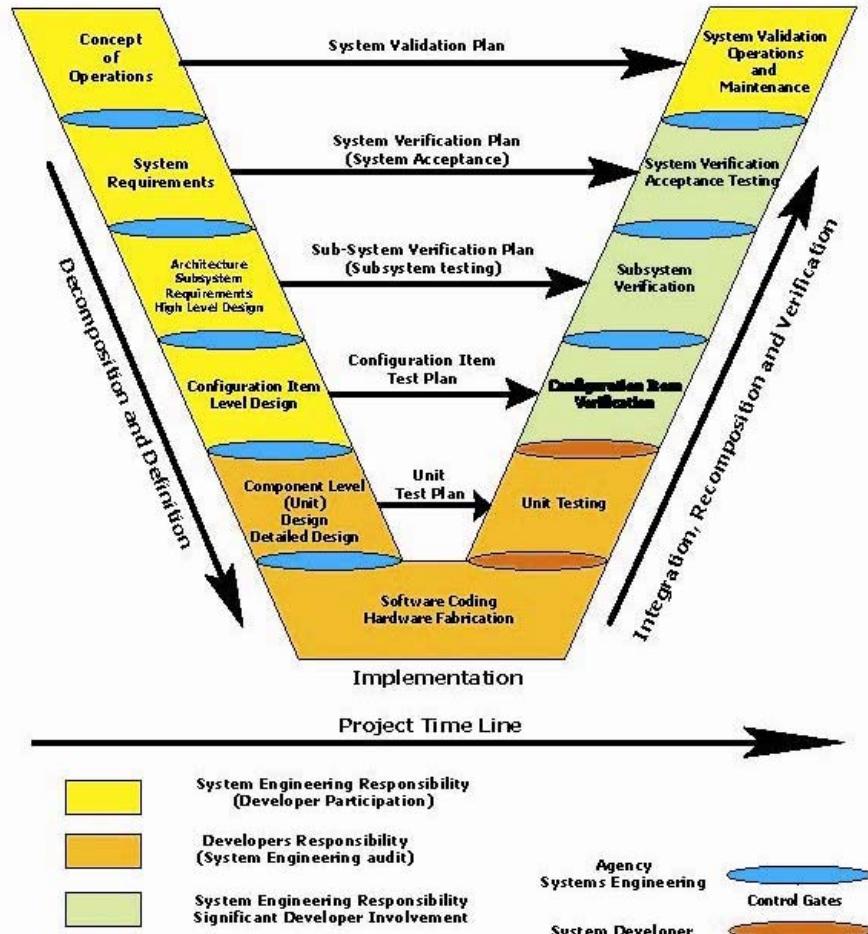


Figure 1.1: The Systems Engineering "Vee" - Figure used in FHWA training courses- This model effectively balances the concept of the system life cycle with the system engineering method of decomposition and integration. Though the entire process is inherently iterative, the first and last step in this model includes the use of a Concept of Operations. (Graphic provided by ASE Consulting LLC)

As one will note in Figure 1.1, the first step in this iterative process is the development of a Concept of Operations. All steps following the development of the Concept of Operations will relate to it in some fashion. Of importance are the second step, the development of system's requirements, and the final step, the validation of the developed, deployed, or refined system. These will be discussed more thoroughly in Chapter 2 (relative to systems engineering), Chapter 3 (relative to the importance of a Concept of Operations), and Chapter 6 (relative to requirements).

## 1.3 What is a Concept of Operations and Why is it Important?

The Concept of Operations serves as the foundation for the systems engineering process. As with anything that is built and utilized, the entire entity is only as strong as its foundation. 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. In the context of a TMS, it should be as readable and relevant to high-level decision makers as it is to the TMS operator. **The Concept of Operations answers the who, what, when, where, why, and how for the new or existing system.** The primary motivation for the development of such a document includes:

- The identification of system stakeholders;
- The assurance of a common communication forum for stakeholders;
- The formulation and documentation of a high-level system definition;
- The foundation for all lower-level sub-system descriptions;
- The definition of all major user groups and activities;
- The identification of the environment in which the system will function.

### 1.3.1 Elements of a Concept of Operations

The ANSI Concept of Operations standard (ANSI/AIAA G-043-1992) provides an excellent framework for developing a Concept of Operations Document for any complex system. In essence, the standard recommends that a Concept of Operations Document "...describes system characteristics from an operational perspective," and answers the question, for each stakeholder, "What does it [the system] look like from my point of view?" The standard is summarized in the diagram of Figure 1.2. The elements of the Concept of Operation are then addressed in more detail following the figure.

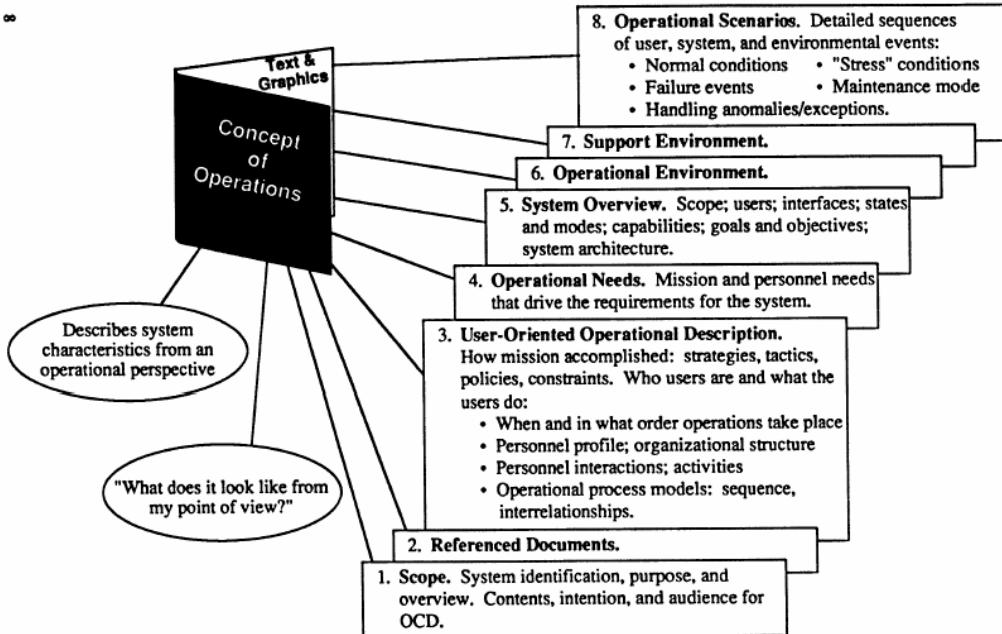


Figure 1.2: The Core Elements of a Concept of Operations - Graphic reproduced with permission by ANSI/AIAA from "Guide for the Preparation of Operational Concept Documents," ANSI/AIAA G-043-1992 – The Concept of Operations includes a Scope, Referenced Documents, User-Oriented Operational Description, System Overview, Operational and Support Environments, and Operational Scenarios while describing the system from an operational perspective yet answering, “what does it look from my point of view?”

- Scope – *an overview of the entire Concept of Operations.* This includes the following elements:
  - Outline the Contents of the Document
  - Purpose for Implementing the System
  - Highlight Major Objectives and Goals
  - Identify the Intended Audience
  - Set Boundaries on the Scope of the System
  - Describe an Overarching Vision for the System
- Referenced Documents – *resources used when developing the document.* This will be useful to clarify the sources of information that went into the document and to provide the reader with guidance to find additional information. Types of reference documents that are typically listed include:
  - Business Planning Documents
  - Concept of Operations for Related Systems
  - Requirements for Related Systems
  - Studies to Identify Operational Needs
  - System Development Meeting Minutes

- User-Oriented Operational Description – *system description from a user vantage point.* It identifies how organization/system-specific goals and objectives are accomplished, including strategies, tactics, policies, and constraints. This portion of the Concept of Operations should be the main focus for the entire document, as it is intended to outline the landscape of the system, and provide a clear working image for each party about how they should expect to integrate themselves within the overall system. Information that should be highlighted in this section includes:
  - User Activities
  - Order of User Operations
  - Operational Process Procedures
  - Organizational/Personnel Structures
- Operational Needs – *details agency- and region-specific goals and objectives that will drive the requirements for the system.* In other words, this section is attempting to answer the question: “What is necessary for the agency or region that would complement and improve the existing system?”
- System Overview – *provides a high-level description of the interrelationships of key system components.* All of the information contained in this section can be found in another section of the document, but this section is designed to focus on the interrelationships among the elements. The areas this section should address include:
  - Scope
  - Interfaces
  - System Capabilities (Functions)
  - Goals and Objectives
- The Operational and Support Environments – *describes the environment or “world” in which the system will operate.* This section includes information about the system’s environment in terms of the following categories:
  - Facilities
  - Equipment
  - Hardware
  - Software
  - Personnel
  - Operational Procedures
  - Support Necessary to Operate the Deployed System
- Operational Scenarios – In this section of the Concept of Operations, the authors place themselves in the users’ position, and detail how the new system would impact their activities under differing conditions, ranging from normal conditions to stress and failure conditions. The operational scenario should tell different stories from perspectives of different user classes over a variety of circumstances. This is a very useful tool in conveying to the reader the event-related usage of the system. It will be through scenarios that the system developer may be able to glean the most

information about how to piece the system together ,and stakeholders and users should be able to easily relate to the system through the 'story-telling' means that operational scenarios utilize. There are four basic elements to considering operational scenario development:

- Included User's Perspectives
- Variety of User Classes
- Stress/Failure Scenarios
- Multiple Circumstances

Chapter 3 presents a thorough description of these elements, including numerous specific examples of content from TMS Concepts of Operation.

### 1.3.2 Benefits of Developing and Using a Concept of Operations

This section highlights the key benefits of developing and using a Concept of Operations, as identified by transportation professionals. Note that throughout the guidance document, text boxes will be used to highlight experiences and examples gathered directly from transportation professionals.

- *Stakeholder consensus* — The overwhelming majority of transportation professionals interviewed for this document cited stakeholder agreement on interrelationships, information sharing, and roles and responsibilities for the system as the most important benefit of the Concept of Operations development process. The following stakeholders describe this benefit in their own words:

- "The Concept of Operations helps define the roles and responsibilities of the participating agencies."
- A testimonial from a transportation professional identified the following benefits of developing a Concept of Operations:
  - It develops a consensus on the priority of needs for the organization.
  - It bridges the gap between the technical and operational sides of the organization.
  - It provides continuity over the ebbs and flows of the economy and politics.
- "The biggest benefit from developing a Concept of Operations is getting all the stakeholders to agree on what they all do and what they need from each other."

*TMS Experience*

- *Reduction of risk for the system*—Transportation professionals agreed that a major benefit of developing a Concept of Operations is the reduction of the risk of failure for the project. The Concept of Operations can reduce cost overrun by more accurately defining the system earlier in the development stage, and decreasing the chances that stakeholder dissatisfaction will terminate the project.

- One transportation professional listed these main benefits of creating a Concept of Operations for a Transportation Management System:
  - It allows the stakeholders to get what they want.
  - It leads to more accurate requirements definition for the system.
  - It helps minimize risk for the operation.
  - It aids in managing expenditure for the project.

Lastly, this professional describes the Concept of Operations as “not a silver bullet [i.e. not a one document cure to the problems of developing and maintaining a TMS], but it does decrease the likelihood of failure for a project.”

- “The most important benefit is that you have a document describing the operations of the system when people begin to doubt that you have a plan.”

*TMS Experience*

- *Improving the quality of operations for the system*—Above all, a well-formed Concept of Operations will provide a clear vision, mission, and goals for the operations of a system, leading to a well managed, efficient, and productive operation. Beyond listing operational procedures, a Concept of Operations will ensure that the focus of all aspects of the system is on the collective vision agreed upon by the stakeholders.

### 1.3.3 The Concept of Operations and Regional Transportation Operations

The Concept of Operations for any TMS does not exist, nor can it be developed or used, in a vacuum. There are regional and organizational entities that exist beyond the immediate system’s “boundaries” that impact the operation and performance of the system in question. This idea is communicated simply in Figure 1.3.

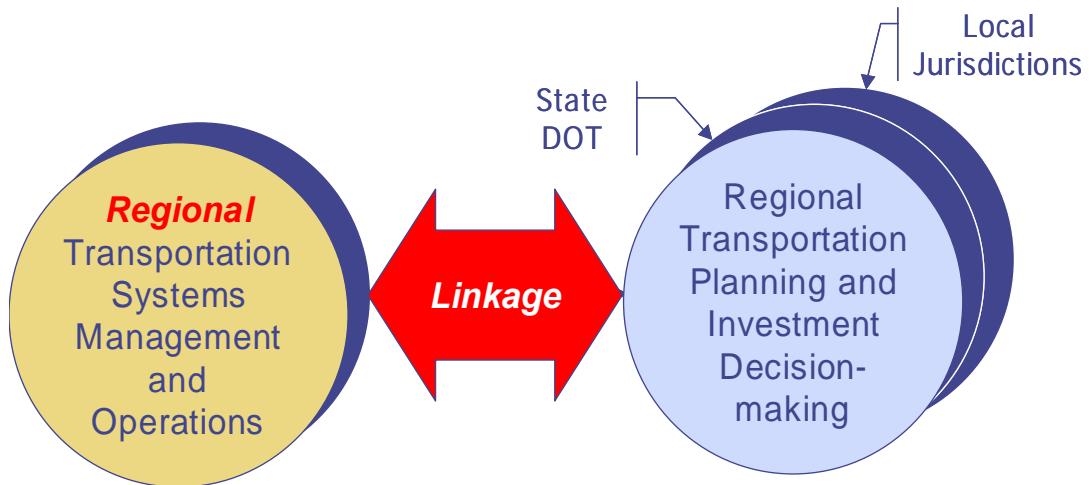


Figure 1.3: Relationship of Operations to Planning – A graphic from the presentation, “Linking Planning and Operations,” TRB 2004 Annual Meeting Session 401, Robin M. Mayhew, FHWA, January 13, 2004. – This highlights many of the interrelationships that must be addressed by any TMS. Thus, their Concept of Operations must reflect these relationships to some degree.

The foundation for the iterative systems engineering development and refinement process is the Concept of Operations document. In serving the operational arena, the TMS’s Concept of Operations document is useful in assuring a strong link with planning. The most effective TMS Concept of Operations will “pull” information from a wide range of planning documents. From the vantage point of the Concept of Operation’s developer, there will be several planning categories to consider.

- “Looking Up” – the plans and planning procedures at a level “above” the TMS. The Concept of Operations must reflect goals of larger agency-level plans. Furthermore, the Concept of Operations can provide excellent input as these larger plans are developed – by clearly articulating transportation management system goals, vision, and functionality.
- “Looking Across” – the plans and planning procedures in the same geographic region. As transportation operations play a larger role in surface transportation; formal planning procedures and practices are becoming prevalent. A Concept of Operations is an important input into regional operations planning. Furthermore, when a regional operations plan or architecture exists, the Concept of Operations should reflect the regional goals and functionality.
- “Looking Within” – the plans and planning procedures specific to the system under development or in existence. Planning is an important activity within a TMS. The Concept of Operations plays a key supporting role in this planning.

Looking Up, Across, or Within will completely depend upon where your organization exists in both an organizational and a geographic context. Figure 1.3 illustrates the relationship between the operational (TMS) world, and the planning world. Figures 1.4 and 1.5 below illustrate the organizational and functional

planning relationships that will need to be considered in developing a Concept of Operations. The challenge of effectively linking a TMS Concept of Operations to planning is discussed thoroughly in Chapter 5.

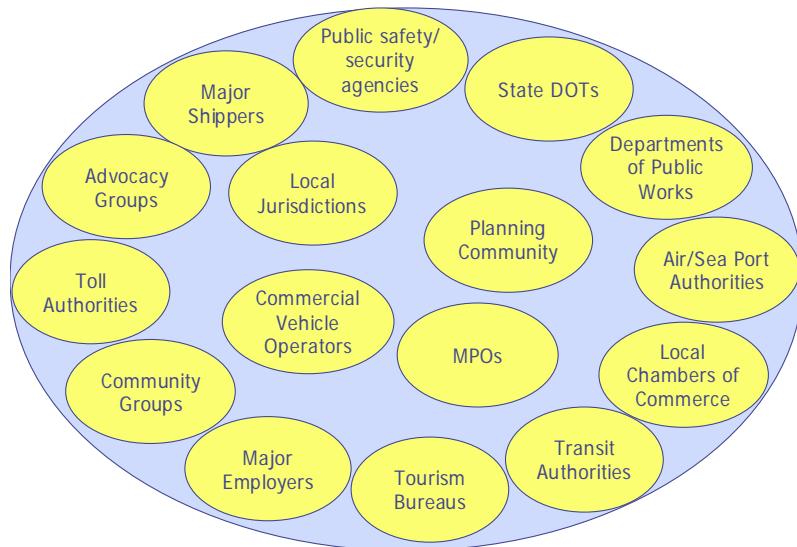


Figure 1.4: Organizations Related to a TMS – A graphic from the presentation, “A NATIONAL CAMPAIGN FOR IMPROVING REGIONAL TRANSPORTATION OPERATIONS,” A Special Session of the National Association Working Group (NAWG), US DOT, February, 2004. – This highlights many of organizations/agencies the TMS’s organization will need to consider in planning and Concept of Operations development.

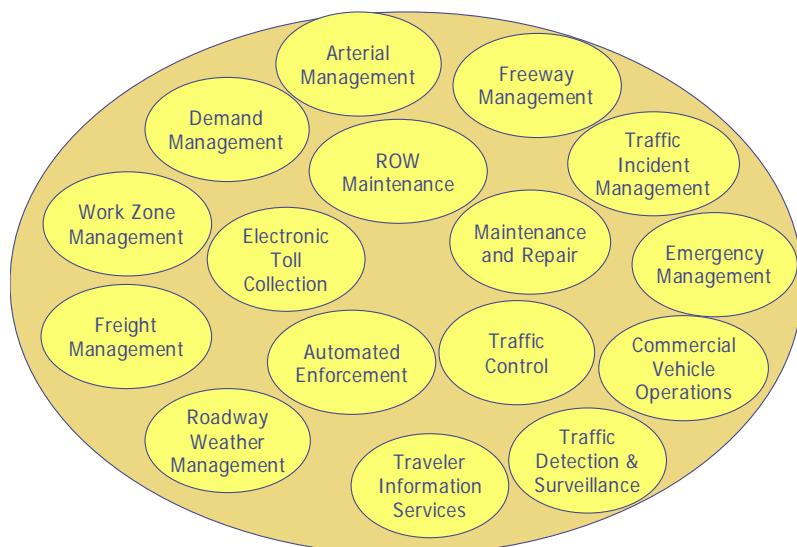


Figure 1.5: Functions Provided by Typical TMS – A graphic from the presentation, “A NATIONAL CAMPAIGN FOR IMPROVING REGIONAL TRANSPORTATION OPERATIONS,” A Special Session of the National Association Working Group (NAWG), US DOT, February, 2004. – This highlights many of transportation functions the TMS’s organization will need to consider in planning and Concept of Operations development.

## 1.4 What is the Challenge?

This section addresses the challenges that face transportation professionals as they seek to develop and effectively use Concepts of Operations. First, the state of the practice and needs will be summarized. This will be followed by the identification of specific challenges that this guidance document is designed to address.

### 1.4.1 State of the Practice & Needs in TMS Concept of Operations Development and Use

In reviewing Concept of Operations documents that have been developed for TMSs to date, key trends can be highlighted. Specifically, there are strengths as well as features that need improvement within these documents. Below, some of these strengths and improvement needs will be reviewed. Later, Chapter 4 of this document, "How to Develop a Concept of Operations," will provide specific guidance to illustrate the desired practice for Concept of Operations development.

- *Active Use of a Concept of Operations*
  - The systems engineering process is an iterative process. As such, every document that is developed in conjunction with every step of the systems process within a phase of the life cycle may be considered a 'living document.' TMSs that find themselves in the context of massive change – for example, the addition of a new function and its associated systemic burdens – need to update their overall Concept of Operations.
  - Most agencies do not update their Concept of Operations after initial development. This limits their use as the system lifecycle moves forward.
- *Use of Graphics*
  - Many TMS Concept of Operations documents use graphics to highlight key points in a variety of sections in the document. When systems diagrams are used, they tend to be thorough without such a high level of detail that the diagram is useless. As the Concept of Operations should be accessible to many different backgrounds, a diagram showing functional flows and communication lines is a valuable tool in conveying the vision of the system to a diverse audience. The main goal of the diagram is to set the scope of the system, which can be achieved without every function or module being detailed. An excellent example of an effective high-level graphic that illustrates the goals of the TMS is that of Maricopa County's Regional Concept of Transportation Operations shown in Figure 1.6.
  - Unfortunately, most Concepts of Operations are text heavy, which is reasonable considering the amount of information the authors must convey in the document. Pictures, while often time consuming to develop, and often believed to be too simplistic, convey significant information.

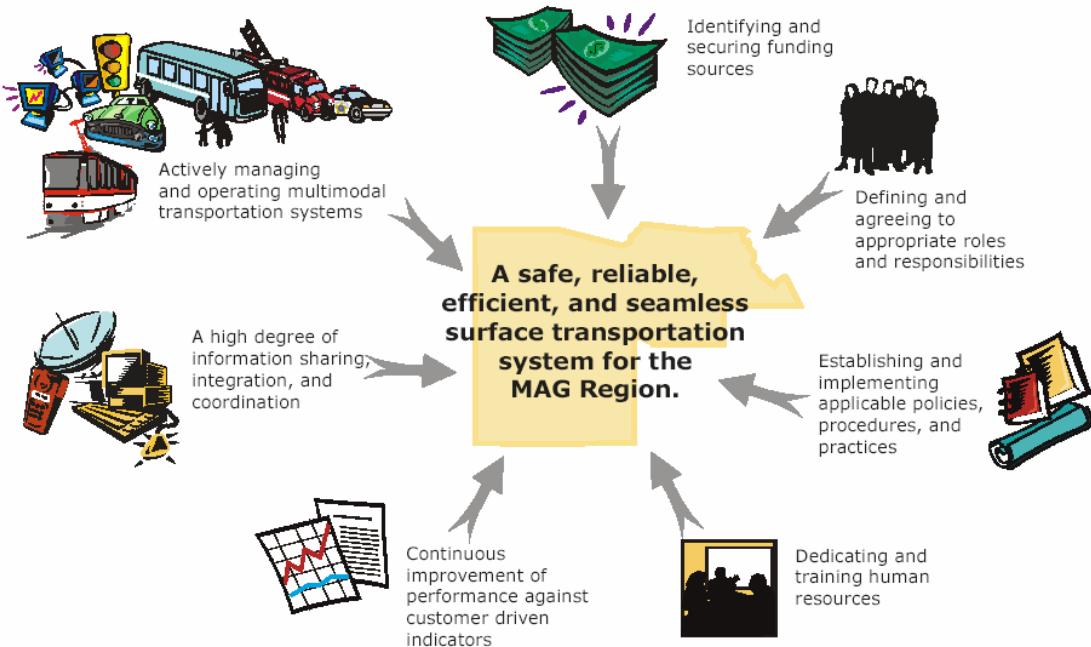


Figure 1.6: TMS Goals – A graphic from the “Regional Concept of Transportation Operations” document, Final Report, Maricopa Association of Governments, November 2003 – Maricopa Association of Governments uses the following diagram to graphically show the different goals and vision for its Regional Concept of Transportation Operations. It succinctly states the goals of the system as a whole and summarizes the high-level vision for the region.

- *Grouping by Functionality*
  - One aspect of organization for many of the documents is to group information around a particular function of the system/organization instead of a more traditional systems approach (scope, system overview, scenarios, etc.). The benefit to the owners of the system is clear: it makes sense to organize the document to mirror the organizational structure of the department.
  - However, there are times when the document suffers from lack of readability because of this, and often the document will not convey the central vision of the system as a whole because of the separation into functions early on in the document. A functional breakdown of the document is by no means detrimental to writing a good Concept of Operations, but there are many documents that need better system definition at the outset before the functional breakdown.
- *Scenarios*
  - The example documents provide scenario development from a variety of different user perspectives. Some documents have well developed descriptions of one user class, but left out other classes, while others include many types of classes without an in depth analysis of any.
  - The Concept of Operations documents offer a variety of operational scenarios that deal with typical occurrences for a TMS. These include failure modes, incident management,

weather, normal operations, etc. The following example provides a list of scenarios on par with most of the documents researched.

**Example – The Advanced Traffic Management System (ATMS) for Austin, Texas provides the following operational scenarios:**

- Incident Management Scenario With Automated Detection
- Incident Management Scenario With Manual Detection
- After Hours Incident Management Scenario With ATMS Up
- After Hours Incident Management Scenario with ATMS Down
- Incident Management Scenario with ATMS Down and TMC Operator on Duty
- Road Closure Scenario
- Maintenance Scenario

*TMS Experience*

- Because of the diversity of the audience, including as many user types as possible will increase the effectiveness of the document, and a thorough scenario development will bring issues to light earlier when they are more easily solved.
- *Level of Technicality in Writing*
  - For a majority of the documents, the level of technical jargon is kept at a minimum, especially at the beginning of the documents when the scope and vision are discussed. However, when the documents switch to specific functions, the level of technical expertise necessary to fully understand the document increases. TMSs are complex software/hardware integration projects with a large number of inputs and outputs, so naturally there will be some level of technical information included in the document.
  - One positive note about nomenclature is that most documents defined terminology when using words that could be unfamiliar to readers. This practice of assuming a low level of technical knowledge is beneficial to preparing readable Concept of Operations documents.
- *Stakeholder Identification*
  - Many documents lacked a section on identifying stakeholders or had an incomplete list. It is clear that stakeholders were included in the development process, since most documents did mention most of the excluded groups.
- *Thoroughness*
  - For the majority of the documents, the level of detail was sufficient for the beginning stage of the systems engineering process. In fact, most documents included all of the elements of a Concept of Operations identified in this document in some form or fashion.
  - The level of detail did not vary to a great extent in the documents. For example, regional Concepts of Operations typically were at a similar level of detail of a Concept of Operations for a single center. The following example highlights this idea with definitions

of traffic management from two different documents, one from a regional perspective and one from a single center perspective.

**Example 1 – The Cross Westchester Expressway Intelligent Transportation System Concept of Operations Document, a document written for a single center in Hudson Valley area of New York State, gives the following functional view of traffic management.**

Traffic Management:

- Monitor traffic flow on the Interstates and lateral connectors via a vehicle detection system
- Verify incidents through a video surveillance system & audio communications
- Enact response plans consistent with regional/local policies and procedures
- Document traffic/incident status and occurrences as necessary
- Control regional traffic as necessary to optimize movement of traffic
- Control roadway traffic signals to support regional traffic flow
- Disseminate traffic information
- Monitor and evaluate the traffic network performance
- Monitor system performance to optimize maintenance

*TMS Experience*

**Example 2 – The Oregon Traffic Operations Center System (TOC), which is a statewide (i.e. regional) view of traffic operations, gives the following functional description of traffic management.**

**Traffic management** is the work done by TOC's , as directed by management, to alert the public to hazards or congestion as well as to control the direction and flow of traffic in an incident area.

The activities of **Traffic management include** control of Variable Message Signs, Variable Speed Limit signs and other Dynamic Message Signs as well as Highway Advisory Radio (HAR) messages to alert the public to potential problems or congestion. Ramp meter timings and traffic signals can be automated to implement pre-planned timing plans to mitigate incident impacts. Incident Responder (Comet etc.) vehicles are dispatched to incident locations for traffic direction and hazard removal.

**Business impacts of the proposed new TOCS system include:**

A single control interface for the majority of ODOT's DMS. This should assist in regional back-up planning and training as well as enable the integration of DMS control with automated responses. Ramp Metering will likely remain an urban traffic control solution for the foreseeable future; however, the system needs to support expansion of this functionality beyond the Portland urban area. Urban areas outside of Region 1 will be able to take advantage of some of the stronger traffic management features of ATMS and will have added options for regional growth including interfaces to traffic signal systems.

*TMS Experience*

### *Operational Needs Assessment*

- Addressing the functionality of the new system as it relates to some organizational need or goal is an important part of the Concept of Operations development process, and the majority of the documents reviewed did this successfully. Some of the documents separated the needs by function, and others, by the overall system.
- It was obvious from the example documents that performing an in-depth needs assessment is a current practice for most systems that develop a Concept of Operations.

**Example – The iFlorida Concept of Operations (Draft), which has been written to describe a statewide TMS integration project across multiple jurisdictions and agencies, provides the following list of needs for the first procurement of the project:**

#### Justification for and Nature of Changes

As this procurement has several different aspects, there are a number of different goals and justifications for the various elements of the deployment.

Travel time / speed monitoring data collection – An overall goal for travel time / speed monitoring on limited access roadways is to achieve 100% coverage in the Metropolitan Orlando area. There is also a need to acquire travel time / speed data on arterials in order to provide information on alternatives to limited access highway routes, as well as facilitate system performance monitoring. Arterial roadways selected for deployment as part of this project are part of the Consortium's top priorities. (The Consortium's 5-year plan calls for 50% of arterials in the Orlando Metropolitan area to be covered.)

Arterial CCTV cameras – There is a need to provide cost effective visual coverage of key arterial intersections/interchanges. This will support verification of incidents as well as weather, pavement, and traffic congestion conditions.

SR 528 Corridor Monitoring System – As part of this project, there is a desire to increase roadway sensor and CCTV coverage along SR 528 and SR 520. This increased coverage is needed to support hurricane evacuations, incident management, and special events.

Telecommunications Network Enhancements and Brevard County Agency Integration – With the expansion of several systems to provide increased data sensor and CCTV coverage, additional fiber-based communications infrastructure is needed. Additionally, part of the purpose of the iFlorida project is to facilitate increased coordination between various local agencies. To support this increased coordination, the involved agencies need to be interconnected via a common communications infrastructure. Both the LYNX and Brevard 911 Center need to be connected to the fiber trunk system in order to allow them to gain access to RTMC data and video information. Moreover, additional communications infrastructure is needed to provide redundancy for the existing communications system.

Variable speed limits – There is a desire to test a variable speed limit (VSL) system in order to determine its effectiveness in increasing safety and roadway capacity. A number of VSL signs will be deployed and tested along I-4 in the Orlando Metropolitan area to accomplish this desire.

*TMS Experience*

- *Support Environment*
  - The ANSI standard lists the support environment (i.e. all aspects of the system that play a supporting role in defining and enabling the system to operate) as a separate section in a Concept of Operations, but few if any documents had a section devoted to this information. Of all the suggested sections given by the standard, this one was the hardest to identify, and the information that should be here was the most scattered throughout the documents.

### 1.4.2 General Challenges for Concept of Operations Development

Developing and effectively using a Concept of Operations is a difficult undertaking. The following challenges must be addressed to effectively deal with issues that will arise during the development and use process. These challenges and guidance come from transportation professionals.

- *Stakeholder Involvement*— Arriving at a consensus for a TMS among a group of transportation organizations can be a difficult task. Transportation professionals explain that both getting all the stakeholders to the table, and coming to a consensus on a complex, integrated system can be a challenge for the Concept of Operations development process:

- “The major challenges in developing a Concept of Operations are the time necessary to meet all the stakeholders and the difficulty in meeting all the stakeholders’ expectations.”
- Stakeholder interaction and involvement can be more difficult than simply gathering groups of people and talking: “It can be very difficult to maintain good relationships with the participating agencies.”
- “Stakeholders should be involved early and often” in the Concept of Operations development process.

*TMS Experience*

- *Time and Money*— Staffing and budget are large concerns for TMS professionals, and these concerns add to the difficulty of developing a Concept of Operations. Diverting staff time from other projects and securing funding for the development process are critical challenges identified by transportation professionals.

- “A Significant challenge is persuading people that the effort to create the Concept of Operations is worthwhile.”
- “Defending your funding is of chief concern when writing a Concept of Operations—those with the money always ask ‘What do you need that for?’ ”
- “An organization should develop a Concept of Operations in a continuing effort [i.e. one meeting, or one week of stakeholder discussion typically is not enough to do a thorough job in developing your Concept of Operations].”

*TMS Experience*

- *System Change*— TMSs are evolving systems; components are being added, modified, and removed with great frequency to assure overall systemic relevancy. TMS professionals have admitted that keeping documentation up-to-date with the system is one of the most challenging, and important, features in systems development. Documentation provides knowledge about the system to the world outside and to newcomers, and most importantly, it serves as long-term memory for system stakeholders. It has been stated by one transportation professional that documenting their system updates and altering the primary system documentation could be its own full time job.
- *Finding the appropriate level*— It has been stated that, to some degree, a Concept of Operations document must be “all things to all people.” Preparing a document to describe a system, with engineers on one side, and policy developers on the other, is a daunting undertaking. If the description of the system is too high, it will likely not be possible for the engineers and the contractors to proceed effectively in the systems engineering process; they will have nothing but guess work. If the description of the system is too low, time-constrained transportation professionals will likely not read it. Finding the appropriate level for the Concept of Operations will always be difficult.

## 1.5 How to Use This Document

### 1.5.1 This Document Complements other ITS Guides

This document serves as a companion to industry standards and existing transportation resources. Sound generic guidance currently exists in the form of industry standards and previously developed transportation-related documents. This document complements these resources by focusing on how to develop and use the Concept of Operations. The focus is addressed through the use of a large number of transportation-specific examples. Key companion documents include:

- *Guide for the Preparation of Operational Concept Documents.* (ANSI/AIAA G-043-1992). American National Standards Institute, 1992. – This standard provides guidelines for creating a Concept of Operations document. It includes practical information on applying and packaging the Concept of Operations and an example of the process's application to the development of a major NASA system.
- BJORKE, PER, ET AL. *IEEE Guide for Information Technology — System Definition — Concept of Operations (ConOps) Documents.* New York: The Institute of Electronics and Electrical Engineers, Inc., 1998. Report No IEEE Std 1362-1998. – This guide presents the format and the contents of a Concept of Operations document to be used when developing or modifying a software-intensive system. It describes the essential elements of the Concept of Operations document as well as the importance of the specific element to the system. This document also has excellent definitions of the terminology related to the Concept of Operations.
- *Metropolitan Transportation Management Center Concepts of Operations.* Intelligent Transportation Systems. Report No FHWA-JPO-99-020. Oct. 1999.  
[http://www.itsdocs.fhwa.dot.gov/jpdocs/repts\\_te/8ff01!.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/repts_te/8ff01!.pdf) – This document describes the backgrounds, summary descriptions, successful practices, lessons learned, issues, and future directions of eight TMCs. For the developer of a TMS Concept of Operations, function, capability, and overall scope and scale, of various TMS systems are described in one document, providing a useful guide. Systems included: Boston Central Artery/Tunnel Integrated Project Control System; Toronto, Ontario Compass Downsview TMC; Long Island, New York INFROM; Detroit, Michigan Intelligent Transportation System Center; Milwaukee, Wisconsin MONITOR; Atlanta, Georgia NAVIGATOR; Phoenix, Arizona TrailMaster; and Houston, Texas TranStar. It also discusses potential future system improvements.
- *TMC Concepts of Operation: Implementation Guide.* ITS Joint Program Office, Federal Highway Works Administration, December 1999.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/TMCCOnOpsImplGuide.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMCCOnOpsImplGuide.pdf) - This document reviews the purpose behind developing a Concept of Operations document for regional TMCs. It demonstrates the importance and provides examples and resources as identified and utilized in several developing TMCs throughout the nation.
- FOWLER, THOMAS B. AND PAUL J. GONZALEZ. *Developing Functional Requirements for ITS Projects* Report No FHWA-OP-02-047. April 2002.  
[http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13621.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13621.html) - This document gives an overview of systems engineering and functional requirements. It illustrates the relationship between functional requirements and the National ITS Architecture and contains a description of the systems engineering life cycle in terms of the "Vee" diagram. This document also identifies the benefits and problems associated with developing functional requirements.

- Gonzalez, Paul J. Building Quality Intelligent Transportation Systems Through Systems Engineering. Report No FHWA-OP-02-046. April 2002.  
[http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13620.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13620.html) - This document introduces the concept and practice of systems engineering and its application to the acquisition, development, and fielding of Intelligent Transportation Systems (ITS). It gives detailed definitions of key concepts and discusses the challenges and benefits within the systems engineering approach. The systems engineering life cycle is also described in detail.

### 1.5.2 The Chapters within this Guidance Document

This section briefly introduces the reader to the content of this document through a description of each chapter.

*Chapter 1: Introduction – Managers, technical staff, and supporting engineering firms with or without systems engineering backgrounds and with or without TMS* will find this chapter useful as it serves in part, to introduce the reader to the purpose of the overall guidance document, but also as an “executive summary” where the highlights of the overall document’s findings have been detailed. This is a good starting place for all readers to determine which section may be most appropriate for them.

Chapter sections:

- Why Use This Handbook?
- What is the Challenge?
- Systems Engineering and TMS
- What is a Concept of Operations and Why is it Important?
- How to Use This Document

*Chapter 2: Role of a Concept of Operations in Systems Engineering – Managers, technical staff, and supporting engineering firms without systems engineering backgrounds* will find this chapter useful as it demonstrates that the Concept of Operations serves a specific and critical function within the systems engineering process, which this chapter also briefly reviews by introducing the key systems engineering principles.

Chapter sections:

- What is Systems Engineering?
- What Role Does the Concept of Operations Play in the System Life cycle?
- What Role Does the Concept of Operations Play in Systems Engineering?

*Chapter 3: What is a Concept of Operations? – Managers, technical staff, and supporting engineering firms without systems engineering backgrounds and with or without TMS experience* will be given guidance and best practices on what constitutes a Concept of Operations and on what comprises their typical content for TMSs.

Chapter sections:

- The Concept of Operations
- Core Elements of a Concept of Operations
- Not a "One-Size-Fits-All" Document

*Chapter 4: How to Develop a Concept of Operations – Managers, technical staff, and supporting engineering firms with or without systems engineering backgrounds and with or without TMS experience* will be given guidance and best practices on how they should develop a Concept of Operations document. The advice and examples come from real-world TMS documents and information acquired through interviews with officials involved with the development process.

Chapter sections:

- Where Do I Start?
- How to Develop the Elements of the Concept of Operations
- Resources Required for Concept of Operations Development
- Stakeholder Identification
- Stakeholder Involvement
- Definition of Performance Measures
- Key Resources for Writing a Concept of Operations

*Chapter 5: Using the Concept of Operations to Support Planning – Managers with or without systems engineering backgrounds and with or without TMS experience* will have illustrated for them how the Concept of Operations can be used to support (and can be supported by) a wide range of transportation planning activities.

Chapter sections:

- Systems Engineering and Planning
- "Looking Up" – Agency and Program Level Planning
- "Looking Across" - Regional Operations Planning
- "Looking Within" - System-Specific Planning

*Chapter 6: The Next Step – Using the Concept of Operations to Drive Requirements – Managers, technical staff, and supporting engineering firms with systems engineering backgrounds and with or without TMS experience* will have detailed for them the transition from the concept phase to developing high-level requirements for the system, while highlighting the assistance a well-formed Concept of Operations document can provide in this process.

Chapter sections:

- What Are Requirements?

- How to Transition from a Concept of Operations to Requirements
- Resources for Concept of Operations to Requirements Transition

### 1.5.3 Guidance for Different Classes of Readers

This document will present information on the development of Concept of Operations for TMS with the understanding that not all of the TMS professionals reviewing this document will be in the same place of overall operations or development. As such, consideration will be given to the following classes of organization and individual:

- *New to Concept of Operations* – Organizations or individuals who have never developed a Concept of Operations before, and who have no existing system from which to begin, will find this document understandable and straightforward. It will be possible to utilize this document to initiate a walk-through of a Concept of Operations development process.
- *Agencies with limited experience, seeking to develop and use Concept of Operations to fullest advantage* – Organizations or individuals with some systems engineering experience will find this document useful in shedding additional light onto the benefits of starting with a Concept of Operations, and will learn how it can integrate and improve their overall system development experience.
- *Agencies seeking to develop and use a Concept of Operations for an existing system* – This document has also given consideration to TMSs that have been developed without Concept of Operations. Interviews and research has been conducted with organizations that have existing TMSs and have later developed a Concept of Operations – their experiences, expression of challenges, expression of benefits have been documented.

## 1.6 Guiding Principles

*Why Use This Document?* – The objective of this document is to provide guidance to transportation professionals as they seek to develop and use the Concept of Operations throughout the life cycle of a TMS.

*What is a Concept of Operations and Why is it Important?* – The Concept of Operations serves as the foundation, the starting point, for the systems engineering process. As such, it should be a document available, and relevant, to all stakeholders in the system, no matter what their background or role within the system. The primary motivations for moving forward with the development of such a document include:

- The identification of system stakeholders;
- The assurance of a common forum for stakeholders;
- The formulation and documentation of a high-level system definition;
- The foundation for all lower-level sub-system descriptions;
- The definition of all major user groups and activities;
- The identification of the environment in which the system will function.

*Elements of a Concept of Operations* – The core elements of a Concept of Operations are:

- Scope
- Referenced Documents
- User-Oriented Operational Description
- Operational Needs
- System Overview
- Operational and Support Environments
- Operational Scenarios

*Benefits of Developing and Using a Concept of Operations* – There are more reasons to develop a Concept of Operations than just because it is the first step in the systems engineering process, these include:

- Stakeholder consensus
- Reduction of risk for the system
- Improving the quality of operations for the system

*The Concept of Operations and Regional Transportation Operations* – There are regional and organizational entities that exist beyond the immediate system's scope that impact the operation and performance of the system. As expected, these entities are also impacted by the operation and performance of the TMS.

The most effective TMS Concept of Operations will “pull” information from a wide range of planning documents.

- “Looking Up” – the plans and planning procedures at a level “above” the TMS;
- “Looking Across” – the plans and planning procedures in the same geographic region;

- “Looking Within” – the plans and planning procedures specific to the system under development or in existence.

*What is the Challenge?* – A Transportation Management System (TMS) is any system focused on improving the efficiency, safety, and predictability of travel. With such a definition, there are therefore many shapes and sizes to existing and developing TMSs. Developers of TMS Concept of Operations must therefore consider, for their own context, the following when developing their document:

- Express the concept in one document, or at least assure that the richness of a Concept of Operations document may be found in specified documents;
- Let the Concept of Operations exist as a living document, improve upon it when there are significant changes to the system as a whole;
- Use graphics, a good picture is worth a thousand words;
- Scenarios help to define the roles of all stakeholders under many circumstances relative to the system;
- Assure that the level of technical jargon is kept at a minimum while retaining technical meaning;
- Identify the stakeholders, keep them involved;
- Be thorough;
- Perform a needs assessment;
- Justify the time and effort involved.

# CHAPTER 2 – The Role of the Concept of Operations in Systems Engineering

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## Chapter Purpose

The Concept of Operations serves a specific and critical function within the systems engineering process, as it is the foundation for all subsequent activities. An understanding of the systems engineering process is necessary for proper development and use of Concept of Operations for a TMS. This chapter provides an overview of the systems engineering process, with special attention on the role of the Concept of Operations.

## Chapter Objectives

The key objectives of this chapter are:

- *To provide summary information describing systems engineering.*
- *To describe the role of the Concept of Operations in systems engineering.*

## Relationship to the Previous Chapter

This chapter transitions from the general introduction of a Concept of Operations in Chapter 1 to provide a detailed introduction to systems engineering. This chapter is designed for readers with relatively little systems engineering experience to provide a foundation for the detailed guidance provided in later chapters.

## Chapter Sections

Brief descriptions of the sections of Chapter 2 are provided below:

### 2.1 What is Systems Engineering?

This section defines systems engineering. It will also introduce the system's life cycle, and the systems engineering process through the "Vee" diagram. Lastly, this section will provide systems engineering reference information useful to TMS professionals.

### 2.2 What Role Does the Concept of Operations Play in Systems Engineering?

This section will discuss more specifically the system engineering elements that are necessary for system development, and it will focus on the role that the Concept of Operations plays in the process. Here the reader will find descriptions relating the Concept of Operations to the "Vee" diagram, addressing requirements, design, testing, and operations and maintenance.

## 2.3 Systems Engineering Considerations for the Development of a Concept of Operations for a New or Existing System

This section addresses how and when an organization may develop a Concept of Operations. Consideration will be given both to newly developing, and pre-existing systems.

## 2.4 Guiding Principles

This section provides a brief overview of the key information provided in this chapter.

## 2.1 What is Systems Engineering?

This section provides an introduction to systems engineering.

### 2.1.1 Systems Engineering Defined

The classic approach to large-scale construction projects focuses on creation of detailed system specifications, the search and acquisition of low-cost, responsive bidders, and finally the construction of the system. For contemporary, large-scale, engineering projects involving large information technology components, this has proven to be an ineffective process. *Systems Engineering* is a method to facilitate the development, maintenance, refinement, and retirement, of dynamic, large-scale systems consisting of both technical components (machines, information systems, etc.) and human components (users, stakeholders, etc.). The application of systems engineering to TMSs is relevant due to the complexities inherent in the development, deployment, and operations of such systems. TMSs are complex, multi-component, systems consisting of multiple human and technical components. Despite the apparent simplicity of the definition of systems engineering, the methods it utilizes are rich enough to manage the most sophisticated system application. These methods will be discussed further throughout this document. The summary information provided in this chapter is based on the document: *Building Quality Intelligent Transportation Systems Through Systems Engineering* (Report No FHWA-OP-02-046. April 2002. [http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13620.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13620.html)). Readers are encouraged to consult this document for further information on systems engineering.

### 2.1.2 The Systems Engineering Life Cycle and the Systems Engineering “Vee”

At the heart of systems engineering is an understanding that every system must be considered from the perspective of a birth-to-death life cycle. In an engineered system, this may be envisioned as a series of engineering activities across time and relevant to the existence of the system being developed, maintained, or retired. Taking into account a system's life cycle, the conceptualization of any developing, or refining, system being engineered may be viewed as "...a decomposition (or design) process followed by a recomposition (or integration) process." (Buede, 2000) This method has been refined through time and across several disciplines to arrive at its current state. This iterative, and step-wise, process is referred to as the systems engineering "Vee" process or model.

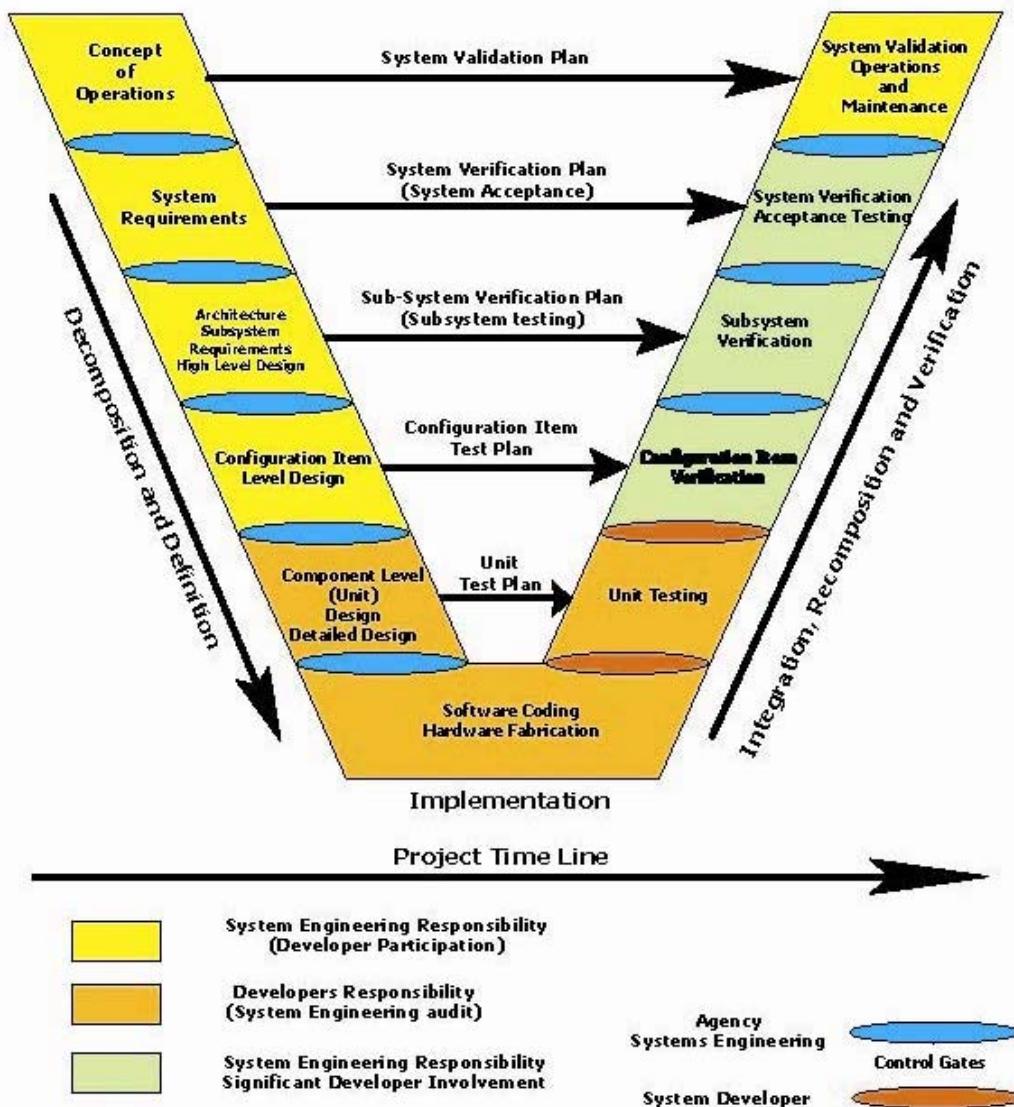


Figure 2.1: The Systems Engineering “Vee” – Figure used in FHWA training courses- This model effectively balances the concept of the system life cycle with the system engineering method of decomposition and integration. Though the entire process is inherently iterative, the first and last step in this model includes the use of a Concept of Operations. (Graphic provided by ASE Consulting LLC)

At the very beginning of this process is the development of the Concept of Operations. *A Concept of Operations is a high-level description of what the major system capabilities will be – it attempts to answer the Who, What, When, Where, Why, and How for the system in general terms for all participants.* This is a critical first step, it sets the stage for the remainder of the development of the system, and it assists in the continual validation of the system once it has become operational. Section 2.2 of this chapter will further

detail the relationship between the Concept of Operations and the systems engineering process. Below are brief definitions of the “Vee” component as shown in Figure 2.1.

- *Concept of Operations* – The Concept of Operations is the first step in the systems engineering “Vee” – while integral throughout the entire process; its most critical, and directly related, roles will be in the direct assistance to the generation of System Requirements, and in System Validation once it has entered an Operations and Maintenance phase.
- *System Requirements* – The second step in the systems engineering “Vee” is the development of the overall System Requirements. The purpose of the requirements is to clearly define what the system will do.
- *Architecture Subsystem Requirements/High Level Design* – The third step is driven by the System Requirements. This step begins the process of organizing system functions into higher-level units. This is commonly referred to as system architecture.
- *Configuration Item Level Design* – This fourth step may be considered entering into the engineering design phase. At this stage, the process moves from a functional perspective of what the system will do, to a definition of how it will accomplish the functions.
- *Component Level (Unit) Design/Detailed Design* – This step involves the detailed design of all elements of the system. It is important to note that this is driven by all previous activities.
- *Software Coding/Hardware Fabrication* – With detailed input from the previous step, the actual build process begins here; software code is written, parts fabricated, and the system integrated.
- *Unit Testing* – At this stage, each subcomponent, or unit, which will exist within the greater system, is tested individually; they are verified by comparing with the component level design completed two steps earlier.
- *Configuration Item Verification* – After each subcomponent has been assembled, integration begins and appropriate configuration for each subcomponent must be performed. This step takes the components past the unit testing and begins to configure them for appropriate system operation. This configuration is tested by examining the original configuration item level design developed several steps earlier.
- *Subsystem Verification* – As subcomponents come together and are configured, they are tested to ensure proper operation.
- *System Verification Acceptance Testing* – This final testing step involves ensuring that all aspects perform as intended, and the system may be “accepted” for operation.
- *System Validation/Operations and Maintenance* – The last step, the system operates to fulfill its mission in the real world.

It is important to mention again that these steps are not terminal—an organization does not finish one step, and begin directly on the next step. The systems engineering process is only effective if viewed as iterative throughout each step of the process, and also iterative in the *long-run*. This dynamic process should take place over a period of years, not months or weeks.

### 2.1.3 Additional Information on Systems Engineering for Transportation

The following resources are focused on systems engineering applied to transportation systems; they provide detailed information on the subject and are recommended to readers that are new to systems engineering:

- Gonzalez, Paul J. Building Quality Intelligent Transportation Systems Through Systems Engineering. Report No FHWA-OP-02-046. April 2002.  
[http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13620.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13620.html)
  - This document introduces the concept and practice of systems engineering and its application to the acquisition, development, and fielding of Intelligent Transportation Systems (ITS). It gives detailed definitions of key concepts and discusses the challenges and benefits within the systems engineering approach. The systems engineering life cycle is also described in detail.
- National Highway Institute Training. The National Highway Institute offers a wide-ranging selection of courses that relate directly to transportation operations. Their series on ITS includes the following courses directly addressing systems engineering (for additional information, please see the NHI web site, <http://www.nhi.fhwa.dot.gov>):
  - 137024A Introduction to Systems Engineering for Advanced Transportation
  - 137026A Managing High Technology Projects in Transportation
- Freeway Management Handbook. 2003 <http://ops.fhwa.dot.gov/Travel/traffic/handbook.htm>
  - This document contains detailed information about freeway management systems, functioning as a "how to" manual for system planning, design, operations, and maintenance. For each specific element of freeway management systems the document contains an overview, an engineering process explanation, the techniques and technology used, any special related issues, and further references.

## 2.2 What Role Does the Concept of Operations Play in Systems Engineering?

The systems engineering “Vee” diagram demonstrates how the development process begins and ends with the Concept of Operations – critical as a starting point, but also critical as the ending point to see if the new system meets the objectives originally laid out. It is obvious that the best development practice, to assure the meeting of the original goals at the end, would be to incorporate the Concept of Operations at every phase of development, keeping the goals and stakeholders involved at every step of the way. Within a systems engineering “Vee”, the Concept of Operations supports each step, but it also goes beyond the “Vee”, beyond system development, construction, and acceptance, and supports the operation, maintenance, and retirement of a system – this is described below:

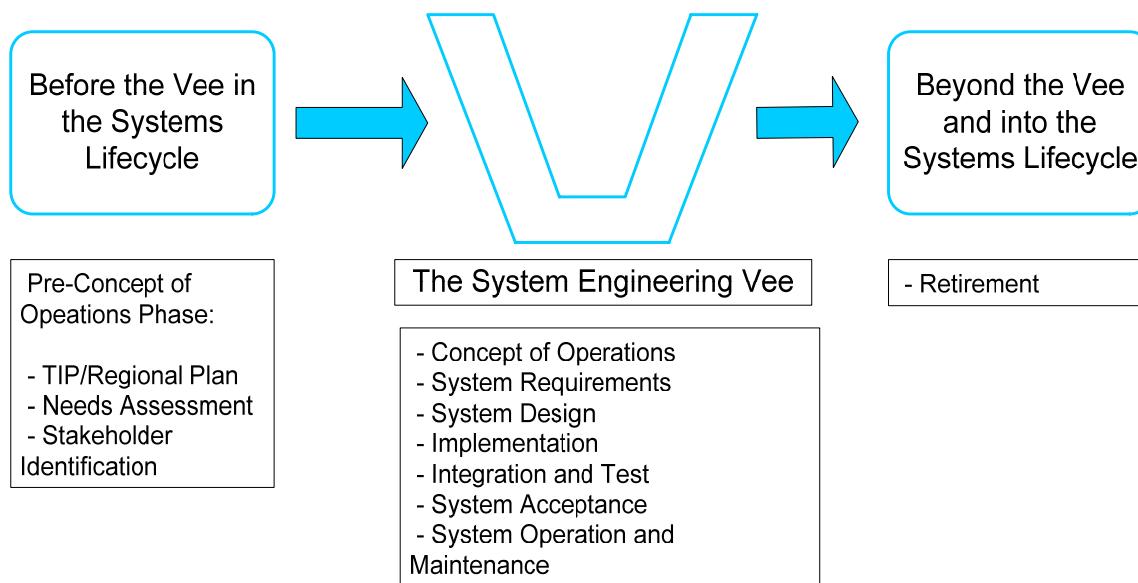


Figure 2.2 – Systems Engineering “Vee” and the Systems Engineering Life-cycle – This diagram shows the breakdown of the systems engineering elements that are within the “Vee” and outside of the “Vee”. It highlights the relationship between systems engineering processes and the systems life cycle.

### 2.2.1 Before the “Vee”

*Pre-Concept of Operations* – There exists a phase for the initiation of the development of a system immediately prior to the first step within the systems engineering “Vee”. This phase is typically initiated by a handful of individuals, often representing several different organizations, when they begin to perceive a need. If they perceive a great enough need, they begin to move forward, often establishing the foundation for early core elements within the systems engineering process. Note that in transportation agencies, this phase includes “traditional” planning processes.

Planning is an essential part of any successful organization, and Transportation Management Systems are no exception. Long term planning efforts such as Transportation Improvement Programs (TIPs) or Regional Plans are necessary for budget and staffing concerns as well as dealing with public agencies that demand certain functionality from TMSs. The process for developing a Concept of Operations can flow directly from both internal (within the organization) and external (including the political environment of the center) planning activities for an organization. While performing both internal and external planning, an organization often discovers certain functions that the current operations cannot support. This *need*

assessment can surface from within the organization or from the needs of external entities which can be best fulfilled by a TMS. The planning process also identifies *a core list of internal and external stakeholders*, which is a fundamental step in the Concept of Operations development process. As the planning activities begin to discuss the vision and goals of either new functionality to an existing system or a new system entirely, then the Concept of Operations process has begun, even if the organization conducts the effort under a different title. For more information on this topic, see Chapter 5, *Using the Concept of Operations to Support Planning*.

### 2.2.2 Within the “Vee”

*Concept of Operations* – The very first step in the systems engineering process, within the “Vee,” is the development of a Concept of Operations.

➤ Highlights of Phase:

- Defines goals, objectives, vision, user operations for the system
- Creates basis for defining functional requirements
- Major role played in validating finished system
- Supportive for all other system engineering elements by providing a guiding vision for the system

Discussions with TMS professionals made it quite clear that the Concept of Operations facilitated the critical activity of stakeholder identification and involvement. One noted that the discussions among stakeholders during the Concept of Operations development were essential for the success of the system, since all organizations came to a consensus on the vision for the project. This allowed each organization that interacted with the system to feel like it could achieve its own goals within the joint vision on the project. This lead to a more successful operation since no group felt infringed upon after the stakeholder discussions.

*TMS Experience*

Another example of a transportation professional identifying the necessity of stakeholder discussion for a successful system deals with cooperation over jurisdiction of organizations: “The development of the Concept of Operations was helpful in showing practical use of the system, it facilitated understanding of the system, and it stressed the cooperative nature of the facility—i.e., we are not taking over.”

*TMS Experience*

*System Requirements* – A set of requirements for a system will describe in detail all the functionality for the system.

➤ Highlights of Phase:

- Formally lists all functions that the system needs in order to meet the high-level goals and user needs outlined in the Concept of Operations.
- Requirements development is an iterative process, from high-level requirements to detailed requirements definition.
- Entire phase is driven and guided by the Concept of Operations.
- The transition to the requirements phase of the system engineering process continues this coordination among stakeholders.

Consensus from transportation professionals indicates there is an essential link between a Concept of Operations and a requirements document: "The Concept of Operations forms an essential reference point for the further development of requirements documentation and for system specifications."

*TMS Experience*

One testimonial provided the following example of the link between the Concept of Operations, requirements, and requirements validation: "Concepts of Operations really are critical to functional requirements and validation. For example:

- The Concept of Operations iterates that the system will allow regional transportation service patrols to communicate with all transportation services to improve traffic incident clearance response.
- The functional requirements state that the service patrols shall be able to communicate data and voice with an operations center.
- Detailed requirements state that the service patrols shall be able to communicate with an operations center using specific protocols within such a frequency, etc.
- After going through the whole systems engineering "Vee", when the system is implemented and put into the field, it can be validated by comparing current operations (as built) to the Concept of Operations (as needed)."

*TMS Experience*

The conceptual views of system objectives and user operations must be decomposed into requirements, and the stakeholders involved must agree with the requirements developed. In this way, the transition between the Concept of Operations phase and the requirements phase is based upon planning, discussion, and cooperation between the design team and the relevant stakeholders. For more detailed information on this topic, see Chapter 6, *The Next Step - Using the Concept of Operations to Drive Requirements*.

*System Design* – A finished system design will take the functionality defined in the requirements and explain how all of the functional processes of the system will actually work.

➤ Highlights of Phase:

- The Concept of Operations supports the design phase of the systems engineering process by providing the overall vision and objectives of the system to which designers can refer back during this phase. The scenarios are especially helpful by providing conceptual tests to consider in the design.
- The context provided by the Concept of Operations (such as personnel and organizational issues) will lead to designs that can “work” under given circumstances.

One testimonial highlighted the supportive roll that the Concept of Operations development process has on the design phase of a project. They noted, “without the scenario development we performed in creating a Concept of Operations, we would not have been able to finalize our software design.”

*TMS Experience*

*Implementation* – Since the design phase of the system defines how the system will be implemented, the next step is to build the system that was designed.

➤ Highlights of Phase:

- The system will be built according to the specifications developed in the design phase.
- Again, the Concept of Operations plays a supporting roll in building the system by keeping the goals and vision of the system at the forefront.

A quote from a transportation professional highlights the necessity of the guiding vision that the Concept of Operation provides as the project moves though the life cycle: “In the systems life cycle, the Concept of Operations defines the players and the objectives, as system developers move through the systems life cycle, going deeper and deeper into the details of the system development, it is often easy to lose track of what one is to accomplish overall, no matter what the stage of the systems' development, the Concept of Operations helps to clear this up – it helps to keep the big picture in mind.”

*TMS Experience*

*Integration and Testing* – This phase entails testing the components built in the previous phase in order to build and integrate the system to meet the design specifications.

➤ Highlights of Phase:

- Functional testing makes sure the system includes all the necessary functions, and it verifies that each system function meets its given requirement.
- Volume or stress testing checks that the system can handle the necessary flow of data, and it also looks for failure points.

- Integration testing looks at the entire integrated system as a whole and checks the interactions among components and subsystems to ensure that all desired operations will functional for the finished system.
- The Concept of Operations plays a role here of defining user scenarios that will help in the integration and test process, since stress and failure modes must be considered in this phase.
- The Concept of Operations gives the final definition of system operations and functionality, and this is the model of what the finished system should do, which is necessary for robust integration testing.

*System Acceptance* – After the software and hardware for the system are fully tested and integrated, a working system exists, but it remains to show that the end users of the system are satisfied with its function and operation.

➤ Highlights of Phase:

- Final user acceptance testing is performed to see if the system built is in fact the system planned.
- The Concept of Operations begins to have more of a direct supporting role, by serving as the basis for verifying whether the system meets the goals and objectives originally outlined in the Concept of Operations.
- The user classes and user operational descriptions developed in the Concept of Operations are essential to the process of verification and acceptance.

If the development of the Concept of Operations process was completed in a robust and complete manner, this phase in theory should be relatively simple. In reality, it is difficult for stakeholders to know exactly what they want during the initial development phase of a project, so that many times this phase causes increased cost and effort for the project, especially when the system functionality is changed this late in the life cycle. A well-discussed and coordinated Concept of Operations development process, as outlined in this document, should help to support user acceptance the system.

*System Operation and Maintenance* – When the system has been fully accepted by all stakeholders, then it is ready for full operation.

➤ Highlights of Phase:

- The Concept of Operations has a major role in this phase, since it is an outline of user operations and procedures for the finished system.
- The Concept of Operations benefits the training of new employees.
- It aids in evaluating performance for existing employees.
- It outlines information that is used to evaluate the performance of the system itself.
- It serves as reference document for users of the system.

It is clear from TMS professionals that the Concept of Operations is used widely during the operational use phase of the life cycle. One common use is as a training tool for new employees. Multiple sources highlighted the benefits that a completed Concept of Operations has in supporting training procedures.

*TMS Experience*

### 2.2.3 Beyond the "Vee"

*Retirement* – This is the phase of the system life cycle where the system is phased out in favor of a new solution, when the current system no longer can provide the functionality necessary to the stakeholders.

➤ Highlights of Phase:

- The Concept of Operations can serve as a guide for a replacement system.
- It will perform a supporting role in the retirement process, demonstrating, to some degree, that the existing system is still meeting its original goals and should remain on-line.
- It will act as a guide to the development of a step-wise retirement plan.

A common link is critical to the transition from one period to the next. From the experiences and highlights described above, it becomes evident that the stakeholders serve as this linkage. It will seem obvious to the reader that sole reliance on often-disparate individuals and organizations to serve as the linkage between development states could prove problematic. This is where the Concept of Operations plays such an important role.

The Concept of Operations:

- Will serve as the starting place, where concept, goals, and objectives are worked out;
- Will serve to keep the system developers and stakeholders 'on the same page' as they progress through the different periods
- Will serve as a tool for validation.

Thus, the Concept of Operations documentation serves as the organizational memory for the stakeholders' relative to the system in question.

## 2.3 Systems Engineering Considerations for the Development of a Concept of Operations for a New or Existing System

The Concept of Operations, as part of the systems engineering process, is applicable to any system whether it is being developed from the ground-up or simply being refined or enhanced. This is so because of the holistic and iterative nature of the process. For systems just starting out, with no previous experience, a tremendous amount of time may be spent on simply identifying the appropriate stakeholders, and seeking consensus on the system concept. In this case, one can "use" systems engineering and the Concept of Operations as they were intended – from the beginning of the "Vee."

In many cases, agencies are in the midst of building or operating systems without a Concept of Operations (or perhaps, without using systems engineering). Generating a Concept of Operations at this point will provide tangible benefits – as follows:

- Much of the material necessary for Concept of Operations development already exists in a variety of existing documents (business planning, system requirements, regional planning documents). Thus, it is often somewhat faster and less costly to generate a Concept of Operations at this point.
- Stakeholder consensus is important to document even if the system development process is past the Concept of Operations phase.

A transportation professional who is currently working on writing a Concept of Operations for an existing system indicated the following benefits a Concept of Operations provides for that existing system:

- A Concept of Operations helps to communicate ideas about the system.
- Concepts of Operations are useful in facilitating discussion about what a system needs to be, through discourse among all stakeholders.
- A Concept of Operations helps me clear up ideas about the system.

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*TMS Experience*

- The Concept of Operations will capture stakeholder agreement and succinctly describe the system. This will support future testing, additional integration, and communications.
- The information in the Concept of Operations is necessary for future steps in the life cycle of the system, so creating a Concept of Operations puts all the necessary information in one place that will play both a passive (e.g. integration and testing) and active (e.g. system acceptance) role in the system development process.
- Operational procedures might not be clearly defined without a Concept of Operations.

If a system is being developed without a Concept of Operations, the team might feel that the information exists and is robust enough to capture the wide range of functions for a TMS, but this testimonial indicates that is not always the case: "Developing operational procedures, operational manuals [for an existing system], to clarify what their client (e.g. a department of transportation) wants of them for certain tasks. Under the present circumstances, if you ask one person who is a user in the system, what they're supposed to do, they will give you a slightly different, but similar, perspective on their duties or tasks. A Concept of Operations would serve as the baseline, spelling out what we do; the operational manuals developed thereafter, would tell us how we do it, but they need the underlying purpose (from the Concept of Operations).

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*TMS Experience*

- Developing the Concept of Operations will help define the overall environment for the existing system, including internal and external interfaces and information flows for the system.

Research has indicated that a benefit for developing a Concept of Operations for an existing system concerns the context for the system, including the reasoning for certain system interactions. Without a formal Concept of Operations, these reasons could be implied but not written for all stakeholders to understand and agree. The following quote highlights this benefit: "Adding a Concept of Operations [to an existing system] provides context to all other aspects of the system; what we're supposed to do; why we support others; how will things be improved; why we should share information."

*TMS Experience*

The costs of adding a Concept of Operations to an existing system include:

- Developing a Concept of Operations for an existing system could put a strain on human resource availability (i.e. the individual leader of this effort, and their colleagues, are doing this in addition to performing their primary tasks).
- The developer of the Concept of Operations could find that the goals, objectives, and features they describe, end up demonstrating some inadequacy of the existing system (as a Concept of Operations document provides support as a system validation tool).

A quote from a transportation professional that highlights the challenge of writing a Concept of Operations for an existing system: "It is difficult to fit something to a moving target."

*TMS Experience*

In such a case where Concept of Operations development identifies an inadequacy of the existing system, one will naturally begin to understand the iterative nature of the systems engineering process. In such a case, it is wise to pursue the Concept of Operations development, to guide the needed enhancement of the system.

## 2.4 Guiding Principles

Systems engineering is defined as a method to facilitate the development, maintenance, refinement, and retirement, of dynamic, large-scale systems, of systems consisting of both technological components (machines, information systems, etc.) and human components (users, stakeholders, etc.). TMSs fit this description of a large-scale, complex system – thus the use of systems engineering processes is critical to successfully deal with the intricacies in defining, developing and operating TMSs.

The system's life cycle is defined as a series of engineering activities across time and relevant to the existence of the system being developed, maintained, or retired. The systems engineering "Vee" diagram serves as an overview of the system's life cycle. The individual phases are as follows:

- Concept of Operations
- System Requirements
- System Design
- Implementation
- Integration and Testing
- System Acceptance
- System Operation and Maintenance

The Concept of Operations will support the entire system's life cycle, from the time it is developed to the fully operational system, and beyond to the retirement of the system. During the requirements phase and system operation and maintenance phases, the Concept of Operations will have a direct role in defining functional requirements and serving as a precursor to the operations manual for all users of the system. As testimonials in this chapter illustrate, the Concept of Operations plays a supportive roll in all other aspects of the systems life cycle, mainly because it outlines the collective goals and vision of the stakeholders for the system, and it helps to keep those goals in the forefront throughout the systems engineering process.

Finally, while the ideal time to create a Concept of Operations is at the beginning of a system's life cycle, experience has shown that there are tangible benefits to developing a Concept of Operations for an existing system.

# CHAPTER 3 – What is a Concept of Operations?

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## Chapter Purpose

Before describing best practices in the development and use of a Concept of Operations, it is important to understand the purpose and content of the document. Given the number and variety of planning activities, and the existence of documents with very similar names (such as the Operational Concept used in regional ITS architectures), there is considerable confusion surrounding the question – “What is a Concept of Operations?”

This chapter provides fundamental information on what a Concept of Operations is. The chapter describes the core elements of the Concept of Operations, and it describes the information that should be included in each element, using detailed examples from existing TMS Concepts of Operations.

## Chapter Objectives

The key objectives of this chapter are:

- *To describe the purpose and role of the Concept of Operations.*
- *To describe the core elements of the Concept of Operations.*
- *To present transportation examples of Concept of Operations elements.*
- *To describe how a Concept of Operations varies based on the system in question.*

## Relationship to the Previous Chapter

Describing the core elements and objectives of a Concept of Operations will build on the high-level role of a Concept of Operations in Systems Engineering given in chapter 2. After this chapter, one will be able to understand the specific questions that the Concept of Operations will answer.

## Chapter Sections

Brief descriptions of the sections of Chapter 3 are provided below:

### 3.1 Defining the Concept of Operations

This section provides a basic definition of a Concept of Operations. Included in this definition are questions the Concept of Operations will answer and the major goals of a Concept of Operations.

### 3.2 Core Elements of a Concept of Operations

This section will describe each core element of a Concept of Operations as defined by the ANSI/AIAA Standard. Each element will be described, the goals of the element will be identified, and examples from TMSs will be provided to link the standard's definitions and descriptions of the elements with its implementation.

### 3.3 The Concept of Operations is not a “One-Size-Fits-All” Document

This section will discuss how the Concept of Operations document must change with respect to the individual system in question. Developers of a Concept of Operations cannot use a standard as a fixed stencil for the document; rather, the standard should be seen as a template or checklist of ideas that should be included in the document.

### 3.4 Guiding Principles

This section provides a brief overview of the key information provided in this chapter.

## 3.1 Defining the Concept of Operations

The ANSI/AIAA standard states that a Concept of Operations is “somewhat all things to all people” (ANSI/AIAA p. 5). While this statement appears to be vague and infeasible – it does effectively communicate the breadth of audience and range of topics that a Concept of Operations strives to address. A Concept of Operations is a high-level description of what the major system capabilities will be, and it should be written such that people with a wide range of technical backgrounds may easily understand it. The Concept of Operations attempts to answer the Who, What, When, Where, Why, and How for the system in general terms. These are described in Figure 3.1:

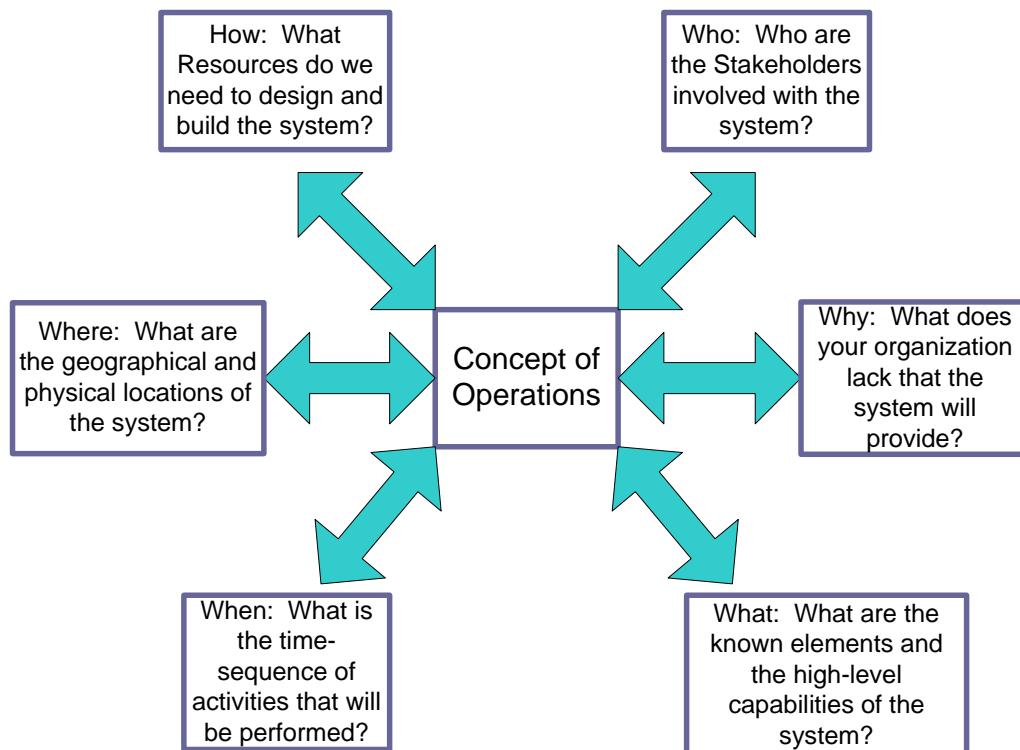


Figure 3.1 – Flow diagram of major questions the Concept of Operations will answer – An iterative information flow will guide the Concept of Operations development process with respect to the Who, What, When, Where, How, and Why of the system.

The figure implies that all of the information required by a Concept of Operations must be contained in a single document entitled “Concept of Operations.” While it is essential for the system engineering process that all of these questions are answered in the Concept of Operations “phase,” it is not crucial that they are

all answered within a single document. For example, Section 3.3.2 shows an example of a TMS that effectively addressed the questions of the Concept of Operations phase, but included the information in three different documents. The key here is that all the information needs to be addressed; the presentation of that information can be molded to best suit specific organizational needs.

### 3.1.2 Major Goals of the Concept of Operations

In order to understand a Concept of Operations – it is essential to comprehend the major goals that it attempts to fulfill. Key goals of a Concept of Operations are as follows:

- *Stakeholder Identification and Communication.* A major goal of a Concept of Operations document is to facilitate discussion, and eventually find middle ground, among the relevant groups associated with system design, development, and operation.
- *High-level System Definition.* All stakeholders must understand, at a high-level, what the system is being designed to do. This will include the major entities within the system, the flows of information among those entities, the information flow to any entity external to the system, the high-level capabilities of the system, and the main daily operational occurrences for the system.
- *Foundation for Lower-level System Description.* The Concept of Operations is a starting point for the lower-level description of the system, beginning with a requirements document. Although the Concept of Operations is not a requirements document, a well-formed Concept of Operations will be a source of information that can be decomposed into a first cut of high-level functional requirements.
- *Definition of Major User Classes and User Activities.* All stakeholders are made aware of the different types of users of the system and activities those users will perform. This allows everyone who uses the document to get an idea of who is performing what task and in what order they are performing those tasks. This information then can be linked to the high-level capabilities of the system for traceability purposes (i.e. who is doing what activity, and which high-level capability is this activity supporting?)

## 3.2 Core Elements of a Concept of Operations

This section provides a general guide describing the information contained within a Concept of Operations. Figure 3.2 illustrates a graphical representation of the eight core elements identified by the ANSI/AIAA standard. In this section, each element will be defined and examples from TMS Concept of Operations documents will be used to illustrate the definitions.

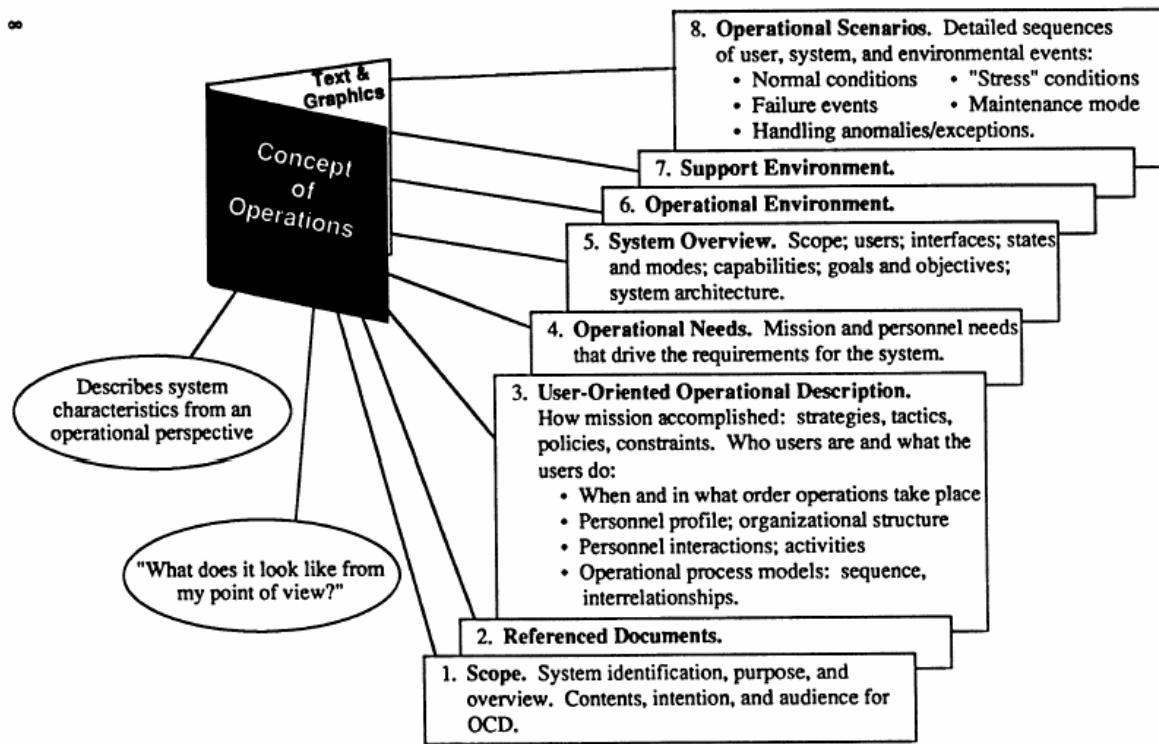


Figure 3.2 – The Core Elements of a Concept of Operations – Graphic reproduced with permission by ANSI/AIAA from “Guide for the Preparation of Operational Concept Documents,” ANSI/AIAA G-043-1992 – The Concept of Operations includes a Scope, Referenced Documents, User-Oriented Operational Description, System Overview, Operational and Support Environments, and Operational Scenarios while describing the system from an operational perspective yet answering, “what does it look from my point of view?”

It is important to note that the reader will find overlap among the elements of the Concept of Operations as defined by the ANSI/AIAA standard. Not all of the information described by each section here has to be in that specific section; it could be included in another section. The breakdown of the core elements by the ANSI/AIAA Concept of Operations Standard and the description of those elements given in this chapter exist as a guideline of things to include in your Concept of Operations document. It is not necessary to attempt to match perfectly the structure given by the standard.

### 3.2.1 Scope

This section presents an overview of the entire Concept of Operations, including the following elements:

- *Outline the Contents of the Document.* This section identifies how the document is composed. Since the document will be tailored to the specific TMS, it could look very different from a Concept of Operations that someone has seen before. Thus, this section typically includes a description of the layout of the document and of the information that is contained in each section.

- *Purpose for Implementing the System.* The scope section of the document briefly describes the rationale behind the system. It explains the necessity of the system being described - often through the description of the lack of capability in the existing system or environment.
- *Highlight Major Objectives and Goals.* This section briefly presents the main goals for the system. Later sections detail the operations of the system and are traceable to particular high-level objectives for the system.
- *Identify the Intended Audience.* The intended audience is identified, including both internal stakeholders (those within the scope of the system) and external stakeholders (those outside the system scope that are affected by the system in some way).
- *Set Boundaries on the Scope of the System.* The scope section defines entities or groups that will be included in the system, as well as identify groups that will require an external interface to the system.
- *Describe an Overarching Vision for the System.* The scope section includes a brief vision statement for the system. A vision statement creates a picture of the future state of the system in which all the stakeholders' needs are met to the greatest degree possible, and all stakeholders have a shared understanding of the purpose for the system.

Transportation examples follow to illustrate elements of the scope section. Note that an analysis of existing TMS Concepts of Operation revealed that most documents do not include a scope section, nor all of the information called for by the ANSI/AIAA standard in this section. This illustrates a need in future TMS development and operation to devote more attention to developing a comprehensive scope. When crafted well, the scope serves as an executive summary for quick communications with multiple stakeholders.

Information on obtaining any or all of the example documents used here can be found in the references section of this document.

*Document Highlight*

**Example 1 — The iFlorida Concept of Operations (Draft), has been written to describe a statewide TMS integration project across multiple jurisdictions and agencies. The document provides a rich and detailed scope – below is an excerpt from the document:**

### 1.0 Scope

This section provides an overview of the Concept of Operations (ConOps) document.

#### 1.1 Introduction

... The model deployment will:

- Expand and integrate existing data collection and monitoring systems;
- Collect and share data;
- Use the data operationally to improve transportation system security, safety, reliability and performance; and
- Where appropriate, distribute the data to the traveling public. ...

##### 1.1.1 Program Objectives

...The Program is designed to deliver information required by operating agencies to manage the transportation network more securely, reliably and efficiently and deliver the decision support information that travelers need to make best use of transportation facilities. ... To be specific, the Program will:

- Expand the existing data collection, transportation management and information delivery infrastructure;
- Integrate data collection, monitoring and management systems both in normal operation and during times of crisis;
- Collect and share data;
- Use data operationally to improve transportation system management;
- Distribute decision-quality data to the traveling public;
- Establish a model for others and share the lessons and experiences learned along the way;
- Define performance measures, collect performance data and evaluate results;
- Illustrate how transportation, hurricane evacuation, weather information and security management can be integrated from both technical and organizational perspectives.

The iFlorida Team will achieve these objectives through the application of resources, experience and expertise within the framework of our proposed approach.

##### 1.1.2 Project Partners

The iFlorida Project Team is composed of representatives from all public and private partners involved in iFlorida. These include:

###### Public Agencies

- Brevard County; • City of Daytona Beach; • City of Orlando; • FDOT District 2; • FDOT District 5; • FHP, Troops D and G; • Florida Division of Emergency Management; • Florida's Turnpike Enterprise ...

TMS Experience

### Example 1 — *iFlorida Concept of Operations (Draft) Scope... continued:*

#### 1.2 Identification

...The ConOps document is utilized to describe the operations concept for a specific system that can be implemented. Since not all of the iFlorida procurements are deployable systems some will not be discussed in this document. Below is a listing of all iFlorida procurements under their corresponding procurement bundle. Those procurements that are listed in italics will be specifically detailed as part of the ConOps.

- Central Florida Field Components

- *Field Components Design/Build (1)*
  - 3M Equipment
  - *City of Orlando Agency Integration (2)*

- Weather

- Central Florida RWIS (3)
  - Road Weather Forecasting (4)

- Security Command and Control

- Security Command and Control (5)
  - Security Cameras

- Data Fusion, Sharing and Use

- iFlorida Conditions System (6)
  - Statewide TTMS Upgrade (7)
  - Data Warehouse Expansion (8)
  - iFlorida Operations (9)

...

#### 1.3 Document Overview

... The ConOps document is intended to be part of an initial effort to collect requirements, develop system concepts and configurations, and to establish how these systems shall operate and interact in the future. This document will provide an understanding of how the various procurements shall be configured and what elements shall be included as part of the procurements. The Draft and Final versions of the ConOps is intended to be a "living" document that reflects the evolving requirements for each of the specific procurements. This ConOps document along with the Requirements Document forms the basis for the development of the various sub-systems within the iFlorida system.

*TMS Experience*

**Example 2 — Fontana/Ontario, a joint TMS project for the I-10 corridor between Fontana and Ontario in Southern California, includes an introduction section, which, among other details, lists the major organizations that will be included in the integrated operation. This clearly sets the boundary of the system and states high-level goals for the project, central elements of the scope:**

### 2 Introduction

#### 2.1 Document Organization

This document sets forth the Concept of Operations for the Fontana/Ontario Advanced Traffic Management and Information System (ATMIS). The document will provide the reader the following information:

- Identification of the issues and problems to be resolved.
- The agency needs to operate and manage the proposed solution.
- Operational and use perspectives to define the use and intent of the ATMIS.

This document flows from the Inventory / Needs Document and forms the basis for the System Requirements Document. ...

### 3 Fontana / Ontario ATMIS

#### 3.1 Background

The 13-mile, Interstate 10 (I-10) corridor, with Ontario on the west and Fontana on the east, has become one of the most congested corridors in Southern California. A large percentage of the commercial vehicle traffic in the Inland Empire passes through this corridor. These vehicles can travel from as far as Barstow, Phoenix and the Mexican Border via the I-15 and eventually the I-10. ...

#### 3.2 System Overview / Purpose of Project

Funded by a Federal ITS grant and local resources, the Fontana/Ontario ATMIS will be one of several ITS projects in the Southern California ITS Priority Corridor. The project is being implemented as a joint venture between Caltrans District 8 (D8) and the cities of Fontana and Ontario. ... [T]he system encompasses several major event generators - among them, Ontario Mills Mall, Ontario Convention Center, Ontario Airport, California Speedway, and commercial transportation from manufacturing facilities adjacent to the California Speedway.

The ATMIS will provide for integration of freeway and surface street operations, and will become the foundation of a "Smart Corridor" along the I-10. With multiple parallel alternatives (both freeway and arterial), ATMIS will facilitate the coordination of traffic management activities on both the freeway network and the local arterials.

*TMS Experience*

### 3.2.2 Referenced Documents (Resources)

In this section, authors of the Concept of Operations list the resources used when developing the document. This can be useful to clarify the sources of information that went into the document as well as providing the reader with guidance to find additional information. Types of reference sources that are typically listed include:

- *Business Planning Documents* – Documentation and resources associated with business processes for an agency and region.
- *Concept of Operations* – Other systems' Concept of Operations that complement the design of the system in question.
- *System Expertise* – Documentation of human resources – individuals who singularly added unique and valuable experience to the development of the system in question.
- *Requirements* – The requirements of other systems - providing detailed insight into their workings.
- *Studies to Identify Operational Needs* – Reviewed documentation related to the system in question, or another anticipated, similar, system that addresses operational needs.
- *System Development Meeting Minutes* – Documentation of most meetings associated with the development of the system in question.

**Example 1 — iFlorida Concept of Operations (Draft) (from page 13) lists the following reference documents:**

Documents that have been utilized in the development of the ConOps include:

- iFlorida Final Work Plan, Version 1.0, PBS&J, June 2003
- Functional Requirements, iFlorida – Statewide and Central Florida Conditions System, FDOT, August 2003.
- Design and Implementation of the Central Florida Data Warehouse (CFDW) – Year 1: The TCSP Funding, UCF, October 2002.
- Design and Implementation of the Central Florida Data Warehouse (CFDW) – Year 1: The TCSP Funding, Approved Revision 6.0, UCF, May 2003.
- iFlorida Field Components Specification, PBS&J, June 2003.
- Scope of Work – Weather Forecasting by Road Segment, Meteorlogix, Version 2.3, FDOT, July 2003.
- Scope of Work – Security Command and Control, Boeing Autometric, FDOT, July 2003.
- iFlorida Conditions System Functional requirements Meeting Summary. PBS&J, July 9, 2003.
- Conditions System ITN Concept Meeting #2 Presentation, PBS&J, July 16, 2003.

*TMS Experience*

**Example 2 — The Alaska Concept of Operations, a document describing a state-wide ITS application document, presents the following list of reference documents in Appendix A:**

- Alaska CVISN Level One Top-Level Design Description. Alaska Department of transportation, MSCVE in conjunction with Alaska Department of Administration. Division of Motor Vehicles & Division of Information Technology. June 2, 2000
- State of Alaska – Statewide Emergency Medical Services Communications Plan. Frank Thatcher Associates, Inc. September 15, 1997.
- <http://www.peoplemover.org/>—the website for the public transportation system for Anchorage, AK.
- <http://www.dot.state.ak.us/external/amhs/home.html>—the website for Alaska's Marine Highway System.

*TMS Experience*

### 3.2.3 User-Oriented Operational Description

This section of the document describes the intended system operation from a user vantage point. It identifies how organization/system-specific goals and objectives are accomplished, including strategies, tactics, policies, and constraints. This portion of the Concept of Operations is the main focus for the entire document, as it is intended to outline the landscape of the system, and provide a clear working image for each stakeholder. Information that is often included in this section:

- *User Activities* – The document identifies who the users are and what the users do. This may take a form as simple as identifying, at a high level, the various classes of users and detailing what their role is relative to the system.
- *Order of User Operations* – Often there is a demonstration of step-wise processes of user activities within the system. Such information assures the incorporation of event-specific information relative to the user, often providing additional insight.
- *Operational Process Procedures* – Operational process models are typically included to effectively demonstrate, through the use of graphics, the relationships of all parts, and given a temporal and event context, highlight the relationships through time.
- *Organizational/Personnel Structures* – System-specific and organizational hierarchic relationships are often included to convey how the users will interact.

If should be noted that in the current state-of-the-practice in Concept of Operations, user-oriented system descriptions often are merged within scenarios. It is clear that there will be overlap in the information contained in these two sections. The guidance presented here is to create a separate user-oriented operational description, and then form operational scenarios to support the entire Concept of Operations effort.

### User-Oriented Operational Descriptions vs. Scenarios

#### *Scenario Drawbacks*

While they may be based on real-events, scenarios are fictitious, and as such, it will be difficult to correctly predict how the system will really behave under the described conditions. Also, scenarios will often involve longer descriptions of the users and their activities within the event: meaning they are not concise; they can be long to write and long to read. Thus, relying on scenarios alone for user-oriented operational descriptions may prove insufficient in capturing the entire breadth of a user's relationship and activities within the system (for additional information, see section 3.2.7 Operational Scenarios).

#### *User-Oriented Operational Description Advantages*

For each class of user, a description of their relationship to the system will prove useful to any reader. As stated earlier, such a description may be supported by many mechanisms, thereby providing user understanding in as concise a means as possible – explaining how a user may completely relate to the system under any circumstance.

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*Document Highlight*

**Example 1 —** *The Cross Westchester Expressway Concept of Operations provides a very succinct and high-level description of the users relative to the system. The document captures what most system participants will experience, something other TMS Concept of Operations documents often fail to accomplish.*

In approaching the issue of developing an Intelligent Transportation System, a customer-specific Concept of Operations is a powerful tool for enabling system designers to gain valuable insight into both the day-to-day needs of a system's users and the ways in which the users envision the system will be used. To fully understand the operational needs of this system, we must first understand who the users are. The classes of users have been defined to include motorists, media, transportation agencies, external agencies, and TMC operators. Each user class's interaction with the ITS is further defined as follows:

### **Motorists**

Motorists will receive both regulatory and advisory information from the Hudson Valley ITS via Variable Message Signs (VMS), Highway Advisory Radio(HAR), and AM and FM broadcasts. Their vehicles passing over and through the Hudson Valley ITS sensor fields generate the data for Traffic Management processing. With the widespread use of cellular phones, the motorists provide additional input for the identification and verification of highway incidents.

### **Travelers**

Travelers or pre-trip planners make travel decisions based on information distributed by the Hudson Valley ITS regarding traffic conditions within the project limits. This information will normally be received through a Traveler Advisory Telephone System (TATS), commercial media, tuning to the HAR, or via the Internet.

### **External Agencies**

External agencies such as individual county Departments of Transportation/Departments of Public Works, law enforcement agencies, and transit authorities will rely on the Hudson Valley ITS for highway information as well as access to VMS and HAR for communications to the motorists. External agencies who choose not to physically occupy the TMC can still be active partners in this project via dedicated, linked communications networks and remote workstations for input and output of transportation related data. Traffic engineers from the NYSDOT and public safety officials from various state and local jurisdictions will continually review response plans and results from response plan initiation. They will provide recommendations for enhancing and modifying system response plans.

### **Information Service Provider**

An Information Service Provider (ISP) operating from the TMC will provide timely traffic information to interested radio stations, television stations , newspapers, and, potentially, cable operators. The ISP will also provide a telephone/cell phone call-in service to provide information directly to interested motorists. This service will be consistent with the X-1-1 dedicated traffic information number currently being spearheaded by the Federal Government.

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*TMS Experience*

### *Example 1 — Cross Westchester Expressway User-Oriented Operational Description continued...*

#### **TMC Operators**

The operators are responsible for the daily operations of Hudson Valley ITS which include:

- Monitoring of traffic flow on the expressway and lateral connections via the vehicle detection system
- Verification of incidents through the video surveillance system and audio communications
- Enactment of response plans consistent with regional/local policies and procedures
- Documenting traffic/incident status and occurrences as necessary

These operations are carried out from the TMC workstations with integrated computer and communications support during normal operational hours and during special events. The Hudson Valley ITS also provides for the on-line training of TMC operators using real-time field data and simulation data but without access to control of the remote field devices. In addition to the expected traffic operators as described above the Hudson Valley TMC will include C911 Call Takers/Dispatchers, HELP Dispatchers, and other remote users. Management and support staff will also occupy the TMC and will have remote access to the same traffic information as the traffic operators through their own workstations.

#### **Hudson Valley ITS Administrator**

The Hudson Valley ITS Administrator is responsible for the quality of work of the TMC operators as well as normal administrative functions. The administrator will set responsibilities for TMC operators and define or limit the range of their monitoring and control of the TMC resources.

#### **Hudson Valley ITS Support Personnel**

The Hudson Valley ITS will be an integration of various technologies that include computers, communications, video, radio, telephone, and vehicle detection sensors. Hudson Valley ITS support personnel will coordinate the maintenance of field equipment and inventories of spares. Support personnel on site will also include hardware and software specialists to tune the computer system performance and to trouble-shoot any problems or "bugs" that may appear. Communications specialists will provide performance monitoring and troubleshooting of the communications, video and radio subsystems.

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*TMS Experience*

**Example 2 — MassHighway's Calvin Coolidge Bridge ATMS**, a implementation and operation plan for the Massachusetts Highway Department's Coolidge Bridge Rehabilitation Advanced Traffic Management System, includes the following list of topics in an overview of daily operating procedures, information that would be included in a user-oriented operational description. In their document, each is explained in detail. This is just an example of elements addressed in this section:

Daily Operations Procedures, Overview:

*This Section describes the basic Daily Operating Procedures of the Coolidge Bridge ATMS, such as:*

- Hours of Operation of the Control Centers
- Daily Start-up Procedures
- Use of the Communications Equipment
- Event Logging Requirements
- Transfer of Control from one Control Center to the other
- Daily and Emergency Shut-Down Procedures

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TMS Experience

**Example 3 — Texas Department of Transportation's (TxDOT) Traffic Operations Division has generated a Traffic Management Center (TMC) Advanced Traffic Management System (ATMS) Operations Concept Document for the application of such technologies in Austin, El Paso, and any future region requiring such an ITS application. Below is an excerpt from the document's Chapter 3, Section 1: TxDOT Roles and Responsibilities; this provides another clear example of a User-Oriented Operational Description.**

### Overview

TxDOT roles and responsibilities include the essential functions that need to be performed by Traffic Management Center personnel to operate, maintain, and support continued readiness of ATMS systems, communications, and traffic devices in the field for management of traffic, incidents, and emergencies. This section does not define the number of people required to support the Traffic Management Center. Manpower allocation may warrant that one person may assume several roles and responsibilities.

### Control Room Operations

Control Room Supervisor:

- If necessary during heavy incident activity, coordinate the assignment of new incidents to the appropriate TMC Operators for tracking and resolution.
- Assist TMC Operators in incident resolution.
- Resolve any conflicts in the use of the Work Stations, CCTV Monitors, or field devices.
- Ensure that all current incidents are being worked and regularly checked for status via the Current Incidents Display, Incident Report Display, Traffic Conditions Display, and Status Logs.
- Monitor TMC/ATMS system computers to view all currently logged in users. Disable and enable any login access.
- Monitor the performance of all TMC/ATMS system computers, networks, and communications.
- Control which video channels are available for output to the media.
- Coordinate training and approve certification of new Control Room operators.
- Coordinate with Maintenance and System Administrator for any outages, testing, repairs, software updates, etc. to minimize impact on operations.
- Inform Emergency Services Dispatchers of system outages.
- Review and analyze Traffic Management Center response to incidents using the Incident Report and Status Logs.
- Keep media informed of incidents and incident clearance.

TMC Operator:

- Initiate Incident Report Display
- Select recommended camera or alternate camera.
- Control camera to find and view incident scene.
- Verify incident as true incident report or false report.
- Assess precise location, severity, and condition of incident; impact on traffic and roadway; and access to incident.
- Notify emergency services of verified incident. Message includes verification, location, severity, conditions, and impact.

*TMS Experience*

### **Example 3 — TxDOT's ATMS Austin Operations Concept Document's Roles and Responsibilities continued:**

#### Courtesy Patrol Operations

##### Courtesy Patrol Supervisor:

- Oversee Courtesy Patrol operations in general.
- Answer phone requests for assistance from citizens and Courtesy Patrol officers.
- Notify TMC Operator of incidents detected by the calling motorist.
- Dispatch appropriate Courtesy Patrol services to requesting motorists and to potential incidents.
- Dispatch Courtesy Patrol as requested by TMC Operator or Emergency Services Dispatcher.
- Support Courtesy Patrol at scene and notify TMC Operator and/or Emergency Services Dispatcher of status, changes, needs, and conditions.
- Log all Courtesy Patrol activities.
- Coordinate incident responses with TMC Operator and other agencies via radio and/or telephone.
- Provide limited TMC Operator functions outside normal working hours.

##### Courtesy Patrol:

- Support Emergency Services at scene as requested.
- Notify TMC Operator, Courtesy Patrol Supervisor, and/or Emergency Services Dispatcher of changes in needs, conditions, plans, and information from scene until incident is cleared.
- Local control of LCS and RMC at cabinets; dial-up control of CMS and HAR.
- Notify TMC Operator, Courtesy Patrol Supervisor, and/or Emergency Services Dispatcher of incident clearance.

#### Computer Room Operation and Maintenance

##### Computer Room Supervisor:

- Supervise Computer Room personnel and support computer systems, network, and database operations and maintenance.
- Coordinate software installation and testing on Transportation Management Center System equipment.
- Communicate with computer system vendors for improvements.
- Arrange for the repair of equipment under warranty, or exceeding in-house repair capabilities.
- Assign problem resolution tasks to technician(s).
- Order supplies & maintenance-related items.

##### System Administrator:

- Maintain all group definitions and security privileges.
- Manage and control the Transportation Management Center data/archive library (computer tapes, discs, voice recordings, video recordings, etc.).
- Install/maintain the online Standard Operating Procedures.
- Monitor the performance of all Transportation Management Center System computers; the Transportation Management Center System networks, including external circuits; and computer system alarms using COTS system network management tools.

*TMS Experience*

### 3.2.4 Operational Needs

In this section, the Concept of Operations details agency- and region-specific goals and objectives that will drive the requirements of the system. In other words, the section attempts to answer the question of what is required by the agency or region that the current system or set of services does not provide.

There are many possible names, or forms, and places within the Concept of Operations that one may find this expressed. In many ways, this is simply the justification for change to some current state of the practice – either to justify the development of an entirely new system, or the integration of additional services into an existing system.

Current practice in writing Concept of Operations does not demonstrate uniformity in conveying such needs – indeed, it would be very difficult to imagine how any given TMS, each at various levels within varying locations, would be able to develop the same way for expressing need. The matter of significance is that some form of “need” should be expressed when writing these documents. It was found that the most effective TMS Concepts of Operations were those that effectively conveyed “need.” Below are examples of “needs” expressed by various TMS Concepts of Operations

**Example 1 — The DalTrans Transportation Management Center Operational Concept Document expresses need in the form of a justification for change. An entire section dedicated to this begins on page 15 of the document. Below is an excerpt:**

### 3.0 JUSTIFICATION FOR AND NATURE OF CHANGES

#### 3.1 Justification of changes

The operational vision for the North Central Texas Region is a “system of interdependent transportation systems” cooperatively providing Intelligent Transportation Systems (ITS) services. The purpose of these ITS services is to assist in achieving regionally established transportation goals. Specific North Texas ITS goals developed through a region-wide consensus process include the following.

- Enhance mobility of people and goods by reducing recurrent traffic congestion
- Enhance mobility of people and goods by reducing traffic congestion caused by incidents

...

#### 3.2 Description of desired changes

As new devices and systems are added to enhance the capability of the DalTrans system, the system will continue to monitor and control the following roadside devices:

- Dynamic message signs
- CCTV video cameras
- Vehicle detection (e.g. loops, VIVDS)

ITS standards-based capability will be added for new and existing Dynamic Message Signs. New

functionality will also be added for the following roadside devices:

- Lane Control Signals
- Highway Advisory Radio

...

The DalTrans system will also include the addition of the following new functionality:

- Incident scenario response
- Maintenance dispatching / tracking system

#### 3.3 Priorities among changes

All functionality that exists in the current DalTrans system is the highest priority for integration into the new TMC. Section 4.3 describes the prioritization among all services that will be integrated into the DalTrans system. New support for roadway devices will be integrated in the following order:

- HOV facilities
- Lane Control Signals

...

*TMS Experience*

**Example 2 —** *The Maricopa Association of Governments of the metropolitan region of Phoenix, Arizona, has recently developed a Regional Concept of Transportation Operations. Beginning on page 18, Section 6, a portion of this document highlights "Institutional Needs and Required Resources – Needed Policies, Practices, and Procedures." The document begins by identifying the various regional stakeholders and formulating how they universally have a common need. Once established, they move on to identify and develop the new, "to-be," overall system's common functional needs. Below is a sample from their identified needs:*

Operational Category	Needed Procedures or Practices	Needed Policies
Freeway Mobility	Traffic Responsive Ramp Metering Notifying Agencies and Organizations of Freeway Incidents Removing Disabled Transit Vehicles from Freeways	Improve Freeway Incident Clearance Times
Arterial Mobility	Optimizing Traffic Signals within a City on 100% of the Smart Corridors and Assessing the Coordination every two years  Optimizing and Coordinating, if beneficial, Traffic Signals between Cities on 100% of the Smart Corridors  Grouping of Signals into Control Sections, irrespective of Jurisdiction  Assessing Coordination Every Two Years	
Freeway Incident Management	Altering Traffic Signal Timing Plans during Incidents  Incident On-Scene Coordination and Communications between Public Safety, Emergency Service, and Transportation Personnel	Shared Operations and Use of CCTV Cameras  Extraction of DPS CAD Information, where available, and Importing this information to ADOT TOC  Shared Operations of State and Local Variable Message Signs  Placement of Response Vehicles at Incident Scenes  Removal of Fatalities from Accident Scenes

*TMS Experience*

### 3.2.5 System Overview

As the name suggests, the purpose of this section of the Concept of Operations is to provide a high-level description of the interrelationships of key system components. All of the information contained in this section can be found in another section of the document, but this section is designed to focus on the interrelationships. The areas in this section typically include:

- *Scope.* The section contains the geographical boundaries of the system, and the breadth of participating stakeholders.
- *Interfaces.* The section identifies and describes both internal and external interfaces: how entities within the system relate to one another, and how different aspects of the system relate to entities outside the system.

The section describes all aspects of the system at once. Often, this information is conveyed via a systems diagram since it provides a way to concisely communicate a large amount of information concerning both the components and functions of the system as well as the interfaces.

**Example 1 — Oregon TOCS**, a statewide transportation operations center system, uses the graphic in Figure 3.3 to depict the interfaces and functional flows from a regional Traffic Operations Center viewpoint. The Oregon graphic is very thorough, capturing all the capabilities and functional flows of the finished system. Separate diagrams showing different builds of the system (e.g. what aspects of the system will be complete after year 1) over the implementation phase of the project were also created, but not released. This example is intended to demonstrate the breadth of possible information that can be conveyed via a systems diagram. It is presented in the Oregon Concept of Operations as a stand-alone figure, without text to guide the reader through the diagram. [See next page for diagram.]

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TMS Experience

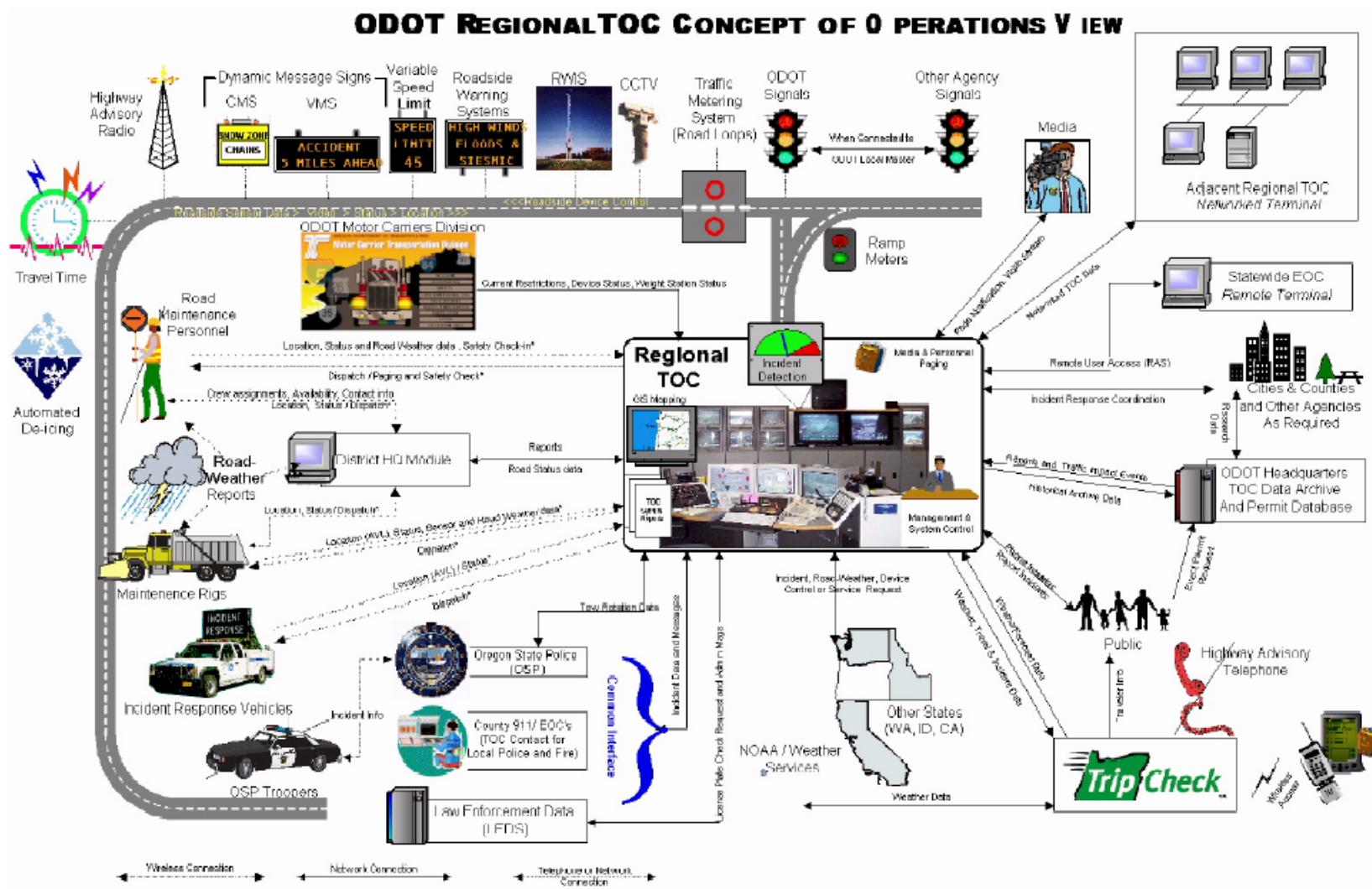
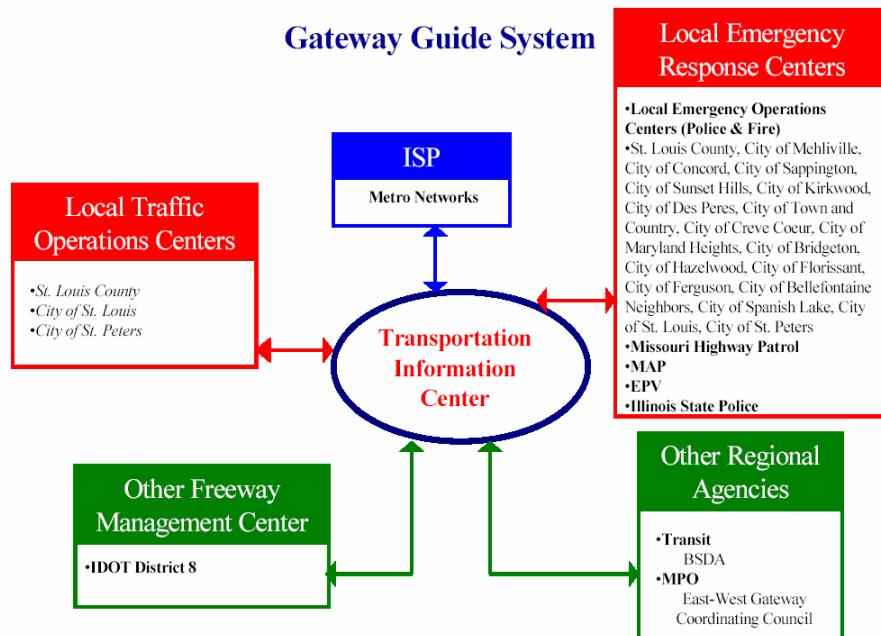


Figure 3.3 – The Oregon TOCS System Overview Diagram, Traffic Operations Center System Concept of Operations Final Version, Oregon Department of Transportation, 2002 – This diagram relates all the functions and stakeholders for the system in one place, showing functional flows of manpower and information.

**Example 2 — The St. Louis Gateway Guide System, an effort to integrate multiple regional operations and control centers/systems, uses the following graphic to illustrate information flows among partners at a very high-level.**

### St. Louis Regional Concept of Operations



TMS Experience

### 3.2.6 Operational and Support Environment

In the ANSI/AIAA standard, two sections are described – Operational Environment and Support Environment. However, upon examination of the standard, there is considerable overlap in these sections. As a result, it is recommended that these sections be combined to provide information about the general environment created for operation of the new system (or created by the change in the current system). In other words, this environment is the “world” in which system operations take place. This section includes information about the system’s environment in terms of the following categories:

- *Facilities* – The section identifies physical facilities necessary to meet the needs of the fully functional system (e.g. buildings, garages, etc.) through high-level descriptions.
- *Equipment* – High-level descriptions identify the equipment necessary for the system to be operational (e.g. closed circuit TV cameras, variable message signs, etc.).
- *Hardware* – Typically, this refers to the physical information systems that the users of the system access. These are also high-level descriptions.
- *Software* – A high-level description of the information system applications necessary for system operations.
- *Personnel* – The section describes the personnel necessary to staff all facilities needed for the system to be operational. This typically includes a concise subset of the system users identified in the User-Oriented Operational Description. Descriptions of the capabilities of these individuals are also sometimes generated.
- *Operational Procedures* – If not already found within the User-Oriented Operational Description, a description of what, and when, the users and system components are performing under specific conditions is also included.
- *Support Necessary to Operate the Deployed System* – This category includes all other supporting labor that is not specifically designated by the operations of the system. This support could include facility management, accounting/finance, human resources, etc.

This section entails many different aspects of the system as a whole, and it is likely that all of this information will not be in one place, especially if the Concept of Operations is separated into functional areas of the system, which is the case in a majority of documents reviewed for this effort. Ideally, the description of the operational and supporting environment will make a clear connection between functional, physical, and logical viewpoints.

**Example 1 — MassHighway's Calvin Coolidge Bridge Advanced Traffic Management System Operations Plan identifies the major operational and system components including a detailed review of personnel requirements. Below is an excerpt from the document's Chapter 1, "Overview of ATMS Operations.**

1.3 Components of the ATMS – The two primary elements of the Advanced Traffic Management System are the Field Equipment and the ATMS Operations and Control Centers. ...

1.3.1. Field Equipment refers to the traffic monitoring and control devices placed in the vicinity of the Coolidge Bridge and on important approach roads and highways. The primary field traffic control devices are:

- Variable Message Signs (VMSs), which are electric, changeable message signs used to communicate detour and special information to motorists;
- Closed-Circuit Television (CCTV) Cameras, used to monitor traffic conditions in the vicinity of the Coolidge and Sunderland Bridges, and;
- Traffic Signals with Preemption Capability, which are used primarily to flush traffic off of the Coolidge Bridge when an ambulance approaches. While the traffic signals are being preempted, a series of flashing beacons will inform motorists that they may experience longer than normal red phases.

*1.3.2. The ATMS Operations and Control Center (OCC) is located in the Mass Highway District 2 Offices in Northampton, with a backup and off-hours facility in the Massachusetts State Police Barracks in Northampton. The Control Center is staffed with an Operator who controls the Field Equipment described above. The Operator can also monitor traffic conditions using the CCTV cameras or by communicating with Police, Fire, EMS, Construction Personnel, or others. The Operator will use this ATMS Operations Plan as a guide for managing the system and responding to congestion and emergency situations. ...*

1.5 Position Descriptions and Personnel Requirements – The ATMS is a tool that interfaces with the existing emergency response and traffic control procedures of the state and local police departments, local fire departments, the emergency medical dispatch system, and the Massachusetts Highway Department. Therefore many of the personnel to be involved with the ATMS are already in place and must only receive training about the operation of the ATMS. Nonetheless, additional personnel are required to operate the system from the Control Center (ATMS Control Center Operators) and to control traffic and incidents at the construction site (Police Details). ...

### 1.5.1 ATMS Control Center Operator

1.5.1.1 Position Description – The ATMS Control Center Operator shall be responsible for the control of the ATMS field devices, traffic monitoring, and implementation of traffic interventions using ATMS equipment. The Operator shall control the System from a console located in the MHD District 2 Offices or the MSP Barracks, depending on the time of day and day of week. The Operator shall have the capability to control all field devices, including control of CCTV cameras, Variable Message Signs, Signal Overrides, and Flashing Beacons, and shall also manage the 800 MHz ATMS radio talkgroup.

*The operator shall have training in Civil Engineering or Traffic Law Enforcement, and shall collect and analyze traffic observations to determine when it is prudent to implement a traffic intervention. The Operator shall, upon request, provide the Emergency Medical Dispatcher with traffic information from cameras and field reports, and, if requested by the Dispatcher, initiate a traffic signal override. The Operator shall coordinate communications among personnel in the talk group, and shall provide traffic information to emergency authorities when requested.*

#### 1.5.1.2 Staffing Requirements:

- Control Center at Massachusetts Highway Department: One (1) Operator during the following period: 6:00am to 6:00pm Weekdays

TMS Experience

**Example 2 —** *The DalTrans Operational Concept gives the following information concerning the support environment of its existing system:*

### Support Environment

Currently there are maintenance contracts for the janitor, grounds, and the air conditioning system. A majority of the software support is performed by TTI. TxDOT Traffic Operations Division (TRF) maintains statewide software components. Systems and equipment required for daily operation are replaced when items have failed or there is a realization of a performance loss.

There is minimal on-site storage of equipment, which requires additional off-site storage in non-environment controlled facility. Supplies are obtained through the TxDOT procurement process (TxDOT Warehouse). There is currently no data archiving system, as the system is not database driven. Thus all data is stored on hard drives. Data and video are distributed via email, web page, leased ISDN lines, TxDOT fiber optic network, and telephone lines. The DalTrans TMC receives information from TxDOT field devices, Courtesy Patrol, Dallas Police, local traffic reporting agencies, local city transportation offices, and the traveling public. The DART network is dependent on a dialup network at the present time.

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*TMS Experience*

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*Example 3 – TxDOT's ATMS Austin Operations Concept Document's Chapter 2 "Traffic Management Operations" highlights various operational roles within the context of the new system. These operational role descriptions include both human and machine identification and activity in a general sense. Throughout the remainder of the document, selected elements of these descriptions are expanded upon as the needs being addressed dictate. Below is an excerpt from their Chapter 2.*

### Traffic Operations

TxDOT Traffic Operations activities involve the monitoring of traffic and various traffic flow data; the control and monitoring of remote traffic devices; the detection, verification, and management of traffic incidents; and the reporting of real-time traffic or routing information to the public.

...

When incidents do occur, traffic operations need to be coordinated with emergency services, other agencies, the public, and the media to minimize the time it takes to detect, verify, respond to, and remove the incident, and thereby restore the freeway to normal capacity.

### Emergency Operations

TxDOT emergency operations are activated in response to the threat of a major weather-related emergency such as a tornado, flooding, icing or any other disaster that has a wide impact on the area roadways. Emergency operations include: the collection and evaluation of data gathered from many sources across the affected areas; emergency planning and direction of TxDOT personnel; informing the public; and coordination of TxDOT response teams' actions with regional Emergency Operations Centers and emergency services.

### Maintenance Operations

Maintenance personnel are responsible for preventive and corrective maintenance of traffic management system components. Maintenance personnel perform fault detection, fault isolation, problem resolution, repair, test, and verification of system operation and performance for system components in the Traffic Management Center, in the field, and in the communications networks.

### Backup Operations

Backup operations refer to operations when the Traffic Management Center is not available due to a major system failure. Since the Center will be equipped with backup emergency power, such a failure would most likely involve the failure of a major computer system or fiber-optic communications link to the Center. Currently, backup operations consist of Closed Circuit Television surveillance and voice communications if available.

### System Operations

System operations involve the operation and use of Traffic Management Center computer systems, computer networks, communications systems and related field equipment. System operations include: daily operation, monitoring, status and control of systems; system, software, and data configuration management, backup, and recovery; routine diagnostics and preventive maintenance; installation and checkout of system changes and improvements; and identification and reporting of system, software, and database problems. System operations personnel will assist Maintenance personnel, as required, with maintenance, installation and configuration of communications.

*TMS Experience*

### 3.2.7 Operational Scenarios

In this section of the Concept of Operations, the system is described under various operating conditions relative to the core users and the stakeholders. It is most effective if the conditions described in this section range from "normal" to stress and failure conditions. The operational scenario tells different stories from perspectives of different user classes over a variety of circumstances. There are four basic elements to operational scenario development:

- Included User's Perspectives – Each user of the system is included to some degree within each scenario; this is typically done by generating a 'story' written from the perspective of each class of user.
- Variety of User Classes – Incorporating many of the user classes related to the system is preferred in assuring system effectiveness (meeting the goals) and assuring stakeholder 'buy in.'
- Stress/Failure Scenarios – Such scenarios describe characteristics that are conceivable to cause the system great stress – even to push the system to the point of failure.
- Multiple Circumstances – More than one scenario with multiple associated sub-events is necessary to develop a rich enough picture and story to illustrate the full extent and capabilities of the system.

**Example 1 — Fontana/Ontario Concept of Operations** gives different user perspectives for several different scenarios. The user types are listed below:

- Fontana TMC Operator
- Fontana Maintenance Operator
- Fontana Engineering
- Police Department: Caltrans District 8 Operator
- Caltrans District 8 Signal Engineer
- Major Event Generator
- Traveling Public
- Ontario International Airport

The following is an excerpt from the Fontana TMC Operator Perspective, which concerns the operator "Joe:"

Alerted by the sudden decrease in vehicle speeds along Sierra, Joe selects the video images from Sierra and Randall. Joe notices that the northbound lanes on Sierra are backing up due to a stalled car on the outside lane. The problem is exacerbated by the fact that there is a construction crew working next to the car on the inside lane. Upon further review he notices the construction crew assisting the driver out of his car and onto the street. He switches the image to the large screen display – it looks like a medical emergency.

Joe logs the incident using the ATMIS 'Incident Management Dialogue' window. He enters information about the incident - reporting agency, contact name, phone, incident location, phone number, lanes affected, place on map, description, notification list, traffic management plan and alternate routes. The incident report is immediately transmitted to the Fontana PD CAD system alerting operators who can react by dispatching police and emergency services. Additionally, Joe updates local DMSs (already in use for the construction activity) to warn on coming traffic of the incident and provide alternate routes.

---

TMS Experience

**Example 2 — TxDOT's ATMC Operations Concept Document for Austin includes a number of scenarios. Below is an excerpt from the document's Chapter 5, Section 1: Incident Management Scenario with Automated Detection.**

### Incident Management Scenario with Automated Detection

#### Overview

The basic incident scenario is used to develop the initial standard operations concepts for use in traffic management systems. The basic operations and tasks defined during analysis of this scenario will be expanded and completed during analysis of significant alternative incident scenarios in the following sections.

The basic incident scenario describes incident management events and tasks in response to a major work day accident on the freeway just prior to evening rush hour involving: multiple vehicles including a tanker, semi-trailer, and two passenger vehicles; a vehicle fire and trapped passengers in another vehicle; serious injuries; and potential hazardous material spill. All northbound (or westbound) lanes are blocked except for part of right-most lane and emergency shoulder.

The ATMS and communications are operational, the TMC Operator is on duty, and no other roadway or system problems exist.

The incident is detected by the ATMS automated traffic monitoring and incident detection functions.

The basic incident scenario tasks, as well as the alternative incident scenarios, are identified, analyzed, and grouped into top-level tasks based mostly on incident management activities defined in the Freeway Incident Management Handbook, Report No. FHWA-SA-91-056 dated July 1991. The following top-level tasks are used: (1) detect incident; (2) evaluate incident; (3) respond to incident; (4) manage traffic; (5) inform motorists; (6) remove incident; and (7) restore free-flow.

Some overlapping and parallel tasks may be confusing in this partitioning. However, use of the definitions provided in Section 8, the Domain Dictionary, should be helpful.

#### 5.11 Detect Incident

ATMS:

- Monitor traffic flow on freeways with volume, occupancy, speed, and classification data derived from detector stations along the roadway.
- Detect potential incident based on comparison of current measured occupancy to the pre-defined occupancy threshold limit for the detector station near incident.
- Notify TMC Operator of potential incident with summary on Current Incidents Display and alarm indication on Traffic Conditions Display. The message includes incident summary of location, direction, type of alarm, time reported, current status, elapsed time, and notification; and identification of nearest camera with recommended preset and monitor; and other traffic devices near the incident.

#### 5.12 Evaluate Incident

TMC Operator:

- Initiate Incident Report Display
- Select recommended camera or alternate camera.
- Control camera to find and view incident scene.
- Verify incident as true incident report or false report.
- Assess precise location, severity, and condition of incident; impact on traffic and roadway; and access to incident.
- Notify emergency services of verified incident. Message includes verification, location, severity, conditions, and impact.

*TMS Experience*

**Example 2 — TxDOT's ATMC Operations Concept Document for Austin Incident Management Scenario continued:**

5.13 Respond to Incident

TMC Operator:

- Plan access route.
- Notify emergency services of recommended access route.
- Notify TxDOT Courtesy Patrol Supervisor to dispatch Courtesy Patrol.
- Notify TxDOT Maintenance Supervisor, TxDot PIO or media, Traffic Signals, and others as needed during response and clearance.
- Update Incident Report.

Emergency Services Dispatcher:

- Plan incident access route.
- Dispatch emergency services.
- Update Incident Report.

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*TMS Experience*

*Example 3 — The Federal Highway Administration's Concept for Operations for Emergency Transportation Operations is scenario driven – that is, the document utilizes scenarios extensively to formulate its vision. Below is an excerpt from the document, providing an example of one of the many scenarios it details:*

### 3.0 Hurricane Evacuation Scenario

#### 3.1 Description of Event

Hurricanes pose a significant threat to coastal regions of the southeastern United States, and to a lesser degree, to the entire eastern seaboard. High winds and rain as well as coastal and inland flooding can have a devastating impact on affected populations and infrastructure. ...

#### 3.2 Preparedness Activities

In a hurricane emergency, the State Emergency Operations Center (SEOC) serves as the communication and coordination "hub" for the state. Decisions are coordinated through statewide conference calls between the appropriate Emergency Support Function(s) and the local agencies. The State Emergency Response Team and the local agencies jointly develop criteria to assist with the decision-making process. ...

#### 3.3 Awareness Activities

The National Hurricane Center gathers and reports information regarding hurricane activity. Potentially affected areas are provided with updated forecast information on a continuous basis to allow time for the implementation of emergency management activities. During a hurricane event, communication and coordination is essential to ensure that affected populations are evacuated safely (if required) and that support services such as food, water, and medical care are delivered. Transportation agencies may use surveillance equipment such as Closed Circuit Television (CCTV) and other sensor devices to monitor traffic flow on evacuation routes and report on the status of evacuation efforts. In addition, reports from field staff may be compiled to evaluate the status of evacuation routes prior to, during and after an event. ...

#### 3.4 Response Activities

A computer program called HURREVAC2 graphically displays forecasted storm paths and evacuation clearance times. HURREVAC also produces information that can be useful in deciding when evacuations should occur by providing suggested evacuation timelines based on storm conditions and clearance time estimates. ...

#### 3.5 Recovery Activities

Once a decision is made to allow reentry into an area, the state transportation agency leads or supports a number of activities designed to restore critical services and manage transportation. Authorities in most situations will not be able to restrict access of the general public to affected areas much longer than 72 hours, or three days, after landfall of a hurricane. Officials prepare for solutions to allow limited access after 72 hours, recognizing that health and safety conditions could still be severely compromised. State and federal agencies will provide assistance and support, but reentry is initiated at the local level.

TMS Experience

### 3.3 The Concept of Operations is not a “One-Size-Fits-All” Document

All Concepts of Operations documents will not be the same since they are documents specifically tailored to support the development and use of a specific system or set of services. The critical function of the Concept of Operations is to encourage careful consideration of the system by multiple stakeholders at the outset of a system development process, and to document agreed-upon high-level details of the system. The formality of the section titles identified above is not necessary, and it is apparent when looking at the current state of the practice for Concept of Operations development that many organizations arrange information in a way that best fits their individual system.

#### 3.3.1 Examples of Concepts of Operations for Different Types of Systems

A Concept of Operations is necessary to support any system-level initiative in a TMS. These initiatives may be the development of a new traffic control center/system, integrating multiple systems in a region, adding a service to an existing system, etc. This section briefly discusses expected differences in Concepts of Operations for different classes of TMS initiatives.

**Stand-Alone Centers** — Transportation Management Centers that have a contained scope of one agency/jurisdiction can approach the Concept of Operations from a straightforward perspective. The outline of core elements listed in this chapter would work well for such a system, since the integration issues will not dictate the form of the final document to the degree that a large statewide or regional system would. However, stand-alone centers tend to arrange the document from a functional perspective, which is intuitive because many jurisdictions organize themselves in this manner. The TxDOT TMC ATMS for Austin is an example of a ‘stand-alone’ center whose Concept, while focused on one activity/one system, relates very well to the core elements.

**Integration Programs** — iFlorida represents a statewide transportation integration effort, and the Concept of Operations document is tailored to fit that scope. As one would expect, the Concept of Operations is divided into various sections, from which the statewide integration project will be built. Each “Procurement” of the project describes all the elements listed in the chapter for each section of the integration. In this fashion, the document conveys all the information for the core elements of a Concept of Operations, but it does so on a “time-step” basis.

**Existing Systems** — A Concept of Operations for an existing system will be different than one created for a new system. There are several reasons for developing a Concept of Operations after systems development has already begun (or the system is already being utilized), including adding functionality to an existing system or addressing groups of stakeholders for jurisdictional concerns. The Virginia Department of Transportation’s Hampton Roads Smart Traffic Center, a regional TMS, is such an example. The Center has existed for several years, while it has been added onto in terms of scale (number of lane-miles managed) and technology (number of additional sensors), their overall mission, stakeholders, users, and associated system have changed little until fairly recently. With the addition of the Archived Data Management System to their capabilities, a new set of stakeholders, and new system connections, have been integrated –, prompting a new look at their relationship to many of the features of their original concept. Thus, the Center is now in the process of developing an entirely new Concept of Operations.

### 3.3.2 Information Contained in Multiple Documents

The State of Maryland's CHART (Coordinated Highways Action Response Team) program is a good example of a system where the elements of the Concept of Operations are separated into multiple documents successfully. The elements are separated into a Business Plan, a Regional Operations Coordination Study, and a Business Area Architecture. The following elements of a Concept of Operations included in these three documents were identified by Glenn McLaughlin at the 2004 ITS America meeting and are summarized by the following table:

<u>Business Plan</u>	<u>Regional Operations Coordination Study</u>	<u>Business Area Architecture</u>
<ul style="list-style-type: none"><li>• Scope</li><li>• System Description</li><li>• Services Provided</li><li>• Performance Measures &amp; Testing</li><li>• Facilities and Equipment</li><li>• Staff</li><li>• Internal Stakeholders</li></ul>	<ul style="list-style-type: none"><li>• Services Provided</li><li>• Facilities and Equipment</li><li>• Information</li><li>• Training</li><li>• External Stakeholders</li><li>• Agency Responsibilities</li><li>• Institutional Changes</li></ul>	<ul style="list-style-type: none"><li>• Business Process Flows</li><li>• Performance Measures &amp; Testing</li><li>• Information</li><li>• Training</li><li>• Communication Networks</li><li>• Software</li><li>• Institutional Changes</li><li>• Integration</li></ul>

Figure 3.4 – Elements of the Concept of Operations divided into three documents for Maryland's CHART program

Therefore, while CHART does not have a document titled "CHART Concept of Operations" – it is clear that the elements of a Concept of Operation, as described in Section 3.2, have been addressed and communicated. This is the most important consideration. Thus, CHART is well positioned to grow using the systems engineering "Vee," based on this solid foundation.

### 3.4 Guiding Principles

#### *What is a Concept of Operations?*

A Concept of Operations is a high-level description of what will be the major system capabilities. It is written in jargon free language so that people with a wide range of technical backgrounds are able to easily understand it. The Concept of Operations attempts to answer the Who, What, When, Where, Why, and How for the system in general terms.

The goals of a Concept of Operations include:

- Stakeholder Identification and Communication;
- High-level System Definition;
- Foundation for Lower-level System Description;
- Definition of Major User Classes and User Activities.

#### *What are the core elements to a Concept of Operations?*

- Establish Scope;
- Identify Reference Resources;
- Develop a User-Oriented Operational Description;
- Establish or Identify Operational Needs;
- Provide a System Overview;
- Describe the Operational and Support Environment;
- Develop Operational Scenarios.

#### *The Concept of Operations is not a "One-Size-Fits-All" Document!*

All Concepts of Operations documents will not be the same since they are documents tailored to support the development and use of a specific system or program. Addressing critical system issues of a group of stakeholders is a much more important activity, in whatever way it is done, than attempting to perfectly fit the template of a particular concept of operations standard.

# CHAPTER 4 – How to Develop a Concept of Operations

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## Chapter Purpose

This chapter provides guidance and best practices to support the development of a Concept of Operations document. The advice and examples come from real-world TMS documents and information acquired through interviews with officials involved with the development process.

## Chapter Objectives

The key objectives of this chapter are:

- *To convey a strategy for development of a Concept of Operations - presenting ideas for gathering, synthesizing, and presenting the information in the document.*
- *To provide specific guidance and examples on how to develop specific Concept of Operations' elements.*
- *To address critical issues related to Concept of Operations development, including resources, stakeholders, and, performance measures.*

## Relationship to the Previous Chapter

Chapter 3 defines the Concept of Operations, including explaining the goals and objectives of the document as a whole, defining the individual core elements of a Concept of Operations, and offering examples of each core element from Concept of Operations from real TMSs. This chapter describes guidance for developing a Concept of Operations for a TMS, including advice for beginning the process, developing each of the individual core elements, and guidance from TMS professionals concerning stakeholder identification and involvement.

## Chapter Sections

Brief descriptions of the sections of Chapter 4 are provided below:

### 4.1 Where Do I Start?

This section is intended to support readers who are at the initial stage of Concept of Operations development. It addresses issues such as the needed level of technical expertise, ideal make-up of a development team, and challenges involved in identifying the scope of the Concept of Operations.

### 4.2 How to Develop the Elements of the Concept of Operations

This section demonstrates, through real-world TMS examples, how to develop the standard elements of a Concept of Operations. Chapter 3 described the elements to the reader – this section describes how to develop the elements.

### **4.3 Resources Required for Concept of Operations Development**

This section addresses the varying resources necessary to complete a Concept of Operations document, depending on the size/scope of the system. Topics discussed in this section include agency staffing, and the use of consultants.

### **4.4 Stakeholder Identification**

This section will review the various stakeholder types typically involved in TMS programs, and it will help the reader identify stakeholders for a particular TMS by offering guidance and examples. From this section, the reader will understand that there are numerous classes of stakeholders, and that much time in the development process will be spent on identifying and involving the appropriate organizations and personnel.

### **4.5 Stakeholder Involvement**

Active participation among stakeholders is essential for a successful Concept of Operations development, and here guidance and testimonials from TMS professionals will be given to offer advice on how best to involve stakeholders.

### **4.6 Definition of Performance Measures**

The development of a Concept of Operations is a natural springboard for creating performance measures for a system. The goals and objectives defined in the Concept of Operations are important high-level performance measures that will be decomposed into specific measures throughout the system lifecycle. Metrics may be developed for nearly every level of the system, for each stakeholder and for each stakeholder sub-system. Generic examples will be demonstrated, as well as specific, real-world TMS examples.

### **4.7 Key Resources for Writing a Concept of Operations**

Reference documents, standards, and key resources that assist in the composition of the document are identified in this section.

### **4.8 Guiding Principles**

This section provides a brief overview of the key information provided in this chapter.

## 4.1 Where Do I Start?

### 4.1.1 What questions must be answered by the Concept of Operations?

For all of the stakeholders involved in the system, the Concept of Operations must address the who, what, when, where, why, and how. This is illustrated in Figure 4.1. Note that this issue is addressed fully in Chapter 3 – readers new to Systems Engineering should read Chapter 3 carefully before proceeding in this chapter.

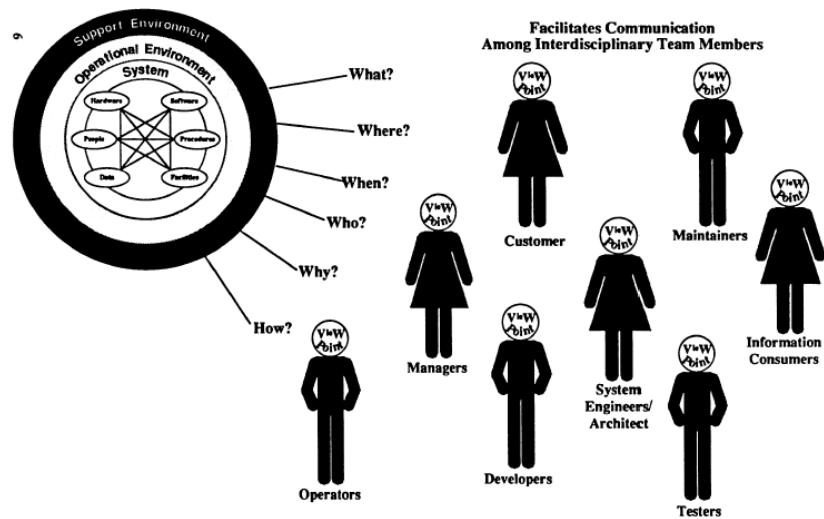


Figure 4.1 – Core Stakeholder Groups of a Concept of Operations – Graphic reproduced with permission by ANSI/AIAA from “Guide for the Preparation of Operational Concept Documents,” ANSI/AIAA G-043-1992 – The Concept of Operations must answer who, what, when, where, why, and how about the system to satisfy each of the system stakeholder perspectives.

- 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?

### 4.1.2 Does This Require Technical Expertise?

The Concept of Operations document is intended to reach a wide audience. As such, its writing must balance generality with specificity. It should be general enough for individuals or stakeholders at the periphery of the system, with limited system knowledge, to understand the overall system. Yet, the Concept of Operations must be detailed enough such that in-system technical stakeholders are able to glean sufficient understanding so as to transition from step-to-step within the systems engineering process to build or refine the system.

This writing balance is often best assured by having a writing team, or group, that consists of a broad set of backgrounds that encompass the very core of the stakeholder group. The leaders of such a group are the

individuals that will be responsible for operating the system. Thus a member of the writing team should provide technical expertise, but it is not necessary for all members of the team to have technical backgrounds.

### 4.1.3 Team Effort

An effective Concept of Operations depends on a solid team effort. A Concept of Operations developed by a single person will prove ineffective – it will almost certainly provide too narrow of a perspective.

- Begin compiling the team immediately – Much like the systems engineering process, of which the Concept of Operations is a part, the process to build the Concept of Operations is iterative. A concept based upon a need will be developed, and it will require refinement by individuals who have a stake in the newly evolving system. The process involves a core group of stakeholders, initially, to define and refine the idea sufficiently to later bring in additional stakeholders. At some point, the scope and scale of the ideal system will evolve where the core stakeholders, and the core idea, have balanced. This is the transition point in pulling together a true Concept of Operations document. Thus, finding individuals who have the time and interest to develop the concept is critical in the earliest stages.
- Focus on those who will be responsible for using the system – as stated earlier, the leaders of the Concept of Operations development should be those stakeholders who will be at the core of the system, those who will be the immediate users. The expansive and reiterative process involved in concept development should involve all stakeholders, but the writing should involve only a core group. This is necessary to assure that system development focuses on those stakeholders whose need for the system is most critical.

### 4.1.4 Scope Depends on Purpose

A Concept of Operations may be developed for many different classes of systems initiatives.

- New Center – To some extent, it will be perceived that a new TMS, without any existing system, will be easier to develop. This is not always true. The challenges in developing a new system lies within the ‘clean slate’ – where are the system boundaries? Who should be involved? What should the system do? In essence, within the systems engineering process, for the new TMS, the greatest of all challenges may simply be defining the new system and meeting the true needs of the people. Therefore, the Concept of Operations, as the starting point for the systems engineering process, becomes a very critical piece. It serves to define scope and need, and assures that the stakeholders are all on the same sheet of paper.
- Regional Integration Program – Such TMSs have the unique challenge of integrating systems representing similar and different technologies, organizations, and missions. A Concept of Operations, in this case, serves as much an assurance to stakeholders as it does an expression of a new system: a system of systems. As assurance, the Concept of Operations generates a new, overarching, mission – demonstrating a new regional systemic need that can only be met by integrating some or all aspects of existing regional TMSs. In this situation, an existing Concept of Operations for each system gives a clear, concise mission and vision for each of the systems in question, which facilitates the integration process.

- Adding/Modifying Functionality to an Existing System – When modifying an existing system – i.e. adding “system-level” services – it is important to develop or refine a Concept of Operations. A key challenge in this is timing – both in the pace of documentation development, and when to develop a new Concept of Operations document when adding new functionality. It is generally considered a good idea to revise/update a Concept of Operations document when substantially new functionality is added to the system. This is entirely dependent on the situation, but it may involve the addition of functionality that changes the nature of the mission, the addition of substantially new capabilities, and the additional of a new stakeholder class.

## 4.2 How to Develop Elements of the Concept of Operations

### 4.2.1 What Should Be Found Within A Concept Of Operations Document And How Is Each Element Developed?

#### 4.2.1.1 *Concept of Operations Element: Scope*

Description – The Scope section of the document serves several purposes:

- It identifies this document as a high-level description of a unique system;
- It details the purpose of the system;
- It identifies the intended audience and outlines and summarizes the remainder of the document.

Guidance in Developing – The scope has the dual role of introducing to the reader both the document and the system. In this sense, it serves as an executive summary for the Concept of Operations document. A reader should be able to walk away from reading the scope with a high-level understanding of the system and its mission, as well as what to expect in the remainder of the document. The scope may be visited in the beginning of your Concept of Operations document development process to consider the mission and system definition as well as the intended audience, but the bulk of the section is best written toward the end of the many iterations of Concept refinement.

The following elements should be considered or included when developing Scope:

- *Outline the Contents of the Document.* The Scope should explain the layout of the document and be clear on the information that is contained in each section of the overall document.
- *Set Boundaries on the Scope of the System.* The Scope should define entities or groups that will be included in the system, as well as identify groups that will be an external interface for the system. Upon a first iteration of a Concept of Operations, this distinction could be difficult to define, but as the development phase continues, these flows will become easier to describe. The following example highlights both the contents and bounded scope of the system.

## Developing and Using a Concept of Operations in Transportation Management Systems

**Example** — Upon conclusion of the introductory *Section A*, the following sections document the Hudson Valley ITS Concept of Operations as derived from the *Lower Hudson Valley Early Deployment Planning Study*, the *Intelligent Transportation System (ITS) Preliminary Design Report*, and technical discussions with the New York State Department of Transportation (NYSDOT), NYS Police, New York State Thruway Authority (NYSTA), and Westchester County officials. More specifically, upcoming items include:

- *Section B* – a detailed approach to integration of the Hudson Valley ITS to develop a foundation for the growing ITS capabilities in the Lower Hudson Valley, including delineation of the functional needs for the Hudson Valley ITS.
- *Section C* – a high-level description of the Hudson Valley ITS's recommended integration logical architecture, including an overview and a list of data-, video-, voice-, and external interface major functional elements;
- *Section D* – a presentation of the software framework for providing the “glue” for integrating the physical subsystems of System Control, Automatic Traffic Recording, Video Surveillance, Variable Message Signs, and Voice Communications;
- *Section E* – a presentation of the Hudson Valley ITS recommended hardware architecture, including an overview and a detailed description of its recommended hardware framework for data collection, surveillance, and communications.
- *Section F* – a presentation of a sample operational scenario to demonstrate the use of the Hudson Valley ITS in a realistic environment.

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- *Purpose for Implementing the System.* The scope section of the document should briefly describe the rationale behind the system. There should be an attempt made to explain the needs for the new system, as well as the shortcomings of the existing situation or system. The following provides such an example.

The Hudson Valley ITS is a logical continuation of the intelligent transportation system development initiated by the New York State Department of Transportation's formal ITS needs study, titled the *Lower Hudson Valley Early Deployment Planning Study*.

The ITS system for the Hudson Valley will be used to detect, verify, and respond to traffic congestion on the major highways and parkways throughout the entire Hudson Valley. In achieving this goal, the Hudson Valley ITS will provide an integrated incident management and emergency notification system within a single Transportation Management Center (TMC); thus, optimizing both of these critical services through enhanced cooperation and the sharing of a common database of incident information. The Hudson Valley ITS is also being developed to accommodate the expansion of ITS services to include advanced traffic control and traveler & transit information services.

This document provides the technical approach to implementing the Hudson Valley ITS and explains how the system will detect, verify and respond to congestion in a timely and efficient manner. It also provides an overview of the Hudson Valley ITS's functional architecture and how it fits into the National ITS Architecture Program, which enables more standardized means of synergistically interfacing with other critical ITS projects that already exist throughout the New York area, the northeast region, and nationally.

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- *Highlight Major Objectives and Goals.* At the very least, the document should make accessible, to the broadest possible audience, the main goals for the system. This is important information to convey in the introductory section for several reasons; first, as the introduction serves as an executive summary, the essence of the system is relayed immediately, and second, so that the later sections detailing the operations of the system will be traceable to particular high-level objectives for the system.

The primary mission of the Hudson Valley Intelligent Transportation System (ITS) is to improve the safety of the traveling community in the Hudson Valley. Improved safety will be realized through efficient use of the major highways with timely and accurate information being made available to the traveling public for making their transportation decisions.

*TMS Experience*

- *Identify the Intended Audience.* The intended audience for the document should be as broad as possible, including both internal stakeholders (those within the scope of the system) and external stakeholders (those outside the system scope that are affected by the system in some way).

This document communicates the vision of the ITS to the planners and stakeholders in this effort, as it has been perceived by the designers. It is very important that the planners and stakeholders review this document carefully & provide their feedback concerning preferences, priorities, or changes desired to the designers. Your feedback ensures that the designers understand your needs, enabling them to make necessary changes to meet those needs.

*TMS Experience*

- *Describe an Overarching Vision for the System.* The scope section should include a brief vision statement for the system. A vision statement creates a picture of the future state of the system in which all the stakeholders' needs are met to the greatest degree possible, and all stakeholders have a shared understanding of the purpose for the system.

In short, this document defines the vision of the Hudson Valley ITS, based upon inputs from its planners and stakeholders, and as perceived by the system's designers. It defines the ITS concept by defining the integration approach to achieve the program's goals, the logical and physical architectures, and the intended software operations. It also defines the system's use through multiple sample operational scenarios.

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Note that an analysis of existing TMS concepts of operation revealed that most documents do not include scopes including all of the information called for by the ANSI/AIAA standard. This illustrates a need in future TMS development and operation to devote more attention to developing a comprehensive scope. When crafted well, the scope can serve as an executive summary for quick communications with multiple stakeholders.

*Document Highlight*

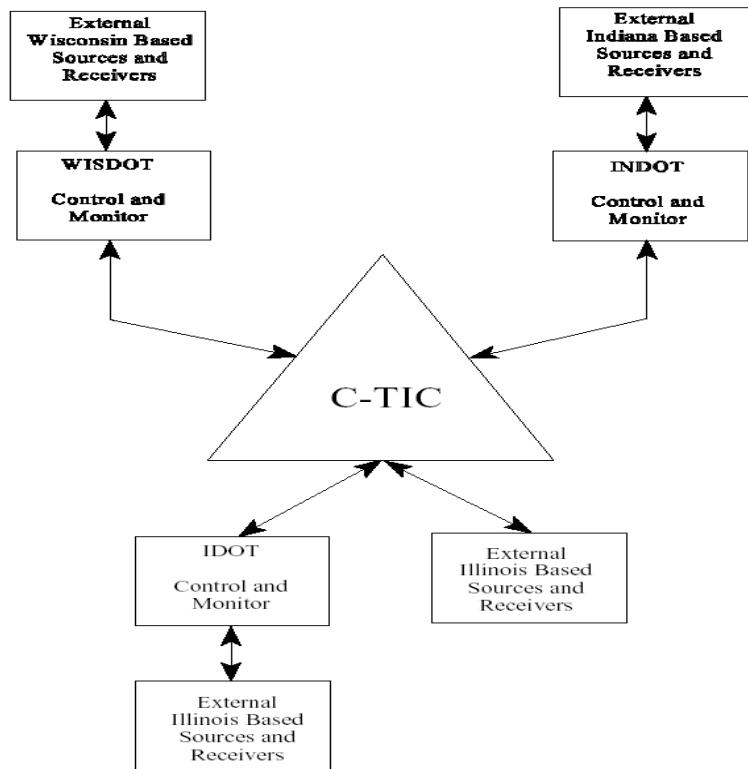
Issues to Consider – There are several issues that are encountered when developing the Scope element.

- Defining mission, goals, or objective – Scope is where the system's overall existence is given support. Its mission, goals, and objectives are laid out and defined to respond to some observed, common, and given needs. This is where the document developers and the stakeholders will need to be unified.
- Many readers will get no further than the scope section of the document – a Concept of Operations is often quite long, and there will be a majority of people that pick up the document

who will not read past the scope section. It is imperative to briefly relate all important high-level goals and objectives in this section so that someone who only reads this section will have a good understanding of the functionality, goals and vision for the system.

- Diagramming – Scope provides an excellent medium to display high-level systems diagrams (for additional insight, see section 4.2.1.5 “System Overview”). In addition to text, diagrams serve to reiterate the relationships and processes within a system. It is often the case that diagrams work better to convey system functions, especially when viewing the entire system.

**Example – The Gary Chicago Milwaukee System Diagram** – This diagram provides high level functional flows among stakeholders for the system in a concise manner.



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#### 4.2.1.2 *Concept of Operations Element: Referenced Resources*

Description – The Referenced Resources element of the Concept of Operations document serves as a guide to resources utilized in the development of the Concept of Operations document, as well as a source for alternative information relevant to systems development or refinement.

Guidance in Developing – The most useful resources in the documents' development should be listed, this includes: other TMS Concept of Operations or TMS development documentation, guides, standards, and Internet resources. These may include:

- *Business Planning Documents* – Documentation and resources associated with business processes for your agency and region may prove valuable in defining vision, identifying stakeholders, and establishing scope.

**Example** — The Cross Westchester Expressway ITS Concept of Operations document cites a planning study as a main source on the development of the document: "The Hudson Valley ITS is a logical continuation of the intelligent transportation system development initiated by the New York State Department of Transportation's formal ITS needs study, titled the *Lower Hudson Valley Early Deployment Planning Study*."

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- *Transportation Planning Document* – From "traditional" planning activities.
- *Concept of Operations* – While it is unlikely that there will exist another system whose purpose, scope, and domain are precisely the same as yours, reviewing other systems' Concept of Operations will prove very useful in assisting you in refining what needs to be considered. The Concept of Operations documents from other systems that will be integrated with, or will work in cooperation with, a regional planning situation will be valuable resources to understand the interfaces and coordination necessary.
- *System Expertise* – Documenting human resources is also important – individuals, who singularly added unique and valuable experience to the development of your document, and system, may prove equally useful to another system's development.
- *Requirements* – There may be systems whose development will be useful to your system's development. Referencing the requirements of these other systems may provide detailed insight into their workings, and thus illustrate how far you may need to go in order to completely specify your system's activities, operation, and concept.

**Example 1** — *Daltrans* cites the system requirements document as a "related document" to the Concept of Operations:

- System Requirements Specification for the Dallas Transportation Management Center, Texas Department of Transportation/Southwest Research Institute/Texas Transportation Institute, January 7, 2002.

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**Example 2 — iFlorida highlights the functional requirements document in the Concept of Operations as a referenced document:**

- Functional Requirements, iFlorida – Statewide and Central Florida Conditions System, FDOT, August 2003.

*TMS Experience*

- *Studies to Identify Operational Needs* – Reviewing documentation related to your, or another anticipated-similar, system that address operational needs will be useful in assuring that your Concept of Operations addresses real-world needs.
- *System Development Meeting Minutes* – Documenting meetings associated with the development of your system will be useful in refining your system in the future.

**Example — iFlorida also references developmental meetings in the Concept of Operations document:**

- iFlorida Conditions System Functional requirements Meeting Summary. PBS&J, July 9, 2003.
- Conditions System ITN Concept Meeting #2 Presentation, PBS&J, July 16, 2003.

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- *Early Deployment/Strategic Plans* – Agencies governing specific functions may have generated strategic plans that may, or may not, explicitly denote the development, or refinement, of your TMS. Utilizing such plans as a starting point for the development of your Concept of Operations should be considered a high-priority for not only institutional issues, but also for defining goals, and later, performance measures.

**Example — Daltrans also identifies a strategic planning document as a resource for the Concept of Operations document:**

- Dallas Area-Wide Intelligent Transportation System Plan, Texas Transportation Institute for the Texas Department of Transportation, July 1996

*TMS Experience*

- *Regional ITS Architecture* – If a regional ITS architecture exists, it should be reviewed to determine how the system “fits” with this architecture and what changes may need to be made.

### Issues to Consider –

- Presentation/organization of referenced resources: In practice, there is tremendous variance on how referenced resources are organized. Organization methods include: list with no organization; list with some level of relative relationship to the system being described; functional list; etc.

It is clear from looking at example Concept of Operations documents from TMSs that many organizations are not including the documents used in developing the Concept of Operations. For a reader who is attempting to gain insight into the system, giving that reader a place to go for more detailed information is helpful, especially in the case of a regional integration project.

#### Document Highlight

- Reference resource availability: Developing a TMS Concept of Operations may have an advantage over other systems because many mature systems have well defined documentation available.

#### *4.2.1.3 Concept of Operations Element: User-Oriented Operational Description*

Description – This core Concept of Operation's section should be devoted to providing an operational description relative to the users and primary system actors. Per the ANSI/AIAA document, this section of the document addresses:

- *Operational overview* – Operational strategies, tactics, policies, and constraints that describe how the goals and objectives are to be accomplished;
- *Personnel* – Organization, activities, and interactions that describe who the users are and what the users do in accomplishing the goals and objectives;
- *Operational processes* – A model that describes when and in what order operations take place, including such things as dependencies and concurrencies.

Guidance in Developing – The ANSI/AIAA document provides further insight into the development of this element. This is summarized and discussed in Table 4.1.

**Table 4.1 – Operational Description Guidance**

*ANSI/AIAA recommended inclusion      How to Develop a Concept of Operations Guidance*

<p>Operational overview</p> <ul style="list-style-type: none"> <li>• Goals and objectives</li> <li>• Policies</li> <li>• Constraints</li> <li>• Existing Operational and Support Environments</li> </ul>	<p>From the vantage point of the primary system users, a holistic overview for the new system, its goals, objectives, governing policies (if known), constraints (such as environmental, geographic, or organizational), and the existing human and technological resources should be expressed.</p>
<p>Personnel</p> <ul style="list-style-type: none"> <li>• Profiles</li> <li>• Type</li> <li>• Organizational structure</li> <li>• Interactions</li> <li>• Activities</li> </ul>	<p>The document should identify who the users are and what the users do. This may take a form as simple as identifying, at a high level, the various classes of users and detailing what their role is relative to the system. The boundary as to what level of description is necessary is subtle. There is no single correct path for this – it will be necessary to determine what is required for your system and document: scope, scale, readability, and time and budget. However, describing the individual class and its relationship to the system is sufficient for the Concept of Operations, and will be useful to any related document where additional details may be found on that user class.</p> <p>Often it will be useful to demonstrate a step-wise process of user activities within the system. The advantage of developing such a process in the</p>

Concept of Operations is that it will involve the incorporation of event-specific information relative to the user, assuring that later technological and functional requirements development will be more robust. However, for the same reason, including this level of step-wise detail within the user descriptions may be too prescriptive at an early stage of system development, and as the system ultimately deploys, it may become necessary to return and refine the user-Oriented steps.

System-specific and organizational hierachic relationships are useful in conveying how the users will interact, and if necessary, under what circumstances.

### Operational processes

Operational process models including sequences and interrelationships are similar, but more encompassing, than that of the order of user operations. Models can effectively demonstrate, through the use of graphics, the relationships of all parts, and given a temporal and event context, highlight the relationships through time. While richer than the order of user operations, the advantages and disadvantages to incorporating this detail of description at an early stage are similar. And while similar to scenarios, this type of demonstration does not necessarily prescribe any particular event.

### Issues to Consider –

- Assuring the whole system is captured. One simple method may be to diagram the system overview first. As the system develops, refine this diagram and use it as a check-off when assembling the operational descriptions.
- Clarifying between existing and proposed systems – Where regions have little ITS, applying TMS descriptions should occur with greater ease. Where regions have a great deal of ITS, and are working on integration of those systems, clarifying your systems role may prove difficult. It is clear that regions containing multiple systems should describe the interaction among those systems – this interaction is essential information to clarify the mission and goals of a TMS.
- Scenarios vs. User Orientated Operational Descriptions – In the current state-of-the-practice in Concept of Operations, user-oriented system descriptions often are found within scenarios. A reasonable question then arises, “is it necessary to provide separate descriptions – non-scenario and scenario based – of users within the system?” The answer again will depend on your circumstances, but separate descriptions provide greater illumination to a broader audience – which will be very useful to the development of your system.

Examples of User Oriented Operational Description from TMS Concept of Operations Documents – The following provides two examples of personnel operations within a proposed system, and one example of operational processes within a proposed system.

## Personnel Activities

**Example 1 -** *The Arizona DOT Concept of Operations gives the following sequence of events for emergency traffic control requests for the Phoenix area:*

Emergency traffic control requests are often received from DPS or other police agencies and will be handled as follows:

1. Ask for the name, call sign, and location of the officer in charge.
2. Log the caller's name and telephone number.
3. Log the type of incident, direction of travel, route, milepost, crossroad, and/or ramp if involved.
4. Determine what type of traffic control is requested and who is now at the location.
5. Request the officer standby for the contact with the ADOT responder.
6. Dispatch the closest four ALERT team members.
7. Use the appropriate VMS signs.
8. Monitor the incident through radio and cameras.

Traffic control requests from other sources will be referred to DPS for review prior to dispatching ADOT resources.

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*TMS Experience*

### Personnel Profiles

**Example 2 - The Cross Westchester Expressway Concept of Operations provides a very succinct and high-level description of the users relative to the system.**

In approaching the issue of developing an Intelligent Transportation System, a customer-specific Concept of Operations is a powerful tool for enabling system designers to gain valuable insight into both the day-to-day needs of a system's users, and the ways in which the users envision the system will be used. To fully understand the operational needs of this system we must first understand who the users are. The classes of users have been defined to include motorists, media, transportation agencies, external agencies, and TMC operators. Each user class's interaction with the ITS is further defined as follows:

#### **Motorists**

Motorists will receive both regulatory and advisory information from the Hudson Valley ITS via Variable Message Signs (VMS), Highway Advisory Radio, (HAR), and AM and FM broadcasts. Their vehicles passing over and through the Hudson Valley ITS sensor fields generate the data for Traffic Management processing. With the widespread use of cellular phones, the motorists provide additional input for the identification and verification of highway incidents.

#### **Travelers**

Travelers or pre-trip planners make travel decisions based on information distributed by the Hudson Valley ITS regarding traffic conditions within the project limits. This information will normally be received through a Traveler Advisory Telephone System (TATS), commercial media, tuning to the HAR, or via the Internet.

#### **External Agencies**

External agencies such as individual county Departments of Transportation/Departments of Public Works, law enforcement agencies, and transit authorities will rely on the Hudson Valley ITS for highway information as well as access to VMS and HAR for communications to the motorists. External agencies who choose not to physically occupy the TMC can still be active partners in this project via dedicated, linked communications networks and remote workstations for input and output of transportation related data. Traffic engineers from the NYSDOT and public safety officials from various state and local jurisdictions will continually review response plans and results from response plan initiation. They will provide recommendations for enhancing and modifying system response plans.

#### **TMC Operators**

The operators are responsible for the daily operations of Hudson Valley ITS which include:

- Monitoring of traffic flow on the expressway and lateral connections via the vehicle detection system
- Verification of incidents through video surveillance system and audio communications
- Enactment of response plans consistent with regional/local policies and procedures
- Documenting traffic/incident status and occurrences as necessary

These operations are carried out from the TMC workstations with integrated computer and communications support during normal operational hours and during special events. The Hudson Valley ITS also provides for the on-line training of TMC operators using real-time field data and simulation data but without access to control of the remote field devices. In addition to the expected traffic operators as described above, the Hudson Valley TMC will include C911 Call Takers/Dispatchers, HELP Dispatchers, and other remote users. Management and support staff will also occupy the TMC and will have remote access to the same traffic information as the traffic operators through their own workstations.

#### **Hudson Valley ITS Administrator**

The Hudson Valley ITS Administrator is responsible for the quality of work of the TMC operators as well as normal administrative functions. The administrator will set responsibilities for TMC operators and define or limit the range of their monitoring and control of the TMC resources.

*TMS Experience*

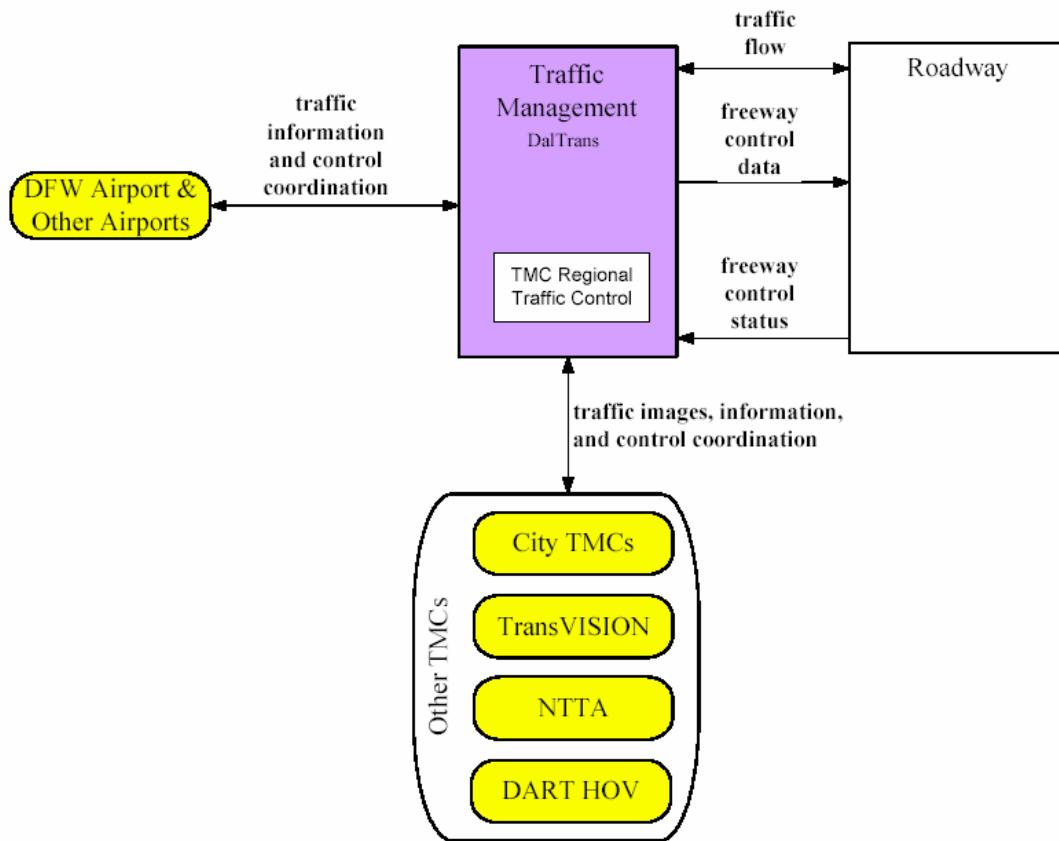
## Operational Processes

**Example 3 - DalTrans uses the following description and graphic to describe the process of regional traffic control for the system:** -Note that the authors made use of materials from the National ITS Architecture to support this section.

### Regional Traffic Control

This market package advances the Surface Street Control and Freeway Control Market Packages by adding the communications links and coordinated control strategies that enable Interjurisdictional traffic control. This market package provides for the sharing of traffic information and control among traffic management centers to support a regional control strategy. The nature of optimization and extent of information and control sharing is determined through working arrangements between jurisdictions. This package relies principally on roadside instrumentation supported by the Surface Street Control and Freeway Control Market Packages and adds hardware, software, and wireline communications capabilities to implement traffic management strategies, which are coordinated between allied traffic management centers. Several levels of coordination are supported, from sharing of information through sharing of control between traffic management centers.

The DalTrans tailored Regional Traffic Control market package is shown in Figure 16.



**Figure 16. ATMS07 – Regional Traffic Control market package**

#### *4.2.1.4 Concept of Operations Element: Operational Needs*

Description – According to the ANSI/AIAA document, the purpose of this section of a Concept of Operations is to provide a mechanism for relaying an identified need for enhancement of the existing and proposed system. Within the Concept of Operations document, it links the User-Orientated Operational Description with the System Overview – within the Systems Engineering Life Cycle, it provides the basis for requirements development.

Guidance in Developing – The ANSI/AIAA document recommends that the questions that should be answered in this section include: What is the old system (if any) lacking that should be addressed? What will the new system require in order to get the job done? If the system exists, developers will discuss how the current system lacks some particular function that is now necessary for the system to allow the organization to meet its objectives. As such, what evolves is a list of features required to accomplish the earlier identified goals and objectives. There is tremendous variance within the domain as to how this is accomplished. This includes developing entirely separate documents that review need, to developing simple lists of justification for changes to an existing system.

#### Issues to Consider –

- User needs assessment – The development of a new system, and therefore the development of a Concept of Operations may occur before, during, or after an officially or unofficially mandated ‘user needs assessment’ has been developed. The linkage between Concept of Operations and such an activity will be crucial.
- Analysis of current system function – as previously stated, an existing system will require a change in design as the mission and goals of the organization transform over time.

Examples of Operational Needs Definition from TMS Concept of Operations Documents – The following examples provide an excellent description of the needs that may be identified in a Concept of Operations document.

**Example 1 - *The following current system weaknesses need to be addressed by the Oregon TOCS project:***

- Multiple software packages must be open and available for use to support operations. Some of the problems associated with using multiple software packages are: duplication of effort, inconsistent response, the occupation of valuable screen space, and less than optimal response times.
- There exists a need for robust ad hoc and comprehensive pre-formatted reporting tools for system and operations management.
- Information is not exchanged between subsystems. The data should be centralized and shared between many types of providers including emergency personnel, transit providers, and highway helpers.
- Region 2 has statewide backup capability for radio dispatch and control to any region's crews and maintenance personnel; however, in most system functions, the TMOC can't backup the TOC, and the TOC can't backup the TMOC.
- There are too many VMS applications in use due to the need to use specific software for each vendor's sign. This is a training and system maintenance problem. This is an especially serious problem in backup situations where the TOC doing the backup may not even have the correct software for a given sign.
- The current CAD system is optimized for law enforcement.
- Systems are not well integrated with external emergency services partners
- Systems are not optimized to support transportation operations and maintenance.
- O&M-specific applications have been homegrown to support immediate needs and are not architected to sustain and support operations statewide.
- There is a need for additional weather alarm systems with integrated notification processes.
- Currently district offices are unable to enter incidents into the CAD system. This is a significant problem for efficient incident tracking and management reporting purposes.

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TMS Experience

**Example 2 -** *The Cross Westchester ITS Concept of Operations document discusses the following needs for the video surveillance function of the system:*

### VIDEO SURVEILLANCE

The video surveillance camera subsystem should provide the capability to monitor traffic headway and to verify incidents relative to their operational locations. Video equipment must be remotely controllable and generate standard video signals for routing to the TMC.

More specifically, the video functional element should as a minimum include:

- Video information collected through a surveillance closed-circuit television (CCTV) network;
- Selectable presentation of video information to ATMS personnel to support validation of congestion conditions, monitoring of overall traffic flow, confirmation of potential incident detections, and status of incident removal;
- Capability to monitor commercial and public television and cable channels for incident information and weather conditions;
- Management and control of all cameras; and
- Video input and output ports for internal and external organizations, including IRVN, and the NYSTA CCTV's.

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*TMS Experience*

OPERATIONAL CATEGORY	NEEDED PROCEDURES OR PRACTICES	NEEDED POLICIES
<b>FREEWAY MOBILITY</b>	<ul style="list-style-type: none"> <li>▪ <b>Traffic Responsive Ramp Metering</b></li> <li>▪ <b>Notifying Agencies and Organizations of Freeway Incidents</b></li> <li>▪ <b>Removing Disabled Transit Vehicles off Freeways</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ <b>Improve Freeway Incident Clearance Times</b></li> </ul>
<b>ARTERIAL MOBILITY</b>	<ul style="list-style-type: none"> <li>▪ <b>Optimizing Traffic Signals within a City on 100% of the Smart Corridors and Assessing the Coordination Every 2 Years</b></li> <li>▪ <b>Optimizing and Coordinating, if beneficial, Traffic Signals between Cities on 100% of the Smart Corridors</b></li> <li>▪ <b>Grouping of Signals into Control Sections Irrespective of Jurisdiction</b></li> <li>▪ <b>Assessing Coordination Every Two Years</b></li> </ul>	
<b>FREEWAY INCIDENT MANAGEMENT</b>	<ul style="list-style-type: none"> <li>▪ <b>Altering Traffic Signal Timing Plans during Incidents</b></li> <li>▪ <b>Incident On-Scene Coordination and Communications between Public Safety, Emergency Service and Transportation Personnel</b></li> </ul>	<ul style="list-style-type: none"> <li>▪ <b>Shared Operations and Use of CCTV Cameras</b></li> <li>▪ <b>Extraction of DPS CAD Information, where available, and Importing this Information to ADOT TOC</b></li> <li>▪ <b>Shared Operations of State and Local Variable Message Signs</b></li> <li>▪ <b>Placement of Response Vehicles at Incident Scenes</b></li> <li>▪ <b>Removal of Fatalities from Accident Scenes</b></li> </ul>

Figure 4.2 – A graphic from the “Regional Concept of Transportation Operations” document, Final Report, Maricopa Association of Governments, November 2003 – The Maricopa Concept of Operations highlights needs by “operational categories” and derives high-level system functionality based on those identified needs.

#### 4.2.1.5 *Concept of Operations Element: System Overview*

Description – The purpose of the System Overview is to provide a general description of what the system will do, when, and how.

Guidance in Developing – The most important feature of your System Overview should be a high-level diagram of your system. This can convey immediate meaning to the readers as to the intended operation and context of your system. For some, this may actually be the starting point of the concept development. In the table below, the ANSI/AIAA document provides further insight into what ought to be included; an attempt should be made to document these both in text and, especially, in graphics. With specific regard to the states and modes of the system, it may be necessary to graphically capture the normal state for the overall system overview, and then re-utilize the graphics under various states and modes during scenario development.

**Table 4.2 – System Overview Guidance**

<i>ANSI/AIAA recommended inclusion</i>	<i>How to Develop a Concept of Operations Guidance</i>
System scope	The section should convey the geographical boundaries of the system, and the range of participating stakeholders.
Users	The users should be identified in their respective relationships to the remainder of the system.
System Interfaces	The section should identify and describe both internal and external interfaces: how entities within the system relate to one another, and how different aspects of the system relate to entities outside the system.
System states and modes	Operating modes and states should be identified, for example, 'start-up' or 'shut-down' or 'emergency' or 'normal', as well as demonstrating how any of the other system components change in such a state.
System capabilities	The system overview section should describe all the high-level capabilities of the system.
System goals and objectives	The goals and objectives conveyed in the scope section should also be included in the system overview section in order to show traceability between system capabilities and goals of the system. It is important to see some user mode or capability of the system for each high-level goal to ensure that stakeholders see that the system has a way to meet their particular goal or objective.
System architecture	A high-level interrelationship architecture should be presented.

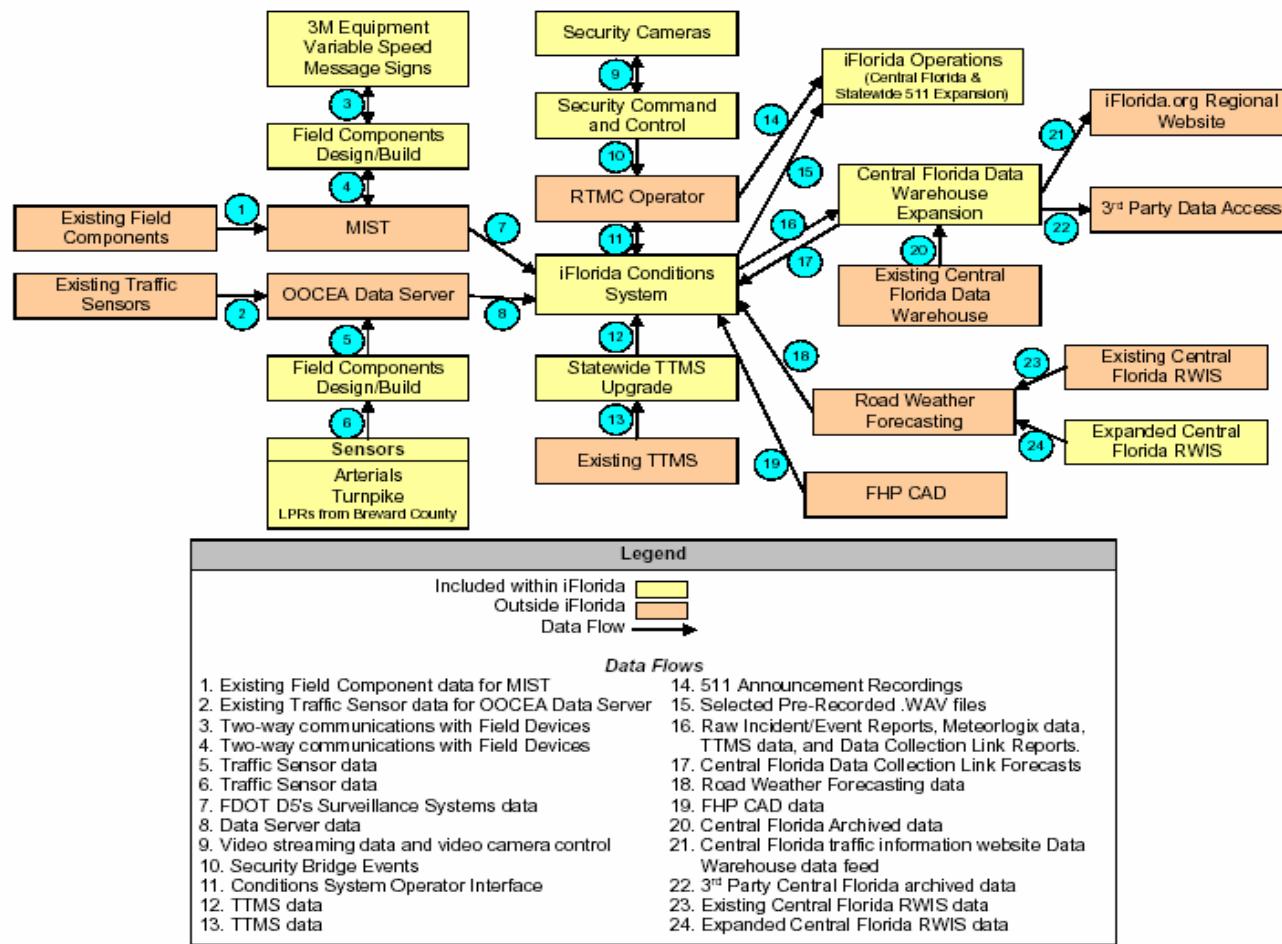
Because this element of the Concept of Operations attempts to describe such a wide range of information to the reader, it is strongly suggested that a diagram be employed in conveying this information. It is important to show, all at once, the interrelationships among users, system functions, and external entities that give the reader a clear high-level viewpoint of the system as a whole.

*Document Highlight*

### Issues to Consider –

- Complexities in system overviews are often summarized well in a diagram – a picture speaks 1000 words – The section is intended to describe all aspects of the system at once, which is typically a difficult task. Often, this information is best conveyed via a systems diagram since that is a way to concisely communicate a large amount of information concerning both the components and functions of the system as well as all the interfaces among them.
- This is not an architecture, nor a requirements document, but only the foundation – In many cases, individuals confuse the system overview (particularly a system diagram) with architecture. It should be noted that these are different entities with different purposes. The System Overview is holistic, giving as much interest to policy and organizational constraints as it does to technological system components and arcs; the architecture focuses on the system's organizational and technological interrelationships, flows, and states.

Examples of System Overview from TMS Concept of Operations Documents – Two examples follow (Figures 4.3 and 4.4) that illustrate the power of providing a graphical depiction of the conceptual TMS.



**Figure 1.1: Overall System Data Flow**

Figure 4.3 – iFlorida's System Data Flow diagram, iFlorida Draft Concept of Operations, Florida Department of Transportation, 2003 – This flow diagram shows interactions among the functional aspects of the system. It does a good job on capturing the entire system.

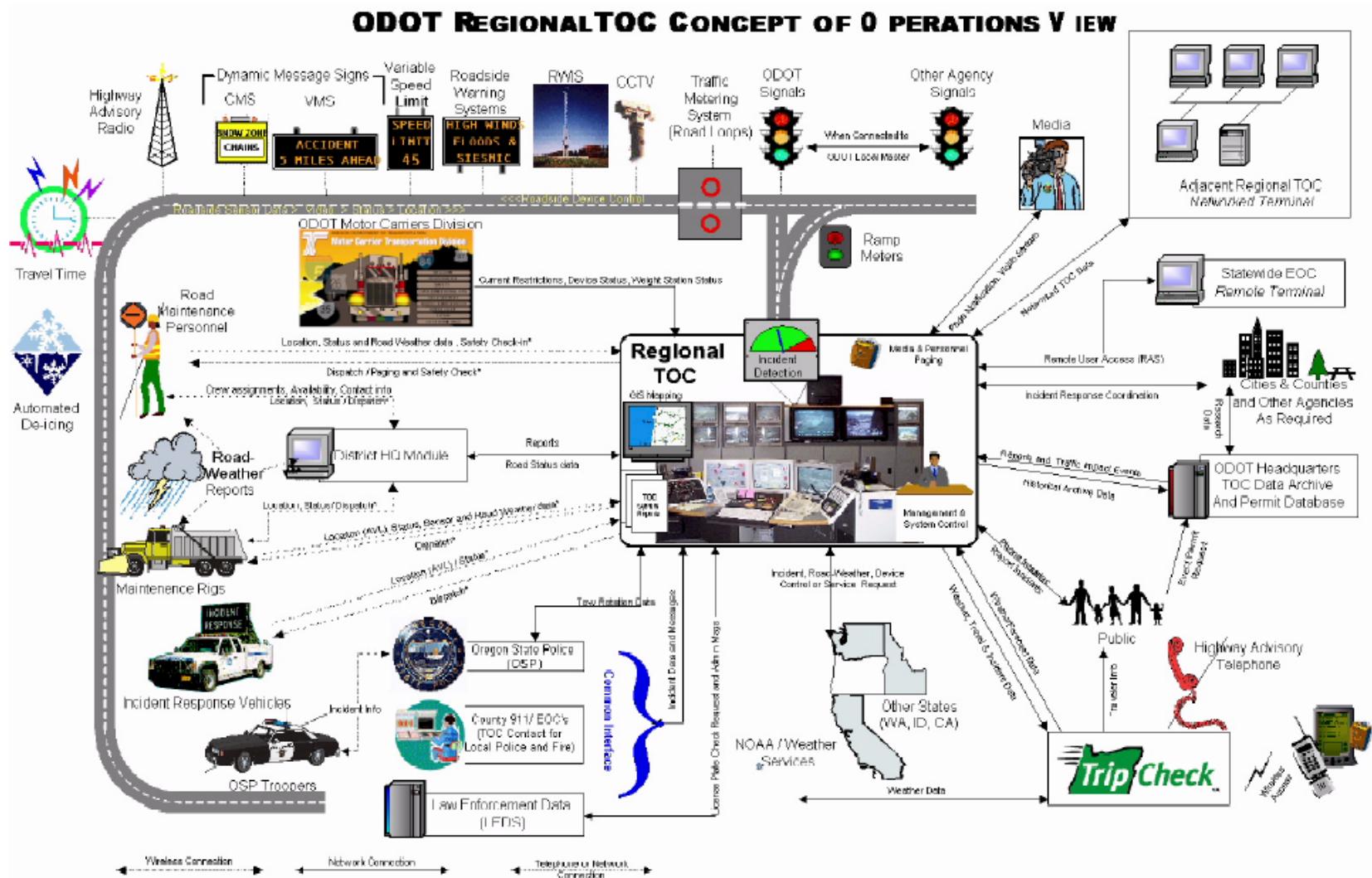


Figure 4.4 – The Oregon TOCS System Overview Diagram, Traffic Operations Center System Concept of Operations Final Version, Oregon Department of Transportation, 2002 – A superb synopsis of the system as a whole, it conveys the information to a broad audience.

#### *4.2.1.6 Concept of Operations Element: Operational and Support Environments*

Description – This element provides: a description of the required physical operational and support environments in terms of facilities, equipment, computing hardware, software, personnel, operational and support procedures, and support necessary to operate and maintain the deployed system.

Guidance in Developing – The ANSI/AIAA standard identifies two environments that need to be described: an Operational Environment and a Support Environment. However, from the perspective of a Concept of Operations for a developing TMS, there is considerable overlap, and for this reason, we recommend one section to deal with both topic areas. In describing the Operational and Support Environments, the writing team should consider having sub-sections that consider the following:

- Facilities – The section should identify physical facilities necessary to meet the needs of the fully functional system (e.g. buildings, garages, etc.).
- Equipment – It should describe, at a high-level, equipment necessary for the system to be operational (e.g. closed circuit TV cameras, variable message signs, etc.).
- Hardware – Typically, this refers to the physical computational machines, or information systems, that the users of the system will access.
- Software – A description of the information system applications necessary for system operations.
- Personnel – The section should describe the personnel necessary to staff all facilities needed for the system to be operational. This should include a concise subset of the system users identified in the User-Oriented Operational Description. Descriptions of the capabilities of these individuals may be generated, but it is generally considered to be beyond a Concept of Operations document; a better place for such descriptions would be the Business Plan for the same system.
- Operational Procedures – If not already addressed within the User-Oriented Operational Description, a description of what and when the users and system components should be performing, under specific conditions.
- Support Necessary to Operate the Deployed System – This category includes all other labor support services that are not specifically designated by the operations of the system. This support could include facility management, accounting/finance, human resources, etc.

#### Issues to Consider –

- The ANSI/AIAA document comments that the availability of information on the computing hardware and software will depend on the approach taken for system development (i.e. software first, hardware first, or concurrent) and the time frame, in relation to the system life cycle.
- Level of detail – Following a path to develop a Concept of Operations to a very detailed level could easily take up a lot of time and money when such detail is not needed at this stage.
- Don't neglect institutional environment – The challenges the development of the Concept of Operations will endure are substantial. The institutional environment will need to be considered, perhaps directly integrated into the Concept of Operations, in order to assure the feasibility of system development.

Examples of Operational and Support Environments from TMS Concept of Operations Documents – The following two examples provide descriptions of operational and support environments, specifically in relation to software systems within a TMS.

**Example 1 — DalTrans gives the following definitions for the system's different modes of operation:**

The DalTrans system will operate in the following modes:

- Normal – This is the normal operational mode of the system in which all services are available. The TMC will operate during normal business hours with a set operational staffing plan.
- Maintenance – This operational mode will be used when system upgrades or repairs are taking place. The system will more than likely be run from a single workstation in this mode.
- Simulation/training mode – This operational mode will be used periodically for the training of a new operator. The user interaction involved in this mode is described in Section 4.5.1.4. January 7, 2002 DalTrans-OCD-1.15
- Emergency – This operational mode will involve the coordination of the DalTrans system and personnel with many external emergency management agencies and the media. There will be other users (possibly not all TxDOT) that will be logging into and using the DalTrans system for emergency management information and control coordination. TxDOT will staff the TMC appropriately until the emergency situation has subsided

*TMS Experience*

**Example 2 — The Arizona DOT Concept of Operations gives the following explanation of computer security:**

### COMPUTER SECURITY

All TOC computer systems are subject to a variety of problems that can degrade performance or compromise the integrity of the system. There are safeguards that every employee must take to maintain the system in proper working order. There are also ethical and legal issues related to equipment use by ADOT employees. The following policies and procedures outline the proper use of ADOT computers.

### COMPUTER SOFTWARE POLICY

"Software piracy" is the illegal copying or use of copyrighted software programs. Federal law prohibits reproducing, transmitting, transcribing, storing in any retrieval system, or translating material into any language by any means without the written permission of the author.

Department employees are not to use computer software in violation of the law. They are not to copy, possess, or use illegally copied (pirated) software in any department facility nor on any department owned or issued computer equipment. This policy includes any copyrighted software purchased by a section or division of the agency that is restricted to a single site.

*TMS Experience*

#### 4.2.1.7 *Concept of Operations Element: Operational Scenarios*

Description – The ANSI/AIAA document recommends that for each identified operational process, there is a description of how the system is used. It should provide typical usage scenarios for each of the operational processes served by the system. Scenarios describe typical detailed sequences of user, system, and environment events.

Guidance in Developing – The ANSI/AIAA document recommends that this portion of the Concept of Operations delve into system processes, given certain system-related events. The operational scenario should tell different stories from perspectives of different user classes over a variety of circumstances. This is a very useful tool in conveying to the reader the event-related usage of the system. It will be through scenarios that the system developer may be able to glean the most information about how to piece the system together – stakeholders and users should be able to easily relate to the system through the ‘story-telling’ means that operational scenarios utilize. There are four basic elements to consider in operational scenario development:

1. Included User’s Perspectives – Key users of the system ought to be included to some degree within each scenario; this should be done by generating a ‘story’ written from the perspective of each key class of user.
2. Variety of User Classes – Incorporating all user classes related to the system will be necessary in assuring system effectiveness (meeting the goals) and stakeholder ‘buy in.’

**Example** — *The Fontana/Ontario Concept of Operations gives different user perspectives for several different scenarios, which are listed below:*

- Fontana TMC Operator
- Fontana Maintenance Operator
- Fontana Engineering
- Police Department: Caltrans District 8 Operator
- Caltrans District 8 Signal Engineer
- Major Event Generator
- Traveling Public
- Ontario International Airport

*TMS Experience*

3. Stress/Failure Scenarios – Special consideration should be given to the ‘extreme event’ scenario. Such a scenario should describe characteristics that could conceivably cause the system great stress – even push it to the point of failure. While it may not be possible to accurately gauge most of the actual failure points of the system, incorporating such thought into the development will most certainly assure that some of the stress points will be identified, and hypothetical solutions developed. Unfortunately, at the writing of this document, there were few identified examples of existing TMS Concept of Operations documents that addressed a stressed or failed system scenario. In the present climate of assuring the graceful degradation of integrated systems to ensure public service and safety, it is of paramount importance to consider such events.

**Example — TxDOT's ATMC Operations Concept Document for Austin includes the following scenario from the document's Chapter 5, Section 5: Incident Management Scenario with ATMS Down and TMC Operator on Duty.**

### Overview

The same basic incident scenario described in Section 5.1. for a major accident is used in this scenario except that the incident occurs during the work day with the ATMS down.

TMC Operator is on duty and communications are operational. The TMC Operator switches the System Control Unit RS-232 interface from ATMS to FTM. The FTM System provides existing incident management capabilities to monitor traffic, detect potential incidents, and monitor and control traffic devices including Lane Control Signals and Ramp Meter Controllers. Cameras are selected and controlled by Control Panels and Pan/Zoom/Tilt Keyboards. Messages are sent to Changeable Message Signs using the existing Master CMS Controllers. The incident is detected by the FTM System and reported to the TMC Operator.

#### 5.51 Detect Incident

FTM:

- Monitor traffic flow on freeways with volume, occupancy, speed, and classification data derived from detector stations along the roadway.
- Detect potential incident based on comparison of current measured occupancy to a pre-defined occupancy threshold limit for the detector station near incident.
- Notify TMC Operator of potential incident and identification of nearest camera with recommended preset and monitor.

#### 5.52 Evaluate Incident

TMC Operator:

- Initiate incident report.
- Select and control camera to find and view incident scene.
- Verify incident as true incident report or false report.
- Assess precise location, severity, and condition of incident; impact on traffic and roadway; and access to incident.
- Notify emergency services. Message includes verification, location, severity, conditions, and impact.

*TMS Experience*

4. Multiple Circumstances – More than one scenario with multiple associated sub-events will be necessary to develop a rich enough picture and storyGiven the specific function of the TMS, each stakeholder should be able to generate a concept of how they will utilize the system and under what circumstances – each stakeholder may be able to generate more than one. These stakeholder usage characteristics can easily be revised into hypothetical scenarios.

*Example — The Cross Westchester ITS Concept of Operations offers three sample operational scenarios:*

- Truck Rollover-Related Closure
- Roadway Debris Report
- Operational Support Request

*For the Truck Rollover-Related Closure, five functional areas were discussed in detail:*

- Incident Detection
- Incident Verification
- Incident Response/Dispatch
- Incident Monitoring
- Incident Closure

*TMS Experience*

### Issues to Consider –

- Scenarios as system “stories” from various vantage points - As the ANSI/AIAA document identifies, the most important part of the Concept of Operations document, the scenarios, help to reveal the developers’ vision of how the system should operate under a wide variety of circumstances, and from a wide variety of vantage points. In some sense, all of the previously mentioned information collection and elucidation was mounting to build these scenarios. They allow the developer to conceptually test the system prior to building the system. The greatest challenge is not whether to generate scenarios, but rather how many to generate.
- The number of scenarios needed – One naturally wants to avoid generating too many scenarios, but performing too few may also be detrimental to your Concept of Operations development. As mentioned above, the ANSI/AIAA standard considers scenarios as one of the most useful and important features of the entire Concept of Operations document. One final note; the list below suggests that a TMS developing a Concept of Operations might end up developing hundreds of scenarios. However, as scenarios are thought pieces and there is an interest in being cost effective (brief) in generating a Concept of Operations, much of what follows for consideration may be rolled up into a handful of scenarios.
- Consider active user and stakeholder focus – The number of scenarios will be dependent on the number of primary, high-level, uses core users and stakeholders will have for the system. While your organization may have multiple users and stakeholders involved in its system, there may only be a handful that are either the primary system operators or entirely dependent on the system’s

existence for their operations. As such, developed scenarios should emphasize these, while referencing the other, more peripheral, users and stakeholders.

- Consider unique features – The number of scenarios will be dependent on the number of unique features in the system. There may be characteristics of the system that have never yet been deployed in a TMS, as such, it will be especially important to include these features in scenarios.
- Consider system boundaries – The number of scenarios will be dependent on the system's boundaries- spatially, temporally, or functionally. For spatial boundaries, develop scenarios that demonstrate how the system interacts with a geographically neighboring system that is functionally relevant. For temporal boundaries, develop scenarios that demonstrate how the system interacts with functionally relevant systems throughout its critical life cycle phases. Finally, for functional boundaries, develop scenarios that relate to systems that are functionally associated but peripheral.
- Consider system states – The number of scenarios will be dependent on the number of critical system states – that is, normal operation, stressed, failing, etc.

Examples of Operational Scenarios from TMS Concept of Operations Documents – The following examples provide a sample of a couple of very good scenario sets developed for two TMS Concept of Operations documents.

**Example 1 — iFlorida presents the following operational scenarios for the iFlorida Conditions System, an integration of current traffic information from sources all over the state:**

In the normal, automatic operating mode, Conditions System data will be collected, fused, and disseminated to FDOT and travelers via the web sites and the 511 systems. In the alert mode, the Conditions System will automatically provide alerts to the RTMC operator that something requires immediate attention. Below are sample scenarios that would initiate an alert mode.

**Calculating a Roadway Diversion Message** – The Conditions System will calculate and compare the travel times a southbound trucker or other traveler might encounter while traveling from the northern intersection of I-4 and S.R. 417 to the I-4 Disney area. For this to occur, two calculations will have to be completed - one for traveling to Disney via I-4 and the other for traveling to Disney via S.R. 417. The Conditions System will perform these calculations using both real-time and Data Collection Link forecasting capability.

If an accident occurs on either of these two roadways, the Conditions System operator will be alerted and the Conditions System will re-calculate the travel times for these two critical roadways. The Conditions System operator will then request that the RTMC operator change/update the appropriate DMS.

**Localized Weather Event** – The Conditions System will provide thunderstorm and tornado bulletins (alerts) for the next hour, as well as 15 and 30-minute forecasts for significant storm motion that will likely affect a roadway segment. Weather-related alerts will be available to the RTMC operator via the Operator Interface and to the public via the statewide website and/or the Central Florida website, depending upon which roads are affected. The weather model deployed as part of iFlorida will also provide the Conditions System operator with Road Speed Impact data, current observational data, and storm corridor data. Road Speed Impact is a short-term "nowcast" of the road speed index (delivered as a "flow factor" where the factor is a percentage (%) of the posted speed limits).

Road Speed Impact is based upon current precipitation levels and can provide Conditions System operators with a valuable tool to assist in managing traffic by giving an estimate of how travel times are affected by inclement weather. If the RTMC operator determines that the alerts are severe enough to warrant updating the 511 Telephone service, the RTMC operator can create an override message, or messages, which the Conditions System will deliver to the Central Florida and/or statewide 511 Telephone service.

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TMS Experience

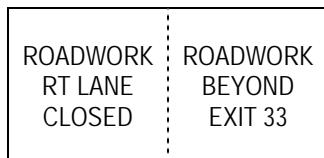
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**Example 2 —** *The Traffic Operations Plan for Massachusetts Highway Department's Regional Traffic Operations Center gives the following scenario for scheduled road maintenance and lane closure:*

### Road Maintenance/Planned Lane Closure

It is now 1:20 in the afternoon. The operator responsible for the northern portion of the network hears an alarm from her terminal. Yesterday, the RTOC received notification from District 4 maintenance that they intended to replace a failing lamp on the southbound side of I-93 just south of Roosevelt Circle at 1:30 PM. The information was entered into the event scheduler by an operator yesterday, and was reviewed by today's operator at the beginning of her shift. The system is now advising the operator that a planned event is about to begin and indicates the appropriate CCTV camera for monitoring the event. The operator pans the system-suggested camera over to the specified work area so that she will be ready to invoke a response when the work crew appears on the scene.

At 1:25 PM, a maintenance truck arrives, escorted by a police car, and the crew proceeds to place traffic cones to close the right-hand lane. The operator informs the system that the planned event has begun ahead of schedule, and the system displays the suggested response, which is a pre-coded message to be displayed on the portable VMS upstream:



The operator approves the message and then shifts the camera upstream of the lane closure to monitor traffic encountering the work area. The maintenance work is, of course, planned and carried out so as to cause the least disruption to traffic. Nevertheless, if traffic does start to back up, the operator and the system are prepared to treat this situation like any other lane-blocking event. If other problems occur, the operator also has the ability to record the CCTV camera feed to videotape for future reference.

At 2:00 PM, the operator receives notification from the District 4 foreman that the crew has completed its assignment and is ready to leave the site. As the truck pulls away, the operator terminates the planned event, and the message is removed from the upstream VMS.

*TMS Experience*

## 4.3 Resources Required for Concept of Operations Development

There is no simple recommendation for proscribing the necessary collection of resources needed for the generation of a Concept of Operations document; this will vary greatly from system to system depending on institutional issues, as well as the size and scope of the system in question. However, there are a few issues to consider:

- *Logistics of a major development – The undertaking of a new system, beginning with the Concept of Operations, involves a tremendous logistical effort. The owning organization should seek out experienced professionals to bare the brunt of the load for select tasks – let their expertise work for you. The acquisition of experienced professionals may include the employment of consultants. However, this does not imply that the owning agency may wash their hands of the Concept of Operations development, rather the writing and the facilitation will be placed on the experts' shoulders while the thinking necessary for the system design and function will be placed squarely on the shoulders of the owning agency and, later, the other stakeholders.*
- *Appropriate Concept of Operations drivers – It would be an error for an organization to pull up one of its own technical system operators to lead the Concept of Operations development. While their insight invaluable to select characteristics of the system, their perspective may be far to narrow to facilitate good overall system development.*
- *Staffing, Duration, and Funding – Information gathered from surveys and interviews suggests that the average development team for a Concept of Operations is between 2-4 people, and that typically this is not the sole project on which involved staff members work. The development processes of those interviewed and surveyed took no less than two months and no more than six months. Budgeting for a Concept of Operations development depends heavily on the salary of the members of the team and the size of the project. Project budgets of those researched here varied from \$10,000 to \$400,000. It is clear that the scope of the project will greatly affect the staff time and funds that are necessary for completing a Concept of Operations. A single center that is developing a Concept of Operations can expect to be on the minimum of the ranges given, whereas a multi-agency integration project can expect to have a significantly larger budget and staff.*

## 4.4 Stakeholder Identification

The ANSI/AIAA standard explains a Concept of Operations as being written to afford better understanding of the system at hand for a wide variety of key players. Many stakeholder groups are readily apparent in the early stages of system development, but others are identified later in the process, as system definition and scope become more detailed. It is beneficial to separate stakeholders into internal and external groups. Internal stakeholders are those individuals, groups and organizations that are considered within the scope of the system. External stakeholders entail those individuals, groups, and organizations that are outside the defined scope of the system but interact with the system. Here are some general attributes of each class:

Internal Stakeholders	External Stakeholders
<ul style="list-style-type: none"> <li>• Within in the primary organization(s) that is developing or operates the system</li> <li>• Play a significant role in system function</li> <li>• Are significantly affected by changes in system design and function</li> </ul>	<ul style="list-style-type: none"> <li>• Interact with the system but are outside the scope of the system</li> <li>• Play a secondary role in system function or are only affected by system function</li> </ul>

Figure 4.5 – Highlights of the Different Attributes of Internal and External Stakeholders

It is important to include both internal and external stakeholders throughout the development process of the system. Internal stakeholders will surface more quickly since system definition will begin with organizations that will use and interact within the system scope. Identification of external stakeholders will become possible as the system definition continues. A more detailed system concept will undoubtedly create more stakeholders, and once these are identified, they should be included in the development process and in the Concept of Operations. Recall that the systems engineering process is iterative, and it is likely that all stakeholders will not be identified on the first try. The Concept of Operations should be a living document throughout the systems engineering lifecycle, and as stakeholders are identified and included in the development process, the Concept of Operations should change along with those additions.

### 4.4.1 Key Stakeholder Categories

It is impossible to create a list that will include every possible stakeholder for any TMS, but there are key classes of stakeholders that will be present in most, if not all, TMSs. Note that these are general categories of stakeholders, and the list for a particular system could be quite different since it will include system specific groups. The categories of stakeholders listed in the ANSI standard include:

- *Users*— This is a very broad category of individuals; as such, it includes any individual, organization, or system, which interacts with the system.
- *Operators*— Staff members who actively manage the system from its core.

- *Maintainers*—Staff within the organization or contracted staff that deal with system upkeep including software, hardware, sources for collecting information (i.e. ESS, CCTV, etc.), and data storage.
- *System Engineers and Architects*—Those internal and/or contracted staff members who design the system from the Concept of Operations stage throughout the systems lifecycle.
- *System Implementers*—Those in charge of building the system or implementing new functionality to an existing system. This can include software coding, implementation of data collection sources, and integration among various sub systems.
- *Customers and Buyers*—Any group that is purchasing some aspect of the system from organizations or contractors outside the scope of the system
- *Testers*—Entails all staff members that test all aspects of the system, from the component level of software development to the completed, working system for user acceptance.
- *Customer and Developer Organization Management*—Managerial-level members of the organizations (commercial or non-commercial) involved in the development or operation of the system in question.

Survey results from transportation professionals identified several different classes of stakeholders including:

- Departments of transportation
- Local government (city, county, etc.)
- Authorities (bridge, port, etc.)
- Local law enforcement
- Emergency response (EMS, fire rescue, etc.)
- Transit operators, state agencies and authorities
- Contractors working on the system
- The public

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*Document Highlight*

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### 4.4.2 Examples of Stakeholder Identification

To see more clearly how existing or developing TMSs handle stakeholder identification, some lists of stakeholders identified in Concept of Operations documents are presented.

**Example 1 — CalTrans TMC Master Plan lists the following partnerships for the state of California's system of Traffic Management Centers:**

*Caltrans*—deals with incident response, planned lane closures, and special events. The Caltrans role also includes designing, constructing, operating, and maintaining the state highway system.

*California Highway Patrol*—is responsible for state highway incident management, emergency road closures, law enforcement, and maintaining the integrity of its automated computer systems and associated information.

*Metropolitan Planning Organizations*—created to provide transportation planning for their communities in urban areas; MPOs are responsible for the development blueprint for mass transit, highway, airport, seaport, railroad, bicycle, and pedestrian facilities

*Local Emergency Responders*—facilitate efficient emergency services to the public, increasing the likelihood of saving lives and reducing congestion and personal injuries.

*Local Mass Transit*—partnerships with transit operators (i.e. bus, train, plane, etc.) are important in making transit ridership a viable alternative to automobile travel. Real-time information provided to and from the transit vehicle allows for vehicle tracking, alternative routing, fleet management, passenger and fare management, maintenance, and security.

*Academia*—their ability to examine, evaluate, and advance available traffic systems technology through student resources provides labor to address current issues while training future professionals for this growing field.

*Media*—partnerships with media are critical in providing accurate information to the public.

*Federal Highway Administration*—provides the means for funding, demonstrating, and implementing Advanced Transportation Systems.

*Private Entities*—these allow collaboration in transportation and information systems projects that need testing, evaluation, and implementation.

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*TMS Experience*

**Example 2 — iFlorida gives the following list of partners on page 7 of the Concept of Operations:**

#### **Project Partners**

The iFlorida Project Team is composed of representatives from all public and private partners involved in iFlorida. These include:

Public Agencies:

- City of Daytona Beach & Orlando
- FDOT District 2 & 5
- FHP, Troops D and G
- Florida Division of Emergency Management
- Florida's Turnpike Enterprise
- Greater Orlando Airport Authority
- LYNX
- METROPLAN
- OOCEA
- Brevard, Orange, Seminole, and Volusia Counties
- USDOT
- University of Central Florida's Advanced Transportation Systems Simulation
- University of North Florida

Private Organizations:

- 3M
- Boeing Autometric
- Cambridge Systematics, Inc.
- International Speedway Corporation
- Meteorlogix
- PBS&J

Together, their role is to facilitate full program team communications. To this end, iFlorida Project Team partners have agreed to host full program team meetings on a rotating basis.

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*TMS Experience*

From these examples, it is clear that there is a wide range of entities that are considered stakeholders. Listing the group of stakeholders in the Concept of Operations document has the major benefit of building goodwill with stakeholders by making them all feel included in the development process. Benefits of stakeholder involvement will be discussed further in the next section on stakeholder involvement.

## 4.5 Stakeholder Involvement

How does one involve stakeholders in a constructive way? Active participation among stakeholders is essential for a successful Concept of Operations development. Advice obtained from transportation professionals overwhelmingly illustrates that stakeholder involvement is necessary, and that the sooner it is done, the better.

All discussions with TMS professionals identified the critical role of stakeholder identification and involvement in the Concept of Operations development process. One noted that “the most important item [in the systems development process] is getting the stakeholders involved and building consensus with regards to systems outcomes, not processes, in order to create a clear vision for the system.”

*TMS Experience*

Another testimonial from transportation professionals highlights the importance of stakeholder consensus: “The biggest benefit [of developing and using a Concept of Operations] is getting all the stakeholders to agree on what they all need to do for each other.”

*TMS Experience*

It is clear that TMS professionals agree that stakeholder involvement is essential. The next sections offer some specifics concerning the benefits of stakeholder involvement for the systems development process.

### 4.5.1 Goal Definition within Organization

Interview information suggests that it is essential for the leading stakeholder or owner to establish its own goals and objectives before opening up to other stakeholder input. Virginia Department of Transportation’s Hampton Roads Smart Traffic Center refers to this as an “incubation stage.” It is critical in this phase that the goals within the organization are aligned before attempting to agree on system function with a group of stakeholders with different, and perhaps competing, interests. If this process is overlooked, the stakeholder agreement can become more difficult than it already is since certain organizations in the process have not yet come to a consensus on vision, goals, and desired function for the system.

A TMS professional recalls the development process for a Concept of Operations: “We didn’t start with bringing the stakeholders in for a first meeting. We had task force meetings within the department to come to a consensus for our organization. This presented a unified front during stakeholder meetings.” This process decreases confusion of communication among stakeholders and presents a unified front for that organization.

*TMS Experience*

#### 4.5.2 Addressing Needs of all Stakeholders

Research suggests that problems occur during the development phase of a project if all stakeholders do not feel like their mission/goals are being met. All parties do not necessarily have to agree on every aspect of the system, but all stakeholders must feel like they are not compromising their major goals as an organization by agreeing to some aspect of the system. A specific TMS professional recollects that the Concept of Operations "would not have been successful without each organization feeling like it could meet its goals and objectives."

Most agree that stakeholder consensus is necessary, but that it is also a challenging process for a TMS that is developing a Concept of Operations. Goal alignment among stakeholders is not always easy, but it is necessary for the success of the system. The following testimonials discuss how TMSs have tackled the issue of stakeholder discussion and goal alignment.

The Emergency Transportation Operations meeting suggested that sometimes a quid pro quo system of negotiating is sometimes necessary to get stakeholders on the same page. The example used was a traffic management center asking what it could give local law enforcement to get on the same page in responding to an emergency. Dialogue among stakeholders here was important—many transportation officials here felt that law enforcement did not even know what transportation organizations could bring to the table.

*TMS Experience*

Jurisdictional concerns also plague stakeholder negotiations. The Capital Wireless Integrated Network (CapWIN) is developing a system to share incident information between public safety and transportation agencies operating within metropolitan Washington, DC. Jurisdictional concerns are at the heart of the issues involving the development of the system. Stakeholders were forced to migrate from informal inter-organization arrangements to formal ones, which put a tremendous weight on defining, conceptually and legally, who would do what and when.

*TMS Experience*

## 4.6 Definition of Performance Measures

Goals and objectives drive requirements development for the operation of a system, but measuring how close or how far one is from those goals and objectives once the system is operational requires some sense of system performance. Metrics may be developed for nearly every level of the system, for each stakeholder and for each stakeholder sub-system. As the Concept of Operations facilitates the communication of the systems' goals, it is an appropriate place to communicate how those goals will be measured. By generating initial performance measures in the Concept of Operations, System Acceptance and System Validation plans, system developers will have a basis from which to build for the later half of the Systems Engineering "Vee." It should be noted that the system will change, and expectations for the system will change over time as it is built, and as such, performance measures outlined in the Concept of Operations, should be high-level enough, or flexible enough, to allow for some re-interpretation and application.

Generally, in TMS, the Concept of Operations developer will need to consider at least these performance measure focus areas:

- Applied System – The final built system is intended to improve some characteristic of the transportation world external to itself; as such, performance measures may be developed to explain the before and after system-states of some transportation characteristic of interest. Examples include: travel time or travel cost.
- Inter/Intra – The system will have features unique unto itself that may be useful to measure to determine efficiency of its own operation. One example is system reliability.
- Peripheral – The system may have associations with other systems, technically or organizationally, that may be of interest in measuring; such measurements may address both applied system performance and inter/intra system performance. For example, regional traveler level of satisfaction with regional transportation services.

#### 4.6.1 Examples of Performance Measures

Figure 4.6, below, provides a sample of performance measures used in conjunction with CalTrans TMSs. Figure 4.7 provides a sample of performance measures associated with the Maricopa, Arizona's regional transportation activities, which demonstrates a very unique way of presenting such measures.

### APPENDIX B: CALCULATION OF ANNUAL SAVINGS\*

#### Reduction in Congestion

Recurrent Congestion<sup>1</sup> = 315,506 veh-hr/day  
 Recurrent and nonrecurrent congestion<sup>2</sup> = 630,952 veh-hr/day  
 Cost per vehicle hour<sup>3</sup>  
     Trucks = \$24/hr      Auto = \$9/hr  
 Percent of traffic which we account for as trucks<sup>4</sup>  
     Heavy Duty Trucks = 5%  
 Percent of reduction in congestion with a TMC<sup>5</sup>  
     Reduction in recurring congestion = 15%  
     Reduction in nonrecurring (incident related) congestion = 30%  
 Number of normal work days per year = 250  
 Cost for mix vehicles per hour  
     5%(\$24/truck-hr) + 95% (\$9/auto-hr) = \$9.75/veh-hr approximately = \$10/veh-hr  
     (This is conservative since we only account for heavy duty trucks without including light and medium duty)  
 Congestion per year  
     Recurrent = 315,506 veh-hr/day x 250 day/yr = 79 million veh-hr/yr  
     Nonrecurrent = 630,952-315,506 veh-hr/day x 250 day/yr = 79 million veh-hr/yr  
 Reduction in Congestion per year  
     Recurrent = 79 mil veh-hr/yr (15%) = 12 mil veh-hr/yr  
     Nonrecurrent = 79 mil veh-hr/yr (30%) = 24 mil veh-hr/yr  
 Reduction in Cost per year  
     Recurrent = 12 mil veh-hr/yr (\$10/veh-hr) = \$120 mil/yr  
     Nonrecurrent = 24 mil veh-hr/yr (\$10/veh-hr) = \$240 mil/yr  
**TOTAL = \$ 360 million/year**

#### Reduction in Fuel Consumption

Excess fuel<sup>6</sup> = 1,084,606 gal/day  
 Fuel cost/gallon<sup>7</sup> = \$1.23/gal  
 Reduction in fuel consumption cost = 1,084,606 gal/day x 250 day/yr x 23% x \$1.23/gal  
**TOTAL = \$80 million/year**  
 (23% is the average reduction in congestion for recurrent [15% reduction] and nonrecurrent [30% reduction])

#### Reduction in Accidents

Accident data<sup>8</sup> (Urban Freeway Total for California, 1995)  
 Property damage only = 59,281 incidents  
 Injury = 27,157 incidents  
 Fatal = 487 incidents  
 Cost of accident<sup>9</sup>  
     Property damage only = \$1,396/incident  
     Injury = \$14,095/incident  
     Fatal = \$831,919/incident  
 Reduction in accidents with a TMC<sup>10</sup> = 25%  
 Reduction in Accident Cost = (25%)[(59,281x\$1,396)+(27,157x\$14,095)+(487x\$831,919)]  
**TOTAL = \$220 million/year**

#### Total Savings

TOTAL = Reduction in: Accidents+Congestion+Fuel Consumption  
**TOTAL = \$660 MILLION**

Figure 4.6 – From CalTrans' 1997 TMC Master Plan, Appendix B: Calculation of Annual Savings – This diagram shows a detailed list of performance measures intended to illustrate improvement following the deployment of a TMC.

## Performance Measures

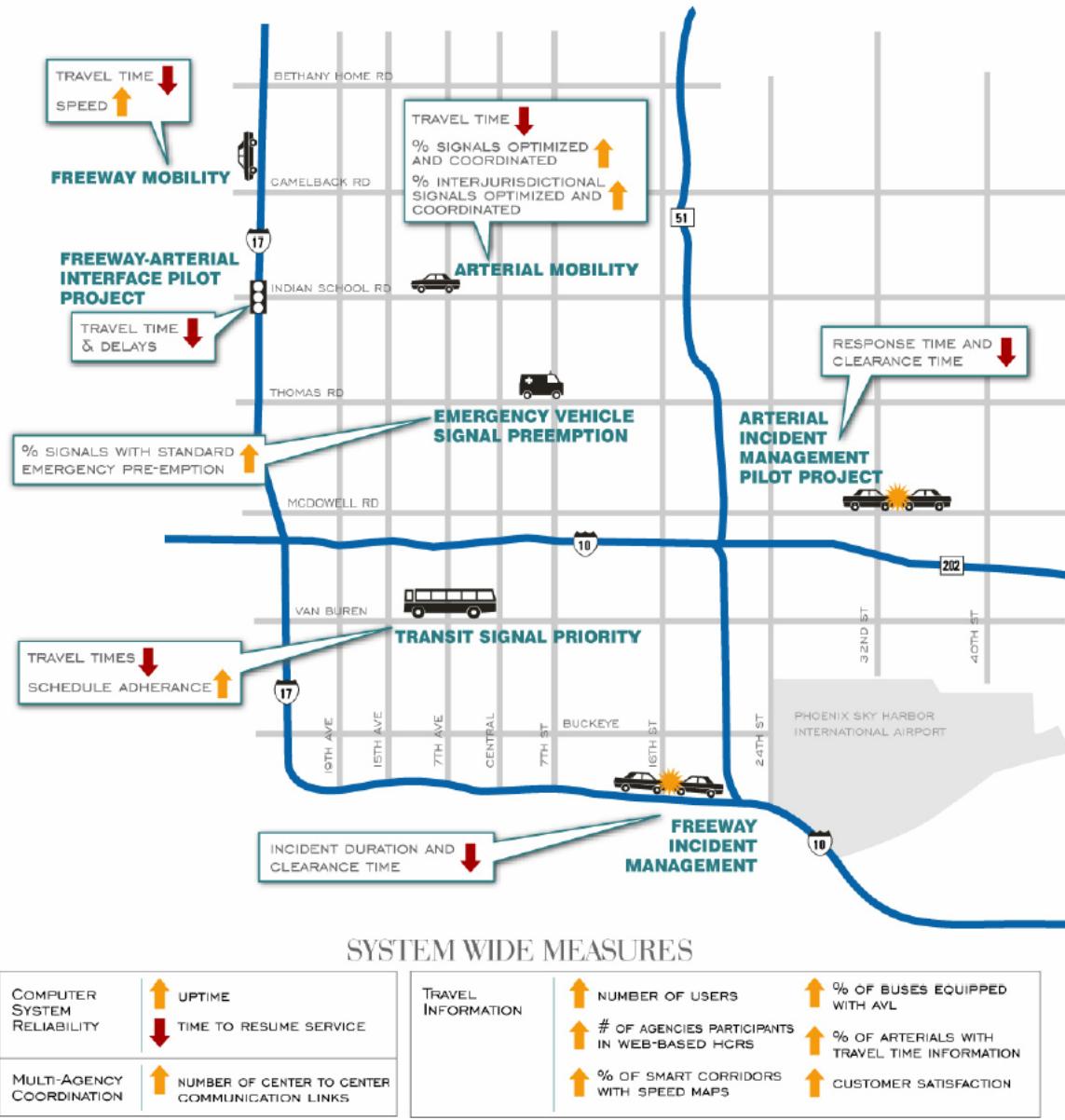


Figure 4.7 – Performance Measures – A graphic from the “Regional Concept of Transportation Operations” document, Final Report, Maricopa Association of Governments, November 2003 – This diagram shows high-level performance measures for the different aspects of system function.

## 4.7 Key Resources for Writing a Concept of Operations

Reference documents and standards that assist in the composition of the Concept of Operations are identified and described below.

- *Guide for the Preparation of Operational Concept Documents.* (ANSI/AIAA G-043-1992). American National Standards Institute, 1992. This report gives guidelines for creating a Concept of Operations document. It includes practical information on applying and packaging the operational concept technique and an example of the process's application to the development of a major NASA system.
- *Transportation Management Center: Concepts of Operation.* Intelligent Transportation Systems. Report No FHWA-OP-99-029. Dec 1999.  
[http://www.itsdocs.fhwa.dot.gov/jpdocs/rept\\_mis/8v@01!.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/rept_mis/8v@01!.pdf) - This document focuses on Transportation Management Centers (TMCs) and concepts of operations. It discusses the importance of concepts of operations, the reasons agencies need them, and the challenges a transportation management center faces when planning, maintaining, and operating the system.
- *National ITS Architecture,* <http://www.its.dot.gov/arch/arch.htm>. - This resource is a comprehensive collection of information designed to aid in the development and implementation of intelligent transportation systems. The Theory of Operations within the architecture should be particularly helpful. The Architecture is also useful in identifying most of the components that will be found within any TMS. As such, it serves as a terrific starting point for defining and refining a TMS concept. Specifically, per the National ITS Architecture, it provides details into:
  - *User Services – ...describe what the system will do from the user's perspective. ... A set of requirements covering each of these User Services is the basis for the National ITS Architecture definition.*
  - *Logical Architecture – ... defines the Processes (the activities or functions) that are required to satisfy the User Services. Many different Processes must work together and share information to provide a User Service. Data Flows identify the information that is shared by the Processes.*
  - *Physical Architecture – ...forms a high-level structure around the processes and data flows in the Logical Architecture. The physical architecture defines the Physical Entities (Subsystems and Terminators) that make up an intelligent transportation system. It defines the Architecture Flows that connect the various Subsystems and Terminators into an integrated system. The subsystems generally provide a rich set of capabilities, more than would be implemented at any one place or time. Equipment Packages break up the subsystems into deployment-sized pieces.*
  - *Market Packages – ...represent slices of the Physical Architecture that address specific services like surface street control. A market package collects together several different subsystems, equipment packages, terminators, and architecture flows that provide the desired service.*

## 4.8 Guiding Principles

### What questions must be answered by the Concept of Operations?

The Concept of Operations should explain the who, what, when, where, why and how of the system, with respect to a variety of stakeholders. Technical expertise is not necessary to develop a Concept of Operations, but it is essential in the overall system development process. Building the development team quickly with a focus on the core stakeholders of the system will facilitate the Concept of Operations development process.

### Stakeholders

Identification and Involvement — Identifying stakeholders early in the development process will ensure that all groups who are a part of the functioning system or who interact with the system will be included in the system development process. This will allow goal alignment between goals of the system and those of the stakeholder organizations. Advice given from TMS professionals highlights this as the key to a successful Concept of Operations development process.

### How to Develop the Elements of the Concept of Operations

- *Scope* — This element should outline the contents of the document, set the scope of the system, describe the purpose of the system, highlight the goals and objectives for the system, identify the intended audience of the system, and convey a vision for the system.
- *Reference Documents* — Documents that will be beneficial in developing a Concept of Operations include example Concept of Operations documents, requirements documents, organizational studies and planning documents, and minutes from meetings concerning system development.
- *User-Oriented Operational Description* — This section should explain the operations of all the various aspects of the system, including personnel activities, operational processes, user classes, and any other system interaction. Adequately capturing all of the functionality of the system is essential for writing a complete and useful Concept of Operations.
- *Operational Needs* — Tying system function to organizational needs is one of the main goals of a Concept of Operations. Thoroughly assessing operational needs will align the goals and vision of the system with those of the organization.
- *System Overview* — This section is the place in the Concept of Operations where the system should be summarized, and the most effective way in which to present this information is via a system diagram.
- *Operational and Support Environments* — This section should describe the world in which the system operates, and it should include information about the facilities, equipment, and supporting staff the system needs to function.
- *Operational Scenarios* — The development of operational scenarios using a wide variety of user classes and system functionality gives the reader of the Concept of Operations a more realistic view of the how the system will work.

## Performance Measures

Goals and objectives drive requirements development for the operation of a system, but measuring how close or how far one is from those goals and objectives once the system is operational requires some sense of system performance. Generally, in TMS, the Concept of Operations developer will need to consider at least these performance measure focus areas:

- Applied System – Examples include: travel time or travel cost.
- Inter/Intra System – One example is system reliability.
- Peripheral – For example, regional traveler level of satisfaction with regional transportation services.

#### 4.8.1 Quick-look at the Concept of Operations Development Process

Figure 4.9 below provides a depiction of what features need to be considered, and when, for the development of a Concept of Operations – this summarizes what has been presented in this section.

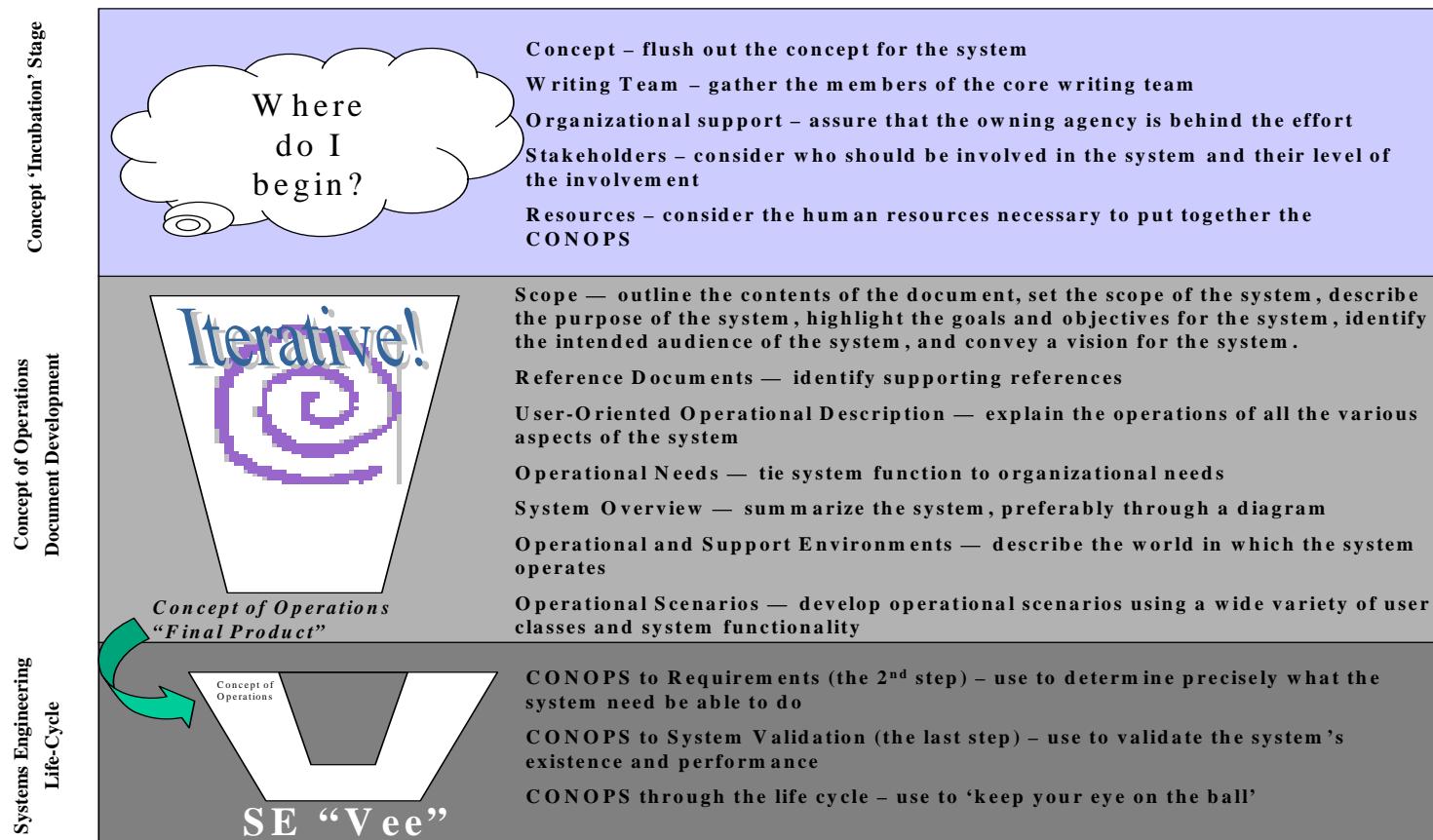


Figure 4.8 – Quick-look at the Concept of Operations Development Process – This graphic presents a summary of all the information contained in Chapter 4.

# CHAPTER 5 – Using the Concept of Operations to Support Planning

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## Chapter Purpose

The purpose of this chapter is to illustrate how the Concept of Operations can be used to support, and is supported by, a wide range of transportation planning activities.

## Chapter Objectives

The key objectives of this chapter are:

- *To document the link between the Concept of Operations and planning.*
- *To provide guidance for both how a Concept of Operations can (a) draw from other plans, and (b) support the development of other plans.*
  - i. *To address the interface with higher-level plans within an agency.*
  - ii. *To address the interface with other operations plans within the region of a TMS.*
  - iii. *To address the interface with plans within the TMS.*

## Relationship to Previous Chapter

This chapter broadens the focus of the guidance document beyond the development of a Concept of Operations to investigate how it is used in planning, and can benefit from other planning efforts.

## Chapter Sections

Brief descriptions of the Chapter 5 sections are presented below.

### 5.1 Systems Engineering and Planning

This section provides an orientation to the reader of this chapter by discussing the Concept of Operations' role in systems engineering and in planning.

### 5.2 “Looking Up” – Agency and Program Level Planning

This section discusses how the Concept of Operations must reflect goals of high-level agency plans. Furthermore, the Concept of Operations can provide excellent input as these larger plans are developed by clearly articulating TMS goals, vision, and functionality. As an example, a long-

term Agency Strategic or Program plan would meet the definition of “looking up” planning in this chapter.

### **5.3 “Looking Across” - Regional Operations Planning**

This section discusses the role a Concept of Operations will play with respect to Regional Operations Planning. A Concept of Operations is an important input into regional operations planning. Furthermore, when a regional operations plan or architecture exists, the Concept of Operations should reflect the regional goals and desired functionality. Regional Transportation Plans and Regional ITS Architectures are examples of “looking across” planning.

### **5.4 “Looking Within” - System-Specific Planning**

This section discusses the influence of the Concept of Operations on System-Specific planning. Since planning is such an important activity within a TMS, the Concept of Operations, foundation of the system development process, plays a key-supporting role. This section will provide examples and testimonials from transportation professionals. Operations Handbooks, Event Plans, and Business Plans are examples of “looking within” planning.

### **5.5 Guiding Principles**

This section provides a brief overview of the key information provided in this chapter.

## 5.1 Systems Engineering and Planning

In systems engineering, the Concept of Operations for any TMS serves as the starting and ending points for the development for that system. It provides the very first general descriptions of the who, what, when, where, why, and how that are built upon, using the systems engineering steps to construct the system. Upon the establishment of the TMS, the Concept of Operations supports the validation of the system relative to its original goals and objectives, and the current environment.

From the perspective of the transportation planning community, the Concept of Operations for any TMS serves as a commentary on function and capability at a given moment for a given region. Planners look to the future by examining trends, needs, and capabilities of the present. For planners, the TMS Concept of Operations provides insight into current regional capability, need, and a subset of regional transportation actors' goals and objectives. From the perspective of the TMS Concept of Operations developer, planners and their documents provide many things - primarily knowledge into regional players and regional prioritization of goals as expressed either explicitly through statements of strategy or program, or implicitly, through the expression of relative allocation of fiscal resources.

The TMS Concept of Operations is a document that effectively supports a wide range of planning activities. In addition, an effective Concept of Operations will "pull" information from a wide range of planning documents. For the TMS Concept of Operations developer and user, the question arises, "How does the Concept of Operations "link" with transportation planning?" From that relative position, it is useful to consider planning activities from three perspectives.

### 5.1.1 Planning categories

For the sake of structuring this chapter, planning is considered in the following categories as described in Figure 5.1.

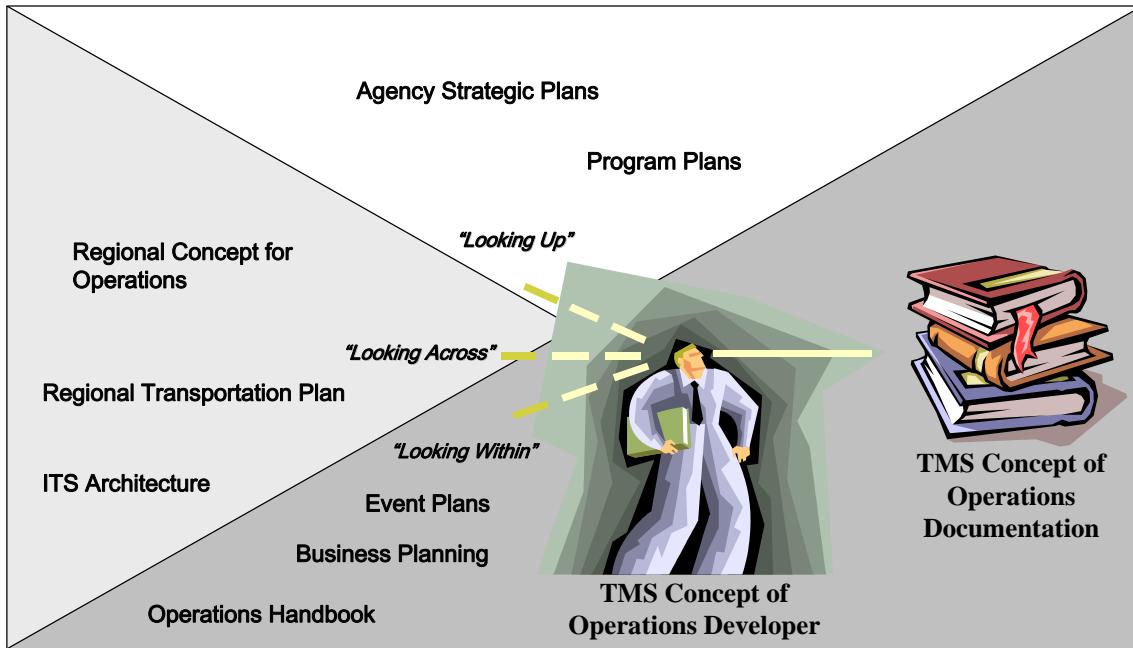


Figure 5.1 – Links from Concept of Operations development to Planning – This diagram shows the relationship of the TMS Concept of Operations Developer, and TMS Concept of Operations Documentation, to the activities and resources of transportation planning.

- "Looking Up" - In this section, plans and planning procedures at a high level ("above" the TMS) will be considered. Examples of these plans include:
  - Agency Strategic Plans – Such plans typically reflect an agency's long-range vision to implement, or achieve, an on-going, or newly established, core business competency.
  - Program Plans – Such plans typically reflect an agency's mid- to long-term (5-20 year) programmatic implementation of a specific transportation feature that has been set forth by a legal planning process.
- "Looking Across" – In this section, plans and planning procedures in a single region will be considered. Examples of these plans include:
  - ITS Architecture – Documents the physical, logical, and functional relationships between the information system components that support ITS elements in a region.
  - Regional Transportation Concept for Operations (RTCO) – A multiple stakeholder expression of regional transportation capabilities as focused on achieving a common objective with respect to the operations of that region.

- “Looking Within” – In this section, plans and planning procedures specific to the system itself will be considered. There are numerous activities in this category. For the purpose of this guidance document, this chapter will focus on the following examples of these plans:
  - Business Planning – An expression for executing long-range TMS vision and goals that maintains a strong relationship to strategic and operational plans.
  - Operations Handbook – An operations manual is a critical tool that agencies develop, maintain, and use in managing and supporting the day-to-day operation and activities that are performed within the TMS.
  - Event Plans – Expressions of the use of a TMS to manage events with significant traffic impacts (such as sporting events, concerts, festivals, etc.), occurring in the region.

## 5.2 "Looking Up" – Agency & Program Level Planning

An effective Concept of Operations must reflect goals stated in larger agency level plans. Furthermore, the Concept of Operations can provide excellent input as these larger plans are developed – by clearly articulating TMS goals, vision, and functionality. This is especially important given the relative "newness" of TMSs as alternative strategies to be considered as transportation improvements, as compared to more traditional initiatives such as new roadway construction. This section will explore these issues, in the following classes of plans:

- **Agency Strategic Plans** – Such plans typically reflect an agency's long-range vision to implement, or achieve, an on-going, or newly established, core business competency. Such plans typically originate from the political establishments, as well as the agency's upper echelons, to describe agency motivation and are generally not legally binding. However, their core features will inevitably be linked, implicitly or explicitly, to those transportation-planning activities required by legislation.
- **Program Plans** – Such plans typically reflect an agency's mid- to long-term (5-20 year) programmatic implementation of a specific transportation feature that has been set forth by a legal planning process at a federal or state level. This may constitute the construction of new roadway facilities, the modification to such facilities, the installation of new technologies, or a combination thereof. While agency strategic plans may be set forth by a political and executive process, program plans are much more well established documents, derived from a planning process that is legally bound and tied to budgets; such programmatic plans are often tied to regional Metropolitan Planning Organization (MPO)-driven Transportation Improvement Programs (TIPs) and State-level, State-wide Transportation Improvement Programs (STIPs).

### 5.2.1 Agency Strategic Plans

From the relative position of any TMS developing, or having developed, a Concept of Operations, agency strategic plans are considered to be guidance from ‘above.’ They serve as leadership expressions of motivations for the agency. The TMS Concept of Operations can both support and gain from such plans.

- Information within these plans that can “feed” a Concept of Operations
  - *Provides overarching institutional goals and objectives* – a TMS developing a Concept of Operations will be able to draw upon the overarching agency’s vision and mission in general, or it can draw from specific information concerning a single function of the TMS. For example, an agency might express their objective to assure the safe transport of people and goods across roadway facilities throughout the agency’s jurisdiction; a TMS developing a Concept of Operations within a subordinate region of that agency will need to align their safety objectives with the agency’s overarching mission and vision, for example, by focusing on systems and measures that help to identify and manage incidents.
  - *Provides agency functional and geographic scope* – Overarching agency strategic plans can provide a TMS Concept of Operations with the primary boundaries, functionally and physically, within the overarching agency’s jurisdiction.
  - *Provides upper-level stakeholder identification* – Agency level planning serves as an initial source for identifying those groups who have a stake in the system at the agency level. All stakeholders will not be identified here, since all stakeholders are not at the agency level; however, the clear inter-agency relationships that exist before developing the system will be influential during the development process.
- Information found within a Concept of Operations that can “feed” these plans. From the ‘bottom-up,’ an existing TMS Concept of Operations provides upper echelon agency strategic plans with:
  - *An understanding of regional, functional scope, mission, and activities* – Agency strategic planners can utilize the TMS Concept of Operations as one of many references to inform their plan relative to the transportation capabilities within a region.
  - *Information regarding regional capital and operational policies and needs* – For example, as TMS staff identify capital infrastructure needs or operational policies as a result of day-to-day operations, there should be procedures in place for these lessons learned to inform strategic thinking.
  - *Education for planners and policy makers on the role and benefits of a TMS* – The high-level description of system goals, functionality, and operations along with the readability of a well-formed Concept of Operations document will convey important information concerning the TMS to decision-makers at the agency level.
- Example: The following example provides a linkage between strategic level planning and a TMS Concept of Operations document, demonstrating some of the principles outlined above. Particularly, this example highlights the broad vision that agency level plans create, and the shared vision of the TMS, which is more focused on implementation of that vision to the transportation system.

## Developing and Using a Concept of Operations in Transportation Management Systems

**Example —** This example shows a clear relationship between the vision stated in the Oregon DOT ITS Strategic Plan (below in Part 1) and the vision statement in the Concept of Operations for the Traffic Operations Center (below in Part 2). The Concept of Operations focuses on disseminating information that will be necessary for Oregon DOT to be able to achieve the high-level goals in the ITS Strategic Plan.

### Part 1 – Oregon DOT ITS Strategic Plan

The vision of ITS in Oregon is to adopt systems, technologies and partnerships that enhance mobility, transportation efficiency, safety, and productivity and promote economic prosperity and livability. The goals of implementing ITS in Oregon are to:

- Improve productivity of the transportation system users;
- Improve safety;
- Improve efficiency of the transportation system;
- Improve mobility and accessibility;
- Improve intermodal connections;
- Promote environmental responsibility and reduce energy use;
- Promote economic development in Oregon;
- Utilize technology as an asset of the transportation system.

ITS can address the current and future needs of the transportation system in Oregon by:

- Allowing for better management of transportation supply and demand: Transportation system managers are able to respond immediately to operational needs.
- Promoting the use of alternative modes and connectivity across the different modes: Improved traveler information gives users better understanding of their choice and options.
- Increasing travel efficiency and mobility without increasing the physical size of the transportation facility: Use of technology to manage highways and transit results in getting the most out of transportation capital.
- Enabling travelers to choose travel time, mode, and route efficiently based on real-time roadway and transit status information: Travelers are provided with better and current information and choices regarding traveling.
- Reducing the cost of operating and maintaining transportation facilities and services: Public sectors can save a significant amount of operating and maintenance costs by using products that are equipped with newer technology and are more reliable.
- Providing increased safety and security to travelers: Reduction in response time and clearance time for incidents, as well as closed circuit television surveillance, significantly improve safety.

### Part 2 – Oregon's TOCS Concept of Operations vision statement:

Mission, vision, goals, and objectives of the business that relate to the services delivered by the system:

"The ODOT Transportation Operations Center System provides a unified, statewide platform for around the clock coordination of transportation related services between internal and external customers."

Goals and Objectives. The goals and objectives of the TOCS is to integrate the hardware and software systems used by the TOC operators and district office personnel to provide a seamless operational platform that provides for immediate information dissemination and close operational ties between TOC's and their customers and partners both public and private.

*TMS Experience*

## 5.2.2 Program Plans

While guidance from agency strategic plans for a TMS Concept of Operations is important for institutional synergistic issues, the relationship to program plans will have more direct institutional, legal, and fiscal implications.

- Information within these plans can “feed” a Concept of Operations by:
  - *Providing similar features as found within agency strategic plans (as identified above)*, such as:
    - Providing overarching institutional goals and objectives
    - Providing agency functional and geographic scope
    - Providing upper-level stakeholder identification
  - *Conveying functional constraints through budget elucidation* – Program plans help to illustrate what programs get what funding. Therefore, a developing TMS Concept of Operations may be able to estimate the extent of its future functional capability by examining a program plan’s budgetary disbursement.
  - *Outlining a plan for large-scale future investments* – Program plans will identify and program large-scale transportation projects that can be sources of funding for future or existing TMSs. For example, enhancements to a TMS may be tied to major capital reconstruction projects of a regional freeway.
- Information found within a Concept of Operations can “feed” these plans by:
  - *Providing similar features as found within agency strategic plans (as identified above)*, such as:
    - Conveying an understanding of regional, functional scope, mission, and activities
    - Providing regional capital and operational policies and needs
  - *Conveying need with regard to infrastructure and facilities* – TMS Concept of Operations will be able to convey information with regard to the needs of the facilities that will be included in the capital improvements program in each applicable MPO and the rest of the state. Information provided in the system’s overview, such as system components, relationships, etc., can very quickly convey extent of such facilities.
  - *Identifying needed TMS capital investment* – A TMS Concept of Operations will provide goals and objectives as well as a needs analysis for the current state of transportation management. This information will provide the program plan with specific uses and needs for the funding at the TMS level.
- Example: Below, a region’s transportation signal optimization program identified in a region’s transportation plan is linked to the region’s Concept of Operations. Similar to the previous example, the following planning document gives the rationale at the agency level for the program in question, and the Concept of Operations document focuses on goals for system-level implementation.

**Example —** *The Maricopa Association of Governments of the metropolitan region of Phoenix, Arizona, has recently developed a Regional Concept of Transportation Operations. The following excerpts show the relationship between the program planning effort, the Maricopa Regional Concept of Transportation Operations & Traffic Signal Optimization Program (below in Part 1) whose goal is of optimizing traffic signals, and the Regional Transportation Concept of Operations (below in Part 2).*

### Part 1 – Maricopa Regional Concept of Transportation Operations & Traffic Signal Optimization Program

Traffic Signal Optimization Program (TSOP) is a project in the FY 2004 MAG Unified Planning Work Program. The purpose of this project is to provide technical assistance to member agencies for improving traffic signal coordination, optimization and review operations through simulation modeling. Individual projects will be launched through the MAG ITS/TE on-call consultant services contract.

This program is supported by federal Congestion Mitigation and Air Quality (CMAQ) funds to provide consultant assistance to member agencies. The TSOP has been championed by the MAG Intelligent Transportation Systems Program to provide traffic engineering assistance for refining signal operations across the MAG region. Eleven traffic signal projects from 9 MAG member agencies have been selected in this fiscal year. The projects range from developing Synchro network, coordinating signal timings among agencies and optimizing existing signal timing plans.

### Part 2 – Excerpt from Regional Transportation Concept of Operations

#### Initiatives

Eleven initiatives are recommended as a framework of actions for the region to follow in pursuit of the stated vision of providing a safe, reliable, efficient and seamless surface transportation system. Through these initiatives, the goals established for the ten categories of regional operations can be achieved. Associated with each initiative are the functions, or action steps, to be carried out in executing the initiative. These functions are at the core of implementing the Regional Concept of Transportation Operations recommendations.

#### REGIONAL TRAFFIC SIGNAL OPTIMIZATION PROGRAM

Improved traffic signal timing within cities and across jurisdictional boundaries will result from better regional traffic engineering collaboration.

- Optimize agency traffic signal system operations.
- Optimize traffic signal operations of cross border traffic signals and regional arterials.
- Develop regional pre-set traffic signal timing structure and criteria for traffic signal timing plan changes during incidents.

*TMS Experience*

## 5.3 "Looking Across" – Regional Operations Planning

As transportation operations play a larger role in surface transportation, formal operations planning procedures and practices are becoming prevalent. A Concept of Operations is an important input into regional operations planning. Furthermore, when a regional operations plan or architecture exists, the Concept of Operations should reflect the regional goals and functionality. This section will address two categories of Regional Operation Planning:

- ITS Architecture – Such documents explain physical, logical, and functional relationships between the information system components that support contemporary transportation facilities.
- Regional Transportation Concept for Operations – *A Regional Transportation Concept for Operations (RTCO) is a comprehensive set of capabilities resulting from sustained collaboration among stakeholders and intended to advance a shared transportation operations objective(s). It describes the desired state of transportation operations that can reasonably be accomplished within a short period of time (about 3 to 5 years). The RTCO presents the physical elements (i.e. projects), relationships and procedures, and resources arrangements that all must be put in place in order to achieve that desired state. The RTCO is created out of ongoing collaboration between managers responsible for managing and operating the transportation system on a day-to-day basis.* (Excerpt from the July 2004 Draft of "Regional Concept for Transportation Operations – A Management Tool for Making Transportation Systems Management and Operations Real," prepared by US DoT FHA, Office of Transportation Management.)

### 5.3.1 ITS Architecture

An ITS architecture identifies the components and relationships functionally, logically, and physically for information networks associated with transportation. Within the ITS architecture framework, there exists a feature that is often confused with a Concept of Operations, it is the ITS architecture's "operational concept." The operational concept focuses in on a specific transportation function, rather than an information function, relative to the ITS architecture being addressed. Within either the overarching ITS architecture, or the derived ITS architecture, there will exist operational concepts – descriptions of transportation services being facilitated by the ITS architecture. In a very general sense, the operational concepts are to the ITS architecture as the scenarios are to the TMS Concept of Operations. It should be noted that the relationship between an ITS architecture and a TMS Concept of Operations should be considered one of the most critical.

- Information within these plans can "feed" a Concept of Operations by:
  - *Providing functionally oriented technological component identification* – ITS architecture, as identified by the national ITS architecture, or the state-level ITS architecture will identify for the developing TMS Concept of Operations the appropriate mechanisms that may be fiscally supported through federally or state sponsored TMS infrastructure procurement and deployment.
  - *Providing additional insight into stakeholder identification* – ITS architecture-identified functions may already be performed in a region, reducing the need for TMS Concept of Operations to technically integrate those capabilities, and look to coordination instead.

- *Conveying additional functional scenario development opportunity* – Operational concepts identified in national and state ITS architectures may provide additional elucidation into the development of new internal functions or relationships – assisting in scenario development, assuring system robustness.
- Information found within a Concept of Operations can “feed” these plans by:
  - *Serving as a source for ITS architecture improvement* – A well-formed Concept of Operations should identify the primary features of the system and generally describe how and when they act and under what circumstances; these may then be reinterpreted into architecture. There may be well functioning capabilities identified for the new TMS that have not been included in related or upper level ITS architectures; these capabilities may improve associated ITS architectures.

- Example: The following example provides samples from a regional ITS architecture and a subordinate region's TMS Concept of Operations, demonstrating a linkage between the two. The description of the specific TMS function aligns with the description of the technical ITS architectural layout in an ITS plan.

*Example — The Oregon DOT Regional ITS Operations & Implementation Plan for the Eugene-Springfield Metro Area (excerpt below in Part 1) provides an extensive list of that region's ITS Architecture Information Flows. The statewide Traffic Operations Center Concept of Operations (excerpt below in Part 2) identifies several operational concepts, such as incident management, and then details roles and relationships within those concepts. The roles for select agencies relate to the ITS Architecture Flows identified.*

### Part 1 – Regional ITS Operations & Implementation Plan for the Eugene-Springfield Metro Area (Regional ITS Architecture Flows)

SourceElement	FlowName	DestinationElement
Central Lane Communications	emergency operations status	Central Lane Communications Personnel
Central Lane Communications	emergency response coordination	City of Coburg Emergency Operations Center (EOC)
Central Lane Communications	emergency response coordination	City of Eugene Emergency Operations Center (EOC)
Central Lane Communications	emergency response coordination	City of Springfield Emergency Operations Center (EOC)
Central Lane Communications	incident report	Eugene Fire and EMS Department
Central Lane Communications	incident response coordination	Eugene Fire and EMS Department
Central Lane Communications	incident report	Eugene Police Department
Central Lane Communications	incident response coordination	Eugene Police Department
Central Lane Communications	emergency response coordination	Lane County Emergency Operations Center (EOC)
Central Lane Communications	incident report	Lane County Sheriff Department
Central Lane Communications	incident response coordination	Lane County Sheriff Department
Central Lane Communications	emergency dispatch requests	Local Emergency Vehicles
Central Lane Communications	incident command information	Local Emergency Vehicles

### Part 2 – Oregon's TOCS Concept of Operations Incident Management Operational Concept

Incident management is the work done to detect and respond to any event that occurs on the ODOT road network that has a potential impact on public safety, traffic flow or asset maintenance.

The activities of Incident Management include incident detection, response planning, resource tracking and coordination as well as output to the traveler information systems. The specific roles and responsibilities for these activities are identified in the Incident Management table below.

...  
Significant incident management partnerships include:

LEDS: The Law Enforcement Data System will continue to be used by TOC operators for license plate checks, for Vehicle Identification Numbers (VIN), as well as for administrative messaging and any other functions authorized by the LEDS system owners.

OSP: The Oregon State Police continues to be a key partner in ODOT's incident response operations. An interface to OSP will be created as part of the new TOC system. The interface will support two-way sharing of open and historical incident data as well as the ability to "hand-off" or send an incident to the OSP system. Messaging capability between operators in both systems will also be supported. The key feature of the new interface is to be re-usable for multiple incident and emergency response partners.

911 Centers: As in the past, it is expected that the 911 Centers operating in Oregon and adjacent states will continue to be the point of contact between ODOT TOCS operations and local law enforcement and local emergency responders. The enhancement offered by the proposed new system is that 911 and other emergency responders will have the option to share their system data with ODOT using a common data interface.

*TMS Experience*

### 5.3.3 Regional Transportation Concept for Operations (RTCO)

This section will explore the link between the emerging regional operations planning focus (the Regional Transportation Concept for Operations) and a system's Concept of Operations.

- Information within these plans can "feed" a Concept of Operations by:
  - *Providing a functionally-oriented regional collaborative common objective* – The RTCO tends to be multi-jurisdictional and collaborative in nature; pooling the resources from many jurisdictions to address select transportation issues common to the region. The RTCO therefore identifies an objective relative to the function it seeks to address. TMS Concept of Operations can draw upon these objectives and incorporate them into its own objectives.
  - *Identifying equipment, technology, facilities, people, and systems needed to achieve the objective* – Like the common objective, the physical features necessary to accomplish the objective are identified; a developing TMS Concept of Operations could utilize this as a list of features it requires to enhance the RTCO mission, and their own.
  - *Providing a list of regional transportation stakeholders associated with their function* – The TMS Concept of Operations could benefit substantially from such a list; functions of regional actors are identified irrespective of their jurisdiction.
  - *Identifying RTCO participant stakeholders' funding and other resources* – Akin to the identified list immediately above, regional transportation actors are listed by function and coupled with their financial and human resources, another potentially very useful feature in understanding the jurisdictional focus on select transportation capabilities. Relative to the TMS Concept of Operations, this will be useful in optimizing one's own capabilities.
  - *Providing additional insight into Concept of Operations development* – The RTCO may serve as a guide to developing or revising a TMS Concept of Operations, specifically with regard to detailed scenarios and user oriented descriptions.
  - *Describing the regional environment* – The RTCO helps to describe the overarching operational environment that the TMS, as a sub-component to the RTCO, exists within.
- Information found within a Concept of Operations can "feed" these plans by:
  - *Conveying a more detailed look at a system that is part of regional operations* – In order for a RTCO to provide a clear and cohesive look at regional transportation operations as a whole, a concise definition of a TMS within that region is necessary. A Concept of Operations provides this information for a TMS, which will then be used to form a holistic view of regional transportation operations
- Example: The Maricopa region is one of the first, fully formed and documented Regional Concept for Transportation Operations. It has been developed by a region that has sought to integrate all operations associated with transportation, coordinating public safety, signal timing, etc., to document the combined aspirations of participating agencies. The example below is not related to any other subordinate TMS Concept for Operations, as at the time of the writing of this document, there was no known TMS Concept of Operations developed within the Maricopa region. Thus, below is a sample from the document, describing the combined operational transportation vision among the stakeholders. It is easy to see that all future systems associated with transportation in

the region, including new and existing regional TMS, will be able to relate directly to these overarching goals; to assure consistency in goal-oriented operations.

**Example —** *The following example discusses the regional vision for the Maricopa Association of Governments that is included in the Regional Concept of Transportation Operations.*

*A safe, reliable, efficient and seamless surface transportation system for the MAG Region.*

To provide a safe, reliable, efficient and seamless surface transportation system for the MAG Region, agencies have identified a need for stronger coordination and collaboration for regional operations. Six key principles provide the foundation for this new approach to regional operations, and guide the development of the Regional Concept of Transportation Operations. To accomplish this vision, coordination needs to happen at all levels to:

- Share information, coordinate resources, and link systems among state, local, transit, and emergency services agencies in the Region;
- Manage and operate our systems to their optimum performance, efficiency and safety;
- Identify and secure the funding for operations, and mainstream operations requirements into annual and program budgets;
- Agree on roles and responsibilities for local and regional agencies, with an emphasis on those roles and responsibilities needed to carry out regional functions;
- Develop the policies that are needed at the regional level to be sure that agencies can make maximum use of available resources, and are able to share resources where it benefits and enhances the safety and efficiency of the Regional transportation system; and
- Actively measure the performance of the strategies and map to the three year and five year goals that have been established.

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*TMS Experience*

## 5.4 "Looking Within" – System-Specific Planning

Planning is an important activity within a TMS. The Concept of Operations plays a key-supporting role in this planning. For many existing TMSs, system planning information can serve as a basis for Concept of Operations development. These system-specific planning documents include:

- Business Planning – A TMS business planning document is a plan for executing long-range TMS vision and goals that maintains a strong relationship to strategic and operational plans. It consists of the following:
  - *The Business Concept* – Outlines, at a high level, the key functions and services of the TMS including: technical and institutional relationships, its 'place' and role in the regional context, the objectives and goals for how the TMS needs to operate, and provision of an overall vision.
  - *Strategies* – The TMS Business Plan documents an overall process for achieving the vision, specifically the actions, implementations, upgrades, enhancements, integration, etc. that need to occur and what they will accomplish.
  - *Value Proposition/Benefit (What's the Payoff?)* – The TMS Business Plan defines the benefits to 'sell' the Business Concept to key decision makers, leaders, partner agencies, etc.
  - *Organization and Management* – Within the TMS Business Plan, roles and responsibilities of primary and partner agencies are defined – who owns, who manages, who participates.
  - *Financial Plan* – Includes budget and timeframes, potential funding mechanisms, working within agency and regional funding/programming processes, as well as outlining procurement issues, requirements and challenges.

*Business planning items above were derived from the TMC PFS web site – Transportation Management Center Business Planning and Plans Handbook ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=54&new=0](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=54&new=0)).*

- Operations Handbook – An operations manual is a critical tool that agencies are encouraged to develop, maintain, and use in managing and supporting the day-to-day operation and activities that are performed with an agency's traffic operations program, TMC control center, or other services. The purpose of an operations manual is to document the policies, procedures, plans, and other support activities that are performed to achieve the mission, goals, and objectives of the TMS. This TMS operation manual is intended to define the roles, responsibilities, functional capabilities, services provided, major tasks, and other day-to-day activities that are performed.

*Derived from the TMC PFS web site – TMC Operations Manual Project Proposal ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=58&new=0](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=58&new=0)).*

- Event Plans – Planned special events include sporting events, concerts, festivals, and conventions occurring at permanent multi-use venues (e.g., arenas, stadiums, racetracks, fair-grounds, amphitheaters, convention centers, etc.). They also include less frequent public events such as parades, fireworks displays, bicycle races, sporting games, motorcycle rallies, seasonal festivals, and milestone celebrations at temporary venues. The term planned special event is used to describe these activities because of their known locations, scheduled times of occurrence, and associated operating characteristics. Emergencies, such as a severe weather event or other major

catastrophe, represent special events that can induce extreme traffic demand under an evacuation condition. However, these events occur at random and with little or no advance warning, thus contrasting characteristics of planned special events.

*Derived from TMC PFS Planned Special Events*

([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=59&new=2](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=59&new=2)).

#### 5.4.1 Business Planning

The Concept of Operations feeds directly into a business plan. The business plan is ideally developed after the Concept of Operations is complete and expands on “business” aspects such as budget, funding, management/governance, and staffing. More than the other planning documents identified within this chapter, the business planning document for a given TMS may be the most closely related document to the given system’s TMS Concept of Operations. The differences are found primarily within the Business Plan. Found in the Business Plan and not typically in a Concept of Operations are:

- *Business oriented strategies* – The TMS Business Plan needs to document an overall process for achieving the vision, specifically what actions, implementations, upgrades, enhancements, integration, etc. need to occur and what they will accomplish. By mapping the current state to the desired state for the TMS, strategic directions can be established. The Business Plan also needs to identify timeframes, dependencies and implementation responsibilities.
- *Value Proposition/Benefit (What's the Payoff?)* – The TMS Business Plan should define benefits, and ‘sell’ the Business Concept to key decision makers, leaders, partner agencies, etc.
- *Organization and Management* – Within the TMS Business Plan, roles and responsibilities of primary and partner agencies are defined – who owns, who manages, who participates. Overall organization, including personnel and staffing should be documented. The TMS’s relationship to other agencies, and within its ‘owning’ agency also is defined.
- *Financial Plan* – Includes budget and timeframes, potential funding mechanisms, working within agency and regional funding/programming processes, as well as outlines procurement issues, requirements and challenges.

The documents still complement one another and provide information into each other’s development. Information found within a Concept of Operations can “feed” these plans. For example, much of the information found within the TMS Concept of Operations may relate directly to the development of a Business Plan. Users, functions, and scenarios will be reinterpreted into implementation strategies and costs.

- Examples
  - See also the TMC PFS Business Planning [see TMC PFS web site – Transportation Management Center Business Planning and Plans Handbook.  
([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=54&new=0](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=54&new=0) )]
  - The example on the following page demonstrates the relationship between a Concept of Operations and a Business Plan by presenting the level of detail found within each with regard to the same types of topics, in this case, personnel. The Business Plan focuses on dollar figures and positions/tasks; the Concept of Operations focuses on staffing requirements to accomplish a mission and does not directly consider cost.

**Example – Florida's Department of Transportation has generated related ITS Business Plans and Concept of Operations for ITS deployment along select interstate highways. From [http://www.floridait.com/Newsletters/12\\_01\\_newsletter/newsletter\\_p2.htm](http://www.floridait.com/Newsletters/12_01_newsletter/newsletter_p2.htm) "A Concept of Operations and Business Plan were prepared that outline how the ITS system will be managed, operated, implemented and maintained. The Concept of Operations discusses specific roles and responsibilities for the corridor deployment from an operational requirements perspective. The Business Plan identifies major program objectives, specific strategies and tactics to accomplish these objectives and the roles and responsibilities of the parties in carrying out the plan." The examples below highlight staffing detail differences.**

## Part 1 – Florida Department of Transportation – Technical Memorandum No. 42 – ITS Business Plan for Deployment along Florida's Principal FIHS Limited-Access Corridors

<i>Phase I – ITS Corridor Master Plans – ITS Business Plan</i>				
<b>Table 6.3 – Annual Costs to Support Operations/Staffing through 2012</b>				
<b>Position</b>	<b>FDOT</b>	<b>Rate<sup>(1)(a)</sup></b>	<b>Number</b>	<b>Costs (\$)</b>
Program Center Manager	FDOT	\$ 120,000.00	10.5	1,260,000.00
	Consultant	\$ 156,000.00	1	156,000.00
Shift Manager/ Supervisor	FDOT	\$ 100,000.00	20	2,000,000.00
	Consultant	\$ 130,000.00	20	2,600,000.00
System Operator	FDOT	\$ 60,000.00	11	660,000.00
	Consultant	\$ 78,000.00	68	5,304,000.00
Road Rangers Dispatcher	FDOT	\$ 60,000.00	0	-
	Consultant	\$ 78,000.00	34	2,652,000.00
Road Rangers Field Personnel/ Drivers	FDOT	\$ 60,000.00	0	-
	Consultant	\$ 78,000.00	334	26,052,000.00
Public Safety Ops Center Liaison	FDOT	\$ 80,000.00	9	720,000.00
	Consultant	\$ 104,000.00	0	-
Computer Network Support	FDOT	\$ 130,000.00	2	260,000.00
	Consultant	\$ 169,000.00	27	4,563,000.00
Admin Support	FDOT	\$ 50,000.00	1	50,000.00
	Consultant	\$ 85,000.00	12.5	812,500.00
			<b>Total</b>	<b>47,089,500.00</b>
			<b>Change</b>	<b>(14,803,500.00)</b>

(1) Rate reflects fully burdened costs for overhead benefits for FDOT staff; 2.0 multiplier assumed.

(2) Rate reflects fully burdened costs for overhead benefits, FCCM, and operating margin for consultants; 2.6 multiplier assumed. The multiplier is based on field office overhead, a benefit rate of 135 percent, and a 10 percent operating margin.

## Part 2 – Florida Department of Transportation – Technical Memorandum No. 41 – ITS Corridor Master Plans: Concept of Operations ITS Deployments along Florida's Principal FIHS Limited-Access Corridors

<i>Phase I – ITS Corridor Master Plans – Concept of Operations</i>																				
<b>Table 9.2 – Summary of Operational Criteria and Staffing Required at Each RTMC</b>																				
District	RTMC	LOS	Number of Centerline Miles of Freeway with RR Service Patrols <sup>(1)</sup>	Program Center Manager		Shift Manager, Supervisor, Operations Engineer, Senior Operator, or Maintenance Engineer		System Operator		RR Service Patrols Dispatcher		RR Service Patrols Field Personnel/ Drivers		Public Safety Operations Center Liaison		Computer Network Support		Administrative Support		Total
				FDOT Min	Others	FDOT Min	Others	FDOT Min	Others	FDOT Min	Others	FDOT Min	Others	FDOT Min	Others	FDOT Min	Others			
1 Ft. Myers	4	205	0.5	4		4		4		3		68		1		0.5		81		
2 Jacksonville	5	85	1			4		6		5		26	3			4	1	50		
3 Tallahassee	4	33	1			2	1	2	3	3		11	3			3	2	31		
3 Pensacola	4	21	1			2	1	2	3	3		7	3			3	2	27		
4 Broward	5	55	1			3	2	3	6	5		52				4	2	78		
4 Palm Beach	5	46	1			3	2	3	6	*		*	*			4	2	21		
5 Orlando	5	130	1			2		9		3		15	0			2	1	33		
6 Miami	5	85	1			2	1	1	11	**		50	0			1	2	70		
7 Tampa	5	70	1	1		5		8		4		35				1	2	59		
T Pompano Beach	5	70	1			3		6		5		23				1		39		
T Turkey Lake	4	140	1			3		6		3		47				1		61		
Total			940	10.5	1	20	20	11	68	0	34	0	334	9	0	2	27	12.5	550	

(1) Assumes existing RR Service Patrols plus the following additional coverage:  

District	Facility	Segments
1	I-75	Remainder of I-75 in District 1
2	SR 9A	Entire Corridor
3	I-10	Tallahassee TMS
3	I-10	Pensacola FMS
3	I-110	Pensacola FMS
4	I-110	District 4 proposes centralized dispatching for the RR Service Patrols from the Broward County TMC.
•		Systems operators will handle these districts.
•		Indicates information provided by the districts. In all other instances, information is based on guidelines in the ITS Strategic Plan.

Total FDOT Positions Needed: 53.5  
Total Consultant Positions Needed: 496.5  
**TOTAL:** 550.0

(2) Sources:  
 Ft. Myers  
 Jacksonville  
 Tallahassee  
 Pensacola  
 Based on information received as of June 26, 2002.  
 I-75 TMS Plan  
 Memo from Carter Vega 5/23/02  
 Memo from Elizabeth McCrary 6/6/02  
 Memo from Elizabeth McCrary 6/6/02

## 5.4.2 Operations Handbook

TMSs seek to document specific operational procedures (including standard operating procedures). These plans further detail the general information presented in the Concept of Operations.

- Information within these plans can “feed” a Concept of Operations by:
  - *Identifying needs that the current system not addressing* – An operations manual may prove useful to the TMS Concept of Operations development in detailing the lowest level operational procedures and systems; when compared to the current state of objectives, this may yield an expression of need that must be addressed by the new TMS.
  - *Identifying personnel and associative activities* – Such a low level document may provide a TMS Concept of Operations with a very detailed list of individual actors within a very specific system; critical in addressing or resolving objectives and capabilities with the new system.
  - *Identifying stakeholders* – The operations manual will likely also identify a list of entities with whom the existing system will communicate or operate. This will be of use in identifying stakeholders for the TMS Concept of Operations.
  - *Identifying sub-level missions and objectives* – This is due to the level of the operations manual, that of ‘street level,’ where user activities often relate directly to one another. The objectives, or tasks, for these lowest level users are often detailed in the operations manual, and will again be of use in the development of a TMS Concept of Operations in assuring that legacy tasks/capabilities are addressed, replaced, or made redundant.
  - *Identifying facilities and technologies* – Akin to the identification of low level stakeholders, users, personnel, tasks, etc., technologies and facilities that are identified by the operations manual will again be of use to the TMS Concept of Operations and assure their inclusion in the needs analysis.
- Information found within a Concept of Operations can “feed” these plans by:
  - Relating the information found within the TMS Concept of Operations to the development of an operations manual. Users, functions, and scenarios will be reinterpreted into low-level tasks given functions and environmental events.
- Example:
  - See also the TMC PFS project on the TMC Operations Manual  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=58&new=0](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=58&new=0)
  - The following example provides a linkage between a statewide Operations Manual and a system-specific Concept of Operations document. The operations manual provides guidance and vision for the statewide view of a particular function, and the Concept of Operations provides details for implementation of that vision within TMS.

**Example –** *The Texas Highway Operations Manual (excerpt below in Part 1) demonstrates a general concept of an incident in the context of Texas highways, whereas the DalTrans systems' Operational Concept Document (excerpt below in Part 2) details how a specific system will handle such incidents given TxDOT's preferences and the regional technical and non-technical capabilities in Dallas.*

### Part 1 – Texas Highway Operations Manual - Chapter 9 - Incident Management Section 2 - Incident Response and Management

#### Incident Management

Incident management refers to a coordinated and preplanned approach for restoring traffic to its normal operations as quickly as possible after an incident has occurred. The approach involves a systematic use of human and mechanical processes for detecting the incident, assessing its magnitude, identifying what is needed to restore the facility to normal operation, and providing the appropriate response in the form of control, information, and aid. The primary goal of incident management is to minimize the impacts of incidents on traffic flow by reducing the duration of the incident and efficiently managing traffic during the incident. This is accomplished by:

- Improving detection, response, and removal activities so as to reduce the duration of the incident.
- Increasing the capacity past the incident by effective on-site management.
- Reducing the traffic demand by providing timely and accurate information to the public.

### Part 2 – DalTrans, DalTrans-OCD-1.15, 4.3.3 ATMS08 – Incident Management System

This market package manages both predicted and unexpected incidents so that the impact to the transportation network and traveler safety is minimized. Requisite incident detection capabilities are included in the freeway control market package and through the regional coordination with other traffic management and emergency management centers, weather service entities, and event promoters supported by this market package. Information from these diverse sources are collected and correlated by this market package to detect and verify incidents and implement an appropriate response. This market package provides Traffic Management Subsystem equipment that supports traffic operations personnel in developing an appropriate response in coordination with emergency management and other incident response personnel to confirmed incidents. The response may include traffic control strategy modifications and presentation of information to affected travelers using the Traffic Information Dissemination market package. The same equipment assists the operator by monitoring incident status as the response unfolds. The coordination with emergency management might be through a CAD system or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other field service personnel.

#### 4.3.3.1 Incident Detection

DalTrans operations personnel will detect that an incident has occurred from the following sources:

- Traffic images – While periodically examining a section of roadway, an operator discovers that an incident has occurred.
- Traffic sensors – Using input from traffic sensors, the Analyze Traffic Data for Incidents process has detected an incident. An operator visually verifies that an incident has occurred at the specified incident location using a camera.
- 911 calls – Drivers discover or are involved in an incident and call 911. 911 personnel input the incident into the 911 system, which automatically notifies the DalTrans system of the incident. An operator visually verifies that an incident has occurred at the specified incident location using a camera.
- Police scanner – While listening to a police scanner, an operator discovers that an incident has occurred.
- Courtesy patrol calls – A driver calls directly into the courtesy patrol number that is often shown on DMSs around the region, and courtesy patrol notifies a DalTrans operator of the incident. If the courtesy patrol dispatcher is currently too busy to field the call, a DalTrans operator will take the call directly.

TMS Experience

### 5.4.3 Event Plans

Plans are often developed to manage specific events. These plans link directly to the system Concept of Operations.

- Information within these plans can “feed” a Concept of Operations by:
  - *Identifying regional stakeholders and their capabilities and needs* – Relative to the given event, such plans will yield a list of transportation users and managers that will provide a developing TMS Concept of Operations with an excellent, event specific (scenario) list of stakeholders for inclusion within their system.
  - *Providing the basis for Concept of Operations scenario development* – Regional event plans may be one of the best possible sources for generating the new TMS concept of operation’s scenarios. If not for a new Concept of Operations, then event plans are useful in validating the TMS Concept of Operations relevancy to the current environmental conditions.
- Information within a Concept of Operations can “feed” these plans by:
  - *Providing event planners with a regional TMS’s capability focus* – Specifically, the scenarios within the TMS Concept of Operations will convey the details of the TMS’s capability.
  - *Providing event planners with a list of the TMS participating stakeholders’ capability relative to a specific regional transportation need* – The TMS Concept of Operations can provide event planners with an understanding of a regional capability – a tool. Further, it will likely also identify other transportation actors, the event planners will need to address.
- Example:
  - See also the TMC PFS Event Planning  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new\\_detail.cfm?id=59&new=2](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=59&new=2)
  - The following example provides a description of a TMS Concept of Operations document, detailing event planning considerations. A Concept of Operations should describe, at the operational level, the goals and implementation strategy for event planning within the TMS.

**Example — Mass Highway's Regional Traffic Operations Center (RTOC), a TMS serving the greater Boston, MA area, developed a regional traffic operations plan. This regional concept of operations document provides a description of how their new system intends to address regional planned events.**

### 3.2.1 Event Management

The event management function encompasses all functions associated with event detection, confirmation and response. An event is defined as something which blocks or closes one or more lanes and/or shoulders on a road, or poses a safety hazard. A blockage is a random occurrence, whereas a closure is an access restriction initiated by agencies such as Police or roadwork authorities. Events can be planned (e.g., roadwork lane closure) or unplanned (e.g., incident, adverse weather conditions). Full highway closures (planned or emergency) are special cases of planned and unplanned events.

...

#### 3.2.1.2 Planned Events

This category includes events for which the operators have prior knowledge and which may generate intense but relatively predictable traffic flows such as:

- Sporting events;
- Planned maintenance or construction work; and
- Special events.

Planned events have different impacts on traffic depending on the:

- Type of event;
- Location of the event; and
- Time of day.

Capacity reductions as a result of ramp or lane closures, segment overloading as a result of event congestion (e.g. at the end of a sporting event), or planned diversions are all results of planned events. These events may occur at one point on the highway (as in the event of maintenance on one lighting pole), or may cover a location range (as in the closure of an interchange-to-interchange highway segment, or construction work on a 500 foot segment of the shoulder). The Southeast Expressway HOV lane operations also fall under the category of planned events.

*TMS Experience*

## 5.5 Guiding Principles

In developing a Concept of Operations for a TMS, it is useful to:

- “Look Up” – Review plans and planning procedures at a level “above” the TMS, such as Agency Strategic Plans and Program Plans, for insight and input into:
  - Overarching institutional goals, objectives, and preferences;
  - Upper-level stakeholder identification;
  - Stakeholder and agency mission, function, and scope;
  - Regional capital disbursement and operational policies and needs;
  - Regional infrastructure and facilities.
- “Look Across” – Review plans and planning procedures at a level “across” from the TMS, such as ITS Architectures and Regional Transportation Concept for Operations, for insight and input into:
  - Institutional goals, objectives, and preferences;
  - Additional stakeholders than found within the upper level plans;
  - Functionally-oriented technological component identification;
  - Functionally-oriented regional collaborative common objectives;
  - Equipment, technology, facilities, people, and systems available regionally for transportation needs;
  - Stakeholders’ funding sources.
- “Look Within” – Review plans and planning procedures at a level “within” the TMS, such as Business Plans, Operations Handbooks, and Event Plans, for insight and input into:
  - Detailed descriptions of funding activities, management/governance, and staffing;
  - Needs that the current system may not be addressing;
  - Regional stakeholder identification, capabilities, and needs;
  - Sub-level missions and objectives;
  - Facilities and technologies;
  - Scenario development.

# CHAPTER 6 – The Next Step: Using the Concept of Operations to Drive Requirements

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## Chapter Purpose

This chapter describes the transition from the first “step” of the systems engineering process, Concept of Operations, to the development of System Requirements. In particular, it will highlight the critical role that a well-formed Concept of Operations document plays in providing the foundation for an effective set of Requirements.

## Chapter Objectives

The key objectives of this chapter are:

- *To provide a description of Requirements and their importance to system development.*
- *To define the relationship between Requirements and the Concept of Operations.*
- *To describe how to effectively transition from a Concept of Operations to Requirements.*
- *To provide information on resources needed and/or available to support this transition.*

## Relationship to Previous Chapter

Beyond supporting planning, a Concept of Operations plays a central role in the development of Requirements. This chapter may serve as a stand-alone section for those primarily interested in Requirements development and use. Readers without a strong background in systems engineering should read Chapter 2 before this chapter.

## Chapter Sections

Brief descriptions of the sections of Chapter 6 follow:

### 6.1 What Are Requirements?

The reader is introduced to Requirements, and their critical role in the systems engineering process. The section includes seven tips on generating good Requirements.

### 6.2 How to Transition from a Concept of Operations to Requirements

This describes considerations necessary to make an effective transition from a Concept of Operations into Requirements development. The section demonstrates how the Concept of Operations supports this transition to Requirements using examples from real-world TMSs.

### 6.3 Guiding Principles

This section provides a brief overview of the key information provided in this chapter.

## 6.1 What are Requirements?

*Developing Functional Requirements for ITS* (FHWA-OP-02-047, April 2002.) defines Requirements as being, "...statements of the capabilities that a system must have, geared to addressing the [needs] that a system must satisfy."

Generally, there are two levels of Requirements: functional and non-functional Requirements. *Requirements Engineering* defines the difference as being, "...functional Requirements describe what the system should do and non-functional Requirements place constraints on how these functional Requirements are implemented." It is often the case, however, that these are combined into one general statement of overall system requirements.

Without a clearly defined concept of a system, developed, and agreed to, by the stakeholders, along with a solid understanding of the environment in which the system will exist, it is impossible to define clear Requirements for a system. It is the effort of individuals and organizations in developing the Concept of Operations that afford systems engineers the opportunity to identify, develop, and document functional and non-functional Requirements.

### 6.1.1 Requirements' Role in Systems Engineering

Requirements generation represents the step of refining and expanding on the concepts developed in the Concept of Operations into clear, unambiguous text that is interpretable for engineers to design, build, and operate a system. A Requirement is a statement of system functionality that conveys some task or objective that the system must perform or meet. Similar to the Concept of Operations development process, the Requirements development process is iterative. The Concept of Operations document should provide the foundation for a set of high-level Requirements, as well as the institutional and environmental characteristics that will help to provide scope extent and context to assist in the constraining of additional Requirements. The systems engineering process, the "Vee" diagram, highlights the sequential relationship from Concept of Operations to Requirements.

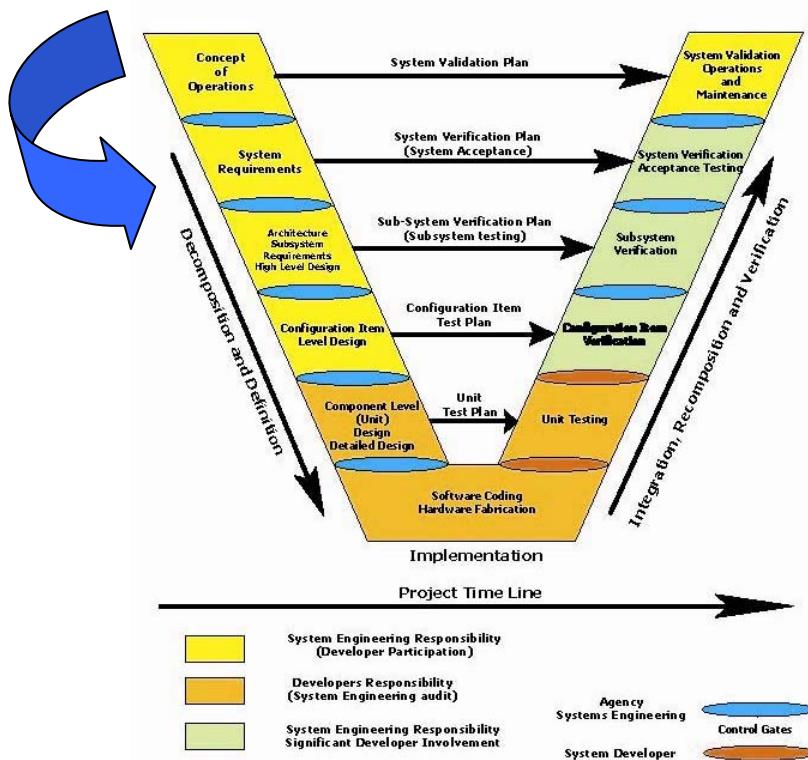


Figure 6.1 – The Systems Engineering “Vee” – Figure used in FHWA training courses – This diagram highlights the iterative process of Requirements development. (Graphic provided by ASE Consulting LLC)

The following examples illustrate the “type” of statements that should be seen in a Requirements document versus a Concept of Operations document. The Requirements document contains more specific information on a particular aspect of functionality for the system, whereas the Concept of Operations document describes the high-level objective for the system that spawns the individual requirement. The examples come from the Concept of Operations and Functional Requirements documents from ADMS Virginia, an archived data system developed by the Virginia Department of Transportation (VDOT).

Concept of Operations Statement*	<i>Example Requirement Statements*</i>
<p>Based on all the archived data (for Hampton Roads Region) hosted at the STL, the system will provide information services to help measure the operation and performance of the transportation system and the TMCs.</p>	<p><i>For any user input, spatial selection and temporal selection, the user shall be able to run the following different query scenarios on the incident database, to either obtain individual records or for counts of the incidents:</i></p> <ul style="list-style-type: none"> <li>• <i>To obtain all the incidents (or counts of incidents) that occurred</i></li> <li>• <i>To obtain all the incidents (or counts of incidents) that occurred under "particular selected weather conditions".</i></li> <li>• <i>To obtain all the incidents (or counts of incidents) that "started within a particular selected time period of the day"</i></li> <li>• <i>To obtain all the incidents (or counts of incidents) that "ended within a particular time period of the day"</i></li> </ul>
<p>The system will also support traditional and innovative regional transportation analyses.</p>	<ul style="list-style-type: none"> <li>• <i>The outputs for the incident database queries (individual incidents or counts of incidents) shall be available in the data format.</i></li> <li>• <i>Plot outputs shall be available for counts of the number of incidents, for any combination of the input selections, for the selected basis of the plot.</i></li> <li>• <i>If the basis of the plot is "incidents type", the plot format shall be a pie chart.</i></li> <li>• <i>For any other basis for the plot (other than the 'incident type'), the plot format shall be histogram, with the incident count on the Y-axis and the basis on the X-axis.</i></li> </ul>

*Examples taken from ADMS Virginia Concept of Operations, Final and Build 1, Functional Requirements Document, Virginia Department of Transportation, 2003. ADMS Virginia is a development effort to create a system enabling the use of archived ITS data for transportation applications such as planning and mobility measurement.*

### 6.1.2 The Requirements Development Process

Like the Concept of Operations development process, and the entire systems engineering development process, the Requirements development process consists of several input and output functions. This is illustrated in Figure 6.2.

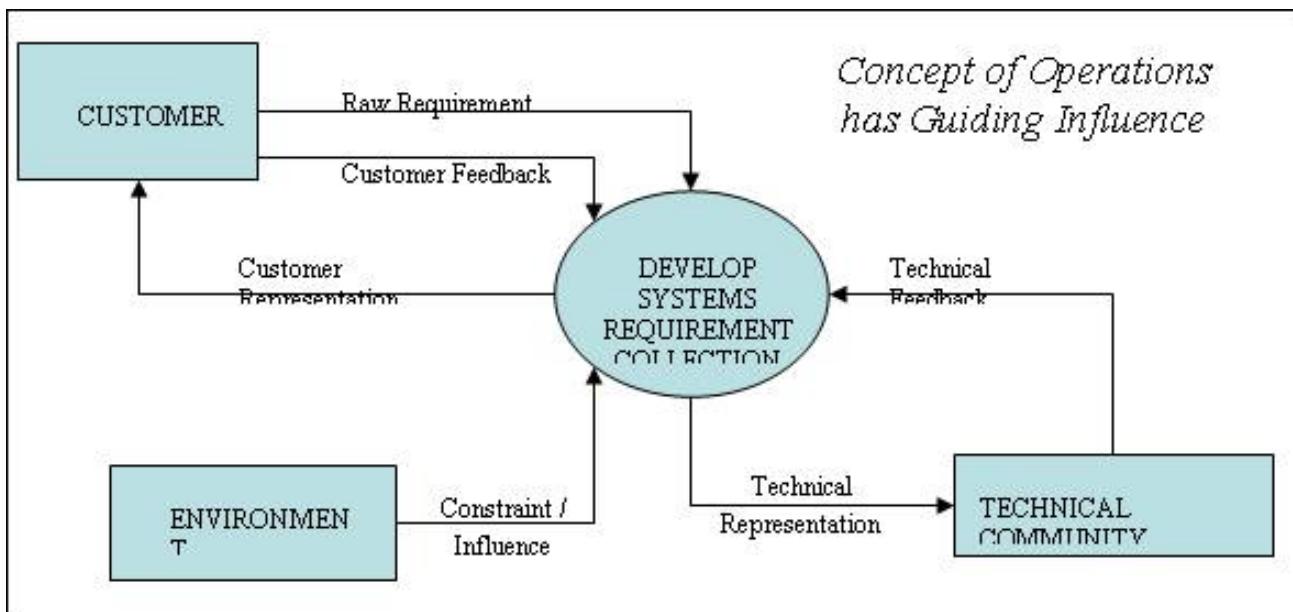


Figure 6.2 – Requirements Development Flow Diagram – IEEE 1233, *Guide for Developing System Requirements Specifications*, IEEE, 1998 – This diagram shows the different input/output flows for developing a set of Requirements for a system. This process will be iterative, and communication among the major entities will be vital for a successful process.

Each of the input elements in Figure 6.2 (i.e. customer, environment, and technical community) in this figure should already be addressed in the Concept of Operations document. The technical community, environment, and customer, have all been identified, established, and agreed upon by the stakeholders, in their earlier effort. The basis for the central node, the development of systems requirement collection, was also established by earlier work.

From the previous Chapters in this document, it becomes clear that the basis for many of the features listed above will be found within a Concept of Operations document. What is occurring in the Requirements development process is a refinement of precisely what is required of the system, in its environment, by its users, given its objectives- a further, more detailed, specification of the activities of the system under development or refinement. Examples of these linkages between the Concept of Operations and the Requirements will be presented later in this chapter.

### 6.1.3 Properties of Good Requirements

*Developing Functional Requirements for ITS* identifies seven properties of effective Requirements.

- Necessary – Each requirement must convey an essential capability or constraint of the system. Requirements documents become very large, very quickly. It is important that unnecessary detail is excluded.
- Concise (minimal, understandable) – Stated in language that is easy to read, yet conveys the essence of what is needed.
- Attainable (achievable or feasible) – A realistic capability that can be implemented for the available money, with the available resources, in the available time.
- Complete (standalone) – Described in such a manner that does not force the reader to look at additional text to know what the Requirement means.
- Consistent – Does not contradict other stated Requirements, nor is it contradicted by other Requirements. In addition, uses terms and language that means the same from one Requirements statement to the next.
- Unambiguous – Open to only one interpretation.
- Verifiable – Must be able to determine that the Requirement has been met through one of four possible methods: inspection, analysis, demonstration, or test.

Obviously, it will be important for the Concept of Operations to be rich and robust enough to ensure that these properties can be met to a satisfactory degree. To do so, the following section will present considerations and examples for the Concept of Operations to Requirements transition.

## 6.2 Transition from a Concept of Operations to Requirements

*Developing Functional Requirements for ITS* states "...the information you gather during this "basic homework" [Concept of Operations] forms the basis of all ... Requirements, since it deals with what the system must do, and the context in which it must operate. Once this information is in hand, you begin to write your Requirements document." *Building Quality Intelligent Transportation Systems Through Systems Engineering* supports this; "...You develop a Concept of Operations to help communicate your vision of the system to the other stakeholders... It also highlights the interfaces that the system has and ensures, through the publication and discussion of the Concept of Operations with others, that you have identified all interfaces. During this stage, you establish the high-level Requirements for the system."

All of the effort expended in identifying systemic need, bringing together a writing team, identifying and collaborating with stakeholders, expressing the concept from multiple viewpoints, and expressing system capabilities under various conditions, now provides the foundation for stating, in detail, what the system must have in order to achieve those features and characteristics detailed in the Concept of Operations. Nevertheless, the transition from a Concept of Operations document to the development of a Requirements document is not necessarily accomplished with the greatest of ease. A good Concept of Operations document simply makes the Requirements development process somewhat easier, affording the developer the opportunity to avoid stepping back into Concept of Operations development territory.

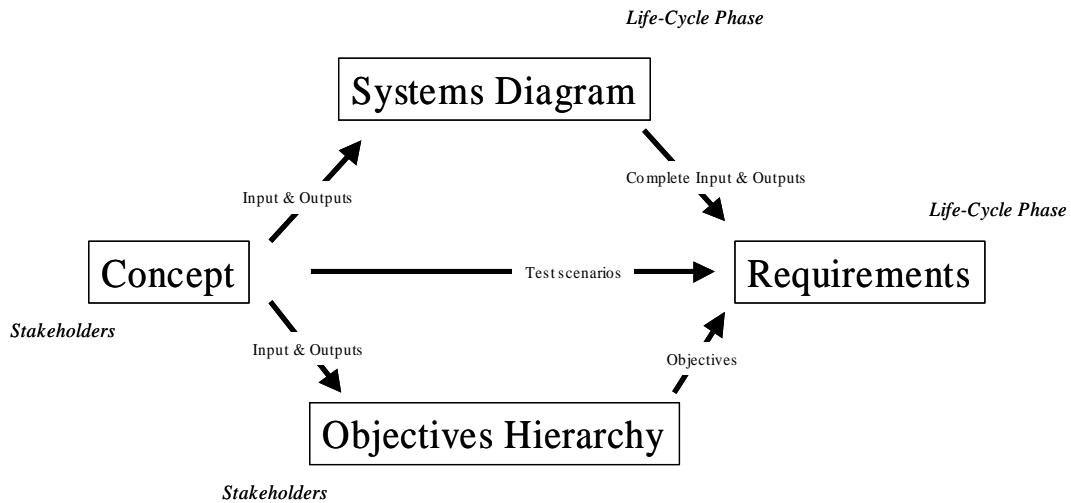


Figure 6.3 – Concept of Operations and Requirements Relationship – Derivative of the “Summary of Originating Requirements Development” diagram from Buede, page 159 – An explanation of Requirements development originating with the concept development.

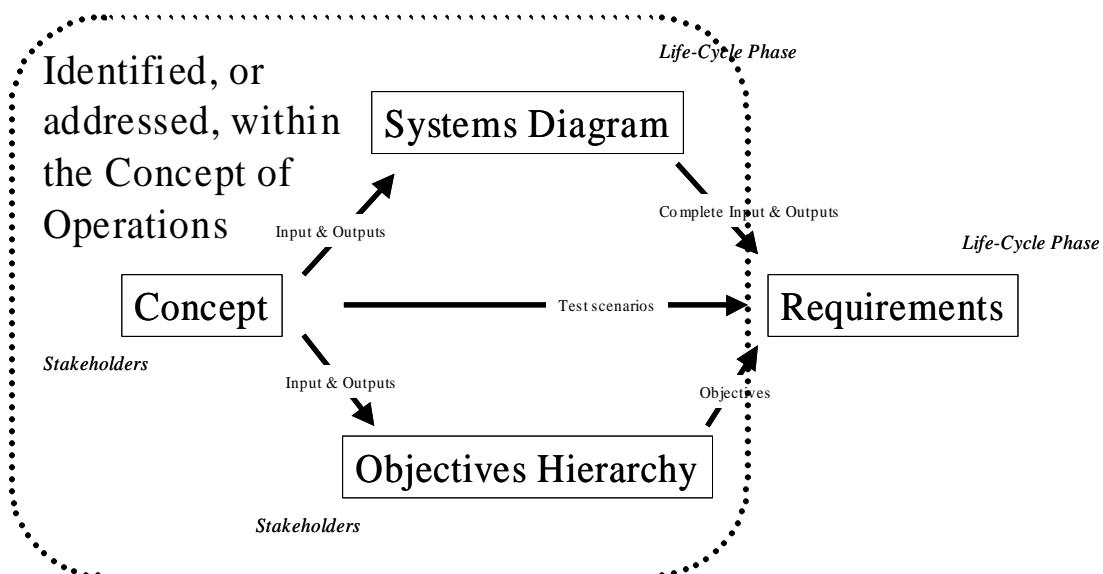


Figure 6.4 – Concept of Operations and Requirements Relationship – Derivative of the “Summary of Originating Requirements Development” diagram from Buede, page 159 – The work done during the Concept of Operations development process directly supports the specification of requirements in the next life-cycle phase.

Figures 6.3 and 6.4 above separate features that are found within the earliest stages of the systems engineering development process; as seen earlier in the first two steps of the systems engineering “Vee,” the Concept of Operations and Requirements. Any Concept of Operations should have addressed and included the integration of the concept, the systems’ diagram, and the commonly accepted stakeholder system objectives, referenced above as an Objectives Hierarchy. These are the features that will be of immense value for the Requirements development team. From such a perspective, the figure above depicts Requirements as having three inputs (displayed separately here, but typically all originating from a well developed Concept of Operations): the systems’ Complete Inputs and Outputs as identified in the Systems Diagram; the systems’ Test scenarios as identified and developed from the originating Concept; the systems’ Objectives as identified, and prioritized, by the Stakeholders. Each of these is addressed below:

- *Diagrammed Inputs and Outputs* – a good Concept of Operations will have developed a Systems Diagram – often a single image depicting critical links and nodes – the connections and the key features of the system in question. Also found within the Concept of Operations document is a textual description of the graphic, often referred to as a User Oriented Operational Description – explaining the links and nodes of the system in its operational context. At the very least, Requirements, as defined above in terms of how they ought to physically and logically relate, will need to address each of these links and nodes, as well as how they connect. In the initial stages of the Concept of Operations development, the concept of the system is laid out – stakeholders work to come to agreement on the human, technical, and organizational components of the system. Much of this is generally, rather than specifically, expressed as features within the system, and inputs and outputs of the system. Capturing these details is often a challenge; hence, diagramming frequently assists in this effort. The diagram generated in the Concept of Operations demonstrates to the Requirements development team the stakeholders’ viewpoint of what the system should logically and physically ‘look like.’ This is a first step in assisting in the functional specification of what each component will do and when.
- *Test Scenarios* – a good Concept of Operations will have developed expressions of the system’s operation under various contexts with respect to select key users. These depictions of the system in action will assist the Requirements developer in understanding the relationships between the features identified above; understanding the environmental, social, and institutional conditions of the system. The System Diagram and User-Oriented Operational Description can step the Requirements development team down the right path – often ensuring that each of the components is addressed. As with any static depiction, they often lack the complexities brought upon the system by external and internal forces through time. Scenarios generated in the Concept of Operations will help the Requirements team in generating lower-level requirements that they may not have been able to generate just by reviewing a User-Oriented Operational Description or System Diagram. If a fairly complete set of Scenarios has been generated, the Requirements development team should have available to them scenarios describing:
  - Key Users’ Perspectives – affording the opportunity to generate requirements based upon each component of the system, relative to key users. Key users will be represented actively in scenarios, giving greater opportunity for Requirements developers to generate and specify thorough requirements;
  - Variety of User Classes – affording the opportunity to generate requirements based upon each component of the system, relative to the multiple classes of users. This is differentiated from the Key Users’ Perspectives by being focused on larger groups;

- Stress/Failure Scenarios – affording the opportunity to generate requirements based upon each component of the system, relative to the extreme events that are expected to cause the system to fail. Such scenarios will give the Requirements developers the opportunity to specify requirements for the system that may assist in its reliable and safe operation;
- Multiple Circumstances – affording the opportunity to generate requirements based upon each component of the system, relative to the multiple normal situations expected by the systems' developers. Key normal events relative to the system being described will further assist the Requirements developers in defining the basic requirements for each element of the system;
- *Objectives* – a good Concept of Operations development process will have assimilated the common objectives of the system's stakeholders. These objectives will serve to provide consistent context and scope for the Requirements development process. A major objective of the Concept of Operations development process is the agreement among all the stakeholders of the overall objectives of the system. This expression of objectives is frequently a non-numerical list of system goals and objectives, often with the implicit assumption that the top-most objective is the one of greatest importance. Such a list assists the Requirements developers in focusing on system components in a manner that assures that each component meets the objectives.

The following quotes from TMS professionals expand on the relationship between the Concept of Operations and Requirements development processes, focusing on the high-level, directional guidance the Concept of Operations offers for Requirements development:

A Concept of Operations is an overarching document for a system engineering process that looks at what the system should do, in broad terms. A Functional Requirements document defines this "what" in a very detailed manner, removing any possible ambiguities. The two must go hand in hand. Once all parties agree upon the Concept of Operations, it serves to guide the Functional Requirements for the project scope.

The objectives contained in a Concept of Operations are central for maintaining consistent context and scope between the Concept of Operations and Functional Requirements.

Diagrams and Test scenarios further facilitate this objective. I am the only person generating documents for the project. So I am aware of all the scenarios fully. I discuss with the partners when doubts arise, and put it in writing if ambiguities surface. Otherwise, I have a fair idea from the beginning as to where we want to go. I can readily see how for a large-scale project, probably with many people doing different parts, diagrams and test scenarios can be very useful.

*TMS Experience*

### 6.2.1 Examples of TMS Requirements

Below are examples of Requirements that have been generated based on the pre-existence of a Concept of Operations. To the extent possible, examples will demonstrate the recommended practices outlined above.

Several of the following examples are taken from the Oregon TOCS Concept of Operations and Functional Requirements documents. Below is a statement describing the fundamental goals and objectives for the system as a whole – communicated in the Concept of Operations:

**Oregon TOCS Goals and Objectives.** *The goals and objectives of the TOCS is to integrate the hardware and software systems used by the TOC operators and district office personnel to provide a seamless operational platform that provides for immediate information dissemination and close operational ties between TOC's and their customers and partners both public and private.*

*TMS Experience*

There is a clear high to low level flow in the transition from Concept of Operations to requirements. The above statement and the needs assessment statements in the examples below show a high level need of certain system functionality that was agreed upon by a group of stakeholders. Operating procedures, goals, vision statements, etc. are not enough to fully define the nuances of system function that will be necessary to build or add functionality to the system in question. The following examples show the level of detail that should be included in a Requirements document, and that level of detail is compared to the goals and procedures outlined in a Concept of Operations document.

There are three examples presented below. The first, example 1, addresses 'how to use' a Concept of Operations to support Requirements development related to the performance parameters of some capability within the system. The second, example 2, addresses 'how to use' a Concept of Operations to support Requirements specification of the "interfaces" with other systems (external or internal). The third, example 3, addresses 'how to use' Concept of Operations to support Requirements specification of the way that a user interacts with the system.

**Example 1 – Performance Requirements and Concept of Operations from Oregon TOCS, a statewide transportation operations center system.** The examples below show a clear linkage between a Concept of Operations and the same system's Performance Requirements. The needs defined in the Concept of Operations (shown by the system diagram) flow down to the Functional Requirements below:

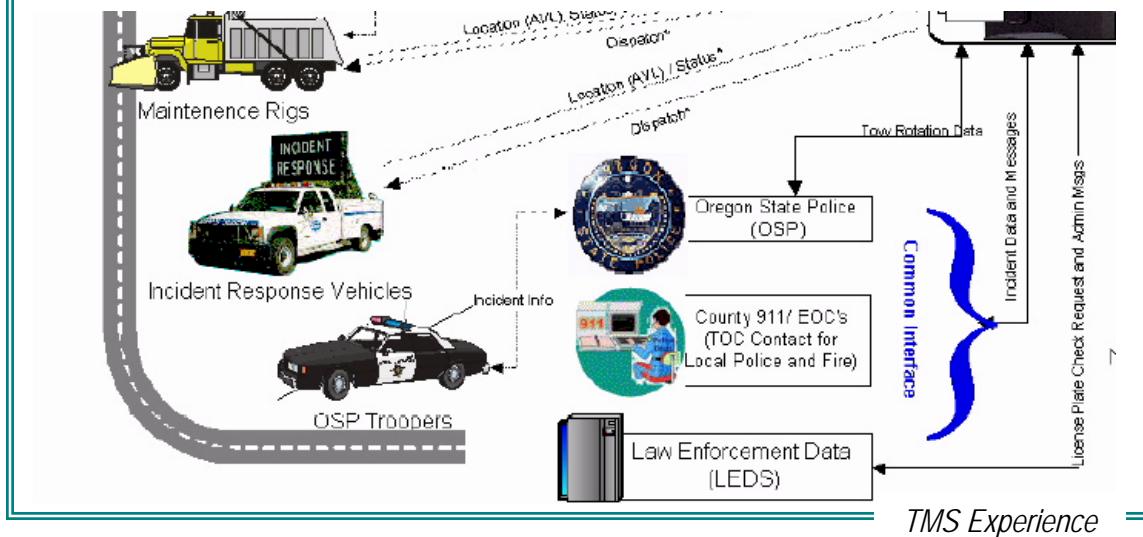
**Identified High-Level Needs Assessment Statement from Oregon TOCS *Concept of Operations***

- There is a need for additional weather alarm systems with integrated notification processes.

**Functional Requirements** concerning the tracking of DOT vehicles via the Automatic Vehicle Location (AVL) system:

- The TOCS shall Track Vehicle Resources
  - The TOCS shall provide communications and data/information flows with all ODOT fleet vehicles equipped with ODOT standard AVL system.
    - The TOCS system shall automatically enter/update an incident location into an Incident Report based on ODOT fleet vehicles' AVL system latitudinal and longitudinal coordinates.
  - The TOCS shall provide the Tracking of ODOT winter maintenance vehicles to support winter maintenance management
    - TOCS system operators shall use the AVL system as a Winter Maintenance Management Tool.
  - The TOCS shall provide the Tracking of ODOT Incident Response vehicles to support incident management
- The TOCS shall track the locations and message displayed on ODOT Incident Response vehicles.

Link to Systems Diagram in the *Concept of Operations* for Oregon TOCS



**Example 2 – Interface Requirements and Concept of Operations from Oregon TOCS.** The examples below show a clear linkage between a Concept of Operations and the same system's Interface Requirements. While the Concept of Operations expresses its need textually and graphically, the graphic depiction is particularly useful when describing interface requirements; the graphic clearly depicts interface relationships:

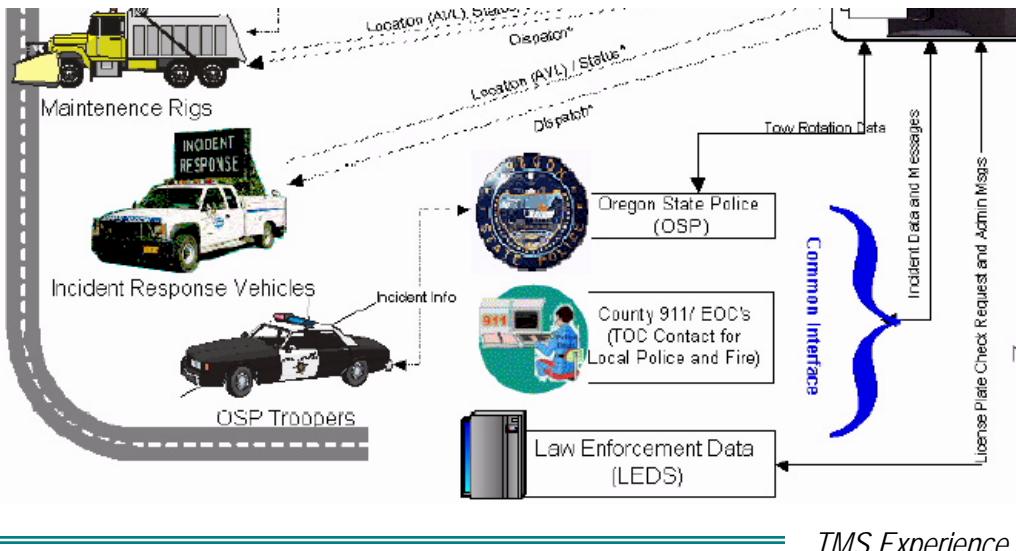
### Link to Needs Assessment from Oregon TOCS *Concept of Operations*

Currently district offices are unable to enter incidents into the CAD system. This is a significant problem for efficient incident tracking and management reporting purposes.

Oregon TOCS gives the following *Requirements* for the interface of data between the TOCS system and the Oregon State Patrol (OSP) Computer Aided Dispatch (CAD) system:

- The TOCS shall do Incident Management.
  - The TOCS shall provide an interface to enable access to LEDS for license and warrant checks.
  - The TOCS shall provide an interface to the OSP CAD system.
    - TOCS Interface to OSP will support geo-coding of incidents to match.
    - TOCS Interface to OSP will enable two-way transfer of incident records between OSP and ODOT TOC.
    - The TOCS shall provide Towing Dispatch functionality using the OSP Tow rotation system.
    - The TOCS system shall provide electronic access to the OSP's tow rotation system.
    - TOCS Interface to OSP will enable read data access to all OSP incidents- both current and archival.
    - TOCS Interface to OSP will include "Administrative Messaging" functionality of PSSI CAD.
    - TOCS Interface to OSP will support "Screen to Screen Messaging" functionality of PSSI CAD.

### Link to Systems Diagram in the *Concept of Operations* for Oregon TOCS



**Example 3 – Human-Machine Interface Requirements and Concept of Operations from Oregon TOCS.** The examples below demonstrate a linkage between a Concept of Operations and the same system's Human Machine Interface Requirements. Graphics and textual descriptions of the system concept help the requirements develop more clearly:

### Needs Assessment Statement in Oregon TOCS *Concept of Operations*

There are too many VMS applications in use due to the need to use specific software for each vendor's sign. This is a training and system maintenance problem. This is an especially serious problem in backup situations where the TOC doing the backup may not even have the correct software for a given sign.

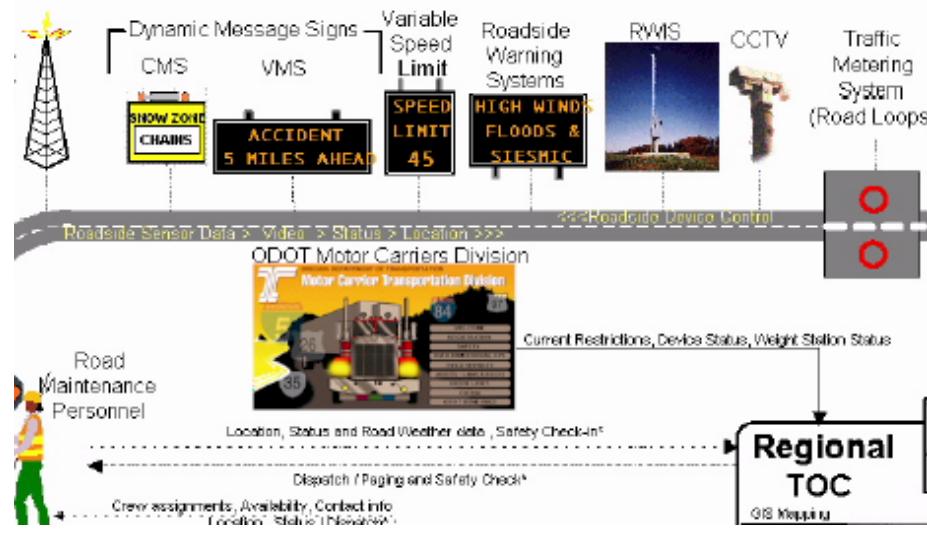
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Oregon TOCS gives the following *Requirements* for the user's interface with the control of Dynamic Message Signs (DMS):

- The TOCS user interface shall have a GUI screen to control DMS signs.
  - The DMS control GUI will incorporate the following abilities:
    - Shall provide a selectable listing of all TOCS signs, where users with permissions can take control of a sign directly from this listing with a single action.
    - Shall provide a message library, which lists all sign messages contained therein and allows users to view selected messages prior to choosing them.
  - The TOCS shall provide a sign properties configuration GUI, where items such as font, brightness, number of phases, time between phase transitions, etc. may be specified.
  - The TOCS system shall support the concept of "tool tips" or "fly-over" help to provide further details to the operator without the need to open additional windows.
    - Within the "tool tips", the TOCS system shall be capable of manual note entry and/or edits to the information/details.
  - The TOCS user interface will allow message to be posted to DMS signs.

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### Link to Systems Diagram in the *Concept of Operations* for Oregon TOCS



*TMS Experience*

## 6.4 Guiding Principles

*What are Requirements? – Developing Functional Requirements for ITS* (FHWA-OP-02-047, April 2002.) defines Requirements as being, "...statements of the capabilities that a system must have, geared to addressing the [needs] that a system must satisfy."

*Requirements' Role in Systems Engineering* – Requirements generation represents the step of refining and expanding on the concepts developed in the Concept of Operations into clear, unambiguous text that is interpretable for engineers to design, build, and operate a system.

*The Requirements Development Process* – Developing a collection of requirements requires the analysis of the interaction between the customer, the environment, and the technical community while assuring that the goals and objectives of the system, outlined in the Concept of Operation are being met.

*Properties for Writing Good Requirements – Developing Functional Requirements for ITS* identifies seven properties for writing good Requirements: Necessary, Concise (minimal, understandable), Attainable (achievable or feasible), Complete (standalone), Consistent, Unambiguous, Verifiable.

*Transitioning from a Concept of Operations to Requirements* – A Concept of Operations should have addressed the integration of the concept, the systems' diagram, and the commonly accepted stakeholder system objectives. From the perspective of the developer of Requirements, the following should be utilized to support their effort:

- Diagrammed Inputs and Outputs – The diagram generated in the Concept of Operations demonstrates to the Requirements development team the stakeholders' viewpoint of what the system should logically and physically 'look like.'
- Test Scenarios – Scenarios generated in the Concept of Operations will help the Requirements team in generating lower-level requirements than may have been possible just by reviewing a User-Oriented Operational Description or System Diagram. If a fairly complete set of Scenarios has been generated, the Requirements development team should have available to them scenarios describing:
  - Key Users' Perspectives – affording the opportunity to generate requirements based upon each component of the system, relative to key users;
  - Variety of User Classes – affording the opportunity to generate requirements based upon each component of the system, relative to the multiple classes of users;
  - Stress/Failure Scenarios – affording the opportunity to generate requirements based upon each component of the system, relative to the extreme events that are expected to cause the system to fail;
  - Multiple Circumstances – affording the opportunity to generate requirements based upon each component of the system, relative to the multiple normal situations the system will experience.
- Objectives – A hierarchy of objectives assists the Requirements developers in focusing on system components in a manner that assures that each component meets the objectives relative to their priority.

## Appendix A – List of References

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### Framework/Table of Contents

#### General Systems Engineering

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#### Concept of Operations

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#### Example Documents - Transportation

- Concept of Operations
- Requirements

## General Systems Engineering

### Books

- Buende, Dennis M. *The Engineering Design of Systems: Models and Methods*. New York: John Wiley & Sons, Inc, 2000. – This book has an explanation of the “Vee” diagram that illustrates the systems engineering process. It also provides detailed key concepts and different methods of requirements tracing. It does not illustrate the systems engineering process using a specific system but gives a broad perspective of the process.
- Martin, James, *Systems Engineering Guidebook: A Process for Developing Systems and Products*, CRC Press, New York, 1997. – This work provides excellent analysis of the systems process, and gives detailed guidelines for systems development throughout the life-cycle of the system. The focus on problem definition will provide a strong background for the development of a concept of operations document.
- Reilly, Norman B. *Successful Systems Engineering: For Engineers and Managers*. New York: Van Nostrand Reinhold, 1993. - This book gives a detailed overview of the systems engineering process. It also has some excellent sections on configuration management and systems management. It has a great deal of information on concepts of operations.
- Sage, Andrew P., " *Systems Engineering*, New York: John Wiley & Sons, Inc., 1992. - This book will be a useful resource because of its thorough coverage of basic systems methodology and systems design. It is considered an excellent resource for many types of systems research.

### Standards

- EIA 632, *Processes for engineering a system* - This document provides a high level framework for systems engineering that can be implemented over a variety of organizations in government and the private sector. Beyond a simple extrapolation of the systems process, 632 included technical processes that are necessary to engineering a system. It provides essential background for any systems related research.
- EIA 731.1 (SECM), *Systems Engineering Capability Model* - This document provides a holistic description of the systems engineering process, covering a wide variety of activities in an organization. It is designed to aid in self-appraisal, process improvement, and process design. The model itself breaks down the processes of an organization by several iterations of categories, beginning with large scale Focus Areas and continuing to more narrowly defined practices that can be specifically targeted for improvement. It will provide a sound and broad systems model that will provide excellent background for defining a concept of operations and requirements. Specifically, one can see how the use of good requirements can lead to process improvement and increased capability of the system.
- IEEE 1220-1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process*. - This document provides an application of the system engineering process directly to the software engineering domain. As they relate to software product development, key areas covered include the Systems Engineering Process (SEP), the Systems Breakdown Structure (SBS), application of systems engineering throughout the system life cycle, and requirements development. While software-development directed, the trial-use standard retains enough generality to prove useful in non-software system engineering application.

- ISO/IEC 15288 2002, System Life Cycle Processes - This standard was developed to describe the entire life-cycle of a system, including conception, implementation, and the end of service for the system. As with other systems engineering standards, this document separates the activities of a system into different levels of processes. It is focused on human interfaces, hardware, and software, and how these components fit into the overall process of the system. It will be a useful resource for how concepts of operations and requirements fit into the life-cycle of the system.
- IEEE 1489-1999, Standards for data dictionaries for Intelligent Transportation Systems - This standard specifies a common set of data concepts and meta-attributes for ITS data dictionaries, as well as associated conventions and schemes, which enable the description, standardization, and management of all ITS data. Through consistent use of these common structures and associated conventions and schemes, data and information can be unambiguously defined. Other ITS standards define such issues as how data elements are combined into messages, how messages are exchanged over specific communications interfaces, what groups of data should coexist within a given system, and the requirements for an ITS data registry. Through the implementation of this family of standards, data can be unambiguously interchanged and reused among the various ITS functional subsystems via their specific application systems.

### *Reports*

- Bate, Roger, et al. Software Engineering Institute. A System Engineering Capability Maturity Model Version 1.1. Report No SECMM-95-01/CMU/SEI-95-MM-003 v1.1 Nov 1995.  
<http://www.sei.cmu.edu/pub/documents/95.reports/pdf/mm003.95.pdf> - This document has a thorough breakdown of the systems engineering process, in a general sense. This document is about the Systems Engineering Capability Maturity Model. This model is a project that is being conducted by Software Engineering Institute where they are defining system engineering and its life cycle. Their project is similar to this project because they are creating a document that will be used as an all-purpose guide to Systems Engineering. This is a useful document because it illustrates how broad this technical document needs to be.

### *Web Resources*

- International Council on Systems Engineering, <http://www.incose.org> - INCOSE is another large source of documents on all systems topics. The council represents over ten years of publishing papers from the annual symposium. The website provides a wealth of information and experience in systems engineering.

### *Transportation Specific Resources*

- Balke, Kevin & et al. Freeway Management Handbook. 2003.  
<http://ops.fhwa.dot.gov/Travel/traffic/handbook.htm> - This document contains detailed information about freeway management systems, functioning as a "how to" manual for system planning, design, operations, and maintenance. For each specific element of freeway management systems the document contains an overview, an engineering process explanation, the techniques and technology used, any special related issues, and further references.

- Developing Freeway and Incident Management Systems Using the National ITS Architecture. U.S.DOT. Report No FHWA-JPO-98-032. Aug 1998.  
<http://plan2op.fhwa.dot.gov/pdfs/Pdf1/Edl04203.pdf> - This document gives a detailed explanation of the National ITS Architecture's role in freeway and incident management systems. It also contains overviews of freeway and incident management systems and some lessons learned and best practices for architecture implementation.
- Gonzalez, Paul J. Building Quality Intelligent Transportation Systems Through Systems Engineering. Report No FHWA-OP-02-046. April 2002.  
[http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS\\_TE/13620.html](http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13620.html) - This document introduces the concept and practice of systems engineering and its application to the acquisition, development, and fielding of Intelligent Transportation Systems (ITS). It gives detailed definitions of key concepts and discusses the challenges and benefits within the systems engineering approach. The systems engineering life cycle is also described in detail.
- National Highway Institute Training. The National Highway Institute offers a wide-ranging selection of courses that relate directly to transportation operations. These include courses on Mathematical Sciences to Materials, Pavements, and Base Design to Design and Traffic Operations, and Intelligent Transportation Systems (ITS). Their series on ITS includes the following courses directly addressing systems engineering (for additional information, please see the NHI web site, <http://www.nhi.fhwa.dot.gov>):
  - 137024A Introduction to Systems Engineering for Advanced Transportation
  - 137024C Introduction to Systems Engineering for Advanced Transportation
  - 137026A Managing High Technology Projects in Transportation
  - 137026C Managing High Technology Projects in Transportation
- National ITS Architecture, <http://www.its.dot.gov/arch/arch.htm>. - This resource is a comprehensive collection of information designed to aid in the development and implementation of intelligent transportation systems. The Theory of Operations within the architecture should be particularly helpful. The Architecture is also useful in identifying most of the components that will be found within any TMS. As such, it serves as a terrific starting point for defining and refining a TMS concept. Specifically, per the National ITS Architecture, it provides details into:
  - User Services – ...describe what the system will do from the user's perspective. ... A set of requirements covering each of these User Services are the basis for the National ITS Architecture definition.
  - Logical Architecture – ... defines the Processes (the activities or functions) that are required to satisfy the User Services. Many different Processes must work together and share information to provide a User Service. Data Flows identify the information that is shared by the Processes.
  - Physical Architecture – ...forms a high-level structure around the processes and data flows in the Logical Architecture. The physical architecture defines the Physical Entities (Subsystems and Terminators) that make up an intelligent transportation system. It defines the Architecture Flows that connect the various Subsystems and Terminators into an integrated system. The subsystems generally provide a rich set of capabilities, more

- than would be implemented at any one place or time. Equipment Packages break up the subsystems into deployment-sized pieces.
- Market Packages – …represent slices of the Physical Architecture that address specific services like surface street control. A market package collects together several different subsystems, equipment packages, terminators, and architecture flows that provide the desired service.
  - Turnbull, Katherine F. ITMS: A Key Strategy to Optimize Surface Transportation System Performance White Papers. Conference Proceedings of 4th ITMS Conference. Report No FHWA-OP-01-145. July 15-18, 2001. Newark, NJ.  
[http://www.itsdocs.fhwa.dot.gov/jpdocs/repts\\_te/13662.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/repts_te/13662.pdf) - This report provides the technical papers prepared for the 4th Integrated Transportation Management Systems (ITMS) Conference held in Newark, New Jersey on July 15-18, 2001. This document describes the importance and benefits of Transportation Management Systems. It discusses how operations planning affects the overall system and the importance of this process. It also addresses the challenges of planning these systems. It illustrates how the National ITS Architecture is a valuable tool in planning for operations. It also discusses the importance of addressing all sorts of institutional interactions when developing and deploying an ITMS.

## Concept of Operations

### *Books*

No books devoted solely to Concept of Operations have been identified to date.

### *Standards*

- Bjørke, Per, et al. IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Documents. New York: The Institute of Electronics and Electrical Engineers, Inc., 1998. Report No IEEE Std 1362-1998. - This guide presents the format and the contents of a concept of operations document to be used when developing or modifying a software-intensive system. It describes the essential elements to the concept of operations document as well as the importance of the specific element to the system. This document also has excellent definitions of the terminology related to the concept of operations.
- Guide for the Preparation of Operational Concept Documents. (ANSI/AIAA G-043-1992). American National Standards Institute, 1992. - This report gives guidelines for creating a concept of operations document. It includes practical information on applying and packaging the operational concept technique and an example of the process's application to the development of a major NASA system.
- IEEE 1362-1998 Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document. New York: IEEE, 1998. - This standard describes the format and contents of a ConOps document used to develop and maintain a software-intensive system. It does not

provide specific techniques for ConOps development but gives possible approaches for ConOps drafting. This IEEE guide will help serve as a reference for the ConOps section of the proposed document.

### Reports

- Cohen, Sholom. Guidelines for Developing a Product Line Concept of Operations. Report No CMU/SEI-99-TR-008 ESC-TR-99-008. Software Engineering Institute. Aug 1999.  
<http://www.sei.cmu.edu/pub/documents/99.reports/pdf/99tr008.pdf> - This document provides guidelines for creating the concept of operations documents for a product line. Most of the material covers the information and detail needed in the concept of operations. It also provides an idea of the factors to be considered when developing the concept of operations.
- TMC Concepts of Operation: Implementation Guide. ITS Joint Program Office, Federal Highway Works Administration, December 1999.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/TMCCOnOpsImplGuide.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMCCOnOpsImplGuide.pdf) - This document reviews the purpose behind developing a Concept of Operations document for regional TMCs. It demonstrates the importance and provides examples and resources identified and utilized in several developing TMCs throughout the nation.
- Transportation Management Center: Concepts of Operation. Intelligent Transportation Systems. Report No FHWA-OP-99-029. Dec 1999.  
[http://www.itsdocs.fhwa.dot.gov/jpdocs/rept\\_mis/8v@01!.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/rept_mis/8v@01!.pdf) - This document focuses on Transportation Management Centers (TMCs) and concepts of operations. It discusses the importance of concepts of operations, the reasons agencies need them, and the challenges a transportation management center faces when planning, maintaining, and operating the system.

## Requirements

### Books

- Fetters, Chris& et al. Software Quality, Validation, and Verification. "Chapter 2 Requirement Tracing". Kansas State University, 1999. <http://www.cis.ksu.edu/~hankley/d841/Fa99/chap2.htm> - This chapter comes from a larger work and deals with requirements tracing. It describes the quality factors, environments, and tools associated with tracing. The TMC requirements section of the proposed document will draw a substantial amount from this paper. It describes the different methods in which one can trace requirements, and it also discusses and distinguishes the different software that is capable of tracing requirements. Finally, the chapter includes factors that can influence requirement tracing and quality.
- Maier, Mark W. and Eberhardt Rechtin. The Art of Systems Architecting. United States of America: CRC Press, Inc., 1997. - This book discusses how requirements should be developed and traced. It includes a number of more broadly applicable architectural concepts and tools, such as heuristic tools, progressive design, and spiral-to-circle software acquisition. Even though it describes the system process, it does so with a focus on software systems.

- Sawyer, Peter and Ian Sommerville. Requirement Engineering. Chichester: John Wiley & Sons, 1997. – This book reviews the steps for the development and analysis of requirements. It provides guidelines for various processes in requirements development and identifies major problems that occur with projects related to system management.
- Thayer, Richard H. ed. Software Engineering: Project Management. Los Alamitos: IEEE Computer Society, 1997. - This book describes the system engineering process through a software engineering prospective. It is a good resource for requirements because it discusses the problems with developing requirements. It also reviews requirement specifications, including what they are and why they are important.

### *Standards*

- IEEE 830, Recommended Practice for Software Requirements Specifications. New York: IEEE, 1998. - This standard provides a description and template of software requirements specification document. It gives a full analysis of the creation of the specification, from characteristics of the document to specific content that should be included. The standard concludes with detailed templates for a software requirements specification document. It will be useful in the general description of best practices for writing a requirements document. The analysis of individual characteristics of good requirements will be especially helpful.
- IEEE 1233, Guide for Developing System Requirements Specifications. New York: IEEE, 1998. – This document offers a high-level and broad scope guide that provides the reader with a sufficient understanding of the steps necessary to develop robust system requirements. The documenting of the requirement development process, its relationship to the systems life cycle, and associated referenced documents suggests that this document is necessary in beginning any requirement development process.\*

### *Reports*

- Fowler, Thomas B. and Paul J. Gonzalez. Developing Functional Requirements for ITS Projects Report No FHWA-OP-02-047. April 2002.  
[http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS\\_TE/13621.html](http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/13621.html) - This document gives an overview of systems engineering and functional requirements. It illustrates the relationship between functional requirements and the National ITS Architecture and contains a description of the systems engineering life cycle in terms of the "Vee" diagram. This document also identifies the benefits and problems associated with developing functional requirements.
- Quality Management Systems—Requirements. 3rd ed. Switzerland: ISO, 2000. - This document specifies requirements for quality management systems where an organization needs to meet customer requirements and provide optimal customer satisfaction.

### *Articles*

- Ambler, Scott. "Tracing Your Design". Software Development. April 1999.  
<http://www.sdmagazine.com/documents/s=815/sdm9904d/> - This article is a resource for information on requirement tracing. It gives a detailed description of the different methods of

tracing a requirement. It also discusses when tracing is necessary as well as the importance of requirement tracing.

## Example Documents - Transportation

*Concept of Operations – for additional information, see Appendix B – List of TMS Evaluated)*

- 8 TMC Case Studies (federal document numbers FHWA-OP-99-003 through FHWA-OP-99-010, EDL numbers 10943, 11063, 10944, 10963, 10983, 11103, 11123, and 11124)
  - Boston Central Artery/Tunnel - Integrated Project Control System ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11063.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11063.pdf))
  - Michigan Intelligent Transportation Systems ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11103.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11103.pdf))
  - Long Island INFORM ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10983.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10983.pdf))
  - Milwaukee MONITOR ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11123.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11123.pdf))
  - COMPASS ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10944.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10944.pdf))
  - Houston TranStar ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10963.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10963.pdf))
  - Arizona TrailMaster ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10943.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10943.pdf))
  - Georgia NaviGATOR ([http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11124.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11124.pdf))

These eight TMC case studies developed by the US DoT provide an overview of the core functions of the more prominent metropolitan transportation management centers throughout the US. The documents provide a high-level review of their primary objective, the functions they perform in achieving those objectives, as well as a list of the technological and human resources they utilize in their day-to-day routine.

- Caltrans TMS Transportation Management Centers: Development Considerations and Constraints. December 2002. –  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Caltrans%20TMC%20Final1.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Caltrans%20TMC%20Final1.pdf) - An excellent example of a document developed for the express purpose of conveying a concept of a particular class of operations center under Caltrans' authority – a general, state-level, concept document. The document would be useful as a template in refining state-level TMC 'vision' and associations (stakeholders).
- Coordinated Highway Action Response Team (CHART), the Maryland State Highway Administration's (MDSHA) multi-jurisdictional and multi-disciplinary initiative to improve traffic safety and mobility statewide has ample documentation on the system's development. The information contained within the on-line documentation provides the same elements found in a single Concept of Operations, but dispersed. The CHART on-line 'reading room' maintains this information: <http://www.chart.state.md.us/readingroom/readingroom.asp>
- COMPARE ITS Strategic Deployment Plan for the Hampton Roads Region—Updated 2000. March 2000. - This document is an update of Hampton Roads' long-term ITS plan, originally written in 1995. It includes sections for the strategic deployment, regional architecture, implementation, and

operations of ITS in this metropolitan area. This paper will serve as an example ITS planning document.

- Fontana/Ontario ATMIS Concept of Operations. Concept of Operations Document. Release 3.0. (Ontario, California) December 13, 2000.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Ontario%20CA%20concept%20of%20ops.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Ontario%20CA%20concept%20of%20ops.doc) - A conceptual document detailing the initial development of a TMC-class system for the Fontana/Ontario region in California. Of particular interest are the sections dedicated to developing stakeholder, or user, perspectives relative to the concept. These 'perspectives' include: TMC Operator, Maintenance Operator, Fontana Engineering, Police Department, Caltrans District 8 Operator, Caltrans District 8 Signal Engineer, Major Event Generator, Traveling Public, and Ontario International Airport.
- GCM Gary - Chicago - Milwaukee ITS Priority Corridor. Corridor Transportation Information Center. System Definition Document. Document # 9931.03. Issue Date: June 12, 1996. Prepared by: De Leuw, Cather & Company. University of Illinois at Chicago, Electrical Engineering and Computer Science Department. The Gary Chicago Milwaukee (GCM) Corridor Transportation Information Center (C-TIC), "...is to be designed to act as a pass-through between various information sources in Illinois, Indiana and Wisconsin." The documentation for this system provided our effort with excellent examples of systems diagramming.
- Intelligent Transportation Systems, Concept of Operations. Draft. Prepared for: Alaska Department of Transportation and Public Facilities. Prepared by: PB Farradyne in November 2000. - The State of Alaska has developed a Concept of Operations for their statewide application of Intelligent Transportation Systems (ITS). The document, "...define[s] operational and institutional relationships, as well as communication elements of the Alaska Statewide ITS Architecture." Of particular note is the detail the document goes into regarding stakeholders, their roles, and the related technologies.
- Maricopa Association of Governments. Regional Concept of Transportation Operations. Final Report. November, 2003. [http://www.mag.maricopa.gov/pdf/cms.resource/RCTO\\_Final\\_Report79101.pdf](http://www.mag.maricopa.gov/pdf/cms.resource/RCTO_Final_Report79101.pdf) - The Maricopa Association of Governments has recently developed an innovative Regional Concept of Transportation Operations document. The RCTO was evaluated for this effort as it sought to take the Concept of Operations documentation development to a new level- that of regional, collaborative, transportation operations.
- Massachusetts Highway Department Coolidge Bridge Rehabilitation ATMS Operations Plan. November, 1999.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/MHD%20operations%20plan.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/MHD%20operations%20plan.doc) - The document describes an operational development concept in sufficient detail to begin to address conceptual day-to-day operations. Specific attention is given to technical, or supporting, technologies.
- Massachusetts Highway Department RTOC Traffic Operations Plan. Draft April, 2002.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/MHD%20RTOC%20Traffic%20Operations%20APR-02.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/MHD%20RTOC%20Traffic%20Operations%20APR-02.doc) - A conceptual document that details the functional operations of the proposed system, given certain events (scenarios). Many of the conceptual functional capabilities of the proposed system, given a specific event, are presented with the assistance of systems diagrams.

- Metropolitan Transportation Management Center Concepts of Operations. Intelligent Transportation Systems. Report No FHWA-JPO-99-020. Oct. 1999.  
[http://www.itsdocs.fhwa.dot.gov/jpdocs/repts\\_te/8ff01!.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/repts_te/8ff01!.pdf) - This document describes in detail the successful practices and lessons learned by eight TMCs: Boston Central Artery/Tunnel Integrated Project Control System; Toronto, Ontario Compass Downsview TMC; Long Island, New York INFROM; Detroit, Michigan Intelligent Transportation System Center; Milwaukee, Wisconsin MONITOR; Atlanta, Georgia NAVIGATOR; Phoenix, Arizona TrailMaster; and Houston, Texas TranStar. It also discusses potential future system improvements.
- NCHRP Synthesis 270, Transportation Management Center Functions, A Synthesis of Highway Practice. - This document reviews the late 1990's national consensus on the functions of a TMC. While lacking some of the more current issues regarding TMC functions, Synthesis 270 provides an excellent outline of core critical functions of TMC operation; an excellent primer on TMC operation.
- New York State DOT Cross Westchester Expressway ITS Concept of Operations. Prepared for the New York State Department of Transportation Region # 8 ITS Unit. October, 1999.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Concept%20of%20Operations\\_10\\_99.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Concept%20of%20Operations_10_99.pdf) - A thorough and useful concept of operations development document to be used as a guide for developing TMC CONOPS. The document details the conceived system, its functions, operators/users, hardware, software, and specific event scenarios. Additionally, the document provides an appendix that reviews the National ITS Architecture and its relationship to the conceived system.
- Operational Concept Document For The DalTrans Transportation Management Center. Southwest Research Institute. SwRI Project No. 10.05594, EO 14 (Doc. No. 261) 07 Jan 2002.  
[http://www.nortex-its.org/Team\\_Meetings/2002/DalTrans-OCD-1.15\\_1.pdf](http://www.nortex-its.org/Team_Meetings/2002/DalTrans-OCD-1.15_1.pdf) - This document gives a high-level explanation of the DalTrans Transportation Management Center's system. It also discusses the new proposed center and the concepts of operations associated with it. This document will be an excellent resource for information on a case study.
- Oregon DOT TOC Concept of Operations (Draft). November, 2002.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/TOC%20Concept%20of%20Operations.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TOC%20Concept%20of%20Operations.doc) - A state-level framework for developing TMCs. The document reviews the core functions of the developing systems, and details how their functions relate to their technological capabilities and missions. An excellent amount of detail has been provided in matrices relating functions to capability.
- Smart Travel Program in the Virginia Department of Transportation Northern Virginia District: December, 1999. Dec 1999. - This report outlines potential Smart Travel projects for the Northern Virginia District.
- State of Tennessee Emergency Support Functions - Concept of Operations.  
[http://www.tnema.org/Plans/ESF\\_COO.htm](http://www.tnema.org/Plans/ESF_COO.htm) - The web site for Tennessee's developing Emergency support functions. This conceptual development document is useful as an example of a state-level, policy-orientated, concept operations statement.
- Surface Transportation Security and Reliability Information System Model Deployment. Cooperative Agreement Number DTFH61-03-H-00105. iFlorida, Draft Concept of Operations. Submitted by: Florida Department of Transportation, District 5. Prepared for: US Dept. of

Transportation, Federal Highway Administration. Jan. 6, 2004.

<http://www.iflorida.net/documents/FinaliFloridaConOps.pdf> - The State of Florida has initiated an ambitious effort, iFlorida. The objective of the new system is "...to demonstrate the wide variety of operational functions that are enabled or enhanced by a surface transportation security and reliability information system." The business plan, requirement and concept documents developed for this system were reviewed for our project

- TMC Concept of Operations Cross Cutting Study (Federal document number FHWA-JPO-99-020, EDL number 10923) or [http://www.itsdocs.fhwa.dot.gov/jpdocs/repts\\_te/8ff01!.pdf](http://www.itsdocs.fhwa.dot.gov/jpdocs/repts_te/8ff01!.pdf) - This document provides a broad scope review of how a TMC concept of operations might be developed through comparisons made to the development and operation of several existing TMCs throughout the U.S. Key sections include setting the stage for a concept of operations as well as the development of a concept of operations for Transportation Management Centers.
- Transportation Incident and Event Management General Plan (Draft). Report No TIEMP –38. 2003. - This document is about how Delaware Department of Transportation (DelDOT), as well as other agencies, will respond in the case of a transportation incident or any emergency event. It describes the concept of operations in terms of the intensity of the risk of the impact to the transportation system. It also illustrates the relationship between the agencies that are working together to keep the situation under control in the case of an incident. This document also defines the responsibility of the Transportation Management Center for DelDOT. In the document, it distinguishes what should be done by the TMC for different levels of response. This document should be used as a resource for one of the case studies, as an example of a concept of operations document.
- VDOT Richmond District ITS Implementation Plan. Sep 1997. - This document provides a framework for the implementation of ITS projects in the Richmond District in Virginia. It also gives an analysis of Richmond area projects, needs, and deployment issues. This plan will be useful as an example of ITS planning in an urban metropolitan region.
- VDOT Staunton District ITS Concept of Operations. January 2001. - This document is a concept of operations plan for the implementation of ITS in VDOT's Staunton district. It is written for both technical and administrative personnel. This paper will be used mainly as an example ConOps for the proposed document.
- Weather-Responsive Traffic Management Concept of Operations. Cambridge Systematics, Inc. Jan 2003. [http://home.nycap.rr.com/karoly/DR1\\_Weather\\_ConOps.pdf](http://home.nycap.rr.com/karoly/DR1_Weather_ConOps.pdf) - The main focus of this document is the needs and activities of transportation officials and how they change during weather-related events. Although this document mainly focuses on the relationship concept of operations pertaining to weather-responsive traffic management, it illustrates the critical elements that are necessary to develop the concept of operations. Even though weather-related events are incorporated into these elements, it gives the reader a basic idea of what a concept of operations is and how it is important. This document will be an excellent resource that illustrates how a specific system in the TMC works.

### *Requirements*

- Arizona DOT TOC Operations Manual. January, 2002.

- Arizona DOT TOC Operations Manual-Cover/Outline  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/toc%20op%20man%20outline.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/toc%20op%20man%20outline.doc)
- Arizona DOT TOC Operations Manual-Table Contents  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/toc-op-man%20enh%20contents.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/toc-op-man%20enh%20contents.doc)
- Arizona DOT TOC Operations Manual-Text  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/toc-op-man%20enh%20text.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/toc-op-man%20enh%20text.doc)

The overall operations guide for Arizona DOT Transportation Operation Centers; the guide is broad enough in scope and detailed enough in depth to provide both the new and the experienced TMC operator an overall picture of day-to-day operations. While not a developmental document, it should prove useful to others in developing their system, their TMC, by providing a rich framework example of a completed system.

- Arizona DOT Tucson Operations Manual. Federal Project Number ITS-9905 (005), ADOT TRACS Number H 5701 01X. February, 2002.  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Tucson%20Operations%20Manual.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Tucson%20Operations%20Manual.pdf) - A guide detailing day-to-day operations for the Tucson metropolitan region; unlike the aforementioned Arizona DOT TOC operational guides, which detail basic operational characteristics for any Transportation Operations Center within the state, this guide details operations for the specific system in this city. There are similarities in framework, but the Tucson document becomes very specific, for example, by detailing precise locations of emergency route plans.
- IDOT District 1 Traffic Systems Center Computer Needs Assessment Project. National Engineering Technology Corp. Contract No B-97-0023. Project No P18-002-95. January 24, 1997.  
([http://www.gcmpic.ai.uic.edu/doc/tech\\_doc/technica.html#IDOT%20District%201%20TSC%20Computer%20Needs%20Assessment%20Project%20Documents](http://www.gcmpic.ai.uic.edu/doc/tech_doc/technica.html#IDOT%20District%201%20TSC%20Computer%20Needs%20Assessment%20Project%20Documents)) - This project report contains documentation of the system process for Illinois Department of Transportation (IDOT) Traffic System Center (TSC). This documentation includes current operations, stakeholders' needs, operational requirements, system functional requirements, and other information pertaining to the computer system upgrade. For the stakeholders' needs, the report contains the findings from interviewing the stakeholders. For the section on operational requirements, it includes a list of the requirements necessary to upgrade the computer system. The section on the system functional requirements breaks down the operational requirements and translates them into functional entities.
- Sample Asset Management Functional Requirements. "Software Requirements Specification for the Inventory Management and Work Order System." Prepared by Transcore. December 23, 2002. - Document reviews the functional requirements for an asset management sub-system to be developed for a TMC; useful as an example when developing functional requirements.
- Traffic Incident Management Enhancement (TIME) Blueprint Version 2.0. April, 2001. - This report provides a structured guide/strategic plan for TIME, the incident management program for the Milwaukee, Wisconsin metropolitan area. It focuses on updated problems, needs, and solutions for the program identified through meetings and working sessions with stakeholders. The updated blueprint also addresses Program Administration requirements, the Regional ITS Architecture, and TIME Evaluation.

## Appendix B – List of Transportation Management Systems Evaluated

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In order to include the numerous examples in the guidance document, the research team analyzed a large number of systems engineering-related documents (i.e. Concept of Operations, Requirements, and other planning and systems engineering-related documents) from systems throughout the nation. The purpose of this appendix is to provide a background on the various systems and documents used as examples in the guidance document. The systems identified below are wide ranging, including classic Traffic Management Centers (TMC)s that manage traffic and incidents on freeways, to more contemporary regional efforts of integration among transportation, public safety, fire, and emergency services.

### Alaska

**Statewide** – The State of Alaska has developed a Concept of Operations for their statewide application of Intelligent Transportation Systems (ITS). The document, "...define[s] operational and institutional relationships, as well as communication elements of the Alaska Statewide ITS Architecture. An analysis of future functionality, and future ITS deployments that will continue to enhance the safety and efficiency of travel in Alaska, as well as internal operations of ADOT&PF is provided." Another central tenant of the document is that of assuring continued statewide ITS connectivity, "...this document has been developed to ensure that ITS projects are not deployed in an isolated or "stove-pipe" manner that can limit the functionality of ITS deployments. An integrated ITS provides the opportunity to enhance the operational efficiency and safety of transportation systems in Alaska by providing those responsible for operating and maintaining transportation systems with a means to exchange real-time data and information." Also of particular note is the detail the document goes into regarding stakeholders, their roles, and the related technologies. Further information on this system and document may be found at:

<http://www.dot.state.ak.us/>

### Arizona

**Statewide** – Regarding the State of Arizona's ADOT TOC, "The Arizona Department of Transportation (ADOT) Traffic Operations Center (TOC) in Phoenix is the statewide control center for traffic operations. Construction started in 1990 and was completed in 1992. Tunnel operations for Interstate 10 were moved to the center in 1995." The TOC assists the Arizona Department of Public Safety (DPS) with incidents on a statewide basis 24 hours per day. The operations staff is also responsible for handling all requests for information, assistance, and response from the public, ADOT personnel, or other agencies in the Phoenix area on a 24-hour-a-day basis. During non-business hours, the staff will also coordinate all requests for ADOT services statewide and maintain up-to-date information on issues affecting ADOT facilities and traffic flow." This description is from the Arizona Department of Transportation, Transportation Technology Group's Traffic Operations Center (TOC) Operations Manual and may be found at

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/toc-op-man%20enh%20text.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/toc-op-man%20enh%20text.doc) Additional

information may be found by reviewing information on the Arizona TrailMaster at:  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10943.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10943.pdf)

**Maricopa** – The Maricopa Association of Governments has recently developed an innovative Regional Concept of Transportation Operations document.. This new and innovative concept is "...mapping out specific strategies of how [regional] transportation agencies, public safety, emergency services, transit, and others can work better together, to get the most benefit out of the region's existing systems and transportation resources." The RCTO was evaluated for this effort as it sought to take the Concept of Operations documentation development to a new level, that of regional, collaborative, transportation operations. Additional information on the RCTO efforts may be found at  
<http://www.mag.maricopa.gov/project.cms?item=1395>, and the report evaluated for this effort may be found at  
[http://www.mag.maricopa.gov/pdf/cms.resource/RCTO-Final\\_Report79101.pdf](http://www.mag.maricopa.gov/pdf/cms.resource/RCTO-Final_Report79101.pdf).

### California

**Statewide** – CalTrans maintains a state-level organizational philosophy with regard to their regional TMC's. Two documents evaluated for this project help to convey this philosophy to their transportation districts: 1) The TMC Master Plan, among other things, describes the objectives of a TMC and lists partnerships for the State of California's system of Traffic Management Centers; 2) The Caltrans Transportation Management Centers: Development Considerations and Constraints provides an excellent example of a document developed for the express purpose of conveying a concept of a particular class of operations center under Caltrans' authority. This document would be useful as a template in refining state-level TMC 'vision' and associations (stakeholders). For additional information, see:

<http://www.dot.ca.gov/>

or, for a copy of the Caltrans Transportation Management Centers: Development Considerations and Constraints:

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Caltrans%20TMC%20Final1.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Caltrans%20TMC%20Final1.pdf)

**Fontana and Ontario** – A joint TMS project for the I-10 corridor between Fontana and Ontario in Southern California. The Fontana/Ontario Advanced Traffic Management and Information System (ATMIS), "...will provide for integration of freeway and surface street operations, and will become the foundation of a "Smart Corridor" along the I-10. With multiple parallel alternatives (both freeway and arterial), ATMIS will facilitate the coordination of traffic management activities on both the freeway network and the local arterials."

The Fontana/Ontario Advanced Traffic Management and Information System (ATMIS) Concept of Operations Document, Release 3.0, was evaluated – A conceptual document detailing the initial development of a TMC-class system for the Fontana/Ontario region in California. Of particular interest are the sections dedicated to developing stakeholder, or user, perspectives relative to the concept. These 'perspectives' include: TMC Operator, Maintenance Operator, Fontana Engineering, Police Department, Caltrans District 8 Operator, Caltrans District 8 Signal Engineer, Major Event Generator, Traveling Public, and Ontario International Airport. The document may be found on the Internet at:  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Ontario%20CA%20concept%20of%20ops.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Ontario%20CA%20concept%20of%20ops.doc)

### Florida

**Statewide** – The State of Florida has initiated an ambitious effort, iFlorida. The objective of the new system is "...to demonstrate the wide variety of operational functions that are enabled or enhanced by a surface transportation security and reliability information system. The model deployment will: expand and integrate existing data collection and monitoring systems; collect and share data; use the data operationally to improve transportation system security, safety, reliability and performance; and where appropriate, distribute the data to the traveling public." The business plan, requirement and concept documents developed for this system were reviewed for our project. Additional information on iFlorida may be found at:

<http://www.iflorida.net/default.htm>

and for the iFlorida Concept of Operations:

<http://www.iflorida.net/documents/FinaliFloridaConOps.pdf>

### Illinois

**Statewide** – One of Illinois Department of Transportation (IDOT) District's TMCs was evaluated. The IDOT District 1 Traffic Systems Center "...is responsible for managing congestion on IDOT's District 1 expressway system. The TSC is also responsible for distributing congestion information to the public and to independent service providers and to the Illinois Gateway." The IDOT District 1 Traffic Systems Center Computer Needs Assessment document was reviewed for our effort. This documentation includes current operations, stakeholders' needs, operational requirements, system functional requirements, and other information pertaining to the computer system upgrade. For the stakeholders' needs, the report contains the findings from interviewing the stakeholders. For the section on operational requirements, it includes a list of the requirements necessary to upgrade the computer system. The section on the system functional requirements breaks down the operational requirements and translates them into functional entities. For additional information on this document, see:

[http://www.gcmpic.ai.uic.edu/doc/tech\\_doc/technica.html#IDOT%20District%201%20TSC%20Computer%20Needs%20Assessment%20Project%20Documents](http://www.gcmpic.ai.uic.edu/doc/tech_doc/technica.html#IDOT%20District%201%20TSC%20Computer%20Needs%20Assessment%20Project%20Documents)

For additional information on the IDOT Dist. 1 TSC, see:

<http://www.catsmpo.com/itsarc/illinois-final-arch/neil/e/46.htm>

**Greater Metropolitan Chicago** – The Gary Chicago Milwaukee (GCM) Corridor Transportation Information Center (C-TIC), "...is to be designed to act as a pass-through between various information sources in Illinois, Indiana and Wisconsin. It is not designed to control and/or monitor traffic control devices but rather to facilitate the sharing of information between various agencies, control centers and private firms. This information will include travel times on selected routes, weather information, incident locations, construction information, etc. Minimal processing of the data will occur in the C-TIC.

Congestion and incident information will be provided to all interested agencies, value added resellers and travelers through a map on the Internet. Eventually, transit information will also be available on the

Internet." The documentation, GCM, Gary - Chicago - Milwaukee ITS Priority Corridor, Corridor Transportation Information Center System Definition Document # 9931.03, for this system provided our effort with excellent examples of systems diagramming. For additional information, see:  
<http://www.gcmcommunicator.com/public-library/pic-technical-docs/pic-ctic-release-one/>

### Maryland

**Statewide** – The Maryland State Highway Administration (MDSHA) maintains the CHART (Coordinated Highways Action Response Team). "This program started in the mid-1980s as the 'Reach the Beach' initiative, focused on improving travel to and from Maryland's eastern shore. It has become so successful that it is now a multi-jurisdictional and multi-disciplinary program. Its activities have extended not just to the busy Baltimore-Washington Corridor, but into a statewide program." The system is operated out of the centralized Statewide Operations Center as well as supporting regional Traffic Operations Centers. The system's web site provides ample documentation about the continued development of the system.

For additional information, see:

<http://www.chart.state.md.us/mapping/chartmap.asp>

### Massachusetts

**Metropolitan Boston** – Three systems of MassHighway's were evaluated in the greater Boston region: the Regional Traffic Operations Center, the Boston Central Artery/Tunnel Integrated Project Control System (IPCS), and the Calvin Coolidge Bridge Advanced Traffic Management System (ATMS).

- The RTOC "...will cover the greater Boston metropolitan area... [and will seek to]... improve safety by warning drivers approaching slow or stopped traffic, reducing the number of incidents; maximize capacity of the region's roadways by managing recurrent and non-recurrent congestion; facilitate coordination with emergency management services, including the Massachusetts Emergency Management Agency (MEMA), the State Police, and local city emergency services; provide information and support for the dissemination of real-time traveler information to the public." The RTOC document used for our effort details the functional operations of the proposed system given certain events (scenarios). Many of the conceptual functional capabilities of the proposed system, given a specific event, are presented with the assistance of systems diagrams. For additional information, see:  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/MHD%20RTOC%20Traffic%20Operations%20APR-02.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/MHD%20RTOC%20Traffic%20Operations%20APR-02.doc)
- The IPCS "...is an integrated traffic management and system control and data acquisition application for Boston's 7.5-mile Central Artery/Tunnel. The project, locally referred to as "The Big Dig," will cost \$73 million to implement both the operations and backup control centers and the first 1.5 centerline miles of system. The system features a high density of field equipment, and double or triple redundancy in many elements. The traffic management components of the IPCS also support travel through the heart of Boston and to and from Logan Airport. The objectives of the Integrated Project Control System are to: Monitor security, traffic, and systems status; Respond to

incidents, nonstandard needs, or equipment failures rapidly and effectively." For additional information, see: [http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11063.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11063.pdf)

- The ATMS, "...is intended to mitigate the traffic impacts of the Coolidge Bridge Reconstruction Project. This includes congestion impacts as well as impacts on emergency vehicles." The implementation and operation plan of this system was evaluated. It includes a list of topics in an overview of daily operating procedures, information that would be included in a user-oriented operational description. For additional information, see:  
[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/MHD%20operations%20plan.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/MHD%20operations%20plan.doc)

### Missouri

**St. Louis** – The St. Louis Gateway Guide System, "...is a partnership among the Missouri Department of Transportation (MoDOT), the Illinois Department of Transportation (IDOT), the Bi-State Development Agency (the regional transit operator) (BSDA), the East-West Gateway Coordinating Council (the Metropolitan Planning Organization for the region) (EWGCC) and other stakeholder agencies, [and] is being implemented to provide the St. Louis Bi-State region with coordinated transportation operations and an advanced transportation management system." It seeks to: "...disseminate real time travel information; improve incident management; improve the overall safety of the transportation network; improve traffic management; reduce non-recurring congestion; coordinate regional resources and databases, such as developing a regional GIS base system; reduce energy consumption; improve air quality." For additional information, see:

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/STL\\_Gateway\\_Guide\\_ConOps.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/STL_Gateway_Guide_ConOps.pdf)

### New York

**Hawthorne** – The Cross Westchester Expressway Intelligent Transportation System "...is envisioned as an integrated communication, video, and data information management system. The design should provide the capability to collect information about the roadway network's transportation conditions, perform analysis, and support management decision making based upon this information. Furthermore, the Hudson Valley ITS should include appropriate elements necessary to provide timely traveler information based on the collected/processed/analyzed data such that travelers and would-be travelers can make informed decisions about their route-, timing-, and modal-related travel options within the Hudson Valley." The system will "...be used to detect, verify, and respond to traffic congestion on the major highways and parkways throughout the entire Hudson Valley. In achieving this goal, the Hudson Valley ITS will provide an integrated incident management and emergency notification system within a single Transportation Management Center (TMC); thus, optimizing both of these critical services through enhanced cooperation and the sharing of a common database of incident information." The document used to evaluate this system was a thorough and useful concept of operations development document that could also be used as a guide for developing a TMC Concept of Operations. The document details the conceived system, its functions, operators/users, hardware, software, and specific event scenarios. Additionally, the document provides an appendix that reviews the National ITS Architecture and its relationship to the conceived system. For additional information, see:

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/Concept%20of%20Operations\\_10\\_99.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Concept%20of%20Operations_10_99.pdf)

### Oregon

**Statewide** – Like its California counterpart, the Oregon Department of Transportation has been working toward generating a standard philosophy for TMS that would later be applied regionally. The basis for transmitting this philosophy is a Concept of Operations document that details what a regional TMS ought to involve. This Oregon Traffic Operations Center System (TOCS) “...provides a unified, statewide platform for around the clock coordination of transportation related services between internal and external customers.” It will do so by providing: Incident Management; Emergency Management; Traffic Management; Traveler Information; Winter Operations; Device Management; Maintenance Operations; Archive Data and Reporting. In evaluating this system for this Guide, the Concept of Operations provided very thorough system diagrams, capturing all the capabilities and functional flows of the system. For additional information, see:

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/TOC%20Concept%20of%20Operations.doc](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TOC%20Concept%20of%20Operations.doc)

### Texas

**Statewide (Austin and El Paso)** – Texas Department of Transportation’s (TxDOT) Traffic Operations Division has generated a Traffic Management Center (TMC) Advanced Traffic Management System (ATMS) Operations Concept Document for the application of such technologies in Austin, El Paso, and any future region requiring such an ITS application. In essence, TxDOT envision’s TMCs for these regions that “...provide automation and decision support for TMC operations related directly to freeway traffic control, incident management, and en-route traveler information.” For additional information, see:

<http://www.dot.state.tx.us/txdot.htm>

**Dallas** – DalTrans is Dallas’ Texas state of the art TMS. “DalTrans shares a common vision with the current and planned Intelligent Transportation Systems (ITS) deployments in the region, state of Texas, and nationwide. This vision focuses on improving safety, reducing congestion, improving traveler mobility, enhancing economic productivity, and promoting energy efficiency and environmental quality.

The TMC represents an application of the National ITS Architecture at a project level and implements the vision by providing the following services to the Dallas area travelers: Pre-trip Travel Information; Traffic Control; Incident Management; Travel Demand Management Emergency Notification.” The DalTrans DalTrans-OCD-1.15 Operational Concept Document was used for this effort and provided a superb example of TMS Concept of Operations documentation. For additional information, see: [http://www.nortex-its.org/Team\\_Meetings/2002/DalTrans-OCD-1.15\\_1.pdf](http://www.nortex-its.org/Team_Meetings/2002/DalTrans-OCD-1.15_1.pdf)

### Virginia

**Statewide** – The Virginia Department of Transportation has undertaken the linking of traffic data archiving capabilities of several regional TMS. The Archived Data Management System (ADMS) collects and archives traffic, and traffic related data, from the regional TMS in Hampton Roads, Northern Virginia, and other locations throughout the Commonwealth, to facilitate advanced rapid data analysis for regional TMS operators. For additional information, see:

<http://smarttravellab.virginia.edu/ADMSVirginia.htm>

and

<http://www.virginiadot.org/infoservice/smart-contacts.asp>

### Wisconsin

*Milwaukee* – “MONITOR is the freeway traffic management system for metropolitan Milwaukee and continues to expand, covering an area beyond Milwaukee. The area freeways were planned in 1961, but the network was never completed. Although the road network provides potential diversion routes, there is no outer belt freeway, so commercial vehicle traffic travels through town. The regional planning commission recommended traffic management as early as 1978 due to congestion problems on, and incident vulnerability of, the existing freeway system. The initial major MONITOR deployment was to support traffic during rehabilitation of I-94, the East-West freeway. The primary objectives of MONITOR are to: Address congestion; Improve safety and air quality.” For additional information, see:

[http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/11123.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/11123.pdf)

### Inter-State and United States Government

*Metropolitan Washington, DC* – The Capital Wireless Integrated Network (CapWIN) is establishing a wireless and wired integrated network with the purpose of sharing incident information among the region’s local and state transportation, fire, emergency services, and public safety agencies. For additional information, see: <http://www.capwin.org/>

### Canada

*Ontario* – “COMPASS is the transportation management program of the greater Ontario area which contains three transportation management centers, each responsible for a separate segment of highway. ...the initial objective of the...system was to balance traffic between express and collector lanes. ...Incident detection and incident management were added to the design.” For additional information, see: [http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded\\_files/10944.pdf](http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/10944.pdf)

# **Developing and Using a Concept of Operations in Transportation Management Systems**



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