

***HANDBOOK FOR DEVELOPING
A TMC OPERATIONS MANUAL***

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16. Abstract This <i>Handbook</i> for Developing a Transportation Management Center (TMC) Operations Manual describes the development of a TMC Operations Manual in the context of the integrated, interdependent world of ITS systems. It describes why operations manuals are important; it identifies the activities and participants needed to produce and update a TMC Manual; and it provides a checklist of topics that can jump start the development of a TMC Manual. This <i>Handbook</i> is a resource for individuals who are responsible for or involved in managing, developing, implementing, operating, maintaining, or supporting a transportation management system. This <i>Handbook</i> may be used developers of a TMC Operations Manual for either a new TMC or for an existing TMC This <i>Handbook</i> also contains case studies illustrating transportation community practices that have been applied to the development and use of TMC Manuals. This <i>Handbook</i> also provides a checklist for developers of a Manual that is cross referenced to specific sections of the <i>Handbook</i> .					
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Table of Contents

<u>Section</u>	<u>Page</u>
1. INTRODUCTION	1-1
1.1. PURPOSE.....	1-1
1.2. INTENDED AUDIENCE	1-2
1.2.1. Institutional Perspective.....	1-2
1.2.2. Staffing Perspective.....	1-3
1.2.3. Role in the Life Cycle of a Project.....	1-5
1.3. HOW WAS THE <i>HANDBOOK</i> DEVELOPED?.....	1-7
1.4. OVERVIEW OF <i>HANDBOOK</i> CONTENT.....	1-7
1.5. ORGANIZATION OF THE <i>HANDBOOK</i>	1-8
1.6. HOW TO USE THE <i>HANDBOOK</i>	1-9
1.7. STATE-OF-THE-PRACTICE.....	1-13
1.8. RESOURCES	1-14
1.9. NOTES AND REFERENCES	1-15
2. OVERVIEW OF TRAFFIC MANAGEMENT CENTERS.....	2-1
2.1. INTRODUCTION.....	2-1
2.2. TMC OPERATIONS	2-1
2.3. INSTITUTIONAL CONSIDERATIONS.....	2-4
2.4. RELATIONSHIP TO OTHER MANUALS, POLICIES, AND PROCEDURES	2-4
3. WHY DEVELOP A TMC OPERATIONS MANUAL?	3-1
3.1. INTRODUCTION.....	3-1
3.1.1. Chapter Purpose and Key Issues.....	3-1
3.1.2. Relationship to <i>Handbook</i> Document.....	3-2
3.2. CHALLENGES IN DEVELOPING AND SUSTAINING TMC OPERATIONS.....	3-2
3.2.1. Moving from a Design/Construct to an Operate/Maintain Regime	3-3
3.2.2. Emphasis on Performance Monitoring and Customer Service	3-3
3.2.3. Planning for Operations.....	3-4
3.2.4. Existence of Multiple Stakeholders	3-5
3.2.5. Resource Constraints	3-6
3.2.6. Personnel Recruitment, Retention, and Training	3-7
3.2.7. Technology Evolution and Integration	3-8
3.2.8. System Failures and False Alarms.....	3-8
3.3. WHY DEVELOP A TMC OPERATIONS MANUAL?	3-9
3.3.1. Formalized and Documented Operational Procedures.....	3-10
3.3.2. Formalized and Documented System Maintenance, Monitoring, and Security Procedures	3-11
3.3.3. Formalized and Documented Data Collection, Analysis, and Warehousing	3-13
3.4. KEY ISSUES IN DEVELOPING AN OPERATIONS MANUAL.....	3-14
3.4.1. TMC Operations Manual Development.....	3-14
3.4.2. TMC Operations Manual Content	3-15
3.4.3. TMC Operations Manual Maintenance.....	3-15
3.5. CONCEPT OF OPERATIONS AND REQUIREMENTS FOR AN OPERATIONS MANUAL.....	3-16
3.5.1. What is a Concept of Operations?	3-17
3.5.2. Using a TMC Concept of Operations Framework to Develop a TMC Operations Manual.....	3-19
3.6. SUCCESSFUL PRACTICES.....	3-36
3.6.1. Using a TMC Concept of Operations Framework to Develop a TMC Operations Manual.....	3-36
3.6.2. Using a TMC Operations Manual to Support Operational Procedures.....	3-36
3.6.3. Using a TMC Operations Manual to Support System Maintenance Procedures	3-42
3.6.4. Using a TMC Operations Manual to Support Data Collection, Analysis, and Warehousing Procedures	3-43

Table of Contents

<u>Section</u>	<u>Page</u>
4. GETTING STARTED.....	4-1
4.1. INTRODUCTION.....	4-1
4.1.1. Chapter Purpose and Key Issues.....	4-1
4.1.2. Relationship to <i>Handbook</i> Document.....	4-1
4.2. OPERATIONS MANUAL IMPLEMENTATION UNDER VARIOUS MANAGEMENT STRUCTURES.....	4-1
4.2.1. Business Model Perspective Introduction.....	4-1
4.3. GEOGRAPHIC AREA COVERED.....	4-2
4.3.1. Single Jurisdiction Management.....	4-2
4.3.2. Multiple Jurisdictions Management Structure.....	4-3
4.3.3. Regional or District Management Structure.....	4-5
4.3.4. Statewide Traffic Management Structure.....	4-7
4.4. NUMBER AND TYPE OF AGENCIES INVOLVED.....	4-8
4.4.1. Single Agency Management Structure.....	4-8
4.4.2. Multiple Transportation Agency Management Structure.....	4-9
4.4.3. Multiple Agency and Disciplines Structure.....	4-10
4.5. OPERATING MECHANISMS.....	4-12
4.5.1. Public Agency Staffed and Operated Management Structure.....	4-12
4.5.2. Contract Operation Management Structure.....	4-13
4.6. GETTING READY.....	4-14
4.7. NOTES AND REFERENCES.....	4-16
5. TMC OPERATIONS MANUAL COMPONENTS	5-1
5.1. INTRODUCTION.....	5-1
5.1.1. Chapter Purpose and Key Issues.....	5-1
5.1.2. Relationship to <i>Handbook</i> Document.....	5-1
5.2. INVENTORY.....	5-3
5.2.1. Area of coverage.....	5-3
5.2.2. Functions.....	5-4
5.2.3. Services Provided.....	5-5
5.2.4. Field Located Traffic Control Devices.....	5-5
5.2.5. Highway Construction Plans.....	5-5
5.2.6. TMC Components.....	5-6
5.2.7. Stakeholders.....	5-6
5.3. DAILY OPERATIONS.....	5-7
5.3.1. Emergency and Other Contact Numbers.....	5-7
5.3.2. TMC Emergency Plan.....	5-8
5.3.3. General Policies.....	5-10
5.3.4. General System Operation.....	5-14
5.3.5. Malfunction Response.....	5-15
5.4. OPERATIONAL CONCEPTS – FREEWAY MANAGEMENT SYSTEMS.....	5-16
5.4.1. Goals of the Traffic Management System.....	5-16
5.4.2. Interagency and Interjurisdictional Coordination.....	5-16
5.4.3. Traffic Monitoring.....	5-17
5.4.4. Traffic Response.....	5-17
5.4.5. Field Devices – Freeway Systems.....	5-18
5.5. CONTROL SYSTEM OPERATION PROCEDURES – FREEWAY MANAGEMENT SYSTEMS.....	5-19
5.5.1. System Start-Up Procedures.....	5-19
5.5.2. System Shut Down Procedures.....	5-19
5.5.3. Operator Interface.....	5-19
5.5.4. Incident Management Procedures.....	5-20
5.6. OPERATIONAL CONCEPTS – TRAFFIC SIGNAL MANAGEMENT SYSTEMS.....	5-20

Table of Contents

<u>Section</u>	<u>Page</u>
5.6.1. Goals of the Traffic Signal Management System	5-20
5.6.2. Interagency and Interjurisdictional Coordination	5-21
5.6.3. Control Area	5-21
5.6.4. Traffic Signal Operations.....	5-22
5.6.5. Agency Responsibilities in Developing Signal Timing	5-22
5.6.6. Field Devices Traffic Signal Systems.....	5-22
5.7. CONTROL SYSTEM OPERATION PROCEDURES – TRAFFIC SIGNALS.....	5-23
5.7.1. System Start-Up Procedures	5-23
5.7.2. System Shut Down Procedures	5-23
5.7.3. Operator Interface	5-23
5.7.4. Incident Management Procedures.....	5-23
5.8. TMC MAINTENANCE PROCEDURES.....	5-24
5.8.1. Routine Maintenance	5-24
5.8.2. Preventative Maintenance.....	5-24
5.8.3. Spare/Backup Equipment	5-25
5.8.4. Emergency	5-25
5.8.5. Agency Maintenance	5-25
5.8.6. Contract Maintenance.....	5-25
5.9. SYSTEM OPERATIONS LOGS	5-26
5.9.1. Incidents and Events.....	5-26
5.9.2. Operations.....	5-26
5.9.3. Maintenance.....	5-26
5.9.4. Citizen Requests	5-27
5.10. SYSTEM REPORTS.....	5-27
5.11. TRAFFIC DATA COLLECTION AND STORAGE.....	5-27
5.12. RISK MANAGEMENT.....	5-28
5.13. SYSTEM DOCUMENTATION.....	5-28
5.14. ORGANIZATIONAL SETTING.....	5-28
5.14.1. Service Providers and Stakeholders.....	5-28
5.14.2. Agreements, Contracts, and Memoranda of Understanding	5-29
5.14.3. Advisory Functions of Other Related Organizations.....	5-30
5.15. ORGANIZATIONAL REPRESENTATION WITHIN THE TMC	5-30
5.15.1. Potential Agencies in TMC.....	5-30
5.15.2. Operating Agreements	5-30
5.15.3. Roles and Responsibilities.....	5-31
5.16. PERFORMANCE MONITORING	5-31
5.16.1. Challenges and Benefits.....	5-32
5.16.2. Performance Measures.....	5-33
5.16.3. Keys to a Successful Program.....	5-33
5.16.4. Other Aspects of Performance Measurement	5-34
6. DEVELOPING AND UPDATING A TMC OPERATIONS MANUAL.....	6-1
6.1. INTRODUCTION.....	6-1
6.1.1. Chapter Purpose and Key Issues.....	6-1
6.1.2. Relationship to <i>Handbook</i> Document.....	6-2
6.2. CREATING A TMC OPERATIONS MANUAL FROM SCRATCH.....	6-2
6.3. UPDATING AN EXISTING OPERATIONS MANUAL	6-4
6.4. DEALING WITH URBAN AND RURAL CHARACTERISTICS.....	6-6
6.5. DEALING WITH TMC COMPLEXITY AND MATURITY	6-7
6.6. THE PERFORMANCE MEASUREMENT PROCESS.....	6-7
6.6.1. Challenges of Performance Measurement	6-9
6.6.2. Benefits of Performance Measurement.....	6-10

Table of Contents

<u>Section</u>	<u>Page</u>
6.6.3. Understanding the Process.....	6-11
6.7. TYPES OF PERFORMANCE MEASURES.....	6-15
6.7.1. What Makes A Good Measure?.....	6-15
6.7.2. Input and Output Classification.....	6-16
6.7.3. Goal-Based Classification.....	6-17
6.7.4. Keys to a Successful Program.....	6-17
6.7.5. Examples of Performance Measures.....	6-18
6.7.6. Recommended Performance Measures.....	6-20
6.7.7. Performance Measures for the Rural Environment.....	6-22
6.8. ESTABLISHING PERFORMANCE MEASUREMENT THRESHOLDS.....	6-23
6.9. DATA FOR PERFORMANCE MEASUREMENT.....	6-24
6.9.1. Methods of Collecting Data.....	6-26
6.9.2. Other Data Issues.....	6-26
6.10. PRESENTING AND REPORTING PERFORMANCE DATA.....	6-27
6.10.1. Common Presentation Pitfalls.....	6-29
6.10.2. Methods of Presenting Data.....	6-29
6.11. REFERENCES.....	6-30
7. TMC OPERATIONS MANUAL CASE STUDIES.....	7-1
7.1. INTRODUCTION.....	7-1
7.2. NORTHERN VIRGINIA SMART TRAFFIC CENTER CASE STUDY.....	7-1
7.2.1. Contents of Manual.....	7-2
7.2.2. Overview of Manual Effectiveness.....	7-7
7.2.3. Summary.....	7-8
7.2.4. Conclusions.....	7-9
7.3. ORLANDO TMC CASE STUDY.....	7-10
7.3.1. Contents of Manual.....	7-11
7.3.2. Overview of Manual Effectiveness.....	7-16
7.3.3. Summary.....	7-17
7.3.4. Conclusions.....	7-18
8. TMC MANUAL CHECKLIST.....	8-1
8.1. INTRODUCTION.....	8-1
8.1.1. Chapter Purpose and Key Issues.....	8-1
8.1.2. Relationship to <i>Handbook</i> Document.....	8-1
8.2. DAILY OPERATIONS (SECTION 5.3).....	8-1
8.2.1. Emergency and Other Contact Numbers (Section 5.3.1).....	8-1
8.2.2. TMC Emergency Plan (Section 5.3.2).....	8-1
8.2.3. General Policies (Section 5.3.3).....	8-2
8.2.4. General System Operation (Section 5.3.4).....	8-3
8.3. OPERATIONAL CONCEPTS – FREEWAY MANAGEMENT SYSTEMS (SECTION 5.4).....	8-4
8.3.1. Goals of the Traffic Management System (Section 5.4.1).....	8-4
8.3.2. Interagency and Interjurisdictional Coordination (Section 5.4.2).....	8-4
8.3.3. Malfunction Response (Section 5.4.3).....	8-4
8.3.4. Traffic Monitoring (Section 5.4.4).....	8-4
8.3.5. Traffic Response (Section 5.4.5).....	8-5
8.3.6. Field Devices – Freeway Systems (Section 5.4.6).....	8-5
8.4. CONTROL SYSTEM OPERATION PROCEDURES – FREEWAY MANAGEMENT SYSTEMS (SECTION 5.5).....	8-6
8.4.1. System Start-Up Procedures (Section 5.5.1).....	8-6
8.4.2. System Shut Down Procedures (Section 5.5.2).....	8-6
8.4.3. Operator Interface (Section 5.5.3).....	8-6
8.4.4. Incident Management Procedures (Section 5.5.4).....	8-6

Table of Contents

<u>Section</u>	<u>Page</u>
8.5. OPERATIONAL CONCEPTS – TRAFFIC SIGNAL MANAGEMENT SYSTEMS (SECTION 5.6)	8-6
8.5.1. Goals of the Traffic Signal Management System (Section 5.6.1)	8-6
8.5.2. Interagency and Interjurisdictional Coordination (Section 5.6.2)	8-7
8.5.3. Control Area (Section 5.6.3)	8-7
8.5.4. Traffic Signal Operations (Section 5.6.4)	8-7
8.5.5. Agency Responsibilities in Developing Signal Timing (Section 5.6.5)	8-7
8.5.6. Field Devices Traffic Signal Systems (Section 5.6.6)	8-7
8.6. CONTROL SYSTEM OPERATION PROCEDURES – TRAFFIC SIGNALS (SECTION 5.7)	8-7
8.6.1. System Start-Up Procedures (Section 5.7.1)	8-7
8.6.2. System Shut Down Procedures (Section 5.7.2)	8-7
8.6.3. Operator Interface (Section 5.7.3)	8-7
8.6.4. Incident Management Procedures (Section 5.7.4)	8-8
8.7. TMC MAINTENANCE PROCEDURES (SECTION 5.8)	8-8
8.7.1. Routine Maintenance (Section 5.8.1)	8-8
8.7.2. Preventative Maintenance (Section 5.8.2)	8-8
8.7.3. Spare/Backup Equipment (Section 5.8.3)	8-8
8.7.4. Emergency (Section 5.8.4)	8-8
8.7.5. Agency Maintenance (Section 5.8.5)	8-8
8.7.6. Contract Maintenance (Section 5.8.6)	8-8
8.8. SYSTEM OPERATIONS LOGS (SECTION 5.9)	8-9
8.8.1. Incidents and Events (Section 5.9.1)	8-9
8.8.2. Operations (Section 5.9.2)	8-9
8.8.3. Maintenance (Section 5.9.3)	8-9
8.8.4. Citizen Requests (Section 5.9.4)	8-9
8.9. SYSTEM REPORTS (SECTION 5.10)	8-9
8.10. TRAFFIC DATA COLLECTION AND STORAGE (SECTION 5.11)	8-9
8.11. RISK MANAGEMENT (SECTION 5.12)	8-9
8.12. SYSTEM DOCUMENTATION (SECTION 5.13)	8-9
8.13. THE ORGANIZATIONAL SETTING (SECTION 5.14)	8-9
8.13.1. Service Providers and Stakeholders (Section 5.14.1)	8-9
8.13.2. Agreements, Contracts, and Memoranda of Understanding (Section 5.14.2)	8-10
8.13.3. Advisory Functions of Related Organizations (Section 5.14.3)	8-10
8.14. ORGANIZATIONAL REPRESENTATION WITHIN THE TMC (SECTION 5.15)	8-10
8.14.1. Potential Agencies in TMC (Section 5.15.1)	8-10
8.14.2. Operating Agreements (Section 5.15.2)	8-10
8.14.3. Roles and Responsibilities (Section 5.15.3)	8-10
8.15. PERFORMANCE MONITORING (SECTION 5.16)	8-10
8.15.1. Performance Measures (Section 5.16.2)	8-10
8.15.2. Other Aspects of Performance Measurement (Section 5.16.4)	8-10
8.16. SUMMARY OF LIFE CYCLE TIMING AND RESOURCES	8-10

1. INTRODUCTION

1.1. Purpose

The transportation community has been developing and operating computer-based transportation systems since the early 1970s. At that time, many of the core building blocks of today's systems were introduced including traffic surveillance cameras, changeable message signs, traffic responsive signal operation, transit priority treatment, highway advisory radio, and ramp metering. Since these systems were typically not interconnected or coordinated and were operated with individual computer systems, separate operational guidelines were established for each system.

Although computer technology changed during the 1980s and more sophisticated control and monitoring capabilities were devised, the systems and technologies remained separated. It wasn't until the 1990s that the transportation community embarked on a journey to integrate systems and to incorporate evolving technologies (like the Internet and personal communications devices) to leverage the effectiveness of their tools. This strategy, Intelligent Transportation Systems (ITS), required a paradigm shift in understanding of the entire transportation system in order to manage the transportation network. No longer do we operate individual systems—instead, we build and operate integrated, interdependent systems where our collective actions are focused on providing transportation services to our customers.

This *Handbook* describes the development of a Transportation Management Center (TMC) Operations Manual in the context of the integrated, interdependent world of ITS systems. It describes why operations manuals are important; it identifies the activities and participants needed to produce and update a TMC manual; and it provides a checklist of topics that can jump-start the development of a TMC manual.

This document also contains case studies illustrating transportation community practices that have been applied to the development and use of TMC manuals.

Sponsorship for the development of this *Handbook* was provided with by the U.S. Department of Transportation (DOT) TMC Pooled-Fund Study Project. Members of the TMC Pooled-Fund Review Team provided oversight to development of this *Handbook* and were influential in shaping this product.

Readers of this *Handbook* are encouraged to review the TMC Pooled-Fund Web site where additional TMC operational resources are pro-

vided including example TMC Operations Manuals. At the time of printing the TMC Pooled-Fund Web site was located at <http://TMCpfs.ops.fhwa.dot.gov>.

1.2. Intended Audience

1.2.1. Institutional Perspective

This *Handbook* is a resource for individuals who are responsible for or involved in managing, developing, implementing, operating, maintaining, or supporting a transportation management system.

The National ITS Architecture provides a framework for defining and understanding the variety of centers, field devices, vehicles, and travelers in the transportation system. This high level perspective of the transportation system is maintained by the U.S. Department of Transportation and updated periodically. At the time of printing, Version 5.1 of the Architecture was available and was posted at the following Web site: <http://www.iteris.com/itsarch/>.

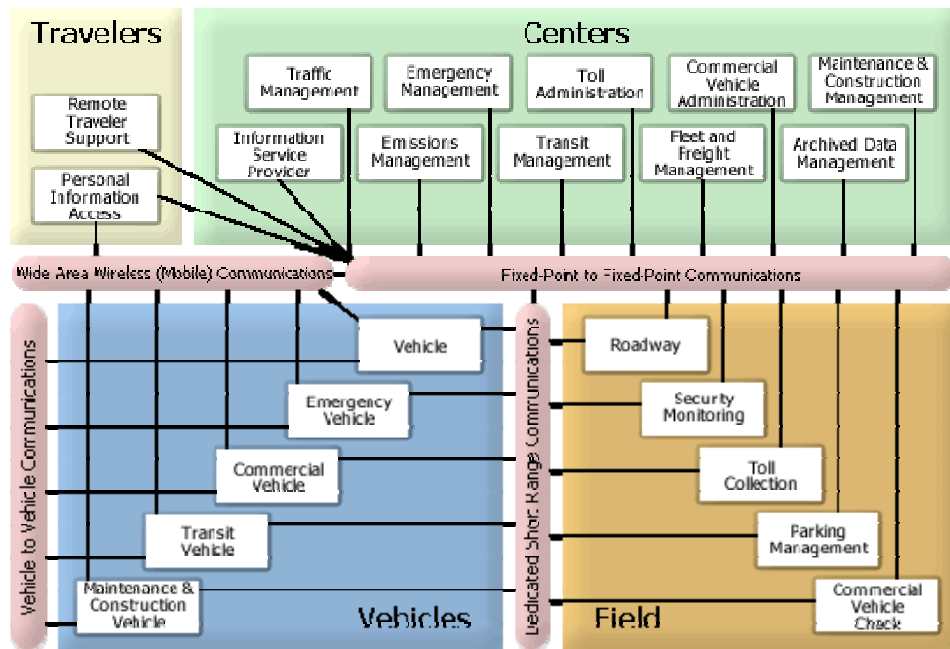


Figure 1-1 National ITS Architecture

Figure 1-1 shows the centers, field devices, vehicles, and travelers in the National ITS Architecture. This drawing depicts the “physical entities” in the Architecture and their relationships with one another.

While the Architecture provides a comprehensive view of transportation, this *Handbook* and the TMC Pooled-Fund Study focus on issues that arise from transportation management centers that are part of traffic signal control systems, freeway management systems, or multimo-

dal systems (1). From the National ITS Architecture perspective, the functions associated these systems would typically be found in centers for traffic management and transit management. However, with the practice of co-locating centers and sharing duties during off-hours, the Handbook may apply to other center configurations as well.

According to the National ITS Architecture Mission Definition document (http://www.its.dot.gov/arch/arch_howto_docs.htm), the kinds of agencies that are typically responsible for transportation infrastructure functions and passenger operations include the following (2):

- State agencies,
- Metropolitan planning organizations,
- City agencies,
- County agencies,
- Toll authorities, and
- Transit agencies.

In addition, it is appropriate to add private companies that perform contracted operations through various concessionaire agreements. The ITS Architecture helps define the institutions, the services and functions that are performed, and the information flows that connect the components of the transportation system.

Therefore, from an institutional perspective this *Handbook* applies to traffic management and transit management centers that are concerned with traffic signal control systems, freeway management systems, or multimodal systems. These functions are typically operated by state agencies, metropolitan planning organizations, city agencies, county agencies, and toll authorities.

1.2.2. Staffing Perspective

From a personnel perspective the *Handbook* has applicability to a number of staffing categories. Perhaps the most commonly named TMC staff member is the Transportation Management Operations Supervisor or Operator. This individual is the person who has daily “hands-on” responsibility for some of the following tasks:

- Providing travel information,
- Records management,
- Congestion management,
- Failure management,
- Incident management,
- Special event management,
- Traffic flow monitoring,

- Emergency management,
- Providing/coordinating service patrols,
- Reversible and high occupancy vehicle (HOV) lane management,
- Traffic signal system management,
- Advanced public transportation systems (APTS) management,
- Environmental and real Time Weather Information Service (RWIS) monitoring,
- Over height vehicle management, and
- Highway-rail intersection management.

A document titled *Guidelines for TMC Transportation Management Operations Technician Staff Development* describes the knowledge, skills, and abilities (aka KSA) associated with a staff member who performs the tasks noted above (3).

In addition to operators, a number of other positions are affiliated with development and operation of Intelligent Transportation Systems. In the late 1990s the Federal Highway Administration (FHWA) sponsored development of a series of capacity building documents to identify the skills needed for ITS workers (4). Those documents include a list of affiliated personnel arranged by the role they play in developing, implementing, and operating ITS systems. While the intended audience for a TMC Operations Manual primarily includes operators, dispatchers, drivers, electronics technicians, engineers, and managers listed in the third bulleted section below, others in this list have a role in providing content for the operations manual. For instance, a human resources staff specialist may be the appropriate individual to provide content for a description of Workplace Policies contained in a TMC Operations Manual (see section 5.3.3.13 for a description of this content). The roles as defined in the FHWA capacity building document that may be applicable to developing a TMC Operations Manual include:

- Roles in developing a regional ITS concept of operations and planning for ITS:
 - Champions,
 - Planners, and
 - Federal field staff;
- Crosscutting roles:
 - Business analysts,
 - Data(base) analysts and managers,
 - Contract specialists,
 - Legal staff,

- Marketing/public relations staff,
- Human resources staff, and
- Systems administrators/support technicians;

- Roles in the design, procurement, installation, operations and maintenance, and evaluation stages:
 - Project managers,
 - Engineers,
 - Software developers,
 - Systems designers/integrators,
 - Operators,
 - Dispatchers,
 - Drivers,
 - Electronics inspection and maintenance technicians, and
 - Operations managers/supervisors;

- Creating change in roles for mainstreaming ITS:
 - Program/agency manager and
 - Interjurisdictional coordinator.

1.2.3. Role in the Life Cycle of a Project

Projects involving traffic management systems and centers have typically followed a systems engineering life cycle. Current practice established by the U.S. DOT on January 8, 2001, requires that ITS projects carried out using funds from the Highway Trust Fund including the Mass Transit Account conform to the National ITS Architecture and applicable ITS standards. These goals are being accomplished through the development of regional ITS architectures and the use of a systems engineering process for ITS project development (5).

The Final Rule on ITS Architecture and Standards Conformity (Final Rule) and the Final Policy on Architecture and Standards Conformity (Final Policy) were enacted by the FHWA and Federal Transit Administration (FTA), respectively. According to section 940.11.c of the FHWA rule, the systems engineering analysis includes at a minimum:

- Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture);
- Identification of participating agencies' roles and responsibilities;
- Definition of requirements;
- Analysis of alternative system configurations and technology options to meet requirements;
- Procurement options;

- Identification of applicable ITS standards and testing procedures; and
- Procedures and resources necessary for operations and management of the system.

Current practices typically represent the systems engineering process in a “V” diagram as shown in Figure 1-2 below (6). This model is simply a graphical representation of a process that can be followed throughout the life cycle of a project. The left-hand side of the “V” depicts the design and decision making process that must come before actual system construction and implementation. Each task adds more detail and corresponds to testing, operations, and maintenance activities on the right-hand side of the “V.”

The point of this discussion is that a portion of the content for a TMC Operations Manual should be developed throughout the life cycle of a system. Potential content for a TMC Operations Manual includes concepts of operations, a description of key functions of the center, goals of the system, and other items that are developed at various stages in the life cycle of a system and center. A TMC Operations Manual should not be developed at the end of a project, but should be developed throughout the life of a system or center to ensure the design and implementation reflects the manner in which the TMC operates.

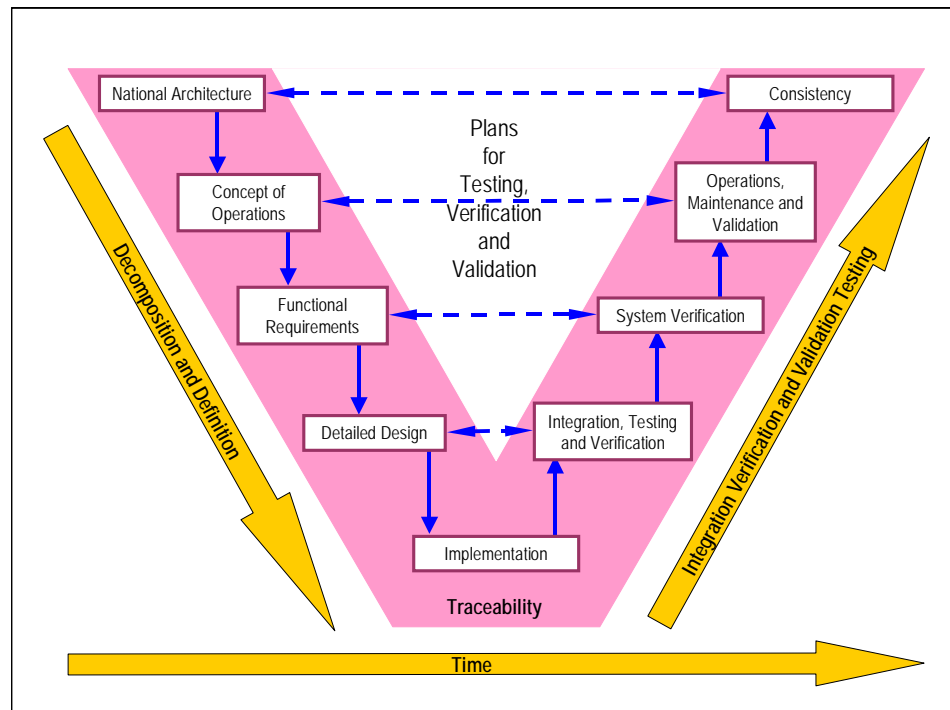


Figure 1-2 “V” Systems Engineering Process

1.3. How was the *Handbook* Developed?

This *Handbook* was developed collaboratively with the TMC Pooled-Fund Study Review Team. The Review Team members included public sector representatives who brought real-world experience to the project tasks and were able to help shape the result so that it is relevant to the intended audience. In addition, a number of associated resources were used to add value to the final product including existing TMC manuals, a recommended outline for a TMC manual produced by the Institute of Transportation Engineers (ITE) in 2001, and documents that cover developmental and operational characteristics such as systems engineering and staffing.

The process for developing the document included writing and iteratively editing three versions of the outline for the *Handbook*. After the final outline was approved by the TMC Pooled-Fund Study Review Team, the authors wrote three versions of the technical document. Each document draft was reviewed by the TMC Pooled-Fund Study Review Team and changes were made that reflected the experience of the team members. The *Handbook's* guidance was enhanced by (a) inclusion of case studies and (b) addition of an updated TMC manual outline that can serve as a checklist for TMC Operations Manual development.

In addition, a distribution plan and some supporting outreach material were developed that are tailored to relevant audiences.

1.4. Overview of *Handbook* Content

The *Handbook* is structured into three parts:

- The first part describes the *Handbook* and explains why operations manuals should be developed;
- The second part describes how to develop an effective operations manual and case studies; and
- The third part provides a checklist of topics that can jump start the development of a TMC manual.

Taken together and augmented with example TMC Operations Manuals, the guidance found in this Handbook allows an agency to involve relevant staff who can contribute their content to a TMC Operations Manual that meets the needs of both the operating agencies and the staff responsible for these activities.

1.5. Organization of the Handbook

Part I

Part I provides an overview of the *Handbook* and background information that establishes the environment for developing and using an operations manual. The introduction describes the purpose, audience, and organization of the document along with an overview of traffic management centers including a high level concept of operations, institutional considerations, and key topics relevant to operations. Finally, it describes why a TMC Operations Manual should be developed. Part I is divided into three chapters as follows.

- Chapter 1 of the *Handbook* states the purpose of this document, identifies the intended audience groups, summarizes how the *Handbook* was developed and the role of the TMC Pooled-Fund Study Review Team, summarizes the structure of the *Handbook*, indicates the state-of-the-practice in 2005, and shows where relevant resources can be found.
- Chapter 2 contains an overview of Traffic Management Centers. It describes a high level concept of operations, provides a summary of key institutional issues relevant to a TMC, identifies the types of operations that are typical of these centers, and lists key topics applicable to daily operations.
- Chapter 3 describes the need for and the challenges in sustaining a TMC Operations Manual. It also highlights successful practices that can be applied to leverage the actions leading to a functional TMC Operations Manual.

Part II

Part II defines the major components of the TMC Operations Manual, provides guidance on how to create and update the manual, and provides case studies of TMC Operations Manual development and use. Part II is divided into four chapters as follows.

- Chapter 4 describes approaches for developing an operations manual based on the organizational setting and business model structure of a TMC.
- Chapter 5 helps an agency review their organizational structure and setting to identify the components of a TMC Operations Manual needed for their situation. It also is cross-referenced to the checklist contained in Part III.
- Chapter 6 identifies the methods, processes, techniques, and tools needed to develop and update an operations manual for TMCs.

- Chapter 7 provides examples or case studies that build off of and demonstrate how the concepts, techniques, and guidance that are identified in the earlier chapters can be applied within an agency or program associated with a TMC or traffic operations program.

Part III

Part III provides a checklist of topics that can be included in a TMC Operations Manual.

- Chapter 8 supplements the material provided in earlier chapters with quick descriptions of the topics to be included in a TMC manual.

1.6. How to Use the *Handbook*

How an agency uses this *Handbook* depends on its current situation. If an agency is building a new Transportation Management System and has no experience in operating a TMC, then all the chapters of this *Handbook* are applicable. If an agency is updating an existing manual (either because of its age or because new components or services are being added), then some chapters could be skipped—especially chapters 1, 2, and 3. This might be appropriate if the TMC Operations Manual Team has not changed substantially since the last iteration. Figure 1-3 shows one approach for using this *Handbook*.

The process shown in Figure 1-3 suggests the following steps.

1. Select the TMC Operations Manual Development Leader,
2. Educate the Development Leader through review of chapters 1, 2, 3 and any existing TMC Operations Manual,
3. Form the TMC manual team that will write the operations manual,
4. Educate the team,
5. Identify components of the manual, and
6. Write the TMC Operations Manual throughout the life cycle of the system.

Figure 1-3 is structured from the viewpoint of the Development Leader that manages the effort to write and/or update the TMC Operations Manual. Section 3.4.1 provides more discussion on the role of a TMC Operations Manual Development Leader.

Chapter 4 describes TMCs operating in the context of typical deployment models and describes the potential impacts of these styles of management and business enterprises on the development and use of a TMC Operations Manual. This discussion could prove useful to an

agency just building a TMC and seeking to understand some of the operational impacts of the business decisions that have been made.

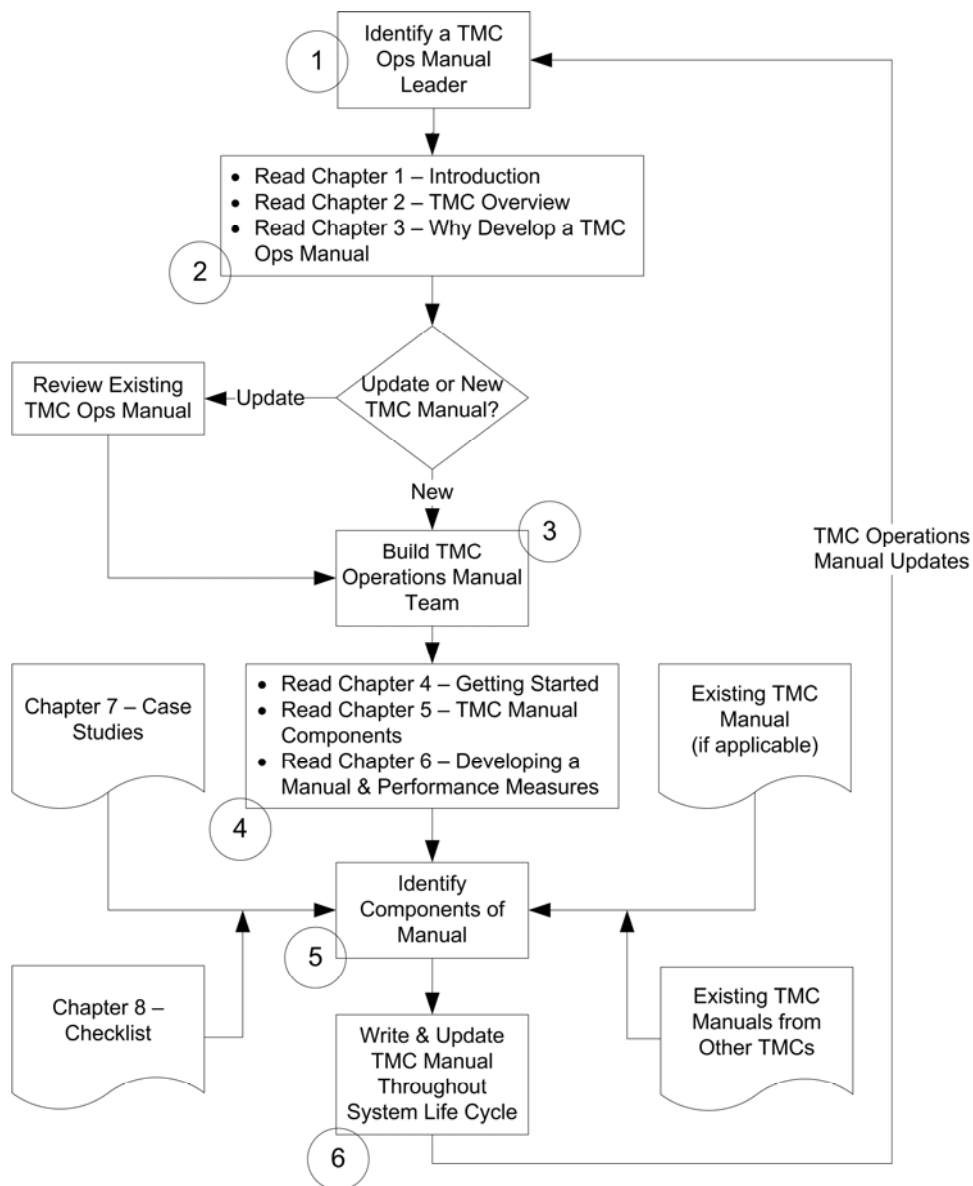


Figure 1-3 Approach for Using the Handbook to Write a TMC Operations Manual

Chapter 5 describes the content that should be considered in a TMC Operations Manual. This chapter arranges the content by category. For instance, some content pertains to the category of “inventory” and describes the physical environment for the TMC. Another category relates to “daily operations” and describes items such as emergency contact telephone numbers. The categories of “freeway management sys-

tems” and “traffic management systems” contain subcategories of “operational concepts” and “operational procedures” that are relevant to those systems. “TMC maintenance procedures” and “logs” are also categories for classifying the content in chapter 5. Table 1-1 shows the range of content for a TMC Operations Manual and provides the section number in chapter 5 where the content is described.

Table 1-1 Range of Content for a TMC Operations Manual

Category		Handbook Section
Inventory		5.2.1. Area of coverage
		5.2.2. Functions
		5.2.3. Services Provided
		5.2.4. Field Located Traffic Control Devices
		5.2.5. Highway Construction Plans
		5.2.6. TMC Components
		5.2.7. Stakeholders
Daily Operations		5.3.1. Emergency and Other Contact Numbers
		5.3.2. TMC Emergency Plan
		5.3.3. General Policies
		5.3.4. General System Operation
Freeway System	Operational Concepts	5.4.1. Goals of the Traffic Management System
		5.4.2. Interagency and Interjurisdictional Coordination
		5.4.3. Malfunction Response
		5.4.4. Traffic Monitoring
		5.4.5. Traffic Response
		5.4.6. Field Devices – Freeway Systems
	Operational Procedures	5.5.1. System Start-Up Procedures
		5.5.2. System Shut Down Procedures
		5.5.3. Operator Interface
		5.5.4. Incident Management Procedures

Table 1-1 Range of Content for a TMC Operations Manual (Cont.)

Category		Handbook Section
Traffic Management System	Operational Concepts	5.6.1. Goals of the Traffic Signal Management System
		5.6.2. Interagency and Interjurisdictional Coordination
		5.6.3. Control Area
		5.6.4. Traffic Signal Operations
		5.6.5. Agency Responsibilities in Developing Signal Timing
		5.6.6. Field Devices Traffic Signal Systems
	Operational Procedures	5.7.1. System Start-Up Procedures
		5.7.2. System Shut Down Procedures
		5.7.3. Operator Interface
		5.7.4. Incident Management Procedures
TMC Maintenance Procedures	5.8.1. Routine Maintenance	
	5.8.2. Preventative Maintenance	
	5.8.3. Spare/Back-up Equipment	
	5.8.4. Emergency	
	5.8.5. Agency Maintenance	
	5.8.6. Contract Maintenance	
System Operation Logs	5.9.1. Incidents and Events	
	5.9.2. Operations	
	5.9.3. Maintenance	
	5.9.4. Citizen Requests	
	5.10. System Reports	
	5.11. Traffic Data Collection and Storage	
	5.12. Risk Management	
	5.13. System Documentation	
Other Organizations	Context	5.14.1. Service Providers and Stakeholders
		5.14.2. Agreements, Contracts, and Memoranda of Understanding
		5.14.3. Advisory Functions of Other Related Organizations
	In the TMC	5.15.1. Potential Agencies in TMC
		5.15.2. Operating Agreements
		5.15.3. Roles and Responsibilities
Performance	5.16.2. Performance Measures	
	5.16.4. Other Aspects of Performance Measurement	

Chapter 6 describes two typical conditions: creating a TMC Operations Manual from scratch and updating an existing TMC Operations

Manual. This chapter is a good place to start reading if agency personnel are familiar with the purpose and activities of a TMC. This is especially true since the chapter also focuses on performance measurement—a key to effective operations.

Finally, chapter 7 includes case studies applicable to all TMC Operations Manual efforts.

Another approach for an agency that has an existing TMC manual and wants to augment its content with a new section is to use the checklist in chapter 8 and the more detailed discussion in chapter 5 after chapter 6 has been reviewed. These two chapters also identify the personnel who can provide relevant information to include in a new section.

If an agency is just starting a TMC manual or a TMC deployment project and would like more information about the purpose of a TMC and key elements such as a concept of operations, then chapter 3 provides important information. In addition, Table 3-1 provides mapping between a concept of operations document and a TMC Operations Manual. This is useful since it allows an agency to leverage the investment in each product. In addition to chapter 3, this agency may also want to review chapters 1 and 2 since together they document the need for and benefits of a TMC Operations Manual.

No matter the existing situation of an agency, a key strategy for development of a TMC Operations Manual is to develop TMC manual content throughout the life cycle of a systems engineering project. It is never too late and almost never too early to start building the teams, content, and experience to develop a good operations manual.

1.7. State-of-the-Practice

The purpose of the TMC Pooled-Fund Study is to initiate projects that address operational and human-centered issues associated with TMCs. Since a TMC Operations Manual has the capability to assist the interaction of operational staff with TMC technology, it meets the objective of the Pooled-Fund Study Team.

In the 2004–2005 time frame, many public agencies and practitioners did not recognize the need, importance, and value of an operations manual. Many were also unaware of how to effectively integrate the use of an operations manual into their daily activities, procedures, policies, and programs.

The Institute of Transportation Engineers developed an outline identifying the key issues and topics that should be covered in an operations manual. Technical guidance and recommended practices had not been developed and made available to assist practitioners on how to de-

velop, what to include, and how to integrate an operations manual into the day-to-day tasks, policies, procedures, and activities. The TMC Pooled-Fund Study gathered a few example TMC Operations Manuals and made them available through their public Web site.

This state-of-the-practice provided the backdrop that led the TMC Pooled-Fund Study Team to identify the development of this *Handbook* as a work project. It was judged a priority to the members and to the larger TMC community and it met the objectives and requirements of the program.

1.8. Resources

The following key documents are useful resources for an agency developing a TMC Operations Manual:

- *Metropolitan Transportation Management Center Concepts of Operations*. Intelligent Transportation Systems. Report No. FHWA-JPO-99-020. October 1999.
http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/8ff01!.pdf
- *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/TMCConOpsImplmGuide.pdf
- *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
- *Developing and Using a Concept of Operations in Transportation Management Systems*. December 2004.
http://TMCpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=38&new=0.
- *Building Quality Intelligent Transportation Systems Through Systems Engineering*. 1992.
http://itsdocs.fhwa.dot.gov/jpodocs/repts_te/13620.html
- *Guidelines for TMC Transportation Management Operations Technician Staff Development*. FHWA Report FHWA-OP-03-071.
http://TMCpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=26&new=2.
- *TMC Business Planning and Plans Handbook*. TMC Pooled-Fund document, under development in 2005.

http://TMCpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=54&new=0

- *ITE Recommended Outline for a TMC Operations Manual*, 2005.
http://TMCpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/ITE%20OM%20Annotated%20Outline.pdf.

1.9. Notes and References

- 1 The Charter of the Transportation Management Center Pooled-Fund Study initiative is located at <http://TMCpfs.ops.fhwa.dot.gov/overview.cfm>.
- 2 The National ITS Architecture contains a series of documents that describe its components. One of those documents, the *National ITS Architecture Mission Definition*, contains a section describing the users of the transportation system. In the October 2003 version, Table 3.3-1 lists those users including the transportation infrastructure providers. See <http://www.iteris.com/itsarch/html/menu/documents.htm> to obtain a copy of the *Mission Definition*. This document is also available through the ITS Electronic Document Library at <http://www.its.dot.gov/itsweb/welcome.htm>.
- 3 FHWA Report FHWA-OP-03-071, *Guidelines for TMC Transportation Management Operations Technician Staff Development*, by Daniel H. Baxter, is available from the Pooled-Fund Web site as a product of a completed project called “TMC Operator Requirements & Position Descriptions, Phase 1.” This site is at <http://TMCpfs.ops.fhwa.dot.gov>. The document uses requirements matrices to show the relationships between TMC functions, operations personnel tasks, and the knowledge, skills, and abilities a person must possess to accomplish the required tasks. Training requirements for operations personnel are discussed.
- 4 These professional capacity building documents are available through the ITS Electronic Document Library at <http://www.its.dot.gov/itsweb/welcome.htm>. The series was titled “Building Professional Capacity in ITS” and contained documents describing staffing, hiring, and development of a training program. The documents are numbered FHWA-OP-99-016, FHWA-OP-99-017, FHWA-OP-99-018, FHWA-OP-99-019, and FHWA-OP-99-033.
- 5 The text of the U.S. DOT Final Rule and Final Policy on ITS can be found on the Web at http://ops.fhwa.dot.gov/its_arch_imp/index.htm.

- 6 The 1992 document *Building Quality Intelligent Transportation Systems through Systems Engineering* gives an explanation of the systems engineering approach and describes the “V” diagram. It is available through the ITS Electronic Document Library at <http://www.its.dot.gov/itsweb/welcome.htm>. The document number is FHWA-OP-02-046.

2. OVERVIEW OF TRAFFIC MANAGEMENT CENTERS

2.1. Introduction

An operations manual is a critical tool that can support the management of day-to-day TMC operation by defining the roles, responsibilities, functional capabilities, services provided, major tasks, and day-to-day activities that are performed in pursuit of a region or agency's transportation system management mission, goals, and objectives.

Operations affect outcomes. With more effective operations there is more effective system performance, and an operations manual is a key tool in leveraging effective operations.

In particular, the potential benefits resulting from the development and use of a TMC Operations Manual include the following:

- Operational procedures lend consistency to day-to-day activities, improve interagency and interjurisdictional working relationships, and ease internal training efforts;
- System maintenance, monitoring, and security procedures improve resource utilization and enhance system safety; and
- Data collection, analysis and warehousing procedures support short- to long-term transportation facility performance improvements and planning efforts.

This chapter describes the operations of a TMC and identifies documents that could be applicable to the content of a TMC Operations Manual.

2.2. TMC Operations

The National ITS Architecture includes a list of services that a TMC might perform including the following:

- Network surveillance,
- Probe surveillance,
- Surface street control,
- Freeway control,
- HOV lane management,
- Traffic information dissemination,

- Regional traffic control,
- Traffic incident management system,
- Traffic forecast and demand management,
- Electronic toll collection,
- Emissions monitoring and management,
- Virtual TMC and smart probe data,
- Standard railroad grade crossing,
- Advanced railroad grade crossing,
- Railroad operations coordination,
- Parking facility management,
- Regional parking management,
- Reversible lane management,
- Speed monitoring,
- Drawbridge management,
- Roadway closure management,
- Transit vehicle tracking,
- Transit fixed-route operations,
- Demand response transit operations,
- Transit passenger and fare management,
- Transit security,
- Transit maintenance,
- Multimodal coordination, and
- Transit traveler information.

These services are accomplished by performing various “functions” such as the following:

- Barrier system management,
- Traffic surveillance data collection,
- Highway-rail intersection (HRI) traffic management,
- Rail operations coordination,
- System management safeguarding,
- TMC environmental monitoring,
- TMC evacuation support,
- TMC for Automated Highway Systems (AHS),
- TMC freeway management,
- TMC HOV lane management,
- TMC incident detection,

- TMC incident dispatch coordination/communication,
- TMC input to in-vehicle signing,
- TMC multimodal coordination,
- TMC multimodal crossing management,
- TMC probe information collection,
- TMC regional traffic control,
- TMC reversible lane management,
- TMC signal control,
- TMC speed monitoring,
- TMC toll/parking coordination,
- TMC traffic information dissemination,
- TMC traffic network performance evaluation,
- TMC work zone traffic management,
- Traffic data collection,
- Traffic maintenance,
- Transit center security,
- Transit evacuation support,
- Transit garage operations,
- Transit environmental monitoring,
- Transit data collection,
- Transit center tracking and dispatch,
- Transit center paratransit operations,
- Transit center multimodal coordination,
- Transit center information services,
- Transit garage maintenance, and
- Transit center fare and load management.

In order to provide services by performing specific functional activities, procedures must be established, documented, and used during operations. It is typical during the design phase of a project to identify specific, detailed activities that are based on functional requirements. These activities can be documented as procedures for inclusion in the TMC Operations Manual. Section 3.5 describes the following content for a TMC Operations Manual that includes “procedures” developed throughout the systems engineering life cycle:

- Emergency and other contact numbers;
- Daily operations including management center functions; personnel, staffing, and hours of operation; after hours, remote operation, and security procedures (i.e., access to control system interfaces); main-

- tenance, startup/shutdown, and failure recovery (automated and manual); and notification procedures;
- Control system operations including operator interface, operational procedures (i.e., manual, automated, demand responsive, default), and incident management procedures;
 - Maintenance procedures including routine, preventative, emergency (nonroutine), and contract maintenance and the location of spare/backup equipment;
 - System operations logs including operations, maintenance, events, system reports, and traffic data and risk management (i.e., what to keep, log, save, or discard);
 - Operational concepts including traffic monitoring, data analysis and warehousing, interagency coordination, interjurisdictional coordination, and emergency procedures (i.e., notification, monitoring, and coordination);
 - Control center/system field device descriptions including location, access/security, layout, fire suppression, power source/location, heating, ventilation, and air conditioning (HV/AC), and data, voice, and network communications; and
 - System documentation including vendor maintenance documentation.

2.3. Institutional Considerations

Since the Final Rule on Architecture and Standards Conformity requires “an operational concept that identifies the roles and responsibilities of participating agencies and stakeholders in the operation and implementation of the systems included in the regional ITS architecture,” many regions will be able to use their ITS architecture work as a resource to define TMC operations.

This means that TMC manual content listed above should reflect the diversity of agencies and stakeholders as they impact operations in a region. For instance, incident management procedures should describe the roles and activities applicable for the region.

2.4. Relationship to Other Manuals, Policies, and Procedures

In order for an operations manual to be effective it must be consistent with the institutional and administrative policies that help guide the environment in which it operates. This section provides a description of the kinds of documents that might be applicable and briefly indicates how they impact the operational concepts and procedures identified in an operations manual.

1. National ITS Architecture and Regional ITS Architecture documents

These resources define the mission, goals, and objectives within which the TMC operates. They also identify the stakeholders, services, and functions that are included as a part of a center's sphere of influence. Information from these documents would typically be included in the following sections (references are to chapter 5 of this *Handbook*).

- 5.2.1. Area of coverage
- 5.2.2. Functions
- 5.2.3. Services Provided
- 5.2.6. TMC Components
- 5.2.7. Stakeholders

2. Agency Employee Manual (sometimes called a Personnel Manual)

These manuals are typically tailored to an organization and could include topics such as compensation and classification, complaint resolution, employee relations, equal employment opportunity, payroll and work schedule information, performance appraisal, safety and emergency procedures, hiring and appointment, position classification, employee ethics and conduct, and disciplinary action. Information from these documents would typically be included in the following sections (references are to chapter 5 of this *Handbook*).

- 5.3.3. General Policies

3. Agency Business Procedures Manual

These manuals describe the procedures for invoice processing, invoices, travel regulations, petty cash funds, identification cards, risk management, account numbers, expenditure codes, budget reallocations, and authorized signature forms. Information from these documents would typically be included in the following sections (references are to chapter 5 of this *Handbook*).

- 5.8.5. Agency Maintenance
- 5.8.6. Contract Maintenance
- 5.12. Risk Management

4. TMC Business Planning and Plans Handbook (1)

The objective of this TMC Pooled-Fund sponsored handbook is to outline the business planning models that have been successfully employed by transportation agencies to ensure the long-term sustainability of transportation management centers and associated ITS applications.

5. Developing and Using Concept of Operations in Transportation Management Systems (2)

The purpose of this TMC Pooled-Fund sponsored handbook is to develop technical resources that provide guidance and recommended practices on the need for, development of, and use of a concept operations and corresponding requirements throughout the life cycle of a TMC. Information from these documents would typically be included in the following sections (references are to chapter 5 of this *Handbook*).

- 5.2.1. Area of Coverage
- 5.2.2. Functions
- 5.2.3. Services Provided
- 5.2.6. TMC Components
- 5.2.7. Stakeholders
- 5.4.1. Goals of the Traffic Management System
- 5.4.2. Interagency and Interjurisdictional Coordination
- 5.6.1. Goals of the Traffic Signal Management System
- 5.6.2. Interagency and Interjurisdictional Coordination

6. TMC Performance Monitoring, Evaluation, and Reporting Handbook (3)

The purpose of this TMC Pooled-Fund sponsored handbook is to achieve improved TMC performance monitoring, data management, evaluation, and reporting practice, which in turn fosters improved planning, design, and performance management of TMCs. Information from these documents would typically be included in the following sections (references are to chapter 5 and chapter 6 of this *Handbook*).

- 5.10. System Reports
- 6.6. The Performance Measurement Process
- 6.7. Types of Performance Measures
- 6.8. Establishing Performance Measurement Thresholds
- 6.9. Data for Performance Measurement
- 6.10. Presenting and Reporting Performance Data

7. National Incident Management System (4)

This document, authored in 2004 by the Department of Homeland Security, establishes a core set of doctrines, concepts, principles, terminology, and organizational processes to enable effective and efficient collaboration. All Federal departments are required to adopt this document and use it in support of all actions in support of state, local, and tribal entities. Information from these documents would typically be included in the following sections (references are to chapter 5 of this *Handbook*).

5.5.4. Incident Management Procedures

5.7.4. Incident Management Procedures

3. WHY DEVELOP A TMC OPERATIONS MANUAL?

3.1. Introduction

3.1.1. Chapter Purpose and Key Issues

Following an introductory description of the intent and use of this *Handbook* and a general overview of TMC structure and operation, this chapter describes the following.

- The motivation for developing a TMC Operations Manual specific to one's locale,
- The potential resultant benefits in achieving agency goals and supporting regional strategies,
- Key issues for consideration before and during the TMC Operations Manual development process,
- Strategies for successful TMC Operations Manual development using a concept of operations framework to define content, and
- Examples of successful developments nationally.

In general, TMC managers, technical staff, and operators must have a thorough understanding of the capabilities of a TMC and the resources available to assist in making sound decisions, efficiently implementing operational strategies and control plans, and employing appropriate procedures in response to current traffic conditions. An operations manual is a critical tool that can support the management of day-to-day TMC operations by defining the roles, responsibilities, functional capabilities, services provided, major tasks, and other day-to-day activities that are performed in pursuit of an agency's mission, goals, and objectives.

Most public agencies and practitioners do not recognize the wide-ranging need, importance, and value of a TMC Operations Manual. In brief, potential benefits resulting from the development and use of a TMC Operations Manual relate to formalized and documented:

- Operational procedures that lend consistency to day-to-day activities, improve interagency and interjurisdictional working relationships, and ease internal training efforts;
- System maintenance, monitoring, and security procedures that improve resource utilization and enhance system safety; and

- Data collection, analysis, and warehousing procedures that support short- to long-term facility performance improvements and planning efforts.

3.1.2. Relationship to *Handbook* Document

This chapter establishes the need for a TMC Operations Manual to support TMC operations, completes *Part I - Introduction and Background* and, in combination with *Chapter 1. Introduction* and *Chapter 2. Overview of Traffic Management Centers*, positions the reader well for developing a TMC Operations Manual specific to their locale. *Part II - Developing a TMC Manual* (chapters 4 through 7) leads the reader through the step-by-step process required to develop a TMC Operations Manual.

3.2. Challenges in Developing and Sustaining TMC Operations

On a day-to-day basis, TMCs are challenged by the unique and dynamic nature of traffic conditions. Traffic situations typically arise without warning, and the impact can create inconvenient and potentially dangerous conditions for travelers. These conditions may change rapidly and, often, unpredictably. The resources used by the TMC in executing its response may be impacted by the very situation to which it is reacting. While these are significant daily challenges, an agency must also consider the longer-term challenges that affect the development and sustainability of TMC operations. These long-term challenges, categorized below, are the focus of this section of the *Handbook*:

- Moving from a design/construct to an operate/maintain regime,
- Emphasis on performance monitoring and customer service,
- Planning for operations,
- Existence of multiple stakeholders,
- Resource constraints,
- Recruitment, retention, and training of personnel,
- Technology evolution and integration, and
- System failures and false alarms.

Because of the variability in TMC structure, operation, agency participation, and interjurisdictional context, unique challenges may exist

that are not addressed here; this discussion is limited to the more common challenges related to TMC operations.

3.2.1. Moving from a Design/Construct to an Operate/Maintain Regime

The design/construction culture that exists in many transportation agencies may prove to be a significant impediment to developing and sustaining TMC operations. Despite ever-increasing congestion and incident occurrence and customers' desire for improved reliability, security, and safety, some transportation agencies have been slow to transition their focus from designing and constructing new facilities to operating and maintaining existing facilities. This lingering focus on design and construction affects prioritization of resources to improve the existing system.

Several factors may explain this latent shift in focus to operations and maintenance. An underlying explanation may relate to the lack of institutional ownership of congestion and its related problems

First, while transportation agencies are an obvious candidate, traffic congestion is very often still viewed as a “public” or community problem, influenced by outside factors such as employment trends, land use patterns, the state of the economy, etc., that are outside the control of a single institution. Second, there is a lack of understanding among transportation agencies and others of the “definition” of operations and the activities that are included in this definition. This lack of understanding leads to an agency's resistance to change the status quo, believing that operations is already being done

However, many times opening a TMC can be the catalyst to shift to operations. When the investment has been made in the facility, the agency(ies) must commit to operations.

Despite these factors, capacity constraints and new facility costs force transportation agencies to move toward operations as a means to improve traffic congestion. Hence, it is important to define operations in a way that is meaningful to TMC managers, technical staff, and operators, as well as agency and political decisionmakers (i.e., using “operations” as an umbrella term for more specific issues and goals or using a more descriptive term(s) such as security, reliability, or safety directly).

3.2.2. Emphasis on Performance Monitoring and Customer Service

However operations is defined, it is important to be able to demonstrate success at related activities. With the shift in focus from de-

sign/construct to operate/maintain, a concurrent shift in focus on customer service and performance measurement is occurring.

Performance measures should:

- Be based on customer expectations;
- Reflect multiple concerns (i.e., mobility, reliability, travel time, predictability, public safety, traveler information, peak/off-peak travel, multimodal travel, etc.);
- Support technical decisions;
- Be tailored to local and regional needs and be consistent with national priorities; and
- Provide the basis for strategic planning and political decision-making (1).

To achieve these criteria, transportation agencies should, as a first step, identify and define customer needs and expectations. This may require developing methods to better understand and communicate with the customer. Based on these needs and expectations, a comprehensive set of performance measures for local, regional, and national management needs should be developed; local, regional, and national priorities require different data and levels of detail to support decisionmaking.

Concurrent with each performance measure, transportation agencies should define benchmarks for achievement. Agency leaders may tie incentives, awards, and accountability to achievement of these performance goals. While technology (i.e., instrumentation, enabling infrastructure) and/or private-sector services can be used for data collection to support performance monitoring, few transportation agencies have adequately planned for or allocated sufficient resources to support comprehensive performance monitoring of TMC operations.

3.2.3. Planning for Operations

Transportation agencies usually have limited experience applying traditional planning processes to operational activities; the planning process has more typically identified and prioritized capital improvement projects rather than activity-based alternatives. Operational activities don't map well to the traditional 3-C planning process that seeks to provide continuing, cooperative, comprehensive solutions to transportation challenges. With continued emphasis on operations, the traditional planning process could be modified to provide consideration of

activity-based alternatives (i.e., development of an operations planning process).

To aid in the transition from the traditional planning process to a planning process that adequately considers activity-based alternatives, transportation agencies should:

- Survey customers and use these results as basis for programming,
- Include local leaders in all aspects of operations planning,
- Promote strong input from operations in capital planning, and
- Establish linkages between operations and land use and development programs (2).

The large geographic scope and multiagency, multijurisdiction stakeholder involvement common to TMCs may make it unclear who has responsibility for planning operations. Metropolitan Planning Organizations (MPOs) may assume a greater role in planning for operations in a TMC.

3.2.4. Existence of Multiple Stakeholders

The development and operation of a TMC not only involves several departments within the implementing agency (or agencies), but also the efforts of a variety of private sector product and service providers.

In many state transportation departments, planning, design, construction, operation, and maintenance are separate entities. These units are often also divided by lines between the headquarters organization and district offices. To achieve the desired capability and impact from the significant TMC investment, effective interaction between these units is critical at all stages: prior to it achieving operational status, on an ongoing basis as it is operated and maintained, and as it evolves (3, 4).

Successful transportation operations require interaction between transportation modes, between agencies within jurisdictions and across jurisdictional boundaries. Thus, the actions of one agency may greatly impact the conditions under which another must labor, and the ability of an agency to optimize travel conditions will almost undoubtedly depend upon cooperation between several agencies. Interactions are not limited to public sector participants. Interaction between public and private sector organizations in the TMC is increasingly common, either under more common contractual arrangements or as part of public-private partnerships (3, 4).

Interagency cooperation should be a part of every phase of the TMC. A number of strategies have been recommended to ensure successful TMC operations when multiple stakeholders are involved:

- Develop an interagency strategic plan that defines a common vision, purpose, and goals; all interests should be included early in the development process (i.e., freight, public safety, multiple modes), and the resulting impacts and benefits should be monitored.
- Develop methods to involve and retain nontraditional partners by focusing on issues of mutual concern and building on initial successes.
- Increase transportation agency presence in existing or new public safety forums (e.g., governor’s office of emergency management).
- Build cooperation around triggering events or activities (e.g., incident or event management, emergency preparedness, etc.) To establish ongoing cooperation: use scenario planning to jump start communication and expand focus over time; use system failure as opportunity to learn and improve; leverage existing relationships and public momentum.
- Establish data and communication protocols among agencies; establish common frequencies among first responders; create multiagency training and personnel management programs; and
- Establish a “report card” on interagency cooperation; measure results; and showcase successes (3, 4).

In most multiagency, multijurisdictional TMCs, a coordinating forum exists to address issues, assure regular and full communication, and identify opportunities for improvement. This often takes the form of interagency committees, typically at multiple working levels (2).

3.2.5. Resource Constraints

Effectively incorporating operations in the planning process will help to ensure adequate resources (i.e., staffing levels and budget) for TMC operations and maintenance. As previously discussed, activity-based projects (i.e., operations) are challenged to compete effectively for resources against capital improvement projects under the traditional planning process.

TMC programs generally grow over time, as new services or new geographic regions are added. TMCs may be regionally focused, looking to provide seamless travel to motorists across jurisdictional boundaries and recognizing that facility disruptions can have far-reaching impacts. Typical service areas include system efficiency, public safety, traveler information, and emergency management and may include freight programs and homeland security. TMC programs may address multi-modal or intermodal facilities, rural or urban environments, and interstate to local street facilities. Transportation agencies are challenged to secure sufficient resources to support these expanded services or coverage areas.

Limited awareness, understanding, and flexibility of funding sources contribute to the challenge. Traditionally, the Intermodal Surface Transportation Efficiency Act (ISTEA) provided funds to develop and initiate TMCs but provided little funding for ongoing operations. Without ongoing operations support at the national level, transportation agencies must either compete within their state or agency for funds or pursue innovative financing mechanisms or other sources of funding such as new user taxes, dedicated local sales taxes, toll revenues, or economic development funds. Transportation agencies may also establish relationships with legislators to benefit from earmarked funds and encourage resource sharing with the Department of Justice (DOJ), Federal Emergency Management Agency (FEMA), etc. When possible, funding requests should reflect life-cycle funding estimates for long-term operation (2).

3.2.6. Personnel Recruitment, Retention, and Training

An artifact of the resource constraints described above, transportation agencies commonly experience limitations on both quantity and quality of TMC personnel. Staffing budgetary constraints limit the number of operations personnel dedicated to the TMC. Staff workload (measured in terms of the number of incidents occurring that require active management, the number of vehicles dispatched and monitored, etc.) is largely outside the control of the TMC. A small staff addressing a substantial incident management workload requires significant automation (i.e., automatic incident detection rather than manual scanning of detector data or camera images, and recommended incident solution scenarios, rather than manually created solutions developed on-the-fly by the operator) (3, 4).

Similarly, if staffing budgetary constraints limit the agency to hiring nondegreed individuals without experience in control center operations or traffic management, then the system is the primary tool that the agency has to control the quality and effectiveness of the outcome of the operations process. In such cases, the system must serve as the

“expert” supplementing the operator, rather than calling upon the operator to make skilled traffic management decisions, often under real-time crisis conditions (3, 4).

Contributing to this challenge, TMCs often experience high rates of personnel turnover. Because of their limited organizational structure within the larger transportation agency, TMCs often don’t provide a clear and progressive career path for personnel. Hence, they may experience a high loss of qualified TMC personnel to other areas in the organization that offer greater opportunities for promotion or to the private sector that offers more competitive salaries. Compounding this problem is the high-stress work environment and challenging 24 hours per day, 7 days per week (24/7), 365-day-a-year operational schedule at many TMCs.

High rates of personnel turnover result in significant training costs each time new personnel are added to the TMC program. Because turnover is often difficult to predict, consequent resources for training are often not sufficiently planned for or allocated. Training for TMC maintenance is additionally challenged. Although innovative procurement methods are in place to reduce the range of needs for maintenance training (i.e., by purchasing fewer or different brands and models of the same general device), the need for training generally increases along with the age and size of the TMC system (3, 4).

3.2.7. Technology Evolution and Integration

TMC managers, technical staff, and operators are not only challenged by the unique and dynamic nature of traffic conditions each day, but they must also implement, operate, and maintain a set of complex, potentially incompatible, and rapidly evolving technologies to support day-to-day operations. Given the typically large geographic scope, monitoring both transportation conditions and technology-based field devices requires modern communications and computing resources. Standards are developing at a rapid pace to support new ITS implementations but may not simplify integration with legacy systems. Throughout the course of its life, a TMC may experience multiple technology generations. Estimating the time it takes for a TMC to become operationally stable or to create an environment and staff that can operate within a changing environment is a challenge for transportation agencies.

3.2.8. System Failures and False Alarms

The number of technological devices and the complexity of the overall TMC system challenge transportation agencies to keep all aspects of the system functional. In addition, technology is not foolproof; trans-

portation agencies must develop methods for detecting and mitigating false alarms when they occur. The occurrence of system failures and/or false alarms can quickly and negatively affect an agency's credibility in the media and among individual travelers as well as the operations staff themselves.

3.3. Why Develop a TMC Operations Manual?

The challenges described in the previous section can be addressed, in part, through the development of a TMC Operations Manual. A TMC Operations Manual is a critical tool that agencies are encouraged to develop, maintain, and use in managing and supporting the day-to-day operations and activities performed by a TMC. The purpose of an operations manual is to formalize and document the policies, plans, procedures, and other support activities that are performed to achieve the TMC's mission, goals, and objectives.

The specific content of a TMC Operations Manual varies based on the structure, operation (i.e. services provided), agency participation, and political context of the TMC. However, general content should include a description of:

- Daily operations including TMC functions, hours of operation, staffing, etc.;
- Policies, plans, and procedures to support daily operations (i.e., managing recurrent congestion, managing incidents, providing traveler information, etc.);
- Routine, preventative, and emergency maintenance procedures,
- TMC equipment and system devices (i.e., inventory) and any supporting documentation; and
- Procedures for longer-term evaluation and monitoring of TMC performance.

Detailed information about TMC Operations Manual content is provided later in this chapter (3.5. *Concept of Operations and Requirements for a TMC Operations Manual*) and throughout *Part II - Developing a TMC Operations Manual*.

A TMC Operations Manual can be designed to support agencies that do not yet have but are planning to initiate a formal traffic management system or agencies with existing TMCs. A TMC Operations Manual goes beyond conventional “system documentation” by providing guidance to support TMC operations activities from initiation to

completion. A TMC Operations Manual is not intended to replace or supersede state law, agency policies, or other regulations; when conflicts occur, these other sources take precedence.

Most public agencies and practitioners do not recognize the wide-ranging need, importance, and value of a TMC Operations Manual. In brief, potential benefits resulting from the development and use of a TMC Operations Manual relate to formalized and documented:

- Operational procedures that lend consistency to day-to-day activities, improve interagency and interjurisdictional working relationships, and ease internal training efforts;
- System maintenance, monitoring, and security procedures that improve resource utilization and enhance system safety; and
- Data collection, analysis, and warehousing procedures that support short- to long-term facility performance improvements and planning efforts.

This section defines and describes the role, identifies the benefits, discusses the need for, and provides a basis for why agencies should pursue developing a TMC Operations Manual.

3.3.1. Formalized and Documented Operational Procedures

Formalizing and documenting a TMC's operational procedures promotes:

- Consistent traffic management performance,
- Improved stakeholder relations, and
- Quality TMC personnel training with less effort.

A TMC Operations Manual promotes consistency in activities which, in turn, improves personnel and public safety, enhances agency productivity, reduces agency liability risk, and improves customer satisfaction. In addition, consistent and documented operational procedures improve collaboration and coordination between traffic management stakeholders. Outside agencies, such as law enforcement or local transportation agencies, will more easily work with and involve transportation agency personnel if their roles, capabilities, responsibilities, and standard procedures are consistent during each interaction.

Perhaps the most tangible benefit resulting from formalized and documented operational procedures relates to personnel training. As mentioned previously, TMCs may experience high rates of turnover

due to lack of a progressive career path or budgetary constraints that limit competitive salary offerings. While development of a TMC Operations Manual is not anticipated to significantly impact recruitment or retention of qualified personnel, it will ease the level of effort required for training new personnel. As a primer for new TMC personnel, an operations manual can comprehensively overview the TMC functions and the recommended policies, plans, and procedures to be followed.

In addition to training new TMC personnel, a TMC Operations Manual can be used to “remind” (i.e., retrain) existing TMC personnel of the correct operational policies, plans, and procedures to follow. This retraining should occur periodically throughout the life of a TMC to ensure consistency in actions. New policies, plans, or procedures adopted by an agency should be incorporated into the TMC Operations Manual as they are developed.

In each case, position descriptions contained in the TMC Operations Manual can be linked to concurrently defined performance objectives to lend focus to actions and to encourage constant improvement in the TMC program.

A third application of a TMC Operations Manual for personnel training includes awareness training for personnel outside of the transportation agency. Understanding the roles, duties, and responsibilities of other agencies engenders trust and patience when working together to improve traffic management. In particular, nontransportation personnel should understand the traffic and safety implications of lane or total freeway closure. If the TMC is multiagency or multijurisdictional in structure, the roles, duties, and responsibilities of each participating agency can be contained within the TMC Operations Manual for all personnel to review. If the TMC is operated singularly by a transportation agency, the TMC Operations Manual can be provided to outside agencies to increase awareness.

3.3.2. Formalized and Documented System Maintenance, Monitoring, and Security Procedures

Formalizing and documenting a TMC’s system maintenance, monitoring, and security procedures as part of a TMC Operations Manual can ease challenges related to technology evolution and integration and can reduce and improve responsiveness to system failures and false alarms.

The number of technological devices and complexity of the overall TMC system challenges transportation agencies to keep all aspects of the system functional. The problem is further complicated by the fact

that today's systems, subsystems, and components are often highly interdependent; a single malfunction can critically impact the ability of overall systems to perform their intended functions (5). Consequently, transportation agencies must plan for and respond to these expected failures by anticipating and furnishing the resources, capabilities, and services necessary to maintain the systems throughout their productive lives.

3.3.2.1. System Maintenance and Monitoring

System maintenance and monitoring refers to a series of methodical, ongoing activities designed to minimize the occurrence of systemic failures and to mitigate their impacts when failures do occur. The system itself is often the first source of an indication that an element of the system is malfunctioning; most systems perform some type of polling to verify status and capability of each element to which they are connected (3, 4). Maintenance includes development and implementation of action plans for responding quickly, efficiently, and orderly to systemic failures. It also includes an infrastructure and procedures for measuring and monitoring maintenance activities.

Both automated and manual logging of suspected and verified failures are critical to improving system performance. In the short term, the logged information assists in isolating the fault and effecting repairs or replacement and possibly obtaining repairs under warranty provisions. In the intermediate term, this information is useful in planning and budgeting for preventative maintenance including periodic replacement of units with limited service lives. In the longer term, the maintenance history of a device or a class of devices provides information that can be used to make purchasing decisions for an overall upgrade of the system or for expansion for the system (3, 4).

A TMC Operations Manual should describe both consistent procedures for conducting maintenance activities and for recording maintenance events to achieve wide-reaching benefits in system functionality and agency efficiency.

3.3.2.2. System Security

A variety of approaches exist for ensuring TMC system security, ranging from complex multilevel approaches where each individual is identified to one or more levels within a series of security tiers to simpler schemes where a common system identification and password exist (typically controlled by a supervisor), which is used by all operations (and often other) staff.

Almost all TMC systems provide some form of remote, dial-in access, even if it uses a simpler user interface in recognition of the bandwidth demands of a fully graphical user interface. Since the dial-in capability represents a potential weak point in the total security program, careful planning, and perhaps consultation with a security expert, is warranted. Conversely, creating a burdensome security program that results in dial-in access that is tediously slow and failure prone defeats the purpose of having established the function.

A TMC Operations Manual helps to ensure that consistent security procedures are followed outside of the automated security features of the system (i.e., changing passwords routinely, shutting computers down during nonoperation hours, etc.).

3.3.3. Formalized and Documented Data Collection, Analysis, and Warehousing

Documentation is often a forgotten detail during traffic management activities. This is especially problematic with increasing threats of litigation. Nonexistent or poor documentation of traffic management actions can severely reduce a responding agency's or company's defense against litigation. Documentation of a TMC's activities is essential for several other reasons:

- To identify critical locations or time periods for traffic problems,
- To evaluate a TMC's effectiveness and demonstrate attributable benefits,
- To identify equipment or personnel needs and justify the need for a TMC or TMC expansion, and
- To effectively communicate and convince administrators and policy makers of the needs.

The benefits of a formalized program of data collection, analysis, and documentation, supported through the development of a TMC Operations Manual, can be significant. Improved documentation of operational activities can better encourage the move from a design/construct to a operate/maintain regime, position operational alternatives to compete better for limited resources in a planning context, and justify continuation of or expansion of existing resource allocations by demonstrating measurable attainment of performance goals and improved customer service.

3.4. Key Issues in Developing an Operations Manual

As mentioned previously, a TMC Operations Manual is a tool that agencies are encouraged to develop, maintain, and use in managing and supporting the day-to-day operations and activities performed by a TMC. The specific content of a TMC Operations Manual will vary based on the structure, operation (i.e., services provided), agency participation, and political context of the TMC. In addition, the process for developing and maintaining a TMC Operations Manual will vary depending on transportation agency resources, priorities, access to outside resources, and other constraints.

3.4.1. TMC Operations Manual Development

The development of a TMC Operations Manual may be motivated by any number of factors, including a priority shift to customer service, an identified need for training and operations support materials, attainment of funding to develop a TMC and support materials, etc. Regardless of the underlying motivation, a successful TMC Operations Manual development process relies on one thing—a champion. This individual can be employed by a transportation agency, law enforcement agency, or other, but must be committed to successfully developing an effective TMC Operations Manual.

The development itself can occur either internally, using agency staff to gather and assimilate information, or an agency can hire an outside contractor/consultant to develop a TMC Operations Manual specific to their locale. Each alternative has advantages and disadvantages. Developing a TMC Operations Manual internally benefits from staff members' knowledge regarding agency policies, stakeholders, and local conditions but may take longer to develop unless staff members are dedicated to the effort (i.e., temporarily released from other work-related duties). Internal development may also inspire greater ownership and use of the document and its procedures. External contractors/consultants can typically provide a completed TMC Operations Manual in less time despite some initial required effort to become familiar with local conditions. External contractors/consultants are also often more familiar with national practice, successful practices, lessons learned, etc., that can be then applied to a specific locale.

Format (i.e., hardcopy or electronic) for the TMC Operations Manual is another consideration during the development stage. Hardcopy manuals are favored for their ease of access, particularly if the TMC system is experiencing a failure that prevents access to electronic documents. Electronic manuals are favored for their “lookup” or search features when a particular topic is sought and for ease of update when policies or procedures change. Many TMCs utilize both ver-

sions, the electronic manual accessible from workstations when the network is functioning and the hardcopy manual when the network is down or the information needs to be mobile. In either case, a version control process must be established.

3.4.2. TMC Operations Manual Content

The specific content of a TMC Operations Manual can vary widely depending on the nature of the TMC (i.e., single agency vs. multi-agency), its size, the level and complexity of its organizational structure, the functions, services, and systems provided, actual and desired levels of interagency/interjurisdictional coordination, etc.

Guidelines such as *An Annotated Outline for Traffic Management Center Operations Manuals* (6) and this *Handbook* are intended to provide a consistent outline or framework from which to develop a TMC Operations Manual; variability in content is left to the most detailed discussion contained in the TMC Operations Manual.

3.4.3. TMC Operations Manual Maintenance

Maintaining a TMC Operations Manual largely includes updating contact lists and/or rosters as personnel changes occur and modifying policies or procedures as needed. Keeping contact lists and/or rosters up to date can be time consuming and difficult if regular communications among agencies or jurisdictions do not make such changes readily apparent. TMCs may implement periodic “requests for update” to be distributed to other agencies and jurisdictions involved with the TMC to try to better capture these personnel changes. Updates regarding modified policies and procedures are easier to identify; agencies should make a regular practice of updating the TMC Operations Manual upon notification to keep the information current. Agencies may need to allocate staff resources to this effort to ensure timely completion.

Additionally, agencies should implement tracking methods to help ensure that the information contained in a TMC Operations Manual is the most current and accurate with respect to agency policies and procedures. Including a date stamp somewhere on the modified document is the simplest way to track changes. Many living documents contain a ‘revisions page.’ When placed immediately prior to the Table of Contents, revision information is easily locatable when auditing the manual for currency.

3.5. Concept of Operations and Requirements for an Operations Manual

The Institute of Transportation Engineers (6) recommends the following content for a TMC Operations Manual:

- Emergency and other contact numbers;
- Daily operation including management center functions; personnel, staffing, and hours of operation; after-hours, remote operation, and security procedures (i.e., access to control system interfaces); maintenance, startup/shutdown, and failure recovery (automated and manual) procedures; and notification procedures;
- Control system operation including operator interface, operational procedures (i.e., manual, automated, demand responsive, default), and incident management procedures;
- Maintenance procedures including routine, preventative, emergency (nonroutine), and contract maintenance and the location of spare/backup equipment;
- System operations logs including operations, maintenance, events, system reports, and traffic data and risk management (i.e., what to keep, log, save, or discard);
- Operational concepts including traffic monitoring, data analysis and warehousing, interagency coordination, interjurisdictional coordination, and emergency procedures (i.e., notification, monitoring, and coordination);
- Control center/system field device descriptions including location, access/security, layout, fire suppression, power source/location, HV/AC, and data, voice, and network communications; and
- System documentation including vendor maintenance documentation.

Chapter 5 of this *Handbook* expands on these key categories of operations manual content. While this information may be organized in multiple documents (i.e., a TMC Operations Manual and a TMC Maintenance Manual); this *Handbook* assumes that the information will be contained in a single TMC Operations Manual.

A TMC concept of operations document that provides a general overview of TMC functionality prior to the design stage contains many of the same categories of information recommended for inclusion in the TMC Operations Manual. The primary distinction between the two documents is the level of detail contained. The operations manual defines step-by-step how to perform each activity and provides specific contact names and numbers for the various interfaces; the concept of operations document defines generically who should be contacted. Nonetheless, the TMC concept of operations document provides a good framework for the development of a TMC Operations Manual. This section details the content of a TMC concept of operations document and describes how it can be used to support development of a TMC Operations Manual. It is assumed that a TMC concept of operations document has been previously developed specific to one's locale; if no such document exists, the *Traffic Management Center Concept of Operations Implementation Guide* (3, 4) provides a good, albeit general, reference for TMC Operations Manual development.

3.5.1. What is a Concept of Operations?

In the systems engineering process, the concept of operations is “a document that defines the environment in which the system is to operate. The environment includes the relationship between the system and the agency's responsibilities, the physical environment, and expectations (performance and life).” Typical content for a concept of operations document in this general application includes the following (IEEE Standard P1362 V.3.2):

- Scope, including an overview of the document and an overview of the system;
- Referenced documents used to support system development;
- Current system or situation, including operational policies and constraints, a description of the current system or situation, and respective modes of operation;
- Justification for and nature of changes, including a description of desired changes, change priorities, and changes considered but not included;
- Concepts for the proposed system, including background, objectives, and scope; deployment strategies; anticipated practices and procedures; anticipated system performance and effectiveness; and utilization environment and life cycle;

- Operational scenarios, including conditions, participants, sequence of events, and information flows;
- Summary of impacts, including operational and organization impacts as well as impacts during development; and
- Analysis of proposed system, including improvements, disadvantages and limitations, and alternatives and trade-offs considered.

Moving toward a more specific application, a TMC concept of operations document defines what the center accomplishes (i.e., functions) and how it goes about accomplishing it (i.e., procedures). The concept of operations document addresses both operations and maintenance of the TMC and the resources for which it is responsible. It describes the interactions that occur within the TMC and between the TMC and its partners (firms and agencies) and customers (motorists, media, etc.) in managing transportation (4).

The *Traffic Management Center Concept of Operations Implementation Guide* (4) recommends the following content for a TMC concept of operations document:

1. BACKGROUND
 - 1.1. Need, Purpose, and Concept for the System
 - 1.2. Mission, Vision, Goals, and Objectives
2. SYSTEM DESIGN AND IMPLEMENTATION
 - 2.1. General System Design Parameters
 - 2.2. Level and Type of Automation
 - 2.3. General Systems Functions Performed/Provided
 - 2.4. System Devices and Interoperation
 - 2.5. System Implementation
 - 2.6. System Testing
 - 2.7. System Training and Documentation
3. SYSTEM OPERATIONS
 - 3.1. Workload and Performance
 - 3.2. Coordination
 - 3.3. Conflict Resolution
 - 3.4. Nonstandard Operation
 - 3.5. Fault Detection and Correction
4. SYSTEM MAINTENANCE
 - 4.1. Configuration Management
 - 4.2. Logistics

- 4.3. Maintenance
- 4.4. Operations Simulation

3.5.2. Using a TMC Concept of Operations Framework to Develop a TMC Operations Manual

Agency personnel can utilize information contained in a TMC concept of operations document to “jump start” development of a TMC Operations Manual with the understanding the supplemental detailed information will be required for completion to:

- Ensure consistency with local, regional, and statewide goals and previously developed guidance documents;
- Best reflect the existing and planned capabilities of the TMC; and
- Make the most efficient use of agency resources.

Using state-of-the-practice recommendations regarding document content, Table 3-1 depicts the mapping of TMC concept of operations information to the TMC Operations Manual.

The remainder of this section is organized to reflect the primary and secondary topic headings recommended for a TMC Operations Manual (i.e., 2. *Daily Operation*, 2.1. *TMC Functions*, 2.2. *Personnel*, etc.). Under each of these headings and subheadings, the reader is directed to related content contained in a previously developed concept of operations document. Note that in some instances content may be drawn from multiple sections within a concept of operations document to accommodate the organizational structure of the TMC Operations Manual (i.e., 2.2. *Personnel* in the TMC Operations Manual is supported by text from sections 2.1. *General System Design Parameters*, 3.1. *Workload and Performance*, 2.7. *System Training and Documentation*, and 3.3. *Conflict Resolution* from the TMC concept of operations). Also note that in some instances TMC Operations Manual subheadings that draw from similar content in the TMC concept of operations document have been combined in discussion for the sake of brevity (i.e., sections 2.2 *Personnel*, 2.3 *Hours of Operation*, and 2.4 *Staffing* in the TMC Operations Manual are combined here for discussion purposes because they each draw from related content in sections 2.1 *General System Design Parameters* and 3.1 *Workload and Performance* in the TMC concept of operations).

Table 3-1 Mapping TMC Concept of Operations Information to a TMC Operations Manual

TMC Operations Manual		TMC Concept of Operations	
1	Emergency and Other Contact Numbers		
1.1	Information Sharing	3.2	Coordination
2	Daily Operation		
2.1	TMC Functions	2.2 2.3	Level and Type of Automation General System Functions Performed/Provided
2.2	Personnel	2.1 3.1 2.7 3.3	General System Design Parameters Workload and Performance System Training And Documentation Conflict Resolution
2.3	Hours of Operation	2.1 3.1	General System Design Parameters Workload and Performance
2.4	Staffing	2.1 3.1	General System Design Parameters Workload and Performance
2.5	After-Hours, On-Call Roster	3.1 3.2	Workload and Performance Coordination
2.6	Remote Operation	2.4 3.1 3.4	System Devices and Interoperation Workload and Performance Nonstandard Operation
2.7	Security Procedures	2.3 2.4 3.1	General System Functions Performed/Provided System Devices and Interoperation Workload and Performance
2.8	Maintenance Checklist	3.5	Fault Detection and Correction
2.9	Startup/Shutdown	2.3 3.1 4.3	General System Functions Performed/Provided Workload and Performance Maintenance
2.10	Failure Recovery	2.2 2.3 4.3	Level and Type of Automation General System Functions Performed/Provided Maintenance
2.11	Agency/Jurisdictional Contacts	2.5 3.2 3.3	System Implementation Coordination Conflict Resolution
2.12	Notification Procedures	2.5 3.1 3.2	System Implementation Workload and Performance Coordination
2.13	Contact with Media	2.5 3.1 3.2 3.4	System Implementation Workload and Performance Coordination Nonstandard Operation

Table 3-1 Mapping TMC Concept of Operations Information to a TMC Operations Manual (Cont.)

TMC Operations Manual		TMC Concept of Operations	
3 Control System Operation Procedures			
3.1	Operator Interface	2.2 2.3 2.4 2.5 3.1	Level and Type of Automation General System Functions Performed/Provided System Devices and Interoperation System Implementation Workload and Performance
3.2	Operational Procedures	2.3 2.5 3.1	General System Functions Performed/Provided System Implementation Workload and Performance
3.3	Incident Management	2.3 2.5 3.1	General System Functions Performed/Provided System Implementation Workload and Performance
4 Maintenance Procedures			
4.1	Routine Maintenance	2.3 3.1 4.3	General System Functions Performed/Provided Workload and Performance Maintenance
4.2	Preventative Maintenance	2.3 3.1 4.3	General System Functions Performed/Provided Workload and Performance Maintenance
4.3	Spare/Back-up Equipment	4.2 4.3	Logistics Maintenance
4.4	Emergency	2.3 3.1 3.4	General System Functions Performed/Provided Workload and Performance Nonstandard Operation
4.5	Contract Maintenance	4.2 4.3	Logistics Maintenance

Table 3-1 Mapping TMC Concept of Operations Information to a TMC Operations Manual (Cont.)

TMC Operations Manual		TMC Concept of Operations	
5 System Operations Logs			
5.1	Operations	2.3 3.1 3.5	General System Functions Performed/Provided Workload and Performance Fault Detection and Correction
5.2	Maintenance	2.3 3.1 3.5	General System Functions Performed/Provided Workload and Performance Fault Detection and Correction
5.3	Events	2.3 3.1 3.5	General System Functions Performed/Provided Workload and Performance Fault Detection and Correction
5.4	System Reports	2.3 3.1 3.5	General System Functions Performed/Provided Workload and Performance Fault Detection and Correction
5.5	Traffic Data	2.3 3.1 3.5	General System Functions Performed/Provided Workload and Performance Fault Detection and Correction
5.6	Risk Management	2.3 3.5	General System Functions Performed/Provided Fault Detection and Correction
6 Operational Concepts			
6.1	Traffic Control Concept Strategy	1.1 1.2 2.1 2.3 2.4 2.5 3.2 3.4	Need, Purpose, and Concept for the System Mission, Vision, Goals, and Objectives General System Design Parameters General System Functions Performed/Provided System Devices and Interoperation System Implementation Coordination Nonstandard Operation
6.2	Traffic Monitoring	2.1 2.2	General System Design Parameters Level and Type of Automation
6.3	Data Analysis and Warehousing	2.1 2.3 3.1	General System Design Parameters General System Functions Performed/Provided Workload and Performance
6.4	Interagency Coordination	1.1 2.3 2.5 3.2	Need, Purpose, and Concept for the System General System Functions Performed/Provided System Implementation Coordination
6.5	Interjurisdictional Coordination	1.1 2.3 2.5 3.2	Need, Purpose and Concept for the System General System Functions Performed/Provided System Implementation Coordination
6.6	Emergency Procedures	2.3 2.5 3.1 3.4 3.5	General System Functions Performed/Provided System Implementation Workload and Performance Nonstandard Operation Fault Detection and Correction

Table 3-1 Mapping TMC Concept of Operations Information to a TMC Operations Manual (Cont.)

TMC Operations Manual		TMC Concept of Operations	
7 Control Center Description/System Field Devices			
7.1	Location	2.1	General System Design Parameters
7.2	Access/Security	2.1 2.4	General System Design Parameters System Devices and Interoperation
7.3	Layout	2.1	General System Design Parameters
7.4	Fire Suppression	2.1	General System Design Parameters
7.5	Power Source/Location	2.1	General System Design Parameters
7.6	HV/AC	2.1	General System Design Parameters
7.7	Data Communications	2.4	System Devices and Interoperation
7.8	Voice Communications	2.4	System Devices and Interoperation
7.9	Network Communications	2.4	System Devices and Interoperation
7.10	Field Device Descriptions	2.4	System Devices and Interoperation
8 System Documentation			
		4.1 4.3	Configuration Management Maintenance

1 Emergency and Other Contact Numbers

1.1. Information Sharing. One of the first recommended items for inclusion in a TMC Operations Manual is a phone list of emergency agencies, support agencies, and personnel that may be called for assistance and coordination. These could include police, fire, courtesy patrol vehicles, transit, emergency maintenance operations (for freeways, streets, bridges, and pump houses), street operations, 911 Public Service Answering Point (PSAP) operations, towing services, and operational personnel contact information (including home phones, cell phones, pagers, and e-mail addresses). In regions characterized by a large number of jurisdictions, supplemental maps illustrating the physical boundaries for agency responsibilities could be included.

A TMC concept of operations document does not contain the level of detail required to complete this information. Section 3.2 *Coordination* in the concept of operations document may, however, offer some direction as to the agencies (emergency and support) that should be represented on this contact list. This section describes the roles and responsibilities of the participating agencies and interactions between TMC personnel and external agencies.

Using the information contained in the TMC concept of operations document to guide general content (i.e., agency inclusion), transporta-

tion agencies can supplement with specific contact names and numbers for each of the entries.

2 Daily Operation

Recommended TMC Operations Manual content to describe daily operations can be categorized as:

- The functions performed by the TMC;
- Personnel, including an organization chart and job descriptions and hours of operation and staffing including workdays, holidays, special events, and emergencies;
- An after-hours, on-call roster, and remote operating and security procedures including access to control system interfaces, equipment, etc.;
- Routine maintenance checks for office and/or field equipment operation and procedures for startup, shutdown, and automated and manual failure recovery; and
- Agency/jurisdictional contacts and notification procedures, including the media.

2.1. TMC Functions. Section 2.3 *General System Functions Performed/Provided* in a TMC concept of operations document summarizes primary and secondary functions of the TMC. General system functional requirements focus on the responsibilities of the TMC personnel; the center, however, may support transportation management operations in a multiagency, multimodal environment. Little additional detail may be required to complete this section of the TMC Operations Manual.

2.2. Personnel, 2.3. Hours of Operation and 2.4 Staffing. Sections 3.1 *Workload and Performance* and 3.3 *Conflict Resolution* in a TMC concept of operations document provides a personnel organization chart, brief descriptions of the roles and responsibilities of key staff positions, and methods for resolving conflicts among personnel. A TMC concept of operations document may include the following staff positions:

TMC Manager – The TMC Manager provides ultimate oversight of TMC operations. The TMC Manager responds to inquiries from higher levels of agency management and/or from external sources regarding general TMC performance or management of a large-scale incident. In certain situations, it may also be appropriate (or agency policy) to involve or work through the agency’s public affairs office. The TMC Manager’s office should be adjacent to the control room for convenient access.

Operations Supervisor – The Operations Supervisor provides “hands-on” management of the day-to-day operations for the TMC. Specifically, the Operations Supervisor is responsible for managing and scheduling operations staff, training operators, assisting operators during periods of high activity or staff shortages, assigning staff authorization to control subsystems, assisting in identifying problems and determining times for preventive/corrective maintenance, and developing procedures dealing with planned and unplanned events. The Operations Supervisor resolves disputes pertaining to TMC operations. The Operations Supervisor carries a cell phone whenever off-site or elsewhere in the building complex.

Operator – Operators monitor and control field devices from the TMC facility. Operators are responsible for responding to public inquiries regarding traffic conditions and notifying appropriate agencies when an incident occurs. Operators distribute traveler information through the highway advisory radio (HAR), Web site, and other means (e.g., 511 system). They evaluate and package data into useful, timely, and accurate traveler information. Operators report to the Operations Supervisor.

Maintenance Supervisor – The Maintenance Supervisor is responsible for maintenance of the TMC. This position troubleshoots both control center and field equipment and works directly with the Maintenance Office to coordinate maintenance crews to repair electronic equipment used in traffic control devices, closed-circuit television (CCTV) systems, and communications systems. This position is responsible for documenting changes made to any component in the system through maintenance or construction operations. This position reports directly to the TMC Manager.

Electronic Technician – The Electronic Technician is responsible for troubleshooting and repairing electronic equipment used in traffic control devices, CCTV systems, and communications systems. This position is also responsible for documenting changes made to any component in the system through maintenance or construction operations. This position reports directly to the Maintenance Supervisor.

Systems Technician – The Systems Technician is responsible for maintaining current and/or consistent computer operating systems on all computer equipment, installing hardware and software upgrades, troubleshooting and repairing equipment malfunctions, maintaining computer communication links with TMC partners, and maintaining database and data files for all TMC activity. The Systems Technician reports to the Maintenance Supervisor (3, 4).

The TMC Operations Manual can enhance the level of detail provided here to identify particular individuals that occupy each position and unique protocols for interactions.

In certain instances, conflicts among staff members may arise that require resolution either with or without supervisory intervention. Section 3.3 *Conflict Resolution* in a TMC concept of operations document may provide useful guidance in developing conflict resolution procedures. Recommendations include:

- Use a combination of manual and automated recordkeeping to effectively document the situation, communications, actions taken, and approvals and
- Define a clear chain of command for decisionmaking (i.e., authority passes from the Operator to the Operations Manager to the TMC Manager).

The TMC Operations Manual should additionally detail how to access key decisionmakers (i.e., by telephone, cellular phone, or pager).

More general information pertaining to the hours of TMC operations and its general staffing plan may be sufficiently detailed in 2.1 *General System Design Parameters* of a TMC concept of operations document. This section generally describes the days and hours of normal TMC operation; contingent TMC operation during construction, special events, or incidents/emergencies; operator overlap during peak periods or shift changes; staff rotations for on-call operations; etc. Little additional detail may be required to complete this section of the TMC Operations Manual.

2.5. After Hours, On-Call Roster, 2.6. Remote Operation, and 2.7. Security Procedures. As when developing 1. *Emergency and Other Contact Numbers*, a TMC concept of operations document does not contain the level of detail required to complete a roster of after-hours, on-call personnel. Again, Section 3.2 *Coordination* in the concept of operations document may, however, offer some direction as to the agencies (emergency and support) that should be represented on this roster. This section describes the roles and responsibilities of the participating agencies and interactions between TMC personnel and external agencies.

The individuals listed on the after-hours, on-call roster likely differs from those contained on the emergency and other contact numbers list, although some duplication is anticipated. Using the information contained in the TMC concept of operations document to guide general content, transportation agencies can supplement the list with specific contact names and numbers for each of the entries.

Remote operation and security procedures are generally defined in section 2.4 *System Devices and Interoperation* in a TMC concept of operations document. Typically, a TMC system allows operators to monitor and control the TMC field devices through workstation consoles and various hardware and software subsystems, either on-site or remotely using dial-up capabilities. Each workstation has access to all field devices, but control of these devices may be assigned to operators through user identification (ID) and a network firewall to protect against unauthorized local and remote access. This section generally defines priority and secondary control for each of the various TMC components.

Supplemental detail, including the agency responsible for each action, how agencies share access to common resources, and what agencies can perform critical actions under nonstandard circumstances (i.e., emergency operations or shortage of essential staff) is required to complete the TMC Operations Manual.

2.8. Maintenance Checklist, 2.9. Startup/Shutdown and 2.10. Failure Recovery. Sections 3.5. *Fault Detection and Correction* and 4.3 *Maintenance* in a TMC concept of operations document provide a good basis for developing a maintenance checklist and startup/shutdown and failure recovery procedures.

A TMC concept of operations document may recommend the following general areas to consider:

- Access control - who controls system privileges, how many levels are maintained, how often do passwords change?
- Network management - what network management tool is used, what performance parameters are monitored?
- Backups - when are they performed, to what media, where they are retained and for how long, how quickly can restorations be made, are they partial or complete, is real-time backup achieved through mirroring?
- Materials and supplies - who can distribute the supplies, who controls their purchasing, what quality standards are established?
- Upgrades and bug fixes - how quickly after release these are implemented and by whom, how they are tested with the custom applications?
- Troubleshooting - what training and tools are acquired, what arrangements are made for expert assistance?

- Monitoring system performance - what performance parameters are monitored, what thresholds are established, can high load simulations be conducted, how are impact assessments made, what program of ongoing fine-tuning is implemented?
- User support - how do users (particularly nonprime shift users) contact the system maintenance team, what level of responsiveness is desired, what kinds of actions are users responsible for taking themselves?
- Participating in testing and system acceptance - how does system management participate in planning, executing, witnessing, and defining acceptability tests?
- Participating in training - how does system management participate in training for nonsystems elements of the system? (3, 4).

Transportation agencies can pursue answers to the questions posed as part of these general considerations when developing the TMC Operations Manual. This approach helps to ensure a sufficient level of detail.

Sufficient detail is also required when describing communications requirements for maintenance events among affected parties. In a TMC concept of operations document, section 4.3 *Maintenance* provides a general description of required communications links between:

- Maintenance and operations personnel to report either a maintenance activity or a need;
- Maintenance and/or operations and other affected departments within the agency (i.e., illumination and signal departments) for signal, flasher, or illumination failures;
- Maintenance and equipment vendor/supplies; and
- Maintenance personnel and a centralized maintenance database used in tracking equipment status and reliability.

and, at times:

- At the beginning of a shift, to determine what maintenance is planned, what the impact will be, and what actions are required;
- At the beginning of a task, to indicate that a change in status is taking place, the potential for danger to personnel exists, and support may be required;
- When the task is done, to indicate that the device can be returned to the appropriate operational status and the potential for harm to maintenance personnel has been terminated; and

- At shift completion, to determine accomplishments during the period, plans for additional action if required, and any changes in status of devices (3, 4).

The TMC Operations Manual should detail the points of contact for each exchange (i.e., individual names and contact information) and a format for consistent information exchange.

2.11. Agency/Jurisdictional Contacts, 2.12. Notification Procedures and 2.13. Contact with the Media. A TMC concept of operations document does not contain the level of detail required to complete this information. Section 3.2 *Coordination* in the concept of operations document may, however, offer some direction as to the agencies and jurisdictions that should be represented as contacts and appropriate notification procedures. For each type of interaction, the following information should be recorded to support development of a TMC Operations Manual:

- The circumstances that bring about interaction,
- Between whom the interactions take place (i.e., which organization and at which levels),
- How it takes place (voice, telephone, radio, fax, e-mail),
- What the interaction contains (what information, what request),
- How each party responds to the interaction (information, action, request for additional information or support),
- How the interaction continues or resumes (monitoring and reporting of status of causative situation, thresholds for additional action),
- What triggers termination of the interaction (return to baseline conditions),
- How the interaction is documented, and
- How the termination is confirmed (3, 4).

Using the information contained in the TMC concept of operations document to guide general content (i.e., agency and jurisdiction inclusion, interactions), transportation agencies can supplement with specific contacts for each of the entries and work with participating agencies/jurisdictions to develop specific and mutually acceptable notification procedures. Content related to contact with the media is best obtained through the agency's Public Information Office, who can provide valuable guidance in working with the media and are aware of any agency policies governing media relations. The TMC Operations

Manual should have consistent media relations policies as the larger transportation agency.

3 Control System Operation Procedures

3.1. Operator Interface, 3.2. Operational Procedures, and 3.3. Incident Management. As part of a TMC Operations Manual, control system operation procedures detail the day-to-day electronic hardware and software system operation (i.e., enters text, zoom, change view, save record, etc.). Procedures for manual, automated, traffic responsive, free, and default operation, as well as operation during non-routine occurrences (i.e., incidents) should be included. These procedures are governed by existing transportation agency policies and procedures.

Sections 2.5. *System Implementation*, 2.2 *Level and Type of Automation*, and 3.4 *Nonstandard Operations* in a TMC concept of operations document provide general information related to the process of monitoring traffic and detecting problems, initiating advisories and providing periodic status reports and estimates for return to normal operations, altering the operations of roadways (i.e., adjusting signal timing to accommodate the unusual traffic patterns or posting messages on the dynamic messaging sign [DMS]), exchanging data within and outside the agency, and automatically and manually logging information and actions.

For the level of specificity required, the transportation agency may better rely upon documentation furnished by system suppliers (i.e., hardware and software vendors) to fully develop the TMC Operations Manual.

4 Maintenance Procedures

Maintenance procedures, as documented in a TMC Operations Manual, should address:

- Routine maintenance, including typical daily checks, adjustments, and minor component replacement;
- Scheduled preventative maintenance performed by the agency or vendor;
- An inventory of spare and backup equipment including a listing of suppliers, vendors, and contractors associated with equipment and software and their contact information;
- Emergency (i.e., nonroutine) maintenance; and
- Contract maintenance including the procedures or warrants by which a private maintenance contractor would be requested.

4.1. Routine Maintenance, 4.2. Preventative Maintenance, and 4.3. Spare/Backup Equipment. TMC maintenance procedures include traditional activities (i.e., replacing bulbs, replenishing lubricants, cleaning lenses) for TMC system components, as well as computer software and hardware maintenance. Software maintenance includes ongoing debugging, testing, and implementation of operating systems; commercial software upgrades; additional protocols and device interfaces for new equipment; additional or modified algorithms; etc. Hardware maintenance typically includes standard maintenance activities and a planned replacement program to prevent obsolescence. Acquiring replacement parts or contract maintenance service on units which have been out of production for more than a year or two is challenging (3, 4). Updates to system and user documentation, training materials, and software configuration materials are required along with most computer maintenance activities.

Sections *4.3 Maintenance* and *3.4 Nonstandard Operation* in a TMC concept of operations document describe general procedures for and recommendations to facilitate TMC maintenance activities including:

- Procuring initial spares, tools, and test equipment through TMC installation contracts;
- Specifying a reasonable duration (i.e., 2 years after acceptance) for installation contractors to provide equipment support;
- For system expansions, specifying that warranties, managed by the system support contractor, begin at system acceptance;
- Identifying other agencies, located nearby and who own identical equipment, who may provide spares on short notice outside the normal agency procurement process;
- Investigating the ability to download software patches from dial-up or Internet connections; and
- Specifying response times for equipment or services in any maintenance or support contract (i.e., rapid response support contract) (3, 4).

4.4. Emergency. A TMC concept of operations document also provides general guidance for performing emergency maintenance activities and operating with partial system functionality until the problem is remedied. During such times, TMCs generally operate using uninterruptible power supplies (UPS) and backup generators. Failures most likely result from failure of a specific piece of critical equipment such as a server, switch, or primary multiplexer (7). The process for addressing this condition may include:

- Identifying and confirming the failure, determining what has failed, and getting work under way to remedy the situation;
- Understanding the impact of failure and determining what types of “workarounds” are available. (i.e., backup systems, use of alternate or remote workstations, use of temporary portable devices, dial-up instead of direct connections, movement of personnel to the field to access the assets directly, etc.); and
- Communicating to the appropriate parties the impact in order to manage expectations; this may include getting information to the public if the failure will be noticed (7).

4.5. Contract Maintenance. A TMC concept of operations document also generally describes and recommends a program of maintenance monitoring to support warranty claims and improve design and operation decisions. Maintenance records in hardcopy or electronic form are eventually recorded in a central maintenance management database; maintenance personnel at the TMC may record and perform the following types of analysis:

- Mean time between failures (i.e., the performance of device, reliability);
- Extent and type of required repairs and mean time to repair; and
- Effort and resources necessary to maintain certain devices or types of devices, including manpower, consumables, and tools, test equipment, and support equipment.

Despite the useful guidance provided through a TMC concept of operations document, maintenance procedures described in the TMC Operations Manual are based largely on documentation furnished by system suppliers. These outside references contain sufficient detail and guidance to support maintenance of on-site and field components.

5 System Operations Logs

5.1. Operations, 5.2. Maintenance, 5.3. Events, 5.4. System Reports, 5.5. Traffic Data, and 5.6. Risk Management. Included as part of a TMC Operations Manual, system operations logs to document system operation may include:

- Operation periods (i.e., on-line/off-line periods, manual overrides, etc.);
- Maintenance activities (i.e., outages, resolution of problems, etc.), events such as planned and unplanned incidents, system operation evaluation parameters, etc.;

- Traffic data to support historical trends, data analyses, etc.; and
- Guidance to operators of what to keep, log, save, or discard in response to the agency's risk-management policies.

A TMC concept of operations document does not contain the type of information or level of detail required to complete this information. Automatic logging features are most often incorporated into system software applications. Hence, the transportation agency may better rely upon documentation furnished by system suppliers (i.e., hardware and software vendors) to describe logging features and capabilities; TMC managers can then decide what information and at what frequency system operation logs will be made. This information should be documented in the TMC Operations Manual.

6 Operational Concepts

In developing 6, *Operational Concepts* of a TMC Operations Manual, transportation agencies should ask:

- What is our role in the regional transportation community and how do we approach delivery of services (i.e., traffic control concept strategy)?
- Physically, how do we monitor traffic/transportation here (i.e., traffic monitoring)?
- How do we work with our internal partners and our regional partners (i.e., interagency and interjurisdiction cooperation)?
- What are our emergency procedures related to notification, monitoring, and coordination?

6.1 Traffic Control Concept Strategy, 6.2. Traffic Monitoring, 6.3. Data Analysis and Warehousing, 6.4. Interagency Coordination, 6.5. Interjurisdictional Coordination, and 6.6. Emergency Procedures. If previously developed, a TMC concept of operations document directly addresses these questions, both in content and level of detail. The following sections from a TMC concept of operations document are most applicable:

1.1 Need, Purpose, and Concept for the System – describes the overall motivation for TMC development (i.e., in response to recurring traffic congestion, mobility constraints, air quality, safety, regional travel, etc.) and broadly overviews its intended functions (i.e., to support functions related to transit operations, emergency management, maintenance, and construction, commercial vehicle operations, and border activities, etc.).

1.2 Mission, Vision, Goals, and Objectives – based on the motivation for development, defines responsive goals and objectives for TMC functionality.

2.4 System Devices and Interoperation – describes the various system devices (i.e., communications and components) used singularly or in combination to achieve the aforementioned TMC functionality goals and objectives.

2.1 General System Design Parameters – describes, with more specificity, the TMC’s various system devices (i.e., communications and components) used to support traffic monitoring and other activities.

2.2 Level and Type of Automation – indicates the level of automation available to TMC operators to conduct traffic monitoring and other activities, as well as system and performance monitoring.

3.1 Workload and Performance – dependent on the level and type of automation, describes performance monitoring in terms of both the system performance (equipment hardware and software) and the personnel performance in delivering expected TMC functions.

3.2 Coordination – describes each of the functions to be performed within the TMC, roles and responsibilities of the participating agencies, and the processes the staff follows in performance of their duties, including interactions between the staff and between staff and external organizations.

2.5 System Implementation – describes the system implementation strategy including integration of multiple traffic operations centers within the same agency (i.e., multiple state transportation agency TMCs) or with other agencies; includes methods for notification, follow-up, and data exchange.

3.4 Nonstandard Operations – describes general procedures for non-standard operations including emergency operations.

Given the comprehensive related content contained in a TMC concept of operations document, little additional detail may be required to complete this section of the TMC Operations Manual.

7 Control Center Description/System Field Devices

7.1. Locations, 7.2. Access Security, 7.3. Layout, 7.4. Fire Suppression, 7.5. Power Source/Location, 7.6. HV/AC, 7.7 Data Communications, 7.8. Voice Communications, 7.9. Network Communications, and 7.10 Field Device Descriptions. In a TMC Operations Manual, recommended content for *7 Control Center Description*

tion/System Field Devices includes a plan view of the center layout, a description of the location and characteristics of the building (i.e., security, access to buildings, access to control rooms, guard duty schedules, etc.), and a description of controls, cutoffs, operation, etc., for various critical infrastructure components including fire suppression equipment, power sources, and HV/AC systems. Also recommended for inclusion is a description of data, voice, and network communications systems including the terminals, equipment location, etc., for landline instruments (i.e., location, numbers, extensions, terminals, policies, etc.), radio communications (i.e., unit locations, call signs, policies, etc.), and local-area and wide-area networks. Identification of the databases where current descriptions of all field devices are maintained, including the locations where any passwords are kept, is contained here as well.

Sections 2.1 *General System Design Parameters* and 2.4 *System Devices and Interoperations* in a TMC concept of operations document may provide a useful framework for completing this information. These sections in a TMC concept of operations document generally describe the location and characteristics of the TMC building and system components including access and control.

Using the information contained in the TMC concept of operations document to guide general content (i.e., building features, communication mediums, field devices, etc.), transportation agencies can supplement with greater detail (i.e., password locations, etc.) to complete the TMC Operations Manual.

8 System Documentation

Related to 4. *Maintenance Procedures*, 8. *System Documentation* includes vendor maintenance documentation and procedures for securing documentation revisions and updating maintenance document bibliographies.

Sections 4.1 *Configuration Management* and 4.3 *Maintenance* in a TMC concept of operations document provide general recommendations for establishing and maintaining an accurate and complete configuration database for all elements of the TMC and field hardware and software (and, potentially, vendor-provided services such as communications) and for monitoring maintenance-related performance.

Despite the useful guidance provided through a TMC concept of operations document, however, system documentation, as described in the TMC Operations Manual, will be largely comprised of documentation furnished by system suppliers. These outside references contain

sufficient detail and guidance to support maintenance of on-site and field components.

3.6. Successful Practices

As described previously, potential benefits resulting from the development and use of a TMC Operations Manual relate to formalized and documented:

- Operational procedures that will, in turn, lend consistency to day-to-day activities, improve interagency and interjurisdictional working relationships, and ease internal training efforts;
- System maintenance, monitoring, and security procedures that will improve resource utilization and enhance system safety; and
- Data collection, analysis, and warehousing procedures that will support short- to long-term facility performance improvements and planning efforts.

Reviews of existing TMCs around the nation revealed several successful practices and programs that reinforce the wide-ranging need, importance, and value of a TMC Operations Manual. This section highlights key findings; a more detailed review is provided in chapter 7, Case Studies, later in this document.

3.6.1. Using a TMC Concept of Operations Framework to Develop a TMC Operations Manual

None of the TMCs considered had developed a concept of operations document, per se, before the TMC was implemented, although most had conducted planning before implementing their systems. Interviewees from TMCs that conducted thorough planning confirmed that the sense of direction gained by documenting the TMCs understood mission, vision, goals, and objectives made center operations much easier (3, 4).

3.6.2. Using a TMC Operations Manual to Support Operational Procedures

Several TMCs have developed and refined their operations procedures; however, evidence of a comprehensive TMC Operations Manual to document these procedures was rare. Most TMCs offer limited documentation to support operations and supplement this information with outside references. The most complete TMC Operations Manual examples were Arizona's TrailMaster TMC in Phoenix, Tennessee's Region 3 TMC in Nashville, and Toronto's COMPASS Downsview TMC (3, 4).

3.6.2.1. Arizona’s TrailMaster TMC in Phoenix

Arizona’s TMC Operations Manual content is provided in Table 3-2. This reference is supplemented with a system users manual, plans, and specifications, a functional decomposition, construction equipment submittals, “before” and “after” evaluation subsystem design documents, and a two-volume software design. The TMC Operations Manual is used to support new-hire training, which is primarily on the job, supervised by senior operators and the operations supervisor (3).

**Table 3-2 Arizona Department of Transportation
TMC Operations Manual (8)**

1. INTRODUCTION	3.3 ADOT District Role & Responsibilities
1.1 Manual Updates	3.3.1 Flagstaff District
1.2 TOC Functions	3.3.2 Globe District
1.2.1 Incident Management Function	3.3.3 Holbrook District
1.2.2 Traffic Management Function	3.3.4 Kingman District
1.2.3 Traveler Information Function	3.3.5 Phoenix Maintenance District
1.3 Urban Characteristics	3.3.6 Prescott District
1.4 Rural Characteristics	3.3.7 Safford District
2. VISION, MISSION, AND GOALS	3.3.8 Tucson District
2.1 Arizona Department of Transportation	3.3.9 Yuma District
2.2 Transportation Technology Group	3.4 DPS and Other Law Enforcement Roles & Responsibilities
3. ROLES & RESPONSIBILITIES	3.5 Phoenix District ALERT Role & Responsibilities
3.1 TOC Operations Role & Responsibilities	3.6 Fire, Rescue, and Emergency Medical Roles & Responsibilities
3.2 Tucson Traffic Control Center (TTCC) Role & Responsibilities	3.7 Towing & Recovery Roles & Responsibilities
	3.8 Freeway Service Patrol Roles & Responsibilities

- | | |
|---|--|
| 3.9 Hazardous Material Roles & Responsibilities | 4.7.12 Animals on the Roadway |
| 3.10 Media Role & Responsibilities | 4.7.13 Rocks and Debris on the Roadway |
| 3.11 ADOT Community Relations Role & Responsibilities | 4.7.14 Traffic Control Requests |
| 4. INCIDENT MANAGEMENT | 4.7.15 Crash Involving ADOT Vehicle or Personnel |
| 4.1 Incident Classification | 4.7.16 Statewide Radio Communications System |
| 4.2 Incident Detection | 4.8 Post-Incident Evaluation |
| 4.3 Incident Verification and Logging | 5. TRAFFIC MANAGEMENT |
| 4.4 Incident Response | 5.1 Closed Circuit Television (CCTV) System |
| 4.5 Site Management | 5.2 Ramp Meters |
| 4.6 Incident Clearance | 5.3 Central Traffic Signal Control System |
| 4.7 Incident Notification Procedures | 5.4 I-10 Deck Tunnel System |
| 4.7.1 ADOT Administration | 6. TRAVELER INFORMATION |
| 4.7.2 Construction Area Notification Procedures | 6.1 Variable Message Sign System |
| 4.7.3 ADOT Risk Management Notification | 6.2 Highway Condition Reporting System |
| 4.7.4 FHWA Requirements for Notification | 6.5 Paging System |
| 4.7.5 Metro Phoenix City/County TMC Notification | 6.6 Internet |
| 4.7.6 Capitol Police Notification | 6.7 511 Traveler Information System |
| 4.7.7 Bridge Group Notification | 6.8 AZTech Model Deployment Initiative (MDI) |
| 4.7.8 School Bus Incident Notification | 7. CONTROL ROOM ADMINISTRATION |
| 4.7.9 Roadway Damage Notification | 7.1 General Administration |
| 4.7.10 Roadway Mainline, Ramp & Bridge Closure Notification | 7.2 Staffing Guidelines |
| 4.7.11 Snow Removal | 7.3 Summer Dress Code |

8. BUILDING SECURITY	Appendix E: Acronyms
APPENDICES	Appendix F: Phoenix Area FMS Implementation Map
Appendix A: Interagency Docu- mentation	Appendix G: FMS Implementation Block Diagram
Appendix B: TOC Organizational CHART	Appendix H: VMS Information
Appendix C: TOC Physical Layout Plan	Appendix I: Troubleshooting
Appendix D: Incident Management- Related Definitions	

3.6.2.2. Tennessee’s Region 3 TMC in Nashville

The Tennessee Department of Transportation recently developed a document comprising a high-level gathering of operational policies that were created and approved by the Tennessee Department of Transportation (TDOT) for the TDOT, Region 3 Transportation Management Center serving the Nashville Metropolitan Area. The policies are divided into functional area/grouping (9).

This Manual deals with global agency policy; more specific operational details can be found in outside references, such as the MIST™ User’s Manual, that contain specific operational procedures for daily operations, control of specific devices, etc. (9).

Since policies may change over time, the individual policies are numbered for tracking purposes; TDOT initiates regular Policy Manual and Operations Manual update cycles (quarterly or as directed by TDOT) to review and update as required. The operations manager, acting under the direction of the TMC manager, is responsible for making and monitoring the updates (9).

3.6.2.3. Toronto’s COMPASS Downsvievw TMC

Operators at Toronto’s COMPASS Downsvievw TMC are provided an operations procedures Manual that contains information on:

- System purpose, background, objective, and overview;
- Job descriptions, conduct, security, and shift start and end procedures;
- Changeable message sign operation and policy and incident detection;
- Closed circuit television cameras and taping;

- Detector placement, use of computer terminals and Road Weather Information System;
- TRIS (traveler and road information system) policy;
- Driver and vehicle terminal, communications, and incident management protocols;
- Media, general public, Ontario Provincial Police liaison, and liaison with other COMPASS and Ministry of Transportation Ontario staff; and
- Radio system protocol, hardware failure procedures, phone directory, and use of operational documents (3).

Other documents provided to TMC operators include:

- A patrol list providing patrol coverage and methods of contact;
- A technical and electrical binder listing applicable personnel, methods of contact, and Ministry of Transportation Ontario signal locations;
- A nuclear emergency/provincial emergency manual;
- Drawings of equipment locations and IDs;
- Emergency telephone numbers;
- Construction contract listings of projects and contacts;
- A driver and vehicle binder providing numbers for Ministry of Transportation of Ontario Commercial Vehicle Operations staff; and
- A service crew binder providing maintenance contacts and emergency operator contacts, including emergency services, automobile clubs, and road agencies (FHWA 1999).

To support and encourage the use of the TMC Operations Manual, Toronto reorganized its operations department to include an individual assigned to maintain and update its procedures (3).

Several other TMCs, including Atlanta (Georgia) NaviGator, Boston (Massachusetts) Integrated Project Control System (IPCS), Houston (Texas) TranStar, and Milwaukee (Wisconsin) MONITOR, provide more limited examples of good practices related to TMC operation development and maintenance:

Table 3-3 Tennessee Department of Transportation TMC Operations Manual (9)

1	INTRODUCTION	5	CONTROL SYSTEM OPERATION POLICIES	8.2.6	Display of Upcoming Special Events that Adversely Affect Travel
2	EMERGENCY/OTHER CONTACT NUMBERS	5.1	Operator Interface	8.2.7	Display of Travel Times
3	GENERAL POLICIES	5.2	Operational Procedures	8.2.8	Traffic Diversion (General)
3.1	Update Status and Record	5.3	Incident Management	8.2.9	Traffic Diversion (Full Highway Closure)
3.2	Change Policy	5.3.1	Incident Classification Policy	8.2.10	Traffic Diversion to Roadways Not Under the Jurisdiction of TDOT
3.3	Visitor and Tour Policy	5.3.2	Incident Response	8.2.11	DMS Messages for Adverse Weather, Environmental, and Roadway Conditions
3.4	ATMS Hardware and Software	5.3.3	Incident Detours	8.2.12	Limits of DMS Influence for Incidents
3.4.1	General Equipment	5.3.4	Incident Information	8.2.13	DMS Message Priority
3.4.2	Operator Specific Equipment	5.3.5	Incident Tracking	8.2.14	Other DMS
3.4.3	General TMC Property	5.3.6	Data Entry	8.2.15	DMS Message Confirmation
3.4.4	Telephone and Fax Usage	5.3.7	Incident Paging and Call-Out	8.2.16	Use of Highway Advisory Radio (HAR)
3.5	TMC Cleaning and Maintenance	5.3.8	Post Incident De-briefs	8.2.17	HAR Messages
3.6	Pass Keys and Controlled Access	6	MAINTENANCE POLICY	8.2.18	HAR Message Format
3.7	MIST™ Software	6.1	Routine Maintenance	8.2.19	HAR Message Confirmation
3.8	Building Security and Parking	6.2	Preventative Maintenance	8.3	Miscellaneous Concepts and Policy
3.9	Staff Meetings	6.3	Spare/Backup Equipment	8.3.1	Media/Interagency Image Requests
3.10	Smoking Policy	6.4	Emergency	8.3.2	Web Site Images
3.11	Uniform and Dress Code	6.5	Contract Maintenance	8.3.3	DMS for Special Events
3.12	Drug-Free Workplace	7	SYSTEM OPERATION LOGS	8.3.4	DMS Regulatory Speed Messages
3.13	Breaks and Lunch	7.1	Operations	8.3.5	Advertising
3.14	Work Shifts, Organization CHART and Training	7.2	Maintenance	8.3.6	Public Service Announcements
3.15	Incident Command System	7.3	Events	8.3.7	Display of Amber Alerts
3.16	Homeland Security	7.4	System Reports	8.3.8	Intermodal Information
3.17	Severe Weather Conditions	7.5	Traffic Data	8.3.9	DMS Test Messages
4	DAILY OPERATION	7.6	Risk Management	8.3.10	Ramp Metering
4.1	Management Center Functions	8	OPERATIONAL CONCEPTS	8.4	Data Analysis And Warehousing
4.2	Personnel	8.1	Traffic Monitoring	8.5	Interagency and Inter- Jurisdictional Coordination
4.3	Hours of Operation	8.1.1	Speed Detector Monitoring and Response	9	CONTROL CENTER DESCRIPTION/SYSTEM FIELD DEVICES
4.4	Staffing	8.1.2	CCTV Image Viewing	9.1	Location
4.5	After Hours On-Call Roster	8.1.3	Video Wall	9.2	Access/Security
4.6	Remote Operation	8.1.4	Video Sequences	9.3	Layout
4.7	Security Policy	8.1.5	Recording Video Images	9.4	Fire Suppression
4.8	Maintenance Checklist	8.1.6	Road Construction Monitoring	9.5	Power Source/Location
4.9	Startup/Shutdown	8.1.7	Road Construction Reporting	9.6	HV/AC
4.10	Failure Recovery	8.1.8	Diversion Route Planning	9.7	Data Communications
4.11	Agency/Jurisdictional Contacts	8.1.9	Highway Maintenance Activity	9.8	Voice Communications
4.12	Telephone Call Etiquette and Notification Policy	8.2	Traffic Response	9.9	Network Communications
4.13	Contact with Media and the Public	8.2.1	Use of Dynamic Message Signs (DMS)	9.10	Field Device Descriptions
4.14	Coordination with HELP Program	8.2.2	Operation of DMS by Law Enforcement Personnel	10	SYSTEM DOCUMENTATION
4.15	Dispatch of HELP Vehicles	8.2.3	Blank Signs		
		8.2.4	Messages during Peak Periods		
		8.2.5	Display of Upcoming Roadwork		

Atlanta created a dedicated training position, maintained in the Operations Center Unit within the Office of Traffic Operations, responsible for managing an in-house training program called the Performance Training Program (PTP). The program includes a 4- to 8-week training course for all new Operations Center personnel. The PTP is supplemented by an “Operations Manual” that covers daily operational procedures taught in the training program.

Boston—due to the constantly changing condition of its road network because of the construction of the Central Artery/Tunnel—has a program of continually updating its procedures. Because of the frequent change of its procedures, Boston implemented desktop rehearsal and new and altered procedure simulations to ensure operational readiness (3).

In Houston, memoranda outline operator roles and responsibilities. Operational procedures are developed on an as-needed basis. New procedures are prepared as new organizational units move to the control room (3).

Milwaukee recognized the need for a different orientation in the training of its law enforcement partner and developed a customized training Manual for its use. Milwaukee provided a system workstation at the law enforcement dispatch site and received positive feedback from the law enforcement dispatchers regarding this access. Also in Milwaukee, student labor was applied successfully to updating operations and system documentation (3).

3.6.3. Using a TMC Operations Manual to Support System Maintenance Procedures

During the review of TMCs, only the TMC Operations Manual developed by the Tennessee Department of Transportation contained information related to system maintenance procedures. Following ITE’s recommended content for a TMC Operations Manual (6), Tennessee’s TMC Operations Manual describes:

- Maintenance, startup/shutdown, and failure recovery (automated and manual) procedures for daily operation;
- Maintenance procedures including routine, preventative, emergency (nonroutine), and contract maintenance and the location of spare/backup equipment;
- System operations logs including maintenance logs and system reports;
- Control center/system field device descriptions including location, access/security, layout, fire suppression, power source/location, HV/AC, and data, voice, and network communications; and

- System documentation including vendor maintenance documentation.

A number of other TMCs cited challenges related specifically to configuration management and preventive maintenance:

- Atlanta's TMC recently staffed two full-time positions for configuration management and has a 100 percent configuration review of its software under way (3).
- In an innovative way to address the challenge of its changing configurations, Phoenix's TMC recently renewed the multiyear purchase agreement with its preferred variable message signs (VMS) vendor, providing ADOT total control over the proliferation of brands and models of VMS installed in its system (3).
- Phoenix has also developed special repair techniques to economically manage ongoing maintenance problems such as damage from gun shots. ADOT performed a logistics analysis to determine appropriate spares levels and how spares should be divided between piece parts and complete units. ADOT also recently completed a study of the 15-year expected cost of maintenance, providing a basis for planning, budgeting, and staffing (3).
- To avoid problems with repairing their legacy equipment, TMC personnel in both Toronto and Milwaukee implemented planned system upgrades; Michigan and Long Island (New York) TMC personnel are examining methods to continue support for their legacy equipment (3).

3.6.4. Using a TMC Operations Manual to Support Data Collection, Analysis, and Warehousing Procedures

Limited evidence of TMC Operations Manual use to support data collection, analysis, and warehousing was uncovered. There was, however, a consensus among TMCs that planning, operations, and maintenance were all more effective when backed by ongoing performance analysis and process improvement. TMC personnel in both Toronto and Atlanta have performed benefits analysis studies for their respective TMCs. In addition, the Atlanta TMC has a vigorous program of monitoring and evaluating responsiveness to traveler calls. Several TMCs reported evaluating their performance after large or unusual incidents, seeking ways to improve. Most of the newer systems provide fully automated logging of data, status, and actions, making such analysis possible. ADOT staffs a main shift traffic analyst to perform ongoing analysis of advanced traffic management system collected data, examine operations performance, and identify areas for improving the region's overall traffic conditions for the Phoenix TMC (3). Formal guidance for these types of performance monitoring activities (i.e.,

performance measures, data to be collected, frequency of analysis, etc.) is lacking in most existing TMC Operations Manuals.

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4. GETTING STARTED

4.1. Introduction

4.1.1. Chapter Purpose and Key Issues

This chapter describes the roles and relationships of a TMC with various management structures. It also outlines at a high level some of the basic preparatory steps that will be further detailed in subsequent sections.

4.1.2. Relationship to *Handbook* Document

The first part of this *Handbook* (chapters 1, 2, and 3) documented the need for, and benefits of, a TMC Operations Manual. This section provides a transition from Part I with its focus on goals and benefits to subsequent sections that describe the detailed content of an operations manual.

4.2. Operations Manual Implementation under Various Management Structures

4.2.1. Business Model Perspective Introduction

Traffic management systems and their associated traffic management centers are deployed in many different configurations. The TMC Pooled-Fund Study sponsored a *TMC Business Planning and Plans Handbook* activity that characterized TMCs into various management and functional categories as follows (1):

- Geographic area covered:
 - Single jurisdiction TMC,
 - Multiple jurisdiction TMC,
 - Regional or district TMC, and
 - Statewide TMC;
- Number and types of agencies involved:
 - Single agency TMC,
 - Multiple transportation agencies, and
 - Multiple agencies and disciplines;
- Operating mechanism:
 - Public agency staffed and operated TMC
 - Private sector staffed and operated TMC, and
 - Hybrid public/private operation.

The following tables identify some of the characteristics for each of these business models and describe the potential impacts of these styles of management and business enterprises on the development and use of a TMC Operations Manual. The reader should note that these impacts are only in-

formational and may not substantially affect a specific TMC Operations Manual. They may be very useful in identifying organizations from which to solicit and review TMC Operations Manuals and historical development activities that can serve as examples for current initiatives.

4.3. Geographic Area Covered

Geographic definition is probably the most basic decision to be made in developing a Traffic Management System (TMS). Although other categorizations (e.g., multiple agencies, disciplines, operating mechanism) may influence the design and mission of the TMS, geographic definition is basic to any structure.

4.3.1. Single Jurisdiction Management

The most common model is the single jurisdiction model. It is probably the easiest structure to operate because decisions and supervision are vested in one entity. In an urban area where there may be multiple other autonomous agencies, there may be a measure of cooperation and coordination without a unified management structure or data communication system. Table 4-1 summarizes characteristics of the Single Jurisdiction Management Structure and the potential impacts on a TMC Operations Manual.

Table 4 -1 Single Jurisdiction Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Limited number of stakeholders.	Development of a TMC Operations Manual involves fewer stakeholders than other management structures. Therefore, the manual development team and advisory group could be smaller and perhaps reach consensus more quickly.
Limited number of inter-agency agreements.	Fewer interagency agreements are required to staff the TMC than with other management structures. However, more interagency agreements could be required to coordinate operations with others in a large multiple jurisdictional region. The inventory and description of interagency agreements could be reduced.

Table 5 -1 Single Jurisdiction Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
<p>Could be located within an existing agency’s office facility.</p>	<p>Established policies and procedures for an existing office facility may be applicable. Costs may be reduced if facilities and resources are shared.</p> <p>Given the lack of influence of transportation operations in some organizations, the selection of location and co-located partners may not be optimal.</p>
<p>With a single jurisdiction it is easier to inventory and track field equipment than with a multiple jurisdiction TMC.</p>	<p>More basic or simplified procedures may suffice in section 5.2 of chapter 5.</p>
<p>Agency operations could be more focused on local solutions rather than the regional mission in a large multiple jurisdictional region.</p>	<p>It may be necessary to carefully examine the text included concerning regional coordination and include it in section 5.2.7 of chapter 5 and the material concerning agency responsibilities in section 5.2.15.</p>
<p>Coordination with adjoining agencies in a large multiple jurisdictional region could be challenging.</p>	<p>Even though the TMC may be unilaterally operated, there are still coordination issues that must be addressed in the manual in sections 5.4.2, 5.6.2, and 5.14).</p>
<p>Resources for operations are typically provided by the operating agency.</p>	<p>The manual reflects less complicated procedures for access to resources.</p>

4.3.2. Multiple Jurisdictions Management Structure

The Multiple Jurisdictions Management Model has application in larger metropolitan areas where multiple jurisdictional boundaries may abut. In a large urban area, a driver can travel on a major thoroughfare and pass through several cities, each with its own computer-based signal system. While drivers are not necessarily aware when they cross a jurisdictional boundary, they may be aware if the signal systems are not compatible. Table 4-2 summarizes characteristics of the Multiple Jurisdiction Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-2 Multiple Jurisdiction Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Efficiency and cost savings. Eliminate duplication and overlap in procurement, installation, and integration of technical systems.	<p>Agreements on maintenance should be developed among the agencies. These agreements should be referenced and summarized in section 5.15.2 of chapter 5.</p> <p>Maintenance procedures described in section 5.8 of chapter 5 should reflect the agreements for agency supplied maintenance, contract maintenance, and procurement of associated equipment.</p>
Resource utilization and availability. Multijurisdictional TMCs are in a position to share and draw upon the technical expertise, strengths, and resources of partner agencies. Pooled resources can extend hours and services.	<p>The concept of shared resources should be included in the concept of operations document described in section 3.5 of chapter 3 and noted in section 5.1.1 of chapter 5 and.</p> <p>Hours of operations, call-in procedures, and other staffing considerations described in section 5.3 of chapter 5 may need to be tailored to accommodate the policies of each agency if a single policy can not be applied to all agencies.</p> <p>Each agency's operational experiences may have led them to unique logging procedures as a means of risk management. Sections 5.3 and 5.12 of chapter 5 may need to be tailored to accommodate the policies of each agency.</p>
Improved working relationships. Collocation of staff from multiple jurisdictions into a common facility facilitates information exchange and elevates trust and understanding.	Co-location and improved working relationships could lead agencies to relax computer system access and administrative polices. The operator interfaces described in sections 5.5.3 and 5.7.3 of chapter 5 should be rigorous enough to allow each agency to control access and use of their equipment and to provide a clear audit path for operator actions.
Systems coordination. Collocation of staff from multiple jurisdictions into a common facility encourages coordinated traffic management across jurisdictional boundaries	Coordination among agencies occurs naturally as they are collocated, but operational procedures and policies should be clearly defined in sections 5.5 and 5.7 of chapter 5.

Table 4-2 Multiple Jurisdiction Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
Could be centrally located for convenient physical access.	Central location should simplify access for most participating agencies. No direct effect on the manual.
Communications demands may become substantially greater as notification/updates/education over multiple jurisdictions becomes a much greater burden since communication protocol can often vary from city to city, county to county, etc.	Ideally, agencies use ITS Architecture standards so that communications challenges can be simplified; this should be included in the concept of operations document (section 3.5 of chapter 3) developed prior to writing the manual and should be included or referenced in sections 5.4.2 and 5.6.2 of chapter 5.
Physical location is not critical with adequate communications network providing a “virtual TMC.” Lessens the opportunity for trust and understanding among staff.	If the model is a virtual TMC, the manual should ensure that points of contact are designated and kept current in sections 5.3.1, 5.4.2, and 5.6.2 of chapter 5.

4.3.3. Regional or District Management Structure

The regional or district model is a further iteration of the multiple jurisdictional model. While the multijurisdictional model likely involves jurisdictions in which boundaries abut or a cluster of jurisdictions, a regional or district model involves such clusters that may be more distantly located. Rural areas may also be incorporated. Table 4-3 summarizes characteristics of the Regional or District Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-3 Regional or District Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Regional traffic management can occur more easily. May include rural areas as well as urban.	Regional management policies and procedures will need to be detailed in sections 5.4.2 and 5.6.2 of chapter 5.
Integrated control of multiple ITS systems more easily achieved when one TMC is operated.	The concept of shared resources should be included in the concept of operations document defined in section 3.5 of chapter 3.
Regional or district TMC may utilize staff from different jurisdictions. Collocation of staff from multiple jurisdictions into a common facility facilitates information exchange and elevates trust and understanding.	Collocation and improved working relationships could lead agencies to relax computer system access and administrative policies. The operator interfaces described in sections 5.5.3 and 5.7.3 of chapter 5 should be rigorous enough to allow each agency to control access and use of their equipment and to provide a clear audit path for operator actions.
Regional or district TMC well-suited to serve as a central repository, synthesizer, and clearing house for work zone, maintenance, and construction information for dissemination to traveler information systems.	This role should be detailed in the concept of operations document (section 3.5 of chapter 3) and referenced or summarized in the manual.
Arrangement requires intergovernmental agreements, memoranda of understanding, or a concept of operations be worked out ahead of time.	Policies, procedures, and agreements among agencies must be reflected in the operations manual in all aspects of operations, maintenance, and coordination.

Table 4-3 Regional or District Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
Projects supported by a regional or district TMC, and inherently by multiple jurisdictions throughout the region, are more likely to receive Federal approval and funding.	The manual must document who maintains communication networks and procedures for response to failures.

4.3.4. Statewide Traffic Management Structure

A statewide management structure is influenced by the geographical size of the state as well as the number of major metropolitan areas contained therein. Although usually the initiator is the state transportation department, other related agencies, such as state highway patrols, may be co-located. Table 4-4 summarizes characteristics of the Statewide Traffic Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-4 Statewide Traffic Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Cost efficiencies, particularly in terms of staffing and central system software.	Staffing responsibilities and hours of operation per memoranda of agreement must be reflected in section 5.34 of chapter 5.
Coordination along major corridors that pass through different regions more easily obtained.	Specific corridors and operational procedures must be included in sections 5.5 and/or 5.7 of chapter 5.
TMC serving an entire state requires extensive, costly communications network.	No direct effect on the manual.

Table 4-4 Statewide Traffic Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
Statewide systems also are frequently tasked with coordinating efforts between a statewide center and regional TMCs designed to represent the statewide ITS Architecture regionally.	Policies, procedures, and agreements among agencies must be reflected in the operations manual in all aspects of operations, maintenance, and coordination.
May be operated by single state agency or with shared operation of other state agencies (DOT, highway patrol).	Policies, procedures, and agreements among agencies must be reflected in the operations manual in all aspects of operations, maintenance, and coordination.

4.4. Number and Type of Agencies Involved

Previously described models centered on geographic and jurisdictional considerations; the agency focus expands the jurisdictional aspects to related agencies. Geographical considerations may still influence some of the agency models.

4.4.1. Single Agency Management Structure

This structure, with a single agency (e.g., traffic department) within a jurisdiction has many of the same characteristics of the single jurisdictional structure. Table 4-5 summarizes characteristics of the Single Agency Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-5 Single Agency Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
All of the control resides within one organization; decisions made without consulting other agencies.	Development of a TMC Operations Manual involves fewer stakeholders than other management structures. Therefore, the manual development team and advisory group could be smaller and perhaps reach consensus more quickly.
May have a limited view of the regional approach to traffic management.	Even though other stakeholders may not be directly involved, relationships and contact points still need to be delineated in the manual in sections 5.2.7 and 5.2.15 of chapter 5. It may be necessary to carefully examine the text included concerning regional coordination and agency responsibilities.
Many of the same characteristics as single jurisdiction model (e.g., inter-agency agreements may not be required).	Even though other stakeholders may not be directly involved, relationships and contact points still need to be delineated in the manual in sections 5.2.7 and 5.2.15 of chapter 5.
Economic, human resource, technical expertise limitations of single agency TMCs may limit the breadth and scope of activities.	Although the effectiveness of multiple agency involvement may be reduced, there is no direct effect on the manual.
Implementation costs are typically higher when each agency develops its own TMC versus having one TMC facility that is shared among multiple agencies.	Although the effectiveness of multiple agency involvement may be reduced, there is no direct effect on the manual.

4.4.2. Multiple Transportation Agency Management Structure

This structure would be characterized by the alliance of several transportation agencies (e.g., transportation departments of two or more cities combine forces to operate the traffic signal systems of the two agencies as a single system).

The definition of this structure would not include related agencies such as enforcement. Table 4-6 summarizes characteristics of the Multiple Transportation Agency Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-6 Multiple Transportation Agency Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Traffic management can be handled across jurisdictional boundaries more effectively.	Coordination among agencies occurs naturally as they are collocated, but operational procedures and policies should be clearly defined in sections 5.5 and 5.7 of chapter 5.
Would not include public safety elements in center; communications may suffer.	Although the TMC may be operated in a partnering agreement among the transportation agencies, there are still coordination issues with non-transportation agencies such as enforcement and emergency medical services (EMS) that must be addressed in the manual in sections 5.4.2, 5.6.2, and 5.14 of chapter 5.
Intergovernmental agreements must be executed and operational procedures documented; this is advantageous as it requires cooperation among the staff of the different transportation agencies.	Policies, procedures, and agreements among agencies must be reflected in the operations manual in all aspects of operations, maintenance, and coordination.
Any given agency may have to compromise on how they operate their system.	Policies, procedures, and agreements among agencies must be reflected in the operations manual in sections 5.5 and/or 5.7 of chapter 5.

4.4.3. Multiple Agency and Disciplines Structure

Because of the complex nature of Multiple Agency and Disciplines Structure, it is the most difficult to implement. Numerous interagency agreements and agreed upon operating policies and procedures must be negotiated. However, the cost efficiencies and benefits of coordinated management usually outweigh these complexities. Table 4-7 summarizes charac-

teristics of the Multiple Agency and Disciplines Structure and the potential impacts on a TMC Operations Manual.

Table 4-7 Multiple Agency and Disciplines Structure

Characteristic	Potential Impacts on a TMC Operations Manual
<p>Efficiency and cost savings. Multiagency TMCs eliminate duplication and overlap in construction and maintenance of facilities; compatible and integrated systems (e.g., Integrated CAD) allow agencies to share costs for new purchases and upgrades.</p>	<p>The concept of shared resources should be included in the concept of operations document (section 3.5 of chapter 3) noted in section 5.1.1 of chapter 5.</p> <p>Hours of operations, call-in procedures, and other staffing considerations described in section 5.3 of chapter 5 may need to be tailored to accommodate the policies of each agency and discipline if a single policy cannot be applied to all agencies and disciplines.</p> <p>Each agency and discipline’s operational experiences may have led them to unique logging procedures as a means of risk management. Sections 5.3 and 5.12 of chapter 5 may need to be tailored to accommodate the policies of each agency.</p>
<p>May be from same jurisdiction or municipality, typically transportation and public safety.</p>	<p>Personnel and other policies being somewhat compatible could make development of the manual less complicated.</p>
<p>More difficult to implement but has many of same advantages of multi-jurisdictional model.</p>	<p>Policies, procedures, and agreements between participants must be reflected in the operations manual in sections 5.5 and/or 5.7 of chapter 5.</p>
<p>Improved communications and working relationships. Collocation of staff of multiple facilitates information exchange and elevates trust and understanding. Agencies see the impact of their activities on the missions of other agencies.</p>	<p>Coordination among agencies and disciplines occurs naturally as they are collocated, but operational procedures and policies should be clearly defined in sections 5.5 and 5.7 of chapter 5.</p>

4.5. Operating Mechanisms

Either of the two operating mechanisms described below may apply to the previously described management structures.

4.5.1. Public Agency Staffed and Operated Management Structure

This is perhaps the most common model for most agencies since they have direct control and management of their system. This assumes that adequate funding is available for both operational activities and personnel. Table 4-8 summarizes characteristics of the Public Agency Staffed and Operated Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-8 Public Agency Staffed and Operated Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
Staff and operate the TMC with personnel from the jurisdiction and agency that owns the TMC. Requires hiring personnel that have the skills or interest in the “operation” of a transportation management center.	Same impacts as single jurisdiction or agency model.
Staff comprised entirely of public agency employees is often preferred. Unified personnel management system facilitates team cohesiveness. Greater sense of ownership of day-to-day as well as emergency operations.	Same impacts as single jurisdiction or agency model.

Table 4-8 Public Agency Staffed and Operated Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
<p>Funding and staffing restrictions have been a continual problem for many agencies. These factors have historically had a detrimental effect on recruiting, retention, and morale. The private sector model also may facilitate termination and replacement of nonperforming personnel.</p>	<p>A comprehensive TMC Operations Manual is vital to ensure consistency of operation when staff turnover occurs.</p>

4.5.2. Contract Operation Management Structure

Depending on available funding, all or part of the operational responsibilities may be contracted to a private organization or even another agency. Table 4-9 summarizes characteristics of the Contract Operation Management Structure and the potential impacts on a TMC Operations Manual.

Table 4-9 Contract Operation Management Structure

Characteristic	Potential Impacts on a TMC Operations Manual
<p>Outsourcing allows agencies to specify qualifications of staff needed and to place the responsibility for hiring and training staff on a private company. The private sector model also may facilitate termination and replacement of nonperforming personnel.</p>	<p>The importance of a comprehensive operational manual is not lessened when the system is operated under contract. Although much of the operations manual as described in chapter 5 will apply to this model, specific responsibilities and reporting structure must be detailed in sections 5.3.3 and 5.3.4 of chapter 5.</p>

Table 4-9 Contract Operation Management Structure (Cont.)

Characteristic	Potential Impacts on a TMC Operations Manual
May be easier for public agency to find funds for contracted operations staff rather than approval and budget to hire their own staff.	No direct effect on the manual.
Introduces contractual issues and the required administration, oversight, and performance measurement of the contractor	A separate chapter or section in chapter 5 may be appropriate to describe relationships, requirements, and other details of the contractor's responsibilities.

4.6. Getting Ready

Operations affect outcomes. With more effective operations there is more effective system performance. And with a strategy to formulate a TMC Operations Manual that mirrors and guides effective operations (as measured through accepted, responsive, and appropriate performance measures), there is a need to build consensus.

The steps required to develop and implement a TMC Operations Manual are as follows.

- Identify a manual development leader,
- Establish a manual development team,
- Identify appropriate stakeholders,
- Designate an advisory group,
- Identify an independent reviewer,
- Collect and assemble relevant system documents,
- Collect and assemble regional agreements and ITS plans, and
- Establish a schedule and assign responsibilities.

These are very similar to the steps that might be used in developing a concept of operations document or developing and delivering a project. Remember that the TMC manual product and the development activity are team oriented. It is very unlikely that a TMC Operations Manual developed by a single individual will adequately address the operational goals

or needs of the system. If the system is built by a team, the manual should be a team effort.

There needs to be a manual development leader who can keep focus on developing and delivering a TMC Operations Manual. This is especially critical when a major systems project is being deployed. It is very easy to lose sight of this operational document when large expenditures and staffing efforts are being directed to software, systems, integration, and field devices. The good news is that many of the same products being developed for the TMC system can be tailored for inclusion in the operations manual.

Section 1.2 described agency and personnel stakeholders that could be involved in developing a TMC Operations Manual. It is important to engage these stakeholders early in the systems life cycle and to keep them involved.

Even with active involvement of appropriate stakeholders, it is likely that a small, focused group will develop the TMC Operations Manual. Many of the other stakeholders can be organized as “advisors” to the work group that is collecting and assembling the documents. Table 8-1 (chapter 8) identifies the kinds of information that can be gathered at various stages in the system life cycle.

And, of course, it is important to develop and keep a schedule that ensures a TMC Operations Manual is ready concurrent with the operational phase of a system.

4.7. Notes and References

(1) The TMC Pooled-Fund Study sponsored a project to develop a *TMC Business Planning and Plans Handbook* during the 2004–2005 time period. The Pooled-Fund Web site is located at <http://TMCpfs.ops.fhwa.dot.gov>. At the time the TMC Operations *Handbook* was completed the drafts of the *Handbook* could be found at http://TMCpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=54&new=0

5. TMC OPERATIONS MANUAL COMPONENTS

5.1. Introduction

5.1.1. Chapter Purpose and Key Issues

This chapter describes the components that should be considered for inclusion in a TMC Operations Manual. It is important to note that not all items listed in this chapter must be included in every TMC Operations Manual. Selection of specific components depends on the management structure of the TMC, services offered by the TMC, the availability of supplemental manuals and procedures, and the size and complexity of the center. It is essential that a concept of operations document be available to developers of a TMC Operations Manual. Such a document defines the functions, goals, services, stakeholders, and interfaces that are necessary for the system. If this document is not available, a high level summary of an operational concept document should be developed.

5.1.2. Relationship to *Handbook* Document

Earlier chapters identified the context and benefits of a TMC Operations Manual. Subsequent chapters present procedures for developing and updating a manual and case studies of successful practice. This chapter provides a description of suggested content, allowing an agency to review its organizational structure and setting in order to develop a tailored outline applicable to its conditions. Using the resulting customized outline as a set of requirements for their TMC Operations Manual, the organization can subsequently develop the activities and resources required to produce the document, train operational staff on the use of the manual, and provide ongoing updates in response to changing circumstances. An implementation path can then be pursued to successfully develop the TMC Operations Manual.

In addition to describing each element of TMC manual content below, this *Handbook* also describes when in the systems engineering life cycle this content might be developed and identifies who might be engaged to provide the information. The basic premise is that an operations manual can be developed throughout the life cycle of a systems project and that this development is a team effort involving numerous people.

As noted in chapter 1, the systems engineering process is illustrated in Figure 5-1 below. For the purposes of discussion in this chapter, the National ITS Architecture, concept of operations, and functional re-

quirements are combined into one category called “Concept of Operations and Requirements.” This followed by “Design,” then “Implementation and Integration,” then “Testing and Verification,” and finally “Operations.” Table 5-1 shows these categories as they apply to the inventory content elements of a TMC Operations Manual.

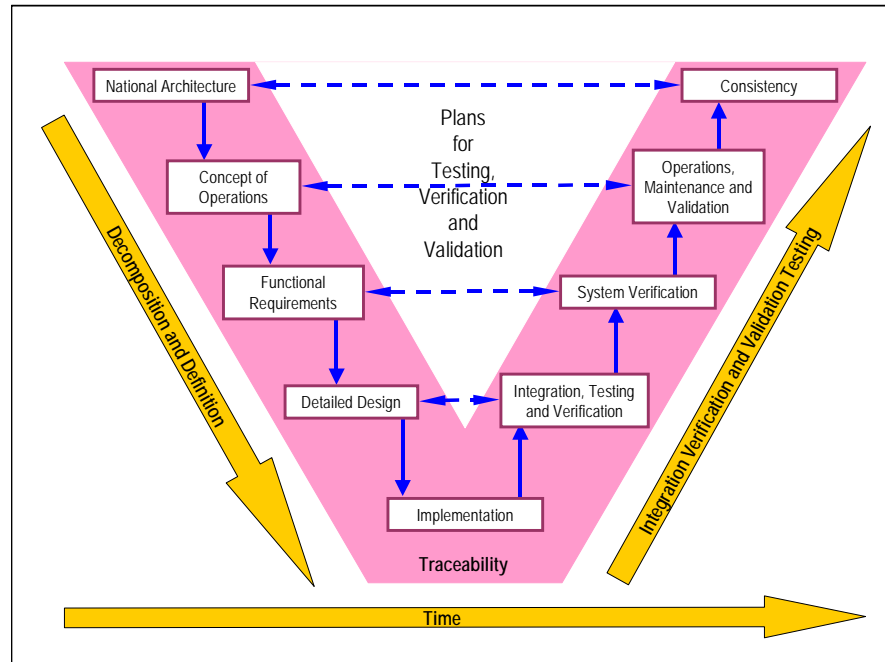


Figure 5-1 V Systems Engineering Process

Chapter 1 also listed personnel who could be involved in the TMC Operations Manual either as a user or as a content provider. This list was categorized as follows:

- Roles in developing a regional its concept of operations and planning for its:
 - Champions,
 - Planners, and
 - Federal field staff.
- Cross-cutting roles:
 - Business analysts,
 - Data(base) analysts and managers,
 - Contract specialists,
 - Legal staff,
 - Marketing/public relations staff,
 - Human resources staff, and
 - Systems administrators/support technicians.

- Roles in the design, procurement, installation, operations and maintenance, and evaluation stages:
 - Project managers,
 - Engineers,
 - Software developers,
 - Systems designers/integrators,
 - Operators,
 - Dispatchers,
 - Drivers,
 - Electronics inspection and maintenance technicians, and
 - Operations managers/supervisors.

- Creating change: roles for mainstreaming its
 - Program/agency manager and
 - Interjurisdictional coordinator.

For purposes of discussion in this chapter the categories of Creating Change and Developing a Regional ITS Concept of Operations have been combined. The resulting three categories “Planning and Change Agent Roles,” “Cross-Cutting Roles,” and “Design, Procurement, and Operations Roles” describe the personnel who might be involved in developing a TMC Operations Manual. Table 5-1 shows these categories as they apply to the inventory content elements of a TMC Operations Manual.

5.2. Inventory

Assemble a comprehensive inventory of documentation for existing and planned TMC-related items to aid in development of the manual. Include any existing procedures as well as an inventory of existing field equipment and communications hardware and media and central management components. Information sources include existing agency files and records; however, some cases may require a physical inventory.

Table 5-1 summarizes when in the systems engineering life cycle each element of the inventory could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

5.2.1. Area of coverage

Define geographical areas for which the TMC performs services as well as subareas and subfacilities. Develop text descriptions as well as hardcopy maps and include municipal boundaries, transit service areas, and other geographic boundaries. Sources of information include existing map and plan bases and documentation in the concept of opera-

tions document. Much of this information can be developed during the early phases of a project prior to actual construction of a TMC system or subsystem.

Table 5-1 Summary of Systems Life Cycle Timing and Resources for “Inventory” Content of a TMC Operations Manual

Category	TMC Operations Manual Content and Handbook Section Reference	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
Inventory	5.2.1. Area of coverage	X					X		
	5.2.2. Functions	X					X		
	5.2.3. Services Provided	X					X		
	5.2.4. Field Located Traffic Control Devices	X	X			X	X		X
	5.2.5. Highway Construction Plans			X					X
	5.2.6. TMC Components	X	X						X
	5.2.7. Stakeholders	X					X		

5.2.2. Functions

Document functions that the existing TMC currently performs or that an upgraded or new TMC will perform. Sources for this information include existing operations manuals as well as system planning documents such as the concept of operations that has been reviewed and approved in concept by all entities that are housed in or interface with the TMC.

The information for these “functions” could be contributed by the planners and FHWA field staff who played a role in the development of the regional ITS concept of operations document and in planning for ITS. The information can be provided during the early phases of the systems engineering process for a project, including the development of a concept of operations document and identification of functional requirements. The approved concept of operations document also serves as a resource.

5.2.3. Services Provided

Functions describe what the system is designed to do. Services describe what those functions do and for whom. Develop a comprehensive list of the services the system provides and who (public and private agencies, drivers) receives these services for use in developing the manual.

The information for these “services” could be contributed by the planners and FHWA field staff who play a role in the development of the regional ITS concept of operations document and in planning for ITS. The information could be provided during the early phases of the systems engineering process for a project, including the development of a concept of operations document. The approved concept of operations document also serves as a resource.

5.2.4. Field Located Traffic Control Devices

Assemble an inventory of existing field control, information, and communications equipment utilized in the traffic management system. A similar inventory of planned field equipment to be installed in a new or upgraded system must also be assembled. Inventories of field located devices are normally available in agency files. In some cases, field checks may be necessary, as files may not be current. Naming conventions should be as consistent as possible. TMC software may have a naming convention to be used by operators that may differ from field device plans. If a common naming convention is not possible, develop a quick reference chart to translate one convention to the other.

This information should be routinely gathered in order to develop the detailed design for a TMC; however, general descriptions of the field deployment are used in the development of the concept of operations document and establishment of TMC requirements. Additionally, continuous updates are required during the operations phase.

5.2.5. Highway Construction Plans

Specify locations for quick access to highway structural plans (e.g., bridges, pump houses, drainage features, etc.) in the event that details on those items are needed in an incident management situation. Inventories of construction plans are normally available in agency files.

While this information is available throughout the life cycle of a TMC project, it is not needed until the implementation phase. During design some of this same information is used to develop plans and specifications. Ideally, operators can access these plans electronically.

5.2.6. TMC Components

Assemble an inventory of existing control and system management equipment utilized in the traffic management system. A similar inventory of existing control and system management equipment to be installed in a new or upgraded system must also be assembled. Agency files for existing equipment, the concept of operations document, and system construction plans, specifications, and estimates (PS&E) are sources for these components.

This information is used in developing the requirements for a system and can be provided by engineers, system designers, software developers, and others associated with design and procurement activities.

5.2.7. Stakeholders

Most TMS, particularly in larger urban areas, have a relationship with other TMS in the area. There may be data and information exchange and coordination of management tasks. At the very least there is informal communication among agencies. Assemble an inventory of stakeholders. Stakeholders in surface transportation management may include:

- State transportation agencies,
- Local municipalities:
 - Emergency medical service,
 - Law enforcement,
 - Fire department, and
 - Traffic control department.
- State highway patrol,
- Area transit agencies,
- Toll authorities,
- Media outlets,
- Private information service providers,
- Regional mobility agencies, and
- Metropolitan planning offices.

Sources for stakeholders include interagency agreements, regional ITS concepts of operations, or a system concept of operations document. These stakeholders are identified early in the life cycle of a systems project and can be one of the first content elements gathered for a TMC Operations Manual.

5.3. Daily Operations

Identify components of an operations manual to support daily operations of a TMC. The components include but are not limited to: personnel and organizational structure, hours of operation, staffing requirements, operations concept, policies and procedures, control plans, remote operation, security procedures, startup and shut down procedures, failure recovery, command structure, emergency contact numbers, notification procedures, operational logs, maintenance policies, procedures, and plans, data archiving and warehousing, emergency procedures, and interagency coordination.

Table 5-2 summarizes when in the systems engineering life cycle each element of daily operations content could be developed and the types of personnel resources which could be engaged to help provide the information for those elements.

Table 5-2 Summary of Systems Life Cycle Timing and Resources for *Daily Operations* Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
Daily Operations	5.3.1. Emergency and Other Contact Numbers	X				X	X		X
	5.3.2. TMC Emergency Plan		X			X			X
	5.3.3. General Policies	X		X				X	X
	5.3.4. General System Operation	X	X			X	X		X

5.3.1. Emergency and Other Contact Numbers

This is a quick reference for emergency situations. Depending on agency (municipal, state highway, tollway, transit, etc.), contacts are subdivided into interagency, intra-agency, and private entities. Typical contacts include the following:

- TMS operations, maintenance, and supervisory personnel contacts (home phone number, pager, cell phone number, portable communications device e-mail address, instant messenger ID);
- Control system technical support;
- Building security and maintenance;
- Police, fire, EMS, motorist assistance patrols, PSAP;
- Street maintenance, freeway maintenance;
- Federal agencies if an interstate facility is to be closed for a significant time period;
- Private information providers, media; and
- Other.

In regions characterized by a large number of jurisdictions, include supplemental maps illustrating the physical boundaries for agency responsibilities in the operations manual.

The agency may already have some of the required phone numbers but more than likely they need to be assembled manually by contacting the related agencies. This is an activity that should begin early in the life cycle of a TMC project and that requires constant update during operations.

5.3.2. TMC Emergency Plan

These procedures serve as a quick reference for emergency action in the control room (not traffic management or homeland security issues).

The emergency plan should specify operator actions in the case of occurrences such as those shown below. Some actions may be standard operating policies of the agency and may be included by reference, although it is more expeditious to have those procedures in the most accessible console document, which in most cases is the TMC Operations Manual.

The emergency plan should also specify procedures for training TMC personnel in familiarization and use of alarm systems, emergency equipment operation, and location of equipment.

Typically, these procedures can begin development during the design phase of a systems project, but they need fine tuning during the operations phase of the project.

5.3.2.1. Fire

Specify actions to be taken in the event of building fire or equipment fire including notification of proper authority as well as equipment safeguarding and personnel safety.

5.3.2.2. Smoke

Specify actions to be taken in the event of building smoke or equipment smoke including notification of proper authority as well as equipment safeguarding and personnel safety.

5.3.2.3. Flood

Specify actions to be taken in the event of flooding due to either external conditions or building plumbing including notification of proper authority as well as equipment safeguarding and personnel safety.

5.3.2.4. Severe Weather

Specify actions to be taken in the event of tornado, storms, icing, earthquake, and other severe weather occurrences including notification of proper authority as well as equipment safeguarding and personnel safety.

5.3.2.5. Security

Describe security for building/control room entry and exit in an emergency.

5.3.2.6. Power Loss

Specify actions to be taken in the event of power loss either to equipment or to the facility including notification of proper authority as well as equipment safeguarding and steps to be taken to activate back-up power if it is not automatically implemented.

5.3.2.7. Communications Loss

Specify actions to be taken in the event of communications loss either to equipment or to the facility including notification of proper authority as well as equipment safeguarding.

5.3.2.8. Evacuation

Describe under what conditions and what actions should be taken in the event building evacuation is necessary.

5.3.2.9. System Shutdown

List the basic steps to shut down the system in a manner to minimize corruption of hardware and software. Documentation furnished as a part of system implementation provides the primary source for this procedure.

5.3.2.10. System Startup

List the basic steps to start up the system after a manual shutdown. Documentation furnished as a part of system implementation provides the primary source for this procedure.

5.3.2.11. System Failure Recovery

Steps for system recovery from an unexpected shutdown should be specified if they are different from the startup procedures. Documentation furnished as a part of system implementation provides the primary source for this procedure.

5.3.3. General Policies

The manual should include a statement of general policies related to daily operation, security, administrative procedures, etc. Many of these policies may be stated in an overall agency human resources or other agency policy. However, those policies that may be especially important to system operation may bear repeating in the TMC manual. There will likely be new policies developed to complement the system operating procedures. Many of these policies will be logical and apparent, but it may be helpful to consult with other agencies on their policies where this is not the case. It is important that any new policies developed be submitted to and approved by the system manager or other designated higher authority.

Many of these policies can be gathered and/or developed early in the life cycle of a systems project. These policies may already exist for other facilities or apply across many services within an agency. Procedures for contacting the media and the public are examples of policies that may have been developed by human resources staff and that have wide applicability within an organization. Others, such as version control for TMC documentation, may be specific to a deployment and developed during the design or implementation phase of a project. Personnel resources depend on the topic. Most of the topics in this section 5.3.3 can be provided to personnel with cross-cutting roles or technical roles in the design and implementation of a system.

5.3.3.1. Documentation of Manual Updates

Documentation of manual updates should include the following:

- Version and date of current manual – indicate the version number and date of the overall document on the title page.
- Change policy – develop a policy and/or procedure that documents steps to be taken for changes to the manual and details to whom the request for changes is made and the approval authority for such changes.
- Update status and record – develop a method for maintaining a record of changes and updates to the manual. A tabular record that documents changes by date, page, and section number should be a part of the manual. Specify a method of disseminating changes.

5.3.3.2. Procedure and Authorization to Change/Suspend Policy

There may be occasions and circumstances where it may be necessary to change or suspend a policy or procedure. Document the procedure for submitting a request and who is authorized to approve such a request in the manual.

5.3.3.3. Requests for DMS Messages from Local Agencies

Requests may be received for information regarding planned occurrences such as parades, athletic events, concerts, etc. Include agency policy in the manual detailing how such requests are handled and who can authorize response to the request. Generally, DMS are used only for specific traffic information purposes. Overuse of DMS for nontraffic messages detracts from their effectiveness in managing traffic. However, requests for public service announcements or other nontraffic messages may be received. The manual should state specifically who is authorized to allow such messages to be posted.

5.3.3.4. Outside Agency Authority

There may be situations when system operators are directed by an outside agency to take action (e.g., the Federal Bureau of Investigation (FBI) directs an operator to display a message on a DMS, as happened in one center on 9/11). Include a clear statement of procedures for approval of outside authorities or agencies to direct use of the system in the manual.

5.3.3.5. Severe Weather Conditions

Include a statement of actions for personnel in severe weather (do they come in to work, can they leave work, who authorizes) in the manual.

5.3.3.6. Authorization, Scheduling, and Handling Visitors

A TMC has numerous visitors ranging from local interest groups to other related operations agencies to representatives from other states seeking information on the state-of-the-practice in freeway management. Specify procedures for requesting such visits and tours to include the person or person to whom the request should be directed. The policy should also outline the responsibilities of the TMC staff on such occasions.

5.3.3.7. Citizen Inquiry and Service Requests

There are occasions when TMC personnel directly communicate with citizens by telephone or other electronic means. Document procedures for responding to citizens, logging requirements, referral, response requirements, follow-up, and other actions. Describe typical telephone etiquette, answering greeting, circumstances for referral to other parties, and other agency telephone policies.

5.3.3.8. Contact with Media and the Public

A typical TMC may receive numerous requests for information from media sources. The manual must specify who can talk to media, what information may be given, and to whom media inquirers should be referred for further information.

5.3.3.9. System and Nonsystem Equipment

In addition to typical office equipment, there is other equipment related to the transportation management tasks. Include specific policy on use of such equipment in the TMC manual including:

- General office equipment,
- Operator specific equipment,
- General agency property, and
- Telephone and fax usage.

5.3.3.10. TMC Building Cleaning and Maintenance

Because of security and the types of high-tech and costly equipment housed in the TMC, it may be necessary to schedule building cleaning and maintenance activities when the TMC is staffed. Detail specific schedules and procedures in the manual.

5.3.3.11. Building Security

Building security is an important consideration for a TMC because of the sensitive nature of the mission and the types of high-tech and costly equipment housed there. Considerations include:

- Allowable access to the building;
- Passkeys/keypads and controlled access; and
- Allowable access to control, communication, and equipment rooms.

5.3.3.12. Organization Chart and Work Shifts

In order to clarify the operational chain of command, the TMC manual should include an applicable TMC staff organizational chart. Since organizational and personnel changes may occur on a fairly frequent basis, date-stamp and replace the chart as changes occur. This is especially useful during an incident or disaster where interactions within the center and with external emergency operations personnel are critical. When a center has co-located functions (like transit or 9-1-1), include the chain of command information for each agency.

It is also useful to have a clearly defined callout policy and procedure to bring in supplemental staff to the TMC in times of emergency. Together with a clear set of work shift guidelines, these staffing resources form a base for ensuring that adequate personnel are available to meet the services promised in the concept of operations document.

If not included in the manual, specify the location of relevant organizational charts and work shift guidelines.

When contract TMC staff members are involved in operations, the information may need to be partitioned for each organization.

The information for these “organization chart and work shift” topics could be contributed by the operations managers/supervisors, systems administrators, and human resources staff. The information could be provided during the early phases of the systems engineering process for a project, including the development of a concept of operations.

5.3.3.13. Other Workplace Policies

Miscellaneous policies such as those mentioned below are typically covered by existing agency policies; it is not unusual for new employee orientation and recurrent training to include information on them. It is still prudent to include a brief paragraph or two in the TMC Operations Manual indicating that these policies exist and referencing

where additional information on the specifics of these policies can be found.

The use of contract TMC staff, part-time personnel, and student labor can sometimes change the scope and applicability of these policies. It may be necessary to partition the description of these workplace policies into appropriate job classifications and employment arrangements so that it is clear to whom they apply. Policies include:

- Arrival and departure procedures,
- Transfer of ongoing incidents at shift change,
- Breaks,
- Drug-free workplace policy,
- Meals,
- Nondiscrimination,
- Overtime,
- Smoking policy, and
- Uniform and dress code.

The information for these “other workplace policies” could be contributed by the human resources staff and legal staff/contract specialists. The information could be provided during the early phases of the systems engineering process for a project, including the development of a concept of operations.

5.3.4. General System Operation

Sources for general system operation include the inventory developed in section 5.2 as well as system documentation such as the concept of operations document and PS&E and general policies developed in section 5.3.3.

Like section 5.3.3, many of these policies can be gathered and/or developed early in the life cycle of a systems project. Much of this information could be a product of the concept of operations document. Some topics like security procedures are developed in the design phase of a project.

5.3.4.1. Management Center Functions

Describe general TMC functions. Refer to more detailed operations and functions in subsequent sections.

5.3.4.2. Control Center Description

Control center description should include:

- Location – detail street and mailing addresses, location within agency grounds, and latitude/longitude. Provide a map of the general area showing the TMC location.
- Layout – provide a general plan view layout of the TMC building and a detailed plan view of the control room to include the following:
 - Consoles,
 - Displays,
 - Voice communication devices,
 - Fire suppression, and
 - Power source location for HV/AC, data communications, and network communications.
- Personnel--Describe typical staffing including job titles and brief duties and designated supervisors for shifts. Provide operations, maintenance, and supervisory personnel contacts (home, pager, and cell).
- Hours of Operation--Specify hours of operation for workdays, holidays, weekends, nights, special events, and emergencies. Note procedures for authorizing nonweekday operations.
- After Hours On-Call Roster
Provide a list of contact numbers (home, pager, and cell) for operations, maintenance, and supervisory personnel contacts.

5.3.4.3. Remote Operation

Describe circumstances for remote operation, authorization, and designated personnel.

5.3.4.4. Security Procedures

Describe security procedures for the control system to include control of access to system interfaces and various levels of access to specific functions of the system.

5.3.4.5. Maintenance Checklist

Typically, the system operator performs only routine maintenance and minor repairs. Describe maintenance checks and responses as well as what actions to take for failures beyond that list (contact numbers for technician or service contractor).

5.3.5. Malfunction Response

Delineate response to system hardware and software malfunctions in the control center and hardware malfunctions for field equipment. De-

scribe notification and dispatch of maintenance personnel and logging of malfunction and resolution of problem.

5.3.5.1. Coordination and Dispatch of Motorist Assistance Patrols (Freeway)

Many freeway management systems involve operation or coordination with a motor assistance patrol. Agency policies on operation of the service should be consulted for guidelines.

5.4. Operational Concepts – Freeway Management Systems

This section describes the overall freeway system operation concept. It enables the user to visualize goals, objectives, and how the discrete parts fit together to accomplish those objectives. Sources for operational concepts include the system documentation, concept of operations document, and general system operation described in section 5.3.3 above. Table 5-3 identifies when in the systems engineering life cycle each topic could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

5.4.1. Goals of the Traffic Management System

Provide a concise statement of the goals and objectives of the TMC and how general components work together (detection, response, data collection, and storage).

5.4.2. Interagency and Interjurisdictional Coordination

Describe the need for interagency and interjurisdictional cooperation and coordination with other stakeholders. Describe other systems and briefly what types of data and information are exchanged and how coordination of operation can be accomplished.

Table 5-3 Summary of Systems Life Cycle Timing and Resources for Freeway Operational Concepts and Procedures Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources			
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles	
Freeway System	Operational Concepts	5.4.1. Goals of the Traffic Management System	X					X		X
		5.4.2. Interagency and Interjurisdictional Coordination	X					X		X
		5.4.3. Malfunction Response	X					X		X
		5.4.4. Traffic Monitoring	X					X		X
		5.4.5. Traffic Response	X					X		X
		5.4.6. Field Devices – Freeway Systems	X					X		X
	Operational Procedures	5.5.1. System Start-Up Procedures		X						X
		5.5.2. System Shut Down Procedures		X						X
		5.5.3. Operator Interface		X						X
		5.5.4. Incident Management Procedures		X						X

5.4.3. Traffic Monitoring

Describe traffic monitoring devices such as:

- Speed detector monitoring and response
- Closed circuit television
- Recording video images
- Road construction monitoring
- Highway maintenance activity

5.4.4. Traffic Response

Describe response to planned or unplanned events.

5.4.4.1. Traffic Diversion

Provide a general description of when diversion is warranted and policy on diverting to specific roadways:

- Full freeway closure
- Partial freeway closure
- Diversion to roadways not under the jurisdiction of agency

5.4.4.2. Dynamic Message Signs

Provide an overview of the purpose and uses of DMS:

- Purpose of dynamic message signs
- Message types
- DMS message priority
- Amber Alert procedures
- Travel time display
- DMS operation by law enforcement personnel

5.4.4.3. Highway Advisory Radio (HAR)

Provide an overview of the uses of HAR:

- Purpose of highway advisory radio
- Criteria for use
- Message types
- Message priority

5.4.4.4. Lane Control Signals (LCS)

Provide an overview of the uses of lane control signals:

- Purpose of lane control signals
- Criteria for use
- Coordination with other devices
- Monitoring operation

5.4.4.5. Ramp Metering

Provide an overview of the uses of ramp metering:

- Purpose of ramp metering
- Criteria for use
- Monitoring operation

5.4.5. Field Devices – Freeway Systems

Provide a functional description of freeway field device capability and specify the locations of field devices controlled or monitored by the traffic management system. Sources for information include system

documentation, inventory, and the concept of operations document.

Typical field devices include the following:

- CCTV
- Communication media
- Detectors
- DMS
- HAR
- LCS
- Ramp meters
- Interchange traffic signals (if not controlled by another agency)
- Other.

5.5. Control System Operation Procedures – Freeway Management Systems

This section depends to a great extent on the individual system, but typical functions can be modified or deleted if not applicable. Most of the required information can be found in the documentation provided by the system installation contractor/integrator.

5.5.1. System Start-Up Procedures

Describe system startup procedures for both planned and unplanned shutdowns.

5.5.2. System Shut Down Procedures

Describe system shut down procedures for both planned and unplanned shutdowns.

5.5.3. Operator Interface

Describe operational procedures and include typical pictures of interfaces, where applicable. Operator interfaces may include:

- Operator console
- Field communication
- CCTV
- Ramp metering
- Interchange signals
- DMS
- HAR
- LCS
- Police communication

5.5.4. Incident Management Procedures

Describe both actions to be taken by the operator to respond as well as notification of other agencies.

5.5.4.1. Reported Incidents

Incident reports come from a variety of sources, both public agency and private. Specify the sources for incident reports and which will be accepted without verification and which should be verified. Sources may include:

- Field located agency staff
- Police two-way radio
- Police scanner
- Nonagency personnel
- Commercial radio
- Citizen cell phone
- Citizen land line

5.5.4.2. Detected Incidents

Detected incidents are those for which the operator has firsthand knowledge including:

- Visual detection via CCTV
- Incident detection software

Depending on the accuracy and reliability of incident detection software, incident alerts may need to be verified visually through CCTV or by reliable field personnel. Sources for operational concepts include the system documentation, concept of operations document, and general system operation in section 5.3.3 above.

5.6. Operational Concepts – Traffic Signal Management Systems

This section describes the overall system operation concept for traffic signal systems and enables the user to visualize goals, objectives, and how the discreet parts fit together to accomplish those objectives. Table 5-4 identifies when in the systems engineering life cycle each topic could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

5.6.1. Goals of the Traffic Signal Management System

Include a concise statement of goals and objectives of the TMS and how general components work together (detection, response, data collection, and storage).

5.6.2. Interagency and Interjurisdictional Coordination

Describe the need for interagency and interjurisdictional cooperation and coordination with other stakeholders. Describe other systems and, briefly, what types of data and information are exchanged and how coordination of operation can be accomplished.

5.6.3. Control Area

Describe in text, supplemented by a map, the control area, number of signals, map, system boundaries, jurisdictional boundaries, and coordination with other operating agencies.

Table 5-4 Summary of Systems Life Cycle Timing and Resources for *Operational Concepts and Operational Procedures* Content of a TMC Operations Manual

Category		Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
			Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
Traffic Management System	Operational Concepts	5.6.1. Goals of the Traffic Signal Management System	X					X		X
		5.6.2. Interagency and Interjurisdictional Coordination	X					X		X
		5.6.3. Control Area	X					X		X
		5.6.4. Traffic Signal Operations	X					X		X
		5.6.5. Agency Responsibilities in Developing Signal Timing	X					X		X
		5.6.6. Field Devices Traffic Signal Systems	X					X		X
	Operational Procedures	5.7.1. System Start-Up Procedures		X						X
		5.7.2. System Shut Down Procedures		X						X
		5.7.3. Operator Interface		X						X
		5.7.4. Incident Management Procedures		X						X

5.6.4. Traffic Signal Operations

Describe in text, supplemented by a map, region/sector traffic signal operations (isolated, pretimed, traffic responsive, system coordination, adaptive operation, etc).

5.6.5. Agency Responsibilities in Developing Signal Timing

Denote who within the agency determines signal timing parameters, schedules, update frequency, and other operations functions.

5.6.6. Field Devices Traffic Signal Systems

Provide functional description and locations of traffic signal field devices:

- Signal heads
- Controllers
- Detectors
- CCTV
- DMS
- LCS
- Communication media
- Other

5.7. Control System Operation Procedures – Traffic Signals

This section depends to a great extent on the individual system, but typical functions can be modified or deleted if not applicable. Most of the required information can be found in the documentation provided by the system installation contractor/integrator

5.7.1. System Start-Up Procedures

Describe system startup procedures for both planned and unplanned shutdowns.

5.7.2. System Shut Down Procedures

Describe system shut down procedures for both planned and emergency shutdowns.

5.7.3. Operator Interface

Describe operational procedures and include typical pictures of interfaces, where applicable. Operator interfaces include:

- Operator console
- Signal system interface
- Field communication
- CCTV
- DMS
- LCS
- Police communication

5.7.4. Incident Management Procedures

Describe response actions to be taken to respond as well as notification of other agencies. Types of incidents are somewhat different from those on freeways; however, incidents such as collisions, power outages, malfunctioning equipment, etc., will require attention.

5.7.4.1. Reported Incidents

Incident reports come from a variety of sources, both public agency and private. Specify the sources for incident reports and which will be accepted without verification and which should be verified. Sources may include:

- Field located agency staff
- Police two-way radio
- Police scanner
- Nonagency personnel
- Commercial radio
- Citizen cell phone
- Citizen land line

5.7.4.2. Detected Incidents

Detected incidents are those for which the operator has firsthand knowledge including:

- Visual detection via CCTV
- System monitoring software

5.8. TMC Maintenance Procedures

Describe routine maintenance to be performed by operators such as equipment cleaning, bulb replacement, minor component changeout, or other functions directed by system a manger. Anything beyond that would be performed by contract or agency maintenance personnel. Maintenance procedures may be found in documentation provided by the system contractor/integrator or in agency documentation for older equipment. Table 5-5 identifies when in the systems engineering life cycle each topic could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

5.8.1. Routine Maintenance

Describe typical daily checks, adjustments, and component exchange.

5.8.2. Preventative Maintenance

Denote scheduled maintenance by agency maintenance personnel or contractor.

Table 5-5 – Summary of Systems Life Cycle Timing and Resources for *Maintenance Procedures* Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
TMC Maintenance Procedures	5.8.1. Routine Maintenance		X			X			X
	5.8.2. Preventative Maintenance		X			X			X
	5.8.3. Spare/Backup Equipment		X			X			X
	5.8.4. Emergency		X			X			X
	5.8.5. Agency Maintenance		X			X			X
	5.8.6. Contract Maintenance		X			X		X	X

5.8.3. Spare/Backup Equipment

Provide inventory of spare and backup equipment and listing of vendors and suppliers.

5.8.4. Emergency

Describe notification procedures for major failures.

5.8.5. Agency Maintenance

Provide listing of maintenance performed by agency personnel.

5.8.6. Contract Maintenance

Describe criteria for calling in contract maintenance and provide phone, fax, and pager listings. List agency personnel authorized call in outside contract or on-call the maintenance provider.

5.9. System Operations Logs

Provide historical logging procedures (manual and automated) as determined by management within capability of specific system. System operation logging procedures may be found in documentation provided by the system contractor/integrator or in agency documentation for older equipment. The types of operations and maintenance logs to be maintained is also determined by agency policy. Table 5-6 identifies when in the systems engineering life cycle each topic could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

Table 5-6 – Summary of Systems Life Cycle Timing and Resources for *System Operations Logs* Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
System Operation Logs	5.9.1. Incidents and Events		X			X			X
	5.9.2. Operations		X			X			X
	5.9.3. Maintenance		X			X			X
	5.9.4. Citizen Requests		X			X			X

5.9.1. Incidents and Events

Describe incident and event logging procedures for planned and unplanned events, road closures, incidents, etc.

5.9.2. Operations

Describe operations logging procedures for on-line/offline times, manual intervention, etc.

5.9.3. Maintenance

Describe maintenance logging procedures for malfunctions, outages, resolution of problem, etc.

5.9.4. Citizen Requests

Describe logging procedures for requests for service, complaints, compliments, reports of field outages, etc.

5.10. System Reports

Describe system reports that may be generated automatically or require manual intervention. These may include system evaluation parameters, maintenance, or other information of interest. Table 5-7 identifies when in the systems engineering life cycle each topic in sections 5.10 through 5.13 could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

Table 5-7 – Summary of Systems Life Cycle Timing and Resources for *System Reports* Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
System Reports	5.10. System Reports		X			X			X
	5.11. Traffic Data Collection and Storage		X			X			X
	5.12. Risk Management		X			X	X		X
	5.13. System Documentation		X			X			X

5.11. Traffic Data Collection and Storage

Describe what types of historical data, analyses, and other types of traffic data are collected and stored and what storage medium is used.

5.12. Risk Management

Provide guidance on what types of data to store and for how long in response to agency risk management policies.

5.13. System Documentation

Provide a list of system documentation and where it is stored. System documentation is provided by the system contractor/integrator.

5.14. Organizational Setting

Few TMCs operate in isolation from other agencies and jurisdictions. The manual should reflect those other organizations as they relate to the mission and goals of this particular agency and what mutual agreements, formal and informal, exist. Identify transportation and traffic system operators and providers and other stakeholders along with the services they provide and how those services relate to the agency. These related agencies may have been identified or participated in the development of the concept of operations document or other planning activities. Table 5-8 identifies when in the systems engineering life cycle each topic in sections 5.14 and 5.15 could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

5.14.1. Service Providers and Stakeholders

Communication with other organizations with an interest and stake in traffic and transportation system operation should be initiated. Where possible, assemble and review missions, goals, functions, and services provided and supported, roles, and responsibilities of these organizations. Stakeholders may have been identified in section 5.2, *Inventory*.

Potential organizations include:

- State agencies:
 - Freeway operations
 - Enforcement
- Local municipalities (cities and counties):
 - Traffic operations
 - Fire fighting
 - Enforcement
 - EMS
- Area transit agencies:
 - Transit traffic operations
 - Enforcement

Table 5-8 Summary of Systems Life Cycle Timing and Resources for Organizational Setting and Representation Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources			
		Concept of Operations & Re-requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles	
Other Organizations	Context	5.14.1. Service Providers and Stakeholders	X					X		
		5.14.2. Agreements, Contracts, and Memoranda of Understanding	X					X	X	
		5.14.3. Advisory Functions of Other Related Organizations	X					X		
	In the TMC	5.15.1. Potential Agencies in TMC	X					X		
		5.15.2. Operating Agreements	X					X	X	
		5.15.3. Roles and Responsibilities	X					X		

- Toll authorities:
 - Traffic operations
 - Enforcement
- Private information service providers:
 - Media
 - Traffic patrols
- Regional mobility agencies
- Metropolitan planning offices
- Private sector information providers
 - News media
 - Traffic patrols
- Towing services

5.14.2. Agreements, Contracts, and Memoranda of Understanding

Assemble and review existing contracts, agreements, and memoranda of understanding to determine what existing relationships are in effect. This activity may reveal the need for additional agreements.

5.14.3. Advisory Functions of Other Related Organizations

Other related organizations may have been involved and had input during the concept phase and preliminary design of a transportation management system. It may be of benefit to involve them at certain points during development of the TMC Operations Manual. This is essential if the agency coordinates operations or otherwise communicates with the agency developing the manual.

5.15. Organizational Representation within the TMC

Organizational representation within the TMC is closely related to the organizational setting described above. There may be multiple sub-units within an agency such as a city traffic department, city police department, and city EMS in addition to entities external to the city. The manual must account for the physical presence as well as the level of operational functions that may be performed or the data and information that may be accessed.

5.15.1. Potential Agencies in TMC

One or more of the stake holders and agencies identified above may be co-located in the TMC. These may include:

- State agencies:
 - Freeway operations
 - Enforcement
- Local municipalities (cities and counties):
 - Traffic operations
 - Enforcement
 - EMS
- Area transit agencies:
 - Transit and traffic operations
 - Enforcement
- Toll authorities:
 - Traffic operations
 - Enforcement
- Private sector information service providers:
 - Media
 - Traffic patrols

5.15.2. Operating Agreements

Likely, formal agreements will have been executed that detail roles and responsibilities. Review these agreements and dialogue with the affected agencies when developing the manual. A need for additional agreements may be identified.

5.15.3. Roles and Responsibilities

Based on agreements mutually developed and executed, spell out specific roles and responsibilities. For example, police personnel may be housed in the TMC with access to a console that provides continuous information on operational conditions and incidents. They may have the ability to call up specific screens but may not have the authority to make changes to sign messages. In some TMCs, police authorities may operate DMS during hours when the TMC is not otherwise staffed. Whatever the circumstances, it is essential that the roles and responsibilities be specified in the manual and that all parties have access to documentation of those roles and responsibilities.

5.16. Performance Monitoring

In recent years, one of the key concepts implemented by agencies and TMCs to improve transportation systems is performance measurement (also called performance monitoring). Performance measurement is a process that allows an agency to collect and evaluate information for the purpose of assessing progress toward goals and objectives, as well as increasing efficiency and meeting customer expectations. Performance measurement seeks to answer the “big-picture” questions such as:

- How well are we operating our roadways?
- Are we meeting our goals?
- Are we effectively using our resources?
- Are we using the data effectively for decisionmaking?
- Are our customers satisfied?
- What improvements are necessary?
- Are there identifiable positive and negative trends?

With origins in the concept of total quality management (TQM) from the early 1940s, performance measurement has evolved as a scientific tool utilized by hundreds of industries worldwide. Basically, the process utilizes statistical evidence of current conditions to compare against agency-defined targets or benchmarks. These statistics are gathered in support of defined viewpoint rather into the system, also known as performance measures.

The performance measurement process can be implemented in nine steps as outlined below:

1. Identify the critical activity.
2. Identify the goals and objectives of the activity.
3. Develop a set of candidate performance measures.
4. Identify performance targets.

5. Identify uses of performance measures and potential audiences.
6. Identify data needs and requirements for analytical tools.
7. Establish data collection and evaluation procedures.
8. Compare actual performance to targeted goals.
9. Determine corrective actions or progress needed to achieve goals.

The reader should understand that the above process is an iterative evaluation methodology. This dictates an ongoing review and refinement procedure. The process will be explored in detail in chapter 6 of this *Handbook*.

Table 5-9 identifies when in the systems engineering life cycle each topic could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

Table 5-9 – Summary of Systems Life Cycle Timing and Resources for *Performance Monitoring* Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
Performance	5.16.2. Performance Measures	X	X				X		X
	5.16.4. Other Aspects of Performance Measurement	X	X				X		X

5.16.1. Challenges and Benefits

A TMC implementing a performance measurement system will find both challenges to overcome and benefits to reap. A major challenge is the ongoing and systematic collection of data required to supply the process. Many TMCs are only just now beginning to collect and store this type of information. While the primary benefit to a TMC is the continual focus on the core mission of meeting customer’s needs and

expectations, many TMCs have also shown benefits in areas of accountability, efficiency, effectiveness, communications, and planning.

5.16.2. Performance Measures

At the heart of the process are the measures themselves. There are thousands of potential measures that a TMC can use. The key is to choose measures that gauge specific progress toward goals. A good measure has four main traits. It should:

- Measure the right item – focus on goals and objectives and determine if they are being met. Remember that performance measurement can be used not only for operations, but for other areas as well.
- Be accepted – the measure should be simple, understandable, unambiguous, and meaningful to the customer. Don't be afraid to use different measures for different customers.
- Be responsive – a performance measure that is insensitive to events will not be meaningful because it can not adequately show progress toward goals.
- Be appropriate – selected measures generally have requirements for both time frame and geographic location. Understanding these requirements allows proper application.

Another aspect to keep in mind is to balance the data collection needs. Measures that require new and expensive data collection efforts are not likely to be successful. This doesn't mean that a TMC shouldn't stretch beyond current practices. Indeed, many agencies have fallen into the trap of only looking at measures that can be supported by data they already collect. This can hinder effective evaluations and often results in choosing measures that don't support the stated goals.

5.16.3. Keys to a Successful Program

A successful program of performance measurement embraces several key principles. These principles are not rigid parameters, but are meant to provide guidance and common sense advice to organizations.

- Keep the number of measures manageable – include significant measures but refrain from using measures merely because they are interesting.
- Use a balance of measures – utilize measures that cover the broad range of responsibilities and tasks performed by the TMC. Remember that some measures are more suited to a particular audience. Ensure that the selection of measures is adequate for each group of stakeholders.

- Be flexible – don't be afraid to test new measures, to find the right mix.
- Go beyond the basics – while simplicity is attractive, don't shy away from the "hard" issues, as this is what pushes a TMC to grow and provide better service to the customers and stakeholders.
- Establish regular reviews – utilize regular review to keep the process fresh and up-to-date with current operational and stakeholder needs.

5.16.4. Other Aspects of Performance Measurement

This section provided an overview of establishing a performance measurement process and discussed some of the important aspects of selecting and utilizing measures. There are, however, many other important aspects to establishing a performance measurement process. The reader is referred to chapter 6 for comprehensive treatment of:

- Data collection needs,
- Establishing performance measurement thresholds, and
- Reporting performance measurement data.

In addition, chapter 6 provides significant detail on the differences in performance measurement between rural and urban TMCs. Urban TMCs are typically established operations, while many rural TMCs are just getting started. The overall goals of these systems may be quite different, and the performance measurement process should reflect that individuality.

6. DEVELOPING AND UPDATING A TMC OPERATIONS MANUAL

6.1. Introduction

6.1.1. Chapter Purpose and Key Issues

Starting with this chapter, this *Handbook* presents in-depth discussions of some of the critical issues that face TMCs. In particular, this chapter discusses some of the issues surrounding development of an operations manual. In addition, this chapter presents detailed information related to performance measurement, a critical component of TMC operations. The text introduces the concepts and components of a systematic performance measurement process to objectively evaluate progress toward stated goals. The chapter also delves into significant detail on individual topics such as choice of performance measures and collection of performance data.

The use of a performance measurement system (and other aspects, presented in future chapters) as a key component of standard TMC procedures dictates that the system operators and other TMC personnel understand and support these systems with a significant level of understanding and expertise.

The key factor to keep in mind while exploring this chapter is that a TMC Operations Manual must provide the detailed information necessary to create this understanding and expertise.

Not only should an operations manual detail the specific process and steps a TMC utilizes in a performance measurement system, it should list all of the particulars, including what performance measures are utilized, what are the performance targets, what are the analysis procedures, and where and how data are obtained and analyzed. The manual should also identify the recipients or end-users of the performance data, by explicitly relating the target groups and how the information should be presented. Along with tabular presentations of the goals, objectives, measures, and targets, the manual should provide visual examples of performance measurement calculations and presentations to give guidance to TMC personnel.

Finally, the operations manual should also detail the ongoing evaluation process, including comparison time frames, again, with a visual example of how comparisons should be made and recorded for historical record-keeping.

These topics are explained in detail throughout the rest of this chapter. Readers should follow the discussions with an overall goal of not only developing their process, but documenting it in explicit detail as the primary reference for TMC personnel.

6.1.2. Relationship to *Handbook* Document

Previous chapters of this *Handbook* provided a context for understanding not only the need for a TMC Operations Manual, but also the typical contents. The information presented included discussions on the typical functions of a TMC as well as examples of management structures, daily operations, and typical staffing. With the previous chapters providing the “*what*” goes into a manual, this chapter begins with a discussion of *how* an operations manual is developed.

In addition, this chapter introduces the need and process for a TMC to embrace a systematic and ongoing process of evaluation. This evaluation capability is a crucial tool in developing (and refining) a TMC that is focused on customer goals and a self-sustaining programming of continual monitoring and improvement. As such, this chapter devotes significant resources to the discussion of performance measurement and its application to transportation operations.

Subsequent chapters of this *Handbook* support this chapter and the performance measurement process by providing significant levels of detail about specific agency functions, such as traffic monitoring and traffic response. These and other functions are a part of the big-picture concept of daily operations. Enough detail is presented on these topics to allow operations personnel the ability to develop significant knowledge in each individual function area.

The combination of detailed functional information in future chapters and the framework for performance measurement presented in this chapter can be utilized by the TMC to develop a comprehensive operations manual that not only supports the execution of daily TMC operations but also long-term assessment and improvement.

6.2. Creating a TMC Operations Manual from Scratch

An operations manual is a document that not only defines the environment within a TMC but also defines how it operates, who operates it, and what are their responsibilities and specific tasks. As explained in chapter 3 of this *Handbook*, the starting point for an operations manual is often the concept of operations document. In general, this document defines what a center will accomplish and how it accomplishes those steps.

By comparison, an operations manual generally goes into greater detail about each step, providing specific instructions, contact names, job functions, agency contacts, and interface information. A detailed listing of the typical information in a TMC Operations Manual was presented in Table 3-1. For reference, the table also contains cross mapping to the concept of operations document, if that is to be used as the starting point. This table illustrates the additional detail and depth present in an operations manual.

Establishing an operations manual generally achieves the following:

- Provides uniform standards, policies, procedures, and expectations for employees;
- Captures and identifies standard operating procedures, techniques, and experiences;
- Creates a training mechanism for new personnel;
- Promotes continuity in management and the application of employee related decisions; and
- Provides an objective framework for comparisons toward meeting the goals and objectives of the center.

An operations manual can be developed using two main methods: in-house or using an outside consultant. There are pros and cons to each approach. Using an in-house group may promote more “buy-in” and support from the employee base, but generally takes longer to accomplish and may require significant additional effort above and beyond the normal operating activities of the agency. Using an outside consultant may bring significant experience to the task, but requires commitment of monetary resources to accomplish. However, it frees up agency personnel to handle other related tasks.

Regardless of the mechanism used to create an operations manual, a critical factor is ownership. Before starting on any aspect of the manual, the first step is to identify the key constituents. This generally includes the member agencies in the TMC. This committee, or group, functions as the primary mechanism for overseeing the manual development, be it done through in-house development or through the use of a consultant.

Of particular note is that it is important to have a representative employee base in this group, since this helps to establish buy-in at all levels of the agency. In some cases, this oversight group may include specific outside parties, such as representatives from emergency services or wrecker services, who interact with the TMC on a regular basis as part of the various policies.

The second step in the process is identifying the goals, objectives, and a vision for the operations manual. Several typical goals have already been identified, such as providing uniform and written standards, policies, procedures, and expectations for employees at all levels within the agency. The oversight group should establish a comprehensive list of goals that the operations manual should fulfill and monitor the progress of the development to ensure that these goals are being met. Examples of additional goals might include items such as defining authority and accountability within the TMC, designating decisionmaking capabilities for various procedures, and establishing clearly documented paperwork (and ownership) trails for agency actions.

Once under way, a critical task related to development of an operations manual is the use of champions or cheerleaders to promote it. While this is related to the aspect of “buy-in” mentioned previously, an operations manual can be a far-reaching and effective means of ensuring that each and every employee understands the mission of the TMC and how their job relates to and supports that mission. However, this level of support and understanding does not come easily and may require a significant level of education to engender support from all levels of the organization. The use of champions to promote the use and integration of the manual into daily operations, as a tool, is critical to creating and maintaining this support.

Finally, once complete, it is crucial that training be utilized to not only discuss and present the manual but also to teach, train, and help employees integrate the manual and the information therein into their daily jobs. As an example, it may be difficult, at first glance, for a database technician to understand how their job is important to accomplishing agency goals. However, when looked at from the concept of performance measurement, the data collected, stored, and analyzed are of the utmost importance in making decisions, creating policies, and providing for future planning and operations. The use of an operations manual can help to create such knowledge and understanding as well as uniform acceptance and support of the agency’s direction and mission.

6.3. Updating an Existing Operations Manual

Once an operations manual is created, the task is not complete. Indeed, many successful agencies have an ongoing evaluation and update mechanism in place to keep the operations manual a viable part of the agency, not only from the standpoint of documentation and employee job requirements, but also from the standpoint of agency operations. As the agency takes on new tasks and responsibilities, so too must the operations manual be updated and maintained to ensure that it does not become so out of date as to be useless.

With the initial development complete, it is far more typical for an agency to accomplish updates in-house. Often, developing updates is easier, as the existing material serves as a good reference or template for creating new components and materials.

To ensure that the same level of attention and detail is focused on updates, many agencies use the same committee that oversaw the initial development, although the makeup of the committee may be altered depending on the specific needs. It must be recognized that regardless of the mechanism used for overseeing updates, the information typically crosses multiple departments and agency resources, and those areas should be equally represented in the process. It is doubtful that one specific department, such as human resources, could adequately update the manual for all areas of the agency, particularly with regard to field or control center floor operations. Likewise, field maintenance personnel know the specifics necessary for maintaining equipment, but may not be able to adequately address employee actions, business procedures, or other such items.

The key point for when to update the manual is when any change occurs in the agency operations. If new tasks are to be undertaken, a comprehensive addition to the operations manual should support those tasks. If existing tasks are changed, by using new equipment, additional data, or different analyses or software tools, procedures should be updated with the new methods. These updates typically cross multiple sections of the manual. Referring back to Table 3-1, an update for a new function may require changes in sections 2 through 7 of the manual, each addressing a particular task or aspect of the function.

Regardless of the type of update, getting that information back into the hands of the employees remains a high priority for ensuring consistent operations and making sure everyone is on the same page. A comprehensive mechanism should be established for distributing updates to ensure that the new information is available and inserted into the existing manuals. Traditionally, many operations manuals have been prepared using a three-ring binder format, which eases the periodic update process. Today, some operations manuals are prepared using electronic formats and posted on internal agency Web sites. While this significantly eases the update process, the agency must ensure that every employee has access to the information and knows that updates have been prepared.

In addition to physical updates, many agencies utilize a periodic training mechanism to train employees in the new aspects of the manual. A planned approach aimed at covering all the updates within a specified time period is generally more consistent at communicating the information, as opposed to multiple, shorter, updates at random intervals.

Updates should be accomplished using a committee or multijurisdictional approach.

6.4. Dealing with Urban and Rural Characteristics

All TMCs are not created equal. While that's a rather obvious statement, it's critical to understand the underlying point. TMCs across the nation differ in multiple ways, such as:

- Area of coverage
- Hours of operation
- Size
- Physical location
- Physical facilities
- Staffing and resources
- Operating characteristics
- Stakeholders
- Organizational structure

These differences are not bad or even problematic; they simply exist and must be recognized. The concept that one size fits all, or that one solution is *the* right solution, is not valid when discussing TMCs. Each TMC must evolve to serve their stakeholders and accomplish their particular mission. While the components and infrastructure may be similar across TMCs, this foundation can be utilized in many ways.

Urban TMCs are typically focused on freeway management, traffic signal management, and/or transit operations. Incident detection, response, and management are at the heart of their systems and mission. Keeping the freeways moving is critical to their success. As a general rule, urban TMCs are typically larger and more developed than their rural counterparts. They've simply been at it longer. While TMCs are now being developed in smaller, more rural areas, the origins of active transportation management originated in the larger cities, and that's where resources, time, and expenditures have traditionally focused. The benefit, however, to newer more rural TMCs is the wealth of knowledge and understanding available to shortcut the learning curve and reduce the time frame from concept to operations.

Urban TMCs may also have established a number of working relationships with other agencies. It is not uncommon to see facilities where traffic operators, transit services, and police or emergency dispatchers are co-located—sometimes in the same building, sometimes in the same room. Newer facilities often feature expansive video systems that provide capabilities to multiple agencies. There are typically a number of specific job categories and responsibilities and a hierarchical management structure for responding to a situation on the roadway.

By comparison, rural TMCs are generally smaller facilities and may cover a wider geographic area. There may not be an expansive infra-

structure and the focus of the agency may be different. While urban TMCs focus on freeway management, signal systems, urban transit and mobility, rural TMCs may focus on emergency services and rural transit service.

In a rural setting, agencies may not be co-located, but the management structure is typically less rigid and one person may do it all.

Despite the differences, both urban and rural TMCs can benefit from this *Handbook*. In particular, the two main concepts of this chapter, how to develop an operations manual and the performance measurement process, can both be valuable tools and assets for any TMC, no matter how small or large, rural or urban. In fact, performance measurement has long been recognized as a vital tool for smaller communities. In many of the sections that follow in this chapter, situations particular to the rural or small TMC are explicitly noted.

6.5. Dealing with TMC Complexity and Maturity

The concepts detailed in this chapter and indeed, this whole *Handbook*, apply to any TMC, urban or rural, mature or new. However, the level of detail or applicability of each particular section may be different. The key is to read this *Handbook* to determine what value can be added to *your* TMC and *your* existing processes. If you are an existing and mature TMC, the information contained in this *Handbook* may simply help you to refine the steps and procedures you already perform and their supporting documentation. If you are a new TMC, these chapters will help you lay out a developmental roadmap, addressing not only the important steps along your evolution, but also the processes, procedures, and documentation that can help you develop as you move along the growth path.

The important concept is that no matter what stage of development your TMC is at, your future growth and the assessment and achievement of your goals can be enhanced by embracing the concepts contained in this *Handbook*. This is especially true for the topic of performance measurement, discussed in detail in the remainder of this chapter.

6.6. The Performance Measurement Process

The early part of this chapter discussed development of an operations manual and the purposes which that document can serve. One of those purposes was creating an objective framework to analyze progress toward the goals and objectives of the center. This framework is known as the performance measurement process and is the focus of the remainder of this chapter.

Chapter 5 introduced the concept of the performance measurement (also called performance monitoring) process. Before proceeding to the overall process, we should first establish exactly what a performance measure is. While the wording varies, a commonly accepted description of performance measurement is:

“The use of statistical evidence to determine progress towards specific defined organizational objectives.” (1)

Said another way, performance measures allow decisions to be made based on data gathered with scientific tools and approaches. It therefore follows that a performance measurement process is a systematic methodology that uses performance measures as a primary decision source.

However, performance measurement is *not* simply the process of collecting data to determine if a threshold or value has been met. Rather, performance measurement *is* an overall management system that allows an agency to collect and evaluate information for the purpose of achieving goals, increasing efficiency, and meeting customer expectations. In terms of a TMC, the use of a systematic performance measurement process can help answer and address the following questions:

- How well are we doing in operating our roadways and transportation system?
- Are we meeting our goals?
- Are our customers satisfied?
- How can we improve our communication to our customers?
- Where are improvements necessary?
- Are there opportunities for a tighter link between operations and other aspects of transportation, such as planning?

It should also be noted that performance measurement is applicable to a wide range of agency actions, not just the operations of any particular roadway. In fact, performance measurement has long been a key component in diverse transportation activities such as planning, maintenance, pavement and bridge management, and more. In reality, the area of operations has lagged many of these other areas in the utilization of performance measures.

Performance measurement is not new. In fact, the formalized evaluation concepts first originated in the 1940s and 1950s with the push for TQM, a management philosophy that aims to integrate all organizational functions to focus on meeting customer needs and organization objectives. The roots of TQM were advanced in the United States by Dr. W. Edwards Deming, an American statistician. Initially, Deming applied his techniques to improve the quality of military products dur-

ing World War II. After the war, Deming taught TQM techniques to Japanese industries, most notably the automobile industry.

Although American industries were somewhat slower to establish TQM programs, over time, the concept has caught on and has been implemented as part of standard business practices. Perhaps the step that best highlighted the use of performance measurement as a scientific and systematic assessment tool was a benchmark study released by the Federal government in 1997 (2). This study advocated the use of performance management across all Federal agencies and provided an overview, best practices summary, and framework to assist in that process.

The next several sections allow the reader to develop an understanding of the performance measurement process as well as its application to the area of operations. A key to understanding these concepts is that performance measurement should be a systematic and ongoing component of TMC operations. Although there are challenges to establishing and maintaining a performance measurement process, there can be substantial benefits. This section of the manual concludes with a checklist for defining and establishing a performance measurement process for a TMC.

6.6.1. Challenges of Performance Measurement

Any system has challenges in both implementation and use. Performance measurement is no different. The biggest challenge of performance measurement, when applied to operations, is that we are behind the curve of both other professions and other areas of the transportation profession.

There are several reasons for this lag. First, looking at the historical context of evaluating operations, the traditional indication of highway mobility and performance has been level of service (LOS). LOS is identified and calculated using procedures outlined in the *Highway Capacity Manual* (HCM). LOS identifies broad ranges in traffic flow but is not indicative of some indicators of current performance, especially on a smaller scale. Also, LOS doesn't directly translate to concepts such as travel time, incident detection and clearance, or other more targeted measures.

In addition, the concept of LOS is geared toward the transportation professional. However, much of the information that the industry needs to convey must go to groups other than transportation professionals. The traveling public may have trouble understanding differences in LOS levels. As such, indicators of performance that are more explicit and more easily understood are necessary. In fact, the indica-

tors used to discuss mobility and performance may change for different groups.

Finally, the use of performance measurement requires a large amount of data, both real-time and historical, which many agencies are only recently beginning to collect and keep for this and other purposes. However, TMCs by their nature are developed to handle and process much of the needed data.

6.6.2. Benefits of Performance Measurement

Despite the challenges listed above, performance measurement can offer a number of significant benefits to transportation operations. In particular, operations is an area that is highly visible to our customers, the traveling public. While a motorist might notice pavement conditions, a reduction in a bridge weight limit, or some other roadway condition, items such as congestion, increased travel times, incidents, blocked routes, and more are attention grabbing and are things that the public has shown they care about.

The real benefit to an effective performance measurement system is the capability to keep the agency (or TMC) focused on their core mission. The primary focus should be on meeting customer needs and expectations, which typically translates mitigating congestion, reducing travel time delay, clearing incidents more quickly, and providing reliable travel time estimates.

In general, performance measurement can provide benefits in multiple areas, including:

- Accountability
- Efficiency
- Effectiveness
- Communications,
- Improvements over time
- Future planning

Accountability identifies if resources are being allocated to the priority needs. The desired effect is to achieve more informed decisionmaking. This goes hand-in-hand with efficiency, which examines the output for any given level of input. A typical example might look at the staff necessary to provide a given level of management and whether improvements in the process can reduce staffing needs, save costs, or free infrastructure for other uses.

Effectiveness typically measures a shift in an agency's approach. By using performance measurement, agencies have been able to shift their

thinking. Instead of recording how many incidents took place in a given time frame, the important concept shifts to questions such as: Has there been a reduction in incidents? Has there been a decrease in the average time of each incident?

Improving communication is perhaps an obvious and self-explanatory benefit of performance measurement. By focusing on primary goals that are important to the customer base and identifying the appropriate information to convey results, communications can't help but improve.

Identifying improvements over time is another obvious benefit of a systematic evaluation process. By collecting and utilizing data in support of an ongoing process, trends can be identified and long-term monitoring put into place. The feedback from these mechanisms allows refinement of programs and services, both internal and external. The results must also be used to convey performance to senior management in the agencies involved. Good performance and improved performance can be justification for maintaining or increasing operating budget.

As a final benefit, performance measurement impacts future planning. As detailed above, the information gained from ongoing focused evaluations allows refinements. These refinements can be planned and accomplished with greater accuracy and efficiency than would be possible without a performance management system. Additionally, the availability of a solid basis for future plans may lead to an increase in the dollars available for operational improvements.

6.6.3. Understanding the Process

Illustrated in Figure 6-1, a performance measurement process can be formalized in nine steps, as identified below:

1. Identify the critical activity.
2. Identify the goals and objectives of the activity.
3. Develop a set of candidate performance measures.
4. Identify performance targets.
5. Identify uses of performance measures and potential audiences.
6. Identify data needs and requirements for analytical tools.
7. Establish data collection and evaluation procedures.
8. Compare actual performance to targeted goals.
9. Determine corrective actions or progress needed to achieve goals.

Figure 6-1 represents an overview of the process. While there are additional details that could be illustrated at each of the steps, the overview

of the entire process is the important aspect to consider at this stage of describing performance measurement.

Step 1 – Select a single activity that a TMC performs, focus on establishing the ongoing performance measurement process for that activity, then return to step 1 and repeat it for another activity.

Step 2 – Every activity has definable goals and objectives. As an example, if the activity is incident management, a typical goal may be to ensure the timely emergency response to incidents. Notice that the goal sets forth the large-scale vision. A corresponding objective may be to reduce the incident detection time. Another objective in support of the same goal may be to reduce the incident verification time. Take note that objectives tend to be more specific and focus on a particular aspect of achieving the overall goal.

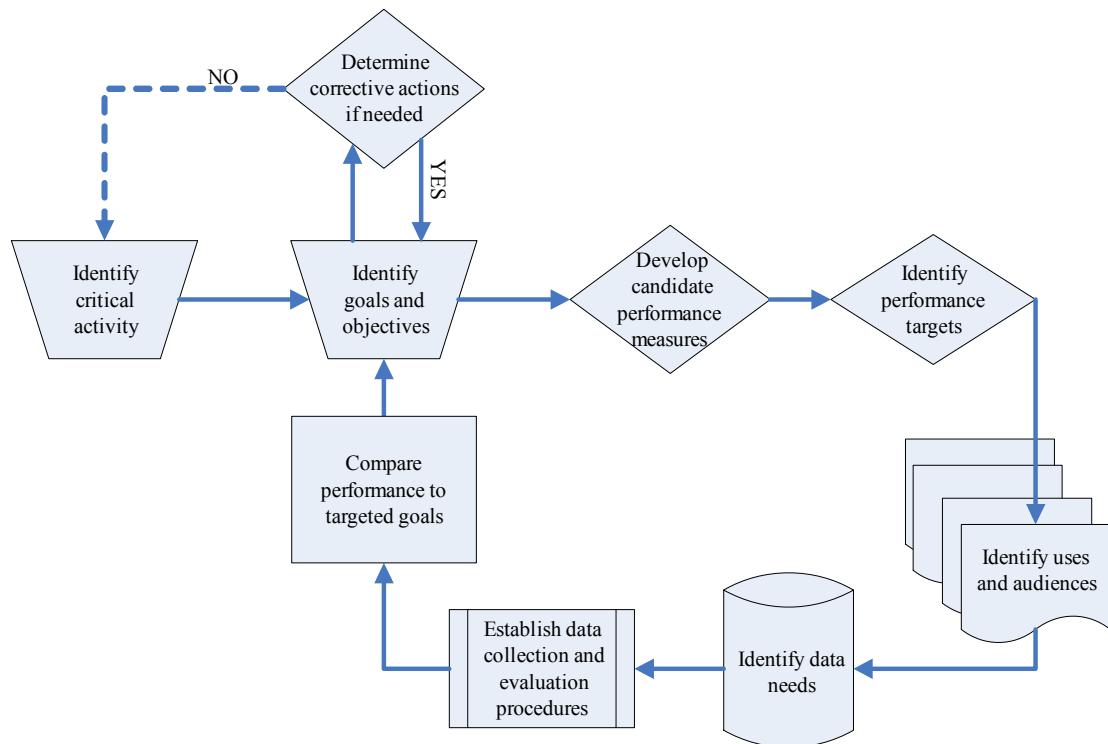


Figure 6-1 The Performance Measurement Process

Step 3 – Identification of performance measures follows directly from the goals and objectives. Continuing with the example from step 2, a performance measure utilized in evaluation of incident detection would be the current average incident detection time. Note that this measure could be stratified by type of incident, location, time of day, or other variables that would provide a more detailed understanding of the system’s response.

Step 4 – Identification of performance targets goes hand-in-hand with step 3 above. Continuing with the example of incident detection, a specific performance target could be to reduce, by 25% from current levels, the incident detection time within a time frame of 1 year.

Figure 6-2 provides a detailed illustration of steps 1-4 and shows the logical progression from vision (step 1) to detailed and measurable targets (step 4).

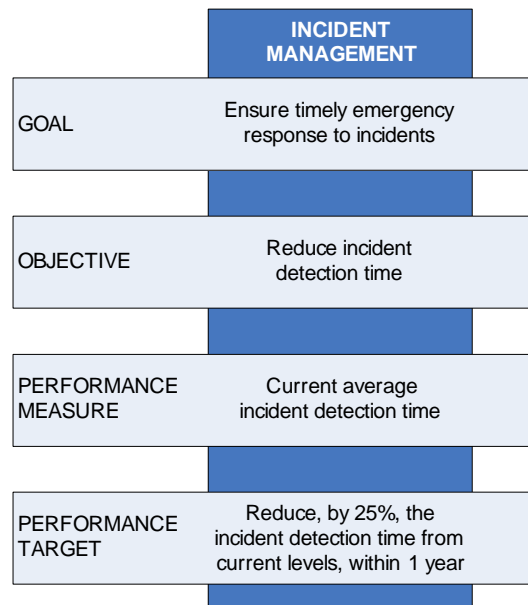


Figure 6-2 Steps 1-4 of the Performance Measurement Process.
Adapted from Figure 2.3, Reference (3)

Step 5 – Any performance measure could be used in a variety of settings, but there are certainly measures that are most appropriate to particular audiences. A measure that is time based is easily understood by a nontechnical audience and can be presented using a variety of methods. On the other hand, measures that are based on rates, such as percent travel delay reduction per 100 million vehicles miles traveled (VMT), may be much more difficult to visualize and effectively display to a nontechnical audience. The concept behind step 5 is to examine the list of measures and ensure that you have information that can easily and quickly be understood by the target audience. It is also important to realize that there may be multiple audiences, including such diverse groups as politicians and city leaders, the general public, agency management, planners, and engineers. Each group has a different need for information and a different capacity for evaluating the information presented to them. Understanding those facets and how your performance measures support those presentations is the outcome of this step.

Step 6 – A detailed discussion of the data needs for performance measurement takes place in section 6.9. The concept, at this step in the process, is to identify exactly what the data requirements are for any given measure. How much data? From what locations? How often? Can it be used “raw” or does it have to be processed? How must it be processed? Do the data need to be stored? For what period of time? What is the reliability of the data? These questions and more can be used to establish detailed technical requirements for the data needs to support performance measurement.

Step 7 – Following directly from step 6, a solid plan for data collection is the result of this step. Whereas step 6 identified the data need (e.g., 5-minute vehicle counts), this step identifies the source and mechanism for obtaining that data (e.g., automatic traffic counters at multiple locations along the freeway: data stored in 5-minute bins in flat files and transmitted automatically on a 24-hour cycle to the TMC.) This step also identifies the specific tools and techniques that may be necessary to produce the final measure.

Step 8 – Perhaps the simplest of steps in the process, this phase of the system compares the actual results of the performance measure to the desired results, or goals, detailed in step 4. An explicit categorization of the comparison results should be made, including date, time, overall result, measure, measure value, target, and difference between the value and target. This level of detail is an important input to step 9 in the process.

Step 9 – Perhaps the most nebulous of all the steps in the process, step 9 seeks to identify what (if any) remedial actions are needed to continue to push the performance measures toward their targets. In essence, step 9 becomes a planning or brainstorming exercise. How can incident detection time be reduced further? Could additional sensors provide a more rapid analysis of the system response? Where should they be placed? How much will they cost? These and other questions can be utilized to analyze the overall system response, evaluate shortcomings, and identify solutions to address those shortcomings.

A critical concept to understand is that even though step 9 is the final step in the sequence, the process is an ongoing and iterative evaluation methodology. This is perhaps best illustrated by the feedback arrows in Figure 6-1, which direct the reader back to other steps in the process depending on the needs. If additional or corrective actions are necessary, the process returns to step 2 to identify the goals and objectives. If no changes are required and the process is working as planned, the outcome of step 9 is to return to step 1, where a new activity is examined and the process starts again.

6.7. Types of Performance Measures

There are thousands of potential measures that an agency or TMC can utilize in the process of developing a performance measurement system. In fact, there are so many that it is easy to become overwhelmed by the magnitude and lose sight of the big picture, choosing measures that support the ongoing, systematic evaluation of the critical functions a TMC. Unfortunately, wading into the sea of performance measures in search of the perfect catch is a somewhat daunting task!

To help prepare for that process, this section examines some of the issues surrounding individual performance measures. We first examine what makes a good measure to establish a foundation for evaluating individual measures or groups of measures and assessing their benefit to a program. Next, we quickly look at how measures can be classified. Classification simply organizes measures into groups or areas. Next, we bring all of the pieces together and look at the keys to a successful performance management system. Finally, the section concludes with examples of typical performance measures and a set of minimum recommended performance measures for freeway operations.

6.7.1. What Makes A Good Measure?

First and foremost, a performance measure must measure or gauge the right item. It does so by focusing on the goals and objectives and determining if they are being met. A performance measure should focus on the end result—not the measurement itself.

The second trait of a good performance measure is that it is accepted. Generally, this means that the measure must be simple, understandable, unambiguous, and meaningful to the customer, regardless of whom the customer is. To best accomplish this, agencies may use different measures for different customers.

The third trait is that performance measures must be responsive and/or sensitive to the data they are measuring. They do this by clearly showing any trends, changes, minimums, or maximums. A performance measure that is insensitive to these events within the data will not be meaningful to the customer because it can not accurately depict progress toward the system goals.

The fourth trait of a good measure is that it is appropriate. The appropriateness of a selection is typically judged in two ways. First, the time frame must be suitable to the desire. If the desire is to determine a percent reduction in incidents, the measure should look at a lengthy analysis period, such as a week, month, or even a year. Reporting on a

time frame of minutes, hours, or even a day would make little sense and would be inappropriate for this measure. Second, the measure must be geographically appropriate. Measures can be directed toward a point, a segment, an entire facility or travel corridor, or even a region. A reduction in travel time wouldn't make sense at a point location but might be a good measure from a corridor or regional perspective.

A fifth and somewhat arguable trait is that a good performance measure should be supported by economical data collection. Measures that require large and expensive data collection are not likely to be determined very often, due to time and/or budgetary constraints. This makes the measure untimely and insensitive to smaller changes, and ultimately it will not convey meaningful results. At the same time, TMCs should recognize that it is desirable to stretch beyond current practices to find and collect additional data sources if the performance measures can provide meaningful results. This trait is arguable, as many agencies have fallen into the trap of only looking at measures that can be supported by data they already collect. This can hinder effective evaluations and often results in choosing measures that don't support the stated goals.

6.7.2. Input and Output Classification

Performance measures can be categorized in any of a number of ways. The main use of classification systems is often to simply provide some organization to a long list of measures. In and of itself, classification provides no additional benefit to any particular measure; it simply helps the practitioner organize measures in effective groups.

One of the simplest methods for classifying performance measures is identifying them as an output, outcome, or input measure.

An outcome measure is primarily subjective. It provides information or an assessment on the results obtained from carrying out a program or activity. By comparison, an output measure is primarily objective and is typically the result of a tabulation or calculation. Output measures are most often numerical in nature.

Another way of expressing these same categories is that an outcome measure typically looks at the effectiveness of something. Has the situation changed? Has a program improved? What has been the progress toward an agency goal? An output measure typically looks at efficiency. What rate of change was seen? What percent reduction was created? What are the numbers associated with each activity?

The third category is measures related to inputs. While output and outcome measures examine the results, input measures examine the resources available to carry out a program or activity.

The key to a successful program is not to rely on a single type of measure. In all likelihood, there will be multiple measures of each type utilized in any ongoing program.

6.7.3. Goal-Based Classification

Another typical classification used to organize performance measures is to group them according to their general goal. Mobility-based measures, as one example, reflect the ease or difficulty of making a trip. Classifying performance measures based on their goal area can help provide continual focus on agency or TMC goals. The list of goal areas typically used in this type of classification includes:

- Accessibility – ensuring convenience and or right-of-entry to customers.
- Mobility – the relative ease or difficulty of making a trip.
- Economic development – the cost, economic health, and vitality of the transportation system.
- Quality of life – the sense of community desires and customer satisfaction.
- Environmental and resource conservation – assets saved or expended, either natural or man-made.
- Safety – levels and rates of incidents or other occurrences.
- Operational efficiency – productivity, manpower, financial resources, etc.
- System condition and performance – physical conditions, service ranges, etc.

It is not uncommon for a goal-based system to use a secondary classification scheme. Mobility may be broken down into passenger or freight mobility. Safety could be broken down into roadway, rail, transit, parking, freight, and more. Note that the secondary classification areas may not be consistent or common across all of the goal areas. To make things even more interesting, classification schemes can be intermingled, resulting in (as an example) a set of output-based performance measures for freight mobility.

6.7.4. Keys to a Successful Program

Over time, a number of key components of a successful performance management program have been identified. These components, listed below, are not set in stone but provide some guiding principles to help organizations navigate through the chore of picking appropriate meas-

ures. This is not an exhaustive list from the literature but rather a compilation of those items and advice that are commonly accepted and indisputable.

- Keep the number of measures manageable – Include measures when significant but exclude measures that are merely interesting and not directly relevant.
- Use a balance of measures – Provide both output and outcome measures. Determine the critical areas of focus in the TMC and select measures for each area. Remember that some measures are more suited to a particular audience, and ensure that the selection of measures can adequately convey understanding to each group of stakeholders.
- Be flexible – TMCs, especially new ones, should experiment with performance measures in order to find the right mix and set that capture and support the specific operating environment.
- Go beyond the basics – While it is recognized that simplicity and ease of measurement are attractive characteristics, especially to a new TMC, an agency should not shy away from the “hard” issues, such as areas that are hard to quantify or where data may be difficult to obtain. This pushes a TMC to grow and increase its capabilities and ultimately provide better service to the stakeholders.
- Establish regular reviews – The performance measurement process should recognize the need for regular reviews. While the framework provides iterative loops, a TMC must embrace this need. Regular reviews of performance measures can add, delete, or revise measures, identify additional data sources, refine the presentation of measures to stakeholders, and ensure a continued focus on operational goals.

6.7.5. Examples of Performance Measures

There are quite literally thousands of performance measures identified in the literature. A comprehensive compilation of those measures is well beyond the scope of this *Handbook*. The list below is a small sample of measures that can be used by a TMC. This sample listing is intended to provide the reader with an awareness of the diversity of available measures. These measures are stratified according to the goal classification system presented in section 6.7.3. This list includes measures that are both outcome based (examine satisfaction levels) and output based (provide a quantitative assessment). It is also possible that measures may support more than one goal area and so may be listed twice.

- Trip Character
 - Average travel time
 - Average trip length

- Modal splits
- Mobility
 - Vehicle miles of travel by congestion level
 - Travel time under congested conditions
 - Delay per vehicle mile of travel
 - Delay due to incidents
 - Lost time due to congestion
 - Annual hours of delay
 - Increase in system reliability
- Economic Development
 - Jobs supported
 - Jobs created
 - Economic cost of accidents
- Quality of Life
 - Perceived satisfaction with commute times
 - Perceived improvements in safety
 - Lost time due to congestion
 - Change in vehicle emissions
 - Accidents per vehicle miles traveled
 - Ease of connections to intermodal transfer points
- Environmental and Resource Conservation
 - Tons of pollutants emitted
 - Fuel consumption per vehicle miles traveled
 - Air quality rating
 - Modal splits
- Safety
 - Fatalities per vehicle mile traveled
 - Number of highway fatalities
 - Crash rate
 - Average duration of incidents
 - Average incident detection time
 - Average incident response time
 - Customer perception of system safety
- Operational Efficiency
 - Public expenditures on transportation system
 - Savings to taxpayers from incident management
 - Average travel cost per mile
 - Change in congested travel
 - Change in delay due to congestion
- System Condition and Performance
 - Lane miles of facilities under active management
 - Pavement serviceability rating
 - Volume to capacity ratios

6.7.6. Recommended Performance Measures

With so many performance measures to choose from in addition to the incredible variety of applications where they can be used, it would be foolhardy for any reference or manual to identify a list of performance measures that *must* be implemented. Indeed, a comprehensive listing cannot be established by anyone other than the particular agency or TMC operating the system.

However, experience and research have provided significant direction on establishing a *minimum* set of performance measures that are *recommended* for implementation by a TMC. Identified in Table 6-1, these measures represent a suggested best practice for all of the characteristics that have been discussed, such as output vs. outcome, corridor vs. facility vs. regional, different goals, different audiences, and more. Agencies should consider this list as a *starting point* and add or subtract measures, as appropriate to local needs and uses. For each measure listed in Table 6-1 the corresponding recommended geographic and time scale are identified. Additionally, the table is stratified by several common areas of performance measurement.

Table 6-1 Recommended Minimum Freeway Performance Measures (adapted from Table 4-5, Reference 3)

Performance Measure	Geographic Scale	Time Scale
Congestion		
Travel Time Index	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Total Delay (vehicle-hours and person-hours)	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Bottleneck (“Recurring”) Delay (vehicle-hours)	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Incident Delay (vehicle-hours)	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Work Zone Delay (vehicle-hours)	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily
Weather Delay (vehicle-hours)	Corridor, Areawide (minimum)	Peak hour, AM/PM peaks, Midday, Daily

Table 6-2 Recommended Minimum Freeway Performance Measures (Cont.)

Performance Measure	Geographic Scale	Time Scale
Delay per Person	Corridor, Areawide	Peak hour, AM/PM peaks
Delay per Vehicle	Corridor, Areawide	Peak hour, AM/PM peaks
Percent of VMT with Average Speeds < 45 mph	Corridor, Areawide	Peak hour, AM/PM peaks
Percent of VMT with Average Speeds < 30 mph	Corridor, Areawide	Peak hour, AM/PM peaks
Percent of Day with Average Speeds < 45 mph	Corridor, Areawide	Daily
Percent of Day with Average Speeds <30 mph	Corridor, Areawide	Daily
HOV volumes	Corridor, Areawide	AM/PM peaks
Reliability		
Buffer Time Index	Corridor, Areawide	Peak hour, AM/PM peaks, Midday, Daily
95 th percentile Travel Time Index	As needed	As needed
Incident Management		
Detection Time	Corridor, Areawide	AM/PM peaks (minimum)
Verification Time	Corridor, Areawide	AM/PM peaks (minimum)
Response Time	Corridor, Areawide	AM/PM peaks (minimum)
Clearance Time	Corridor, Areawide	AM/PM peaks (minimum)
On-scene Time	Corridor, Areawide	AM/PM peaks (minimum)
Total Duration	Corridor, Areawide	AM/PM peaks (minimum)
No. of Incidents by Type	Corridor, Areawide	AM/PM peaks (minimum)
Reporting by (citizens, police, other agencies) per month	Corridor, Areawide	AM/PM peaks (minimum)
Service Patrol Assists (total and by incident type)	Corridor, Areawide	AM/PM peaks (minimum)
Work Zones		
No. of Work Zones by Type of Activity	Corridor, Areawide	Daily
No. of Lane-Miles Lost	Corridor, Areawide	AM/PM peaks, Midday, Night
Lane-Mile-Hours of Work Zones	Corridor, Areawide	AM/PM peaks, Midday, Night
Average Work Zone Duration by Work Zone Type by Lanes Lost	Corridor, Areawide	Daily
Average Time Between Rehabilitation Activities	Areawide	N/A

Table 6-2 Recommended Minimum Freeway Performance Measures (Cont.)

Performance Measure	Geographic Scale	Time Scale
Average Number of Days Projects Completed Late	Areawide	N/A
Ratio of Inactive Days to Active Days	Areawide	N/A
Weather		
Hours Affected by (rain, snow, ice, surface ice, high winds, fog, dust, smoke)	Corridor, Areawide	Daily
Lane-miles Affected by (rain, snow, ice, surface ice, high winds, fog, dust, smoke)	Corridor, Areawide	Daily
General Operations		
Service Patrol Vehicles per Mile	Corridor, Areawide	Annually
Service Patrol Vehicles in Operation per Shift	Corridor, Areawide	Annually
Percent Freeway Miles with (electronic data collection, surveillance cameras, DMS, service patrol coverage)	Areawide	Annually
Number of Messages Placed on DMSs	Corridor, Areawide	Annually
Individuals Receiving Traveler Information by Source (511, other direct means)	Corridor, Areawide	Annually
Percent of Equipment (DMS, surveillance cameras, sensors, ramp meters, RWIS) in "Good" or Better Condition	Corridor, Areawide	Annually
Percent of Total Device-Days Out-of-Service (by type of device)	Corridor, Areawide	Annually
No. Devices Exceeding Design Life	Corridor, Areawide	Annually
MTBF [Define] for Field Equipment (by type of device)	Corridor, Areawide	Annually

6.7.7. Performance Measures for the Rural Environment

Earlier sections of this chapter identified and discussed some of the differences in TMCs developed for urban or rural settings. In particular, the use of performance measurement, choice of performance measures, data collected, and communications to stakeholders may be significantly different in rural or smaller areas. The following list identifies some of the major differences and contains recommendations for

where smaller communities should focus their efforts:

- In smaller communities, planning agencies often take the lead in conducting operational performance measurement.
- Operations in smaller communities typically focus on major arterials and signal operations.
- Mobility measures are likely of greatest interest to smaller communities.
- Because the typical activities of agencies in smaller communities involve planning, performance measures focusing on the facility level are likely to provide the best starting point.
- There are currently only a few small communities using travel time reliability measures.
- Performance measures looking at operational efficiency measures should be of interest to small communities.
- Most small communities are interested in measures that are readily understandable by the general public.
- Few small communities have developed a dedicated performance measurement system.
- In smaller communities, accessibility measures may not be as critical except where transit service is present.

6.8. Establishing Performance Measurement Thresholds

A threshold can be thought of as a bar or even a line in the sand. The objective is to reach the bar or cross the line. The line in the sand may be 15 percent fewer crashes or reducing average trip delay by 5 percent. Regardless of which measure is utilized, a threshold serves as the evaluation point for determining progress.

Without thresholds, there is no real basis for choosing what to measure, how to assess it, or what action to take. Establishing reasonable thresholds is a critical step in the performance measurement process.

The key consideration is reasonability. Targets should stretch and challenge an agency or TMC but not be unrealistic. It wouldn't be prudent to set a threshold of a 100 percent reduction in accidents on the freeway. It may, however, be reasonable to establish a target of 5 percent, or perhaps even 15 percent. When that target has been reached, the iterative nature of performance measurement will lead the TMC to establish a new target, therefore pushing for continuous improvement.

Previous sections identified numerous sample performance measures as well as a recommended minimum set of freeway performance measures. It is, however, beyond the scope of this *Handbook* to offer suggestions on specific thresholds that an agency should establish as part of their overall system. The information necessary to establish

specific thresholds is entirely local in nature and cannot be identified at the level of this document. However, what can be offered are some simple guidelines that an agency can use to establish appropriate thresholds.

Thresholds should be:

- Realistic
- Specific
- Challenging, but should not punish the agency
- Achievable (lest staff feel they are out of reach and doomed for failure)

In addition, thresholds should include a time frame for completion. An open-ended time frame does not promote focused and consistent efforts for meeting targets

6.9. Data for Performance Measurement

As may be evident by the discussions thus far, there are literally hundreds, if not thousands, of types of information that could be collected and used as the basis for performance measures. In fact, it is next to impossible to create a comprehensive list of this information, since the functions of TMCs (and therefore the performance measures they use), vary by type, location, size, responsibility, partnerships, and more.

However, any listing of information or data that serves as the basis for performance measures will certainly have some commonalities. Examples of these common data are shown in Table 6-3. Practically everyone will want to collect some type of speed information and use it as the basis for a performance measure. Speed is readily understood by every audience, is easy to relate to, and is one of the most obvious indicators of roadway conditions.

Table 6-3 Typical Information Sources for Performance Measurement Data

Travel Times	Speeds	Densities	Capacities
<ul style="list-style-type: none"> • Corridor • Facility • Average • Regional • Peak vs. off-peak 	<ul style="list-style-type: none"> • Average • Estimated • Corridor • By vehicle type 	<ul style="list-style-type: none"> • By lane • By facility • By time of day • Incident vs. nonincident 	<ul style="list-style-type: none"> • By section • By facility • Incident vs. nonincident
Queues	Throughput	Incident Characteristics	Other Sources
<ul style="list-style-type: none"> • Length • Speed • Duration • Rate of growth 	<ul style="list-style-type: none"> • By facility • By vehicle type • By time of day 	<ul style="list-style-type: none"> • Detection time • Duration • Response measures • Extent 	<ul style="list-style-type: none"> • Weather • Work zones • Staffing • Expenditures • Customer satisfaction

Notice that the table lists numerous data sources that originate from real-time or historical roadway information, such as speed, density, or incident response information. However, the table also lists several other information sources, such as staffing and performance levels, expenditures, and customer satisfaction surveys. These types of information are perfectly valid as data sources for performance measures. Indeed, as detailed in previous sections, a balanced approach to performance measures is best.

Aside from the question of *what* data should be collected, steps 6 and 7 of the performance measurement process (Figure 6-1) contain a number of other important parameters that affect the ultimate usefulness and/or application of the performance measure. These include items such as:

- Frequency of data collection
- Schedule of data collection
- Location(s) of data collection activities
- Data collection responsibilities
- Data analysis needs (cleaning, quality screening, aggregation, etc.)
- Data manipulation or calculation needs
- Data analysis responsibilities
- Database or historical recordkeeping requirements

- Data presentation needs.

A careful performance measurement process identifies the answers to each of these questions for every performance measure in use. In fact, it is recommended that a standard format be developed for the operations manual that explicitly identifies each measure in use and details all of the pertinent information, from data source(s) to method(s) of presentation.

6.9.1. Methods of Collecting Data

Data collection can be one of the most labor intensive, and therefore costly, aspects of performance measurement. While some information can be obtained from typical roadway devices, it cannot provide the full extent of the data necessary for the wide range of measures likely to be employed. In fact, roadway devices can not provide all of the data necessary for the minimum recommended list of performance measures identified in Table 6-1. Additional methods of collecting data must be employed.

Typical methods of collecting data include:

- Automatic collection
- Regular (manual) collection
- Periodic collection
- Random sample collection
- Small-scale samples such as travel time runs using the floating car method
- Simulation modeling data rather than direct measurement

Each of these methods has advantages and disadvantages. Wherever possible, agencies should use automatic data collection, as that is the most cost-efficient mechanism, as well as providing the most comprehensive coverage both in terms of geography and time. In fact, data costs, more than any other factor, will likely govern the amount of data collection that can be performed. An agency just beginning a performance measurement process would be wise to take a minimum or bare-bones approach at first in order to establish a smooth process, work out all of the bugs, and create a positive experience. Use of automatic data collection equipment requires good maintenance of field devices, and there must be a commitment to provide adequate funding for this maintenance.

6.9.2. Other Data Issues

As if the difficulties of determining which data to use and where to find that data weren't enough, there are a number of other considera-

tions that may need to be addressed before performance measures are calculated.

Data storage is always an issue. Although the physical cost of storing data in electronic form has continued to fall, there are other factors to consider such as the format of the data (e.g., flat files or internal to a database). Regardless of the choice, it takes time and effort to take raw data from any source and make it be ready for long-term storage.

Data manipulation is another hidden issue. As an example, freeway speeds are often collected in bins of 20 to 30 seconds. However, a presentation to external audiences would typically show average speeds over a much longer time period, such as a day, week, or month. This aggregation, or averaging, while a simple calculation to perform, must be accounted for in the process of creating performance measures. Likewise, speed information may need to be averaged along the length of a facility instead of at point locations where it is typically collected.

Some performance measures require more than one type of data, requiring data from more than one source to be matched up or “fused.”. This can be a difficult and time-consuming task, especially if the data originate from different devices or systems that do not share common time clocks, formats, or even definitions.

As a final note, small or rural TMCs may face special challenges in data collection. Typically, small TMCs either do not have or simply cannot afford to allocate all of the resources necessary to support large-scale data collection efforts for performance measurement. In these situations, it is recommended the agencies seek data sources from external agencies, such as the city, county, or state. Also, agencies should explore sharing the cost of data collection efforts, particularly in the case of automatic devices, as the same data can often be used for multiple purposes by multiple agencies.

6.10. Presenting and Reporting Performance Data

After identifying all of the performance measures to be used; developing a comprehensive process for finding, collecting, compiling, and analyzing all of the necessary data; and establishing reasonable performance targets and comparing them to the data to determine if corrective actions are necessary, one of the most important (and daunting) aspects of performance management still remains. The information must be communicated to others, either internally or externally.

The key to communicating performance measurement information well is to understand the audience. When speaking to external agen-

cies, political or legislative office holders, or even the general public, the golden rule of “less is more” is generally applicable. While you want to be sure to present a fair and accurate assessment, the display of significant levels of detail, with countless charts, tables, and figures, will likely be confusing. These types of audiences need an overview and the bottom line—the numbers that make up the bottom line are generally not as important.

When communicating to the public or an agency not involved in the day-to-day operations of the TMC, one recommended approach is:

- Start with the message – identify the reason for communication. Work with the agency public information office, if possible.
- What is the area of concern? (Identify it as a roadway, a corridor, the region, a particular location, etc)
- What is being measured? (Keep it simple – speeds, travel times, accident rates, etc.)
- How is performance being measured? (Provide a brief description of the performance measure and its purpose.)
- Where did the data come from? (Identify the data sources used and an overview of any necessary manipulations.)
- What are the results? (Strive for clear, effective, concise information.)
- What do the results mean for your audience? (Make it personal—relate this information back to them.)
- What are the next steps? (Identify the options or future actions.)

This approach is not intended to imply that audiences are incapable of understanding the details associated with the performance measurements. It is likely, however, that the details of data collection, manipulation, storage, and more are not necessary for your audience to understand the results and, most importantly, the actions or next steps.

In essence, this same outline can also work for presenting material to a more technically oriented audience. While the steps remain the same, the level of detail presented at each step may increase.

Perhaps the most difficult step in the above process is item 6, the clear and concise communication of results. As engineers, a typical approach is to use charts, tables, and figures to graph or otherwise illustrate large amounts of information. This typically works well, but be careful to avoid common pitfalls.

6.10.1. Common Presentation Pitfalls

One common pitfall is to use a chart that shows every piece of data. While technically accurate, this typically leads to needless complexity and can actually hide the bigger picture or trends. If data were collected at 5-minute intervals but the performance measure illustrates information on a daily basis, 1 data point will probably suffice instead of showing the 288 individual 5-minute intervals.

Another common pitfall is to make information on charts or displays too small. Before presenting any information, view it from the back of the room. If you can't read it or see it clearly, neither can your audience!

Avoid excessive use of colors and fonts. Colors and fonts can be used effectively to separate and group information, but too much is overkill and distracts from the message.

Be very aware of how the information will be presented. Charts designed for a color presentation do not translate well to black and white. If information will be printed in a local newspaper or other publication, make sure that displays that are tailored to that particular media.

Finally, don't assume that the charts will adequately communicate the message. Charts are a backup and a visual aid—they are not the primary method of getting information across to the audience. Follow the presentation outline provided in the previous section for a consistent and tried-and-true approach to communicating information.

6.10.2. Methods of Presenting Data

Section 6.9 discussed the requirements that should be identified for every performance measure in use. The final item in that list was data presentation needs. What method(s) will be most effective for presenting that particular performance measure to the intended audience(s)? Indeed, if the measure will be used in multiple settings, there may be more than one method of presenting the information. The final step in that process should identify not only the method of presentation but also the audience. Also suggested in the section was the use of a form to explicitly define and record the information associated with each performance measure. The typical audience and method of presentation would be valuable information to record as part of the operations manual.

The presentation of many performance measures will be supplemented or aided using typical and well-known types of charts. Charts are easily understood, can be adapted to a variety of audiences and situations, and can be used at multiple levels of detail as the audience warrants.

However, some guidance on when to use what type of chart to use is warranted. The information below applies to typical situations. Like most aspects of engineering, individual judgment should be used to determine the most appropriate method of displaying information.

- Line – highlights trends or changes over time; can show multiple series of data, but be careful of overcrowding the chart.
- Pie – shows the relationship of the parts to a whole; good for expressing percentages.
- Bar – shows variations over a period of time. Horizontal bar charts typically give the impression of time flow; vertical bar charts typically give the impression of movement in space (e.g., different roadways).
- Area – shows variations of data over time but emphasizes the overall magnitude of the change rather than individual changes or rate of change.
- Combination – excel at showing the background data while highlighting the significant trend. A typical combination chart utilizes a bar graph in conjunction with a line graph.
- 3-D charts – may help highlight information or improve the visualization. There are 3-D versions of all of the charts above.

6.11. References

The following material can be used as reference information for agencies wishing to obtain addition information about performance measurement.

(1) A synthesis of performance measures for monitoring and operating highway systems and segments. Reference contains examples of measures and several case studies of current DOT programs.

Performance Measures for Operational Effectiveness of Highway Segments and Systems. NCHRP Synthesis 311. Transportation Research Board, National Research Council, Washington, DC, 2003.

(2) A synthesis on the use of performance measurement in research, development, and technology programs. Synthesis contains a good overview of the performance measurement process.

Performance Measures for Research, Development, and Technology Programs. NCHRP Synthesis 300. Transportation Research Board, National Research Council, Washington, DC, 2001.

(3) A broad background of performance measures for all modes of transportation.

Performance Measurement in State Departments of Transportation. NCHRP Synthesis 238. Transportation Research Board, National Research Council, Washington, DC, 1997.

(4) Conference proceedings that contain an overview of performance measurement as well as identifying and discussing many of the issues relating to a successful program.

Performance Measurement to Improve Transportation Systems and Agency Operations. Report of a Conference. Irvine California, October 29, 2001- November 1, 2001. National Research Council. National Academy Press. Washington, DC, 2001.

(5) This TMC Pooled-Fund Study site provides draft chapters on the project developing a TMC performance monitoring, evaluation, and reporting handbook. Available draft chapters provide an overview of a performance monitoring program as well as significant details on data requirement and collection.

TMC Performance Monitoring, Evaluation and Reporting Handbook
http://TMCpfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=62&new=0

(6) FHWA Web site material on performance measurement, containing overview and fundamental information on the performance measurement process as well as resources and links to additional material.

FHWA Office of Operations
http://ops.fhwa.dot.gov/perf_measurement/index.htm

FHWA Management and Operations Toolbox
<http://plan4operations.dot.gov/toolbox.asp?id=ToolPM#toolmenu>

(7) Freeway Management and Operations Handbook – Chapter 4 contains detailed discussion each step in the performance measurement process as well as sample measures and several examples of current programs.

Freeway Management and Operations Handbook. FHWA/OP-04-003. Federal Highway Administration, Washington, DC, 2003.

Publication is also available online at:
http://ops.fhwa.dot.gov/freewaymgmt/freeway_mgmt_Handbook/toc.htm

(8) In addition to an overview of the performance measurement process, this report contains a highly structured listing of sample performance measures across goal areas and modes of transportation.

A Guidebook for Performance Based Transportation Planning. NCHRP Report 446. Transportation Research Board, National Research Council, Washington, DC, 2000.

(9) A highly detailed and effective coverage of information relating to all aspects of performance measurement, from process to presentation. Material referenced is draft version as final publication is not yet available.

Guide to Effective Freeway Performance Measurement. NCHRP Report 8-36. Transportation Research Board, National Research Council, Washington, DC, 2004.

(10) A cross-cutting study on the application of performance measurement as applied to United States government agencies.

“Serving The American Public: Best Practices in Performance Measurement” National Performance Review by Vice President Al Gore. June 1997.

<http://govinfo.library.unt.edu/npr/library/papers/benchmrk/nprbook.htm>

(11) An excellent, nonfield specific overview and discussion of performance measurement and each step in the process.

How to Measure Performance. A Handbook of Techniques and Tools. U.S. Department of Energy, Special Projects Group. Oak Ridge, TN, October 1995.

Publication is also available online at:

<http://www.ornl.gov/pbm/documents/Handbook1.html>

(12) A report that focuses on the use of performance measurement in smaller communities and identifies the changes or differences from traditional implementation in larger, more metropolitan areas.

Performance Measures for Small Communities. FHWA-OP-03-080. Federal Highway Administration. Washington, DC, 2003.

Endnotes

1. “Performance Measures for Operational Effectiveness of Highway Segments and Systems.” NCHRP Synthesis 311. Transportation Research Board, National Research Council, Washington, DC, 2003.
2. “Serving The American Public: Best Practices in Performance Measurement” National Performance Review by Vice President Al Gore. June 1997.
<http://govinfo.library.unt.edu/npr/library/papers/benchmrk/nprbook.htm>
Accessed October 29, 2002.
3. “Guide to Effective Freeway Performance Measurement” NCHRP 8-36. Interim Report. National Cooperative Highway Research Program. Washington, DC, 2004.

7. TMC OPERATIONS MANUAL CASE STUDIES

7.1. Introduction

This chapter contains case studies that highlight the development and use of a TMC Operations Manual.

7.2. Northern Virginia Smart Traffic Center Case Study

The Northern Virginia (NoVA) District of the Virginia Department of Transportation (VDOT) operates one of the department's three existing Smart Traffic Centers (STC). The STC is similar to a Traffic Management Center concept and is situated in a very urbanized and congested area of metropolitan Washington, focused on management of the interstate route freeways, overseeing more than 100 miles of roadway. It operates on a 24/7 schedule.

NoVA STC operations include: congestion mitigation with extensive reversible HOV lane operations, incident management, and traffic planning. The elements of the system include:

- 109 cameras
- 222 VMS
- 2 gate groups (entrance and exit) on I-66 HOV lanes for use during peak travel hours
- 2 gate groups on I-95/I-395 for reversible HOV lanes
- 25 ramp meters for inside the beltway on I-66 and I-395
- 30 lane control signals
- 23 vehicle classification stations
- 177 controllers with sensors and loop detectors
- Advanced Transportation Management (ATMS) software
- An automatic incident detection system
- A meteorological weather satellite to monitor rain, snow, and ice conditions
- 4 HAR sites
- 3 operator workstations, each dedicated to specific interstate freeway sections
- 2 call-taker workstations
- Enclosed supervisor work area

A regional ITS architecture, called the Northern Virginia Regional Architecture, presents the VDOT Northern Virginia District's interfaces to other transportation systems within and adjacent to the region. The

NoVA STC must follow operational concepts that conform to the architecture.

7.2.1. Contents of Manual

The TMC Operations Manual used for the NoVA STC is called the “Standard Operating Procedures” (SOP). The manual is very comprehensive, with 157 pages. The operations staff members in the STC are comprised of traffic controllers and call takers, with supervisors.

Each section of the SOP is described below in the order in which it is published in the SOP.

1. Introduction

This section describes the purpose and layout of the SOP and how updates are made. The purpose is to act as a reference guide for situations when supervisors are not present.

In order to assure authenticity of the material, each section has a validation system presented in a table at the beginning, followed by another table with revision information. It is explicitly noted that the SOPs must remain at the each workstation.

2. NoVA Operational Concepts

This section focuses on the overall responsibilities of the traffic controllers and call takers. The operations are put in context by stating the STC objectives and presenting the operations division organizational chart before the STC responsibilities are detailed. It has a map showing the STC coverage area.

The responsibilities include a description of all the tools used in the STC. Responsibilities include a checklist (detailed in section 6), fault monitoring of equipment, and fairly detailed incident management procedures. Finally, the different responsibilities for each of the three operations workstations and the call-taker workstations are described. This avoids conflicting operations, plus protocols are included for coverage if a workstation is not staffed.

3. Administrative Procedures

This section does not address traffic operational issues, but rather procedures to better manage and keep the STC facility working properly. Responsible procedures detailed in this section include: cleanliness, maintaining supplies (office and system-related equipment), subsystem crashes, backup procedures, and facility security.

Subsystem crashes are handled using a specific process presented in steps to follow to restore the system. If a step does not work, the next step must be taken. The process ultimately includes contractor support, with information on who to call and their number, and a second designated person if the first person does not respond in 15 minutes. System backups are detailed in a similar stepped process manner, including contacts if the process does not work properly.

The facility security procedures address access codes for entering the controlled space in the building of the STC. It even addresses how visitors can access the STC.

4. Telephone Procedures

This section is rather brief, but is considered very important due to the frequency and nature of calls to this nerve center. Items include etiquette, note taking, and protocols and instructions for transfers. Communications are critical to the STC operations, and mishandled phone calls can cause serious consequences and embarrassment.

5. Internet Operations

Another very brief section focuses on restricting misuse of Internet access. As in any work office environment, workers abusing Internet access is a serious concern. Yet, the Internet is a powerful tool for information access. The benefits are recognized, especially e-mail, but warnings are provided regarding interference with work responsibilities.

6. Daily Operations

This section describes the shift hours and staffing for daily operations and procedures for taking a break and provides a shift procedures checklist for each workstation assignment. Procedures for taking a break identify the protocols that must be followed, as continuous coverage of managing the system is critical.

Copies of the checklists are presented in this section, unique to each workstation and each time shift. The checklist requires a name and date at the top, followed by a list of scheduled operations with specific times for each. These operations include system maintenance activities and specific traffic operations (i.e., HOV controls, information dissemination). At the bottom of the checklist is a note with a brief description of other duties that are not time specific, namely system monitoring and incident management.

The night shift checklist is similar for all workstations, as specific traffic control responsibilities of specific interstate operations for com-

mute periods are not needed. The weekend checklists are similar for each workstation too, but include spaces for logging any traffic control operations that may be required to be activated and nonrecurring events. A special log is also included for operations of moveable bridges.

The checklists are excellent means to avoid operations mistakes that could lead to serious hazards to the traveling public.

7. Incident Management Procedures

This section describes procedures for various types of incidents, considered a core duty of the traffic controller, in specific detail. Due to the extensive detail, the procedures are followed by a “Quick Reference Guide” that simply lists operational steps without details. At the end is a list of potential agencies to coordinate activities, but no phone numbers.

The incident management procedures begin with methods for incident detection and verification, followed by notification of other agencies for response actions, including extensive detail for notifying the media (what to say and what not to say). There are also procedures for activation of field devices with conditional requirements, followed by notification of incident clearance.

8. Radio Operations

This section relates to operations of various radio equipment, including: VDOT two-way radios, emergency service scanner, and HAR. A reference to the governance by the policies of the various operating agencies of each piece of equipment and the Federal Communications Commission (FCC) is made.

Items in this section include: radio “ten codes,” channel numbers, and call signs, protocols, and radio usage etiquette, the phonetic alphabet, scanner utilization, and HAR. HAR procedures are very detailed, including general use, message development and format, and the locations of each HAR. Several example message formats for various incident scenarios and conditions are provided.

9. NoVA STC Monitoring Devices

This section identifies the field equipment that is operated from the ATMS and the respective procedures for operations. Equipment includes:

- CCTV
- HOV for I-66

- HOV for I-395/95
- Ramp metering
- VMS

The section concludes with equipment malfunction procedures. This is the longest section.

10. NoVA STC External Systems

This section identifies equipment that is not part of the ATMS but operable from the STC, with respective procedures for operations.

Equipment includes:

- Information Exchange Network with agencies in the I-95 Corridor Coalition
- National Warning System operated by the Washington, DC, emergency management
- Call box system
- NoVA pagers
- Woodrow Wilson Bridge operations
- Statewide database for tracking incidents

11. Roadwork Procedures

This section addresses STC procedures for various roadwork scenarios. These include:

- What to do upon notification of roadwork
- Information dissemination procedures related to roadwork
- Information dissemination procedures upon accident notification in work zones
- Information dissemination upon notification of roadwork time extensions
- Logging of roadwork activities
- What to do when roadwork overlaps commute peak periods

The overall theme is to provide timely information to key stakeholders and disseminate updates to traveler information services.

12. OZONE Alert Procedures

This section relates to actions the STC must take when a “code RED” ozone alert is issued. Activities include: initiating advisories to the public, sending e-mail messages to all VDOT employees, and placing appropriate messages on VMS and HAR. The manual identifies specific messages for each device.

13. Call Taker Procedures

This section describes the procedures taken by call takers in the STC. It is very specific for the actions to be taken. It applies during normal working hours and off hours, and it applies for a variety of possible scenarios, including:

- Accidents/incidents
- Bridge maintenance repair
- Dead animal
- Debris in roadway
- Graffiti
- Vegetation obstruction
- Guardrail damage
- Damage to impact attenuators/glarefoil
- Roadwork lane closure notifications
- Manhole covers missing/removed
- Noise complaints
- Potholes
- Property damage
- Traffic signals
- Roadway signs
- Snow/ice complaints
- Steel plates
- Storm drains
- Overhead lighting
- Tree obstruction
- High water/flooding
- Wrecker requests

14. NoVA STC Operation Logs

This section covers the various reporting logs required to be completed by the STC. For each of the activities below, a brief description of the purpose of the form, when to fill it out, and sometimes a copy of the form are included:

- Equipment failure
- VMS request
- Equipment repair request
- NoVA STC maintenance database
- Incident reports
- STC activity log
- Maintenance action request system
- STC snow/ice complaint

- Wrecker request

Each of these activities is seen as important enough to warrant documentation of logging, providing a record for future analysis.

7.2.2. Overview of Manual Effectiveness

The previous section examined the contents of the SOP for the VDOT NoVA District. This section will assess the overall effectiveness of the SOP. An interview with the STC supervisor, T.F. (Jimmy) Chu, provides the content for this section. The interview consisted of several items that are presented below followed by a summary of the appropriate response from Mr. Chu.

1. Why did the agency develop an operations manual?

Primarily for training purposes and to get new staff trained quickly.

2. Relationship to other manuals and agency policies and procedures.

The operations are unique to the STC, except for radio operations. There are many references to radio operating procedures from other units and agencies. There is a direct relationship to the training manuals provided to new STC staff. The training manual has other contents, but much of the SOP contents are included. This is necessary for obvious consistency purposes.

Also, as mentioned in the introduction, the STC operations must conform with the Northern Virginia Regional Architecture. Furthermore, the regional focus is expanding through coordinated efforts with the State of Maryland and District of Columbia for incident management across Metro Washington.

3. The challenges in developing and updating the manual.

Development is very time-consuming. Due to the various demands on staff with respect to operations, available time is difficult to acquire. Because of this, consultant services were retained to develop the manual. However, the hiring process took a long time. Furthermore, the available funding budget was tight; therefore, it was difficult to get as much as desired from the services.

Since the consultant procurement process is both lengthy and not generally affordable due to the STC budget, SOP updates are generally provided by the STC supervisor. The supervisor's time, though, is limited, and there are concerns that some items requiring updates may be missed.

4. Key issues that have led to the successes of the operations manual.

The success of the SOP is the background it provides for training new employees. Furthermore, it relieves the STC operators from having to commit procedures to memory, leading to more efficient operations.

5. Overall effectiveness of the manual.

Primarily, the SOP has been very helpful for new employees, allowing for quick start-up in their training. The STC operations responsibilities are very specialized within VDOT, so the SOP is very helpful. The ability to deliver effective operations is proof of the SOP's effectiveness.

6. Aspects of the manual that are most useful, and those that need to be changed.

The aspects that are most useful include:

- Answering the question “how to do it” in response to various scenarios.
- Serving as a reminder for STC staff.
- Supporting consistent operations among various personnel.

The aspects that need to be changed include:

- More useful if the SOP can be integrated electronically into the system, so that operators can view within their workstation, rather than search for the hardcopy SOP.
- In the electronic version, providing a “help” button for operators to click when a situation arises for which the response is not known or forgotten. This can be something similar to what many commercial software packages offer from a menu or “button” format on the computer screen display.

7. Lessons learned along with recommendations on manual development as it relates to the life cycle of system development.

Over the life cycle of the system, new SOPs are required to add to the manual. It is rare to go back to modify existing SOPs due to time constraints. Because of the time constraints, it is recommended that a dedicated person be in charge of updating the manual as needed.

7.2.3. Summary

The NoVA STC SOP, or operations manual, is very comprehensive, incorporating most elements identified by the ITE Annotated Outline

as key items (though presented in a different order). The main items that seem unique to this manual are telephone and Internet procedures. Both are recognized as important elements in the day-to-day operations, especially call taking. Emphasis is placed upon using these devices in a professional manner for State business purposes, discouraging abusive use.

The SOP does not contain contact phone numbers for the external agencies with which they may need to interact, as those are maintained on a separate list. This seems to be primarily due to the frequent changes to such lists. However, the SOP does include very detailed procedures, including when to use such list for appropriate contacts.

Extensive procedures are detailed regarding daily operations and control functions of the operations systems. Maintenance procedures included in the SOP focus on system fault monitoring, but not specific maintenance troubleshooting or repairs. These procedures and information are documented elsewhere. Procedures for maintaining operator logs are extensive and detailed, reflecting the importance of such information.

The operational concepts provided in the SOP are comprehensive, yet not too lengthy. This section should serve as an excellent model for other TMCs. If this information is too long, it may not be read or may be forgotten. While sufficiently detailed, it is right to the point. The SOP includes a good description of the overall system, including an inventory of the elements. It also has an effective date on the cover.

7.2.4. Conclusions

The NoVA STC is a very busy operation, and it requires additional resources to focus on updating and maintaining manual. The VDOT NoVA District STC is seen as a leader in its region. Its focus is on freeway operations and incidents. It includes some references to Maryland, the District of Columbia, and local agencies for incident management information sharing, but there is not much mention of coordinated operations activities. This coordination seems to be directed by field personnel.

Training needs are a key to TMCs, and the use of the manual as a training tool is very helpful. The TMC operator is a developmental position and requires on-the-job and formal training to advance to full performance level.

VDOT NoVA STC is a relatively mature TMC, and their SOP was more encompassing than what is normally found at local agency TMCs, most of which are not too experienced. It seems to be of

greater importance to freeway-based TMCs to have a TMC Operations Manual, due to the greater importance of its information from public and the media. But even compared to other freeway-based TMCs, NoVA's experience is evident in such a detailed document.

It is understood that performance measures related to incident response and clearance times are to be incorporated in the STC. These are statewide measures developed for consistency purposes. It is expected that more performance measures, including more specific STC measures, will be developed in the near future by VDOT.

Clearly, the VDOT NoVA STC recognizes the need, importance, and value of an operations manual. The management is aware of how to effectively integrate the use of an operations manual into their daily activities, procedures, policies, and programs. As relationships continue to grow with regional partners, it is expected that the requirements in the SOP will increase.

7.3. Orlando TMC Case Study

The City of Orlando TMC and its staff are responsible for operation and maintenance of a Regional Computerized Signal System (RCSS). The RCSS is a multijurisdictional traffic signal control system that coordinates 384 traffic signals within the borders of Orange County, Florida. The City of Orlando's partner in this system is Orange County. There are future plans for the RCSS to cover Seminole, Orange, and Osceola Counties.

The City of Orlando staffs and operates the TMC for these agencies and thereby provides some interagency coordination in order to provide the motorist with a seamless transition when crossing jurisdictional boundaries. The TMC is in operation 24/7, as their saying states: "We never close because there is always traffic on the roadways." The TMC also provides a help line for reporting traffic problems via telephone and facsimile.

The City of Orlando's Traffic Signal Maintenance (TSM) facility is responsible for maintenance of the RCSS. As a part of the RCSS, the TSM maintains remote communication units (RCUs) and National Electrical Manufacturers Association (NEMA) TS-1 controllers and cabinets at the 384 signalized locations, 14 CCTV cameras, and more than 40 miles of twisted pair communication cable to the signalized locations.

Florida DOT District 5 provides video feeds from its CCTV cameras and information on diverted traffic from I-4. The City can develop sig-

nal control plans and adjust signal timing to accommodate the traffic diversions.

The City of Orlando also has a relationship with the Central Florida Regional Transportation Authority (Lynx) for a transit customer information and fleet management system. This is done through the use of installed electronic bus stop displays and a vehicle location system integrated with an existing signal preemption system. Electronic emitters are installed in transit buses and are read by existing signal electronic detectors at signalized intersections. Vehicle data are then relayed from the signalized intersection to the TMC, and then to the transit operator, who provides “next bus” information to customers through the bus stop displays. Vehicle data are also used to monitor transit fleet performance and improve service.

7.3.1. Contents of Manual

The Operations Manual used by the City of Orlando TMC is a composite of customized instruction sheets from the system vendor and SOPs. The operations staff in the TMC is composed mostly of military veterans; therefore, the manual is presented in an understandable manner that relates to their background.

Each section of the manual is described in the order in which it is numbered. Step-by-step procedures are presented in each section to perform the titled function with figures of the screen display the TMC operator would see during operations.

1. Server Rack

This section describes the different computer hardware servers of the system network and the software that resides on each server. A figure depicting the server rack illustrates where each server, the UPS power source, and the keyboard and computer screen are positioned on the rack. A brief description of the software functionality and accessibility is provided, along with warnings to operators about accessibility under certain conditions that could be detrimental to the system.

2. System Sign In

This section describes how a TMC operator should sign in to the system. It contains figures that show the operator what the screen looks like and where the sign-in functionality is positioned. Each figure matches a step in the instructions.

3. Alarm Status Display

This section presents the procedures to be used to display and utilize the Alarm Status Display. The display alerts the TMC operator to any possible controller problem. Instructions include how to display the screen and how to read the status display.

4. Controller Communications Status

The procedures in this section permit the operator to monitor any selected controller's communication status. Additionally, it permits the operator to view information pertaining to the signal timing operations of the controller (i.e., phase, current pattern, current mode, existing preemption, etc.). Instructions to access each piece of information are detailed.

5. Change Controller/Flex Group Status

These procedures are used by the TMC operator to manually change the status of the controller or "flex group" of controllers, allowing the controller to be placed in "free" mode, flash mode, or revert to local time-of-day mode. A flex group is basically assigned controllers to a particular grouping. By strategically assigning these flex groups, an operator can adjust multiple controllers simultaneously that are associated with a particular event (i.e., route diversion, special event).

6. Preemption Report

These procedures are used to display a preemption report for any controller and any specific time frame as requested by the TMC operator. These reports are an effective means of monitoring the performance of the signal preemption system.

7. Activate/Deactivate Special Functions

Special functions are programmed features that do not require intervention by the TMC operator. These procedures are used by the TMC operator in the event these features need to be activated/deactivated outside scheduled time frames and under special circumstances. An interesting note, one of the instruction steps describes what a particular "button" looks like on the screen that the operator must click to perform the particular operation.

8. Server Power Down/Up

The procedures in this section are used by the TMC operator to power down/up the network servers.

9. Split Table Changes

These procedures allow the TMC operator to change the length of time for a phase at an intersection or remove a phase from the pattern cycle (e.g., remove a left-turn arrow from the cycle). The operator can use this tool to help reduce traffic jams and maintain traffic flow during major events and/or unusually heavy traffic periods (i.e., basketball and football game traffic, road detour, construction, etc.). This set of instructions is somewhat lengthy.

10. Special Pattern Set-up

The procedures in this section are used by the TMC operator to help reduce traffic jams and maintain traffic flow during major events (basketball and football game traffic, etc.) and/or unusually heavy traffic periods. There are instructional procedures for three different event generators, covering both pre- and post-event scenarios. A warning is noted for TMC operators to check the event schedule at the beginning of their shift.

11. Data Backup/Restore

These procedures allow the TMC operator to use special software to perform manual backups, as well as perform restoration of system data in the event the current data are lost or corrupted. It is noted that automatic data backups are scheduled on a weekly basis too. Special instructions note the specific type of data tapes to be used. A figure is presented to show where the drive door is located on the server computer of the appropriate rack.

A further note of interest is a requirement that the TMC operator keep documentation describing the reason(s) for restoration, any problem(s) encountered while following these restoration procedures, and the date/time of the backup tape used. The operator is also requested to include any information that may seem important that can lead to the cause of the data corruption.

12. Time Check

The procedures in this section are used by the TMC operators to provide time check for signal maintenance personnel in the field and/or download real-time clock controller device(s). The instructions in this section include steps for the use of noncomputer equipment; specifically, two-way radios.

13. Controller's IP Address

These procedures contain instructions that TMC operators can use to locate a controller's Internet provider (IP) address as well as instructions to "PING" an IP address. The PING operation sends a signal to the IP address requesting a response. If Internet communication over Ethernet is working, a "device responding" message is transmitted. If unsuccessful, a "device not responding" message is transmitted.

14. Computer on Video Wall

These procedures are used by the TMC operator to set up the video wall to display different options, including the system network computer screens. It includes instructions to set up the video wall from different computer workstations. It also includes instructions on how to select a couple of preset options and how to return to normal video wall operations.

The following is a list of SOPs, presented in numerical order, that are not performed through the network computer system:

Procedure 1	Frequently Called Phone Numbers and LYMMO Service Contact List
Procedure 2	After Normal Duty Hours Call Procedures
Procedure 3	Signals under Contract Call List
Procedure 4	Public Works Emergency Call Procedures
Procedure 5	Orange County Signal Technicians on Call
Procedure 6	Orange County Signal Flash Schedule
Procedure 7	Orange County Traffic Engineering Department Telephone Numbers
Procedure 8	Shift Changeover Checklist
Procedure 9	Splice Forms
Procedure 10	Radio Call Numbers
Procedure 11	"TEN" Signals
Procedure 12	I-4 Surveillance Camera Locations
Procedure 13	Disaster Emergency Contact List
Procedure 14	Parking Bureau Phone Numbers
Procedure 15	FDOT Emergency Maintenance Contacts
Procedure 16	Video Wall Power Outage Procedures
Procedure 17	Expressway Authority Maintenance Contact List
Procedure 18	Freeway Incident Management Notification
Procedure 19	Orange/Osceola/Seminole Emergency Contact List
Procedure 20	R/R Crossing Phone List and Crossing IDs

Some of the procedures are described further as follows:

Procedure 2 - After Normal Duty Hours Call Procedures

This SOP addresses how the TMC operator should handle traffic problems within the City of Orlando that occur outside of normal duty hours. If the problem call is in another jurisdiction, phone numbers to notify appropriate resources are provided. The types of traffic problems that are addressed with required TMC operator responses are:

- Signal operation malfunctions
- Sign problems
- Fallen trees blocking roadway
- Road service for city vehicles
- Railroad crossing gates or signals
- Calls for traffic barricades (i.e., during a special event)
- Pedestrian bulb outs (not urgent)

Procedure 8 – Shift Changeover Checklist

The checklist is to be used to ensure a smooth transition between outgoing and incoming shift personnel. Operators are not limited to this checklist; operators may pass and/or document any information they feel may have an impact on the day-to-day operation.

The checklist includes task responsibilities of both the outgoing and incoming personnel. In addition, it lists requirements to ensure proper documentation is maintained on all problems/situations.

Procedure 9 – Splice Forms

Splice forms are documents used to describe wiring connections in order to connect two or more cables together. The SOP describes six types of forms that may be used. It also identifies the program to use to create new forms or update forms. Finally, it describes how to save and store new or updated forms.

Procedure 11 – “TEN” Signals

This SOP presents a list of radio signals/codes that are commonly used. The list includes common “TEN” codes used for radio communications and codes describing various problems to signals, signal controllers, and detectors. Using these radio codes minimizes the amount of air time required for communications, reserving more time for emergencies.

Procedure 16 – Video Wall Power Outage Procedures

During a TMC power outage or UPS system test, the TMC’s systems automatically convert to the UPS system without any action by TMC

personnel. However, the video wall unit and video cassette recorders (VCRs) are not connected to the UPS system; therefore, they can fail during the commercial/UPS power transfer. This SOP identifies procedures to be used to restore the video wall unit and associated equipment to normal operation. The SOP includes documentation requirements by the operator during these instances, and required checks of other equipment are listed.

7.3.2. Overview of Manual Effectiveness

The previous section examined the contents of the TMC Operations Manual for the City of Orlando. This section will assess the overall effectiveness of the manual. An interview with the TMC supervisor, Chris Kibler, provides the content for this section. The interview consisted of several items, presented below, followed by a summary of responses from Mr. Kibler.

1. Why did the agency develop an operations manual?

The TMC staff needed help, and written direction was found to be the best form of assistance. Many of the staff members have military backgrounds and were receptive to this approach.

2. Relationship to other manuals and agency policies and procedures.

The manual does not relate to any other city manuals or SOPs; however, it does have relationships among regional partners. The manual has strong relationships with respective manuals of the Florida DOT District 5 and other stakeholders involved in regional incident management. Information sharing and close coordination of incident management activities among the regional partners is key to effective responses and clearances of incidents.

3. The challenges in developing and updating the manual.

Much of the information does get out-of-date. This includes changes to the system, different contacts for various agencies, and changes in protocols related to incidents. Updates are made upon notification of such changes. Furthermore, an annual review is performed of the entire manual to assure the information is up-to-date.

4. Key issues that have led to the success of the operations manual.

As most of the TMC staff members have military backgrounds, a set of SOPs is very effective in providing focus for the TMC operations.

5. Overall effectiveness of the manual.

The city does not have any performance measures to evaluate effectiveness; however, the supervisor says that the number of phone calls to him during off-hours has been reduced. This shows that the TMC operators are more independent and therefore able to implement responses quicker.

6. Aspects of the manual that are most useful and those that need to be changed.

The aspects that are most useful include:

- Written direction for operators
- Easier to train new staff
- Helps identify other procedural needs for operations

The aspects that need to be changed include:

- Increase the comprehensiveness of the manual
- Include procedures to handle out-of-the-ordinary events and once-a-year events

7. Lessons learned along with recommendations on manual development as it relates to the life cycle of system development.

The initial manual, provided by a previous software system vendor, was too generic and it did not serve the specific needs of the operators. Furthermore, a maintenance manual was also provided, but its focus was on the system hardware and not on software problems. It is recommended that all the various needs of the TMC operators be included in a single manual. This includes troubleshooting hardware and software problems, as well as operational procedures required for all possible activities.

7.3.3. Summary

The TMC Operations Manual provides an extensive number of call lists. Its detail of daily operations and control system operational procedures can serve as an excellent model for other TMCs, especially those that operate traffic signal systems. It is apparent that the use of figures and diagrams make the procedures simpler to follow versus using text descriptions only.

There are several maintenance fault monitoring and some simple troubleshooting procedures identified in the manual. There is also a call out procedure for contractor assistance for larger problems. Hardware maintenance procedures are compiled in a separate document.

There is no mention of formal operator logs in the SOP, although it is assumed there is logging capability within the system functionality. Furthermore, there are checklists for each shift and opportunities to exchange important information. There is no mention of data collection, data analysis, or data warehousing functions, but again it is known that the system offers these features to some degree. Performance measures are not mentioned in the manual, so their extent is not known. Effective dates or version identification of the SOPs are not presented.

There are extensive procedures for emergency situations, although nothing directly targeted toward emergencies impacting the TMC facility.

Likewise, there is no specific mention of a concept of operations document or a separate description of the system. It is assumed much of this information is documented elsewhere. Additionally, most of this information can certainly be derived from the manual contents.

7.3.4. Conclusions

While researching local agency TMCs, it was discovered that few have operations manuals, formal or informal. This was surprisingly found even with some of the more sophisticated TMCs.

Unplanned incidents are not as frequent for city TMCs as for freeway TMCs, and impacts are not as severe on city streets as they are on freeways and tollways. However, planned incidents are a greater concern for the city. Interagency arrangements for incident operations plans are important to local agencies. Generally, the effort is led by the state DOT. However, regional focus on signal operations has a greater impact on the city, who serves as a leader in that effort. The City of Orlando reflects these findings.

The standard manual developed by the original software system developer was not sufficient as an operations manual for the city. It did not cover every situation an operator encounters. Usually, such procedures are written from the software programmer's point-of-view, not sufficient for an operator.

Training needs are a key to TMCs, and the use of the manual as a training tool is very helpful. The TMC operator is a developmental position and requires on-the-job and formal training to advance to full performance level.

Although a very serious focused operation, a city TMC is less sophisticated than most freeway-based TMCs. Information from local agency TMCs seems to be less important to the media; there is no mention of

media communications in the SOP. Judging from recent outreach effort from ITE and the FHWA on the importance of signal timing operations, look for greater interest in local agency TMC operations in the near future.

Clearly, the City of Orlando TMC recognizes the need, importance, and value of an operations manual. This is exemplified by the 24/7 operation of the TMC. The management is aware of how to effectively integrate the use of an operations manual into their daily activities, procedures, policies, and programs. It is understood that many other activities occur in the TMC, such as other maintenance procedures, that are not documented in the manual. As the system grows to cover more areas outside of the city, it is expected the scope of the manual will increase.

8. TMC MANUAL CHECKLIST

8.1. Introduction

8.1.1. Chapter Purpose and Key Issues

The purpose of this appendix is to provide a checklist of topics for a TMS/TMC manual. Sections of this chapter are cross-referenced to discussions in chapter 5 of the *Handbook*. Relevant headings in this chapter are followed in parentheses by the applicable section in chapter 5.

8.1.2. Relationship to *Handbook* Document

This checklist is meant to support in a very specific manner the material provided in the *Handbook*. While much of the *Handbook* provides conceptual and procedural guidance on development of a manual, this chapter supplements that material with quick descriptions of the topics to be included in the manual.

8.2. Daily Operations (Section 5.3)

Components of an operations manual to support daily operations include the following.

8.2.1. Emergency and Other Contact Numbers (Section 5.3.1)

Quick reference for emergency situations:

- Police, fire, EMS, motorist assistance patrols, PSAP
- Street maintenance, freeway maintenance
- Private information providers, media
- Other

8.2.2. TMC Emergency Plan (Section 5.3.2)

Quick reference for emergency action in the control room (not related to traffic management or homeland security issues):

8.2.2.1. Evacuation (Section 5.3.2.8)

8.2.2.2. Fire (Section 5.3.2.1)

8.2.2.3. Smoke (Section 5.3.2.2)

8.2.2.4. Flood (Section 5.3.2.3)

8.2.2.5. Communications Loss (Section 5.3.2.7)**8.2.2.6. System Shutdown (Section 5.3.2.9)****8.2.2.7. System Startup (Section 5.3.2.10)****8.2.2.8. System Failure Recovery (Section 5.3.2.11)****8.2.3. General Policies (Section 5.3.3)**

Statement of general policies related to daily operation, security, administrative procedures, etc. Many of these policies may already be covered in an overall agency human resources or other policy.

8.2.3.1. Documentation of Manual Updates (Section 5.3.3.1)

- Version and date of current manual
- Change policy
- Update status and record

8.2.3.2. Procedure and Authorization to Change/Suspend Policy (Section 5.3.3.2)**8.2.3.3. Outside Agency Authority (Section 5.3.3.4)****8.2.3.4. Severe Weather Conditions (Section 5.3.3.5)****8.2.3.5. Authorization, Scheduling, and Handling of Visitors (Section 5.3.3.6)****8.2.3.6. Citizen Inquiry and Service Requests (Section 5.3.3.7)****8.2.3.7. Contact with Media and the Public (Section 5.3.3.8)****8.2.3.8. System and Non-System Equipment (Section 5.3.3.9)**

- General office equipment
- Operator specific equipment
- General agency property
- Telephone and fax usage

8.2.3.9. TMC Building Cleaning and Maintenance (Section 5.3.3.10)**8.2.3.10. Building Security (Section 5.3.3.11)**

- Allowable access to the building
- Passkeys/keypads and controlled access
- Allowable access to control, communication, and equipment rooms

8.2.3.11. Organization Chart and Work Shifts (Section 5.3.3.12)

Documentation of reporting schedule and standard work shifts.

8.2.3.12. Other Workplace Policies (Section 5.3.3.13)

Miscellaneous policies such as those mentioned below are typically covered by existing agency policies but need to be modified for the TMC.

- Breaks
- Drug-free workplace policy
- Meals
- Nondiscrimination
- Overtime
- Smoking policy
- Uniform and dress code

8.2.4. General System Operation (Section 5.3.4)**8.2.4.1. Management Center Functions (Section 5.3.4.1)**

General TMC functions. Refer to more detailed operations and functions in subsequent sections.

8.2.4.2. Control Center Description (Section 5.3.4.2)

- Location – street and mailing address, location within agency grounds, and latitude/longitude; include a map of the general area showing TMC location.
- Layout – general plan view layout of TMC building and detailed plan view of the control room:
 - Consoles
 - - Displays
 - - Voice communication devices
 - - Fire suppression
 - - Power source location
 - - HV/AC
 - - Data communications
 - - Network communications
- Personnel – typical staffing including job titles and brief duties and designated supervisor for shifts. Include operations, maintenance, and supervisory personnel contacts (home, pager, cell).

- Hours of operation – workdays, holidays, weekends, nights, special events, and emergencies.
- After hours on-call roster – contact numbers (home, pager, and cell).

8.2.4.3. Remote Operation (Section 5.3.4.3)

Circumstances for remote operation, authorization, and designated personnel.

8.2.4.4. Security Procedures (Section 5.3.4.4)

Control of access to interfaces and various levels of access.

8.2.4.5. Maintenance Checklist (Section 5.3.4.5)

Routine maintenance checks and minor repairs that may be performed by operators.

8.2.4.6. Coordination and Dispatch of Motorist Assistance Patrols (Freeway) (Section 5.3.4.6)

8.3. Operational Concepts – Freeway Management Systems (Section 5.4)

Overall concept description enabling user to visualize goals and objectives and how the discreet parts fit together to accomplish those objectives.

8.3.1. Goals of the Traffic Management System (Section 5.4.1)

Concise statement of goals and objectives of the TMS and how general components work together (detection, response, data collection and storage).

8.3.2. Interagency and Interjurisdictional Coordination (Section 5.4.2)

Description of the need for interagency and interjurisdictional cooperation and coordination with other stakeholders.

8.3.3. Malfunction Response (Section 5.4.3)

Dispatch maintenance, logging, testing.

8.3.4. Traffic Monitoring (Section 5.4.4)

Description of traffic monitoring devices such as:

- Speed detector monitoring and response
- Closed circuit television
- Recording video images
- Road construction monitoring
- Highway maintenance activity

8.3.5. Traffic Response (Section 5.4.5)

Response to planned or unplanned events and general description of functionality.

8.3.5.1. Dynamic Message Signs (DMS) (Section 5.4.5.2)

Overview of uses of DMS:

- DMS message priority
- Display of travel times
- Blank signs
- Operation of DMS by law enforcement personnel

8.3.5.2. Traffic Diversion (Section 5.4.5.1)

General description of when diversion is warranted and policy on diverting to specific roadways:

- Full freeway closure
- Partial freeway closure
- Diversion to roadways not under the jurisdiction of agency

8.3.5.3. Highway Advisory Radio (HAR) (Section 5.4.5.3)

8.3.5.4. Lane Control Signals (LCS) (Section 5.4.5.4)

8.3.5.5. Ramp Metering (Section 5.4.5.5)

8.3.6. Field Devices – Freeway Systems (Section 5.4.6)

Functional description and locations of field devices in TMS:

- CCTV
- Communication media
- Detectors
- DMS
- HAR
- LCS
- Ramp meters
- Other

8.4. Control System Operation Procedures – Freeway Management Systems (Section 5.5)

This section depends greatly on the individual system but typical functions can be modified or deleted if not applicable.

8.4.1. System Start-Up Procedures (Section 5.5.1)

8.4.2. System Shut Down Procedures (Section 5.5.2)

8.4.3. Operator Interface (Section 5.5.3)

Typical pictures of interfaces where applicable:

- Field communication
- CCTV
- DMS
- LCS
- HAR
- Police communication

8.4.4. Incident Management Procedures (Section 5.5.4)

Procedures vary widely among agencies but provide typical examples. Response includes both actions to be taken to respond as well as notification of other agencies.

8.4.4.1. Reported Incidents (Section 5.5.4.1)

8.4.4.2. Detected Incidents (Section 5.5.4.2)

8.5. Operational Concepts – Traffic Signal Management Systems (Section 5.6)

Overall concept description enabling user to visualize goals and objectives and how the discreet parts fit together to accomplish those objectives.

8.5.1. Goals of the Traffic Signal Management System (Section 5.6.1)

Concise statement of goals and objectives of the TMS and how general components work together (detection, response, data collection and storage).

8.5.2. Interagency and Interjurisdictional Coordination (Section 5.6.2)

Description of need for interagency and interjurisdictional cooperation and coordination with other stakeholders.

8.5.3. Control Area (Section 5.6.3)

Description of control area, number of signals, map, system boundaries, jurisdictional boundaries.

8.5.4. Traffic Signal Operations (Section 5.6.4)

Description by region/sector: isolated, pretimed, traffic responsive, system coordination, adaptive operation, etc.

8.5.5. Agency Responsibilities in Developing Signal Timing (Section 5.6.5)

Who within agency determines signal timing parameters, schedules, update frequency, etc.

8.5.6. Field Devices Traffic Signal Systems (Section 5.6.6)

Functional description and locations of traffic signal field devices in TMS:

- Signal heads
- Controllers
- Detectors
- CCTV
- DMS
- LCS
- Communication media
- Other

8.6. Control System Operation Procedures – Traffic Signals (Section 5.7)

This section depends greatly on the individual system but typical functions can be modified or deleted if not applicable.

8.6.1. System Start-Up Procedures (Section 5.7.1)

8.6.2. System Shut Down Procedures (Section 5.7.2)

8.6.3. Operator Interface (Section 5.7.3)

Typical pictures of interfaces where applicable:

- Operator console
- Signal system interface
- Field communication
- CCTV
- DMS
- LCS
- Police communication

8.6.4. Incident Management Procedures (Section 5.7.4)

Procedures vary widely among agencies but provide typical examples. Response includes both actions to be taken to respond as well as notification of other agencies.

8.6.4.1. Reported Incidents (Section 5.7.4.1)

8.6.4.2. Detected Incidents (Section 5.7.4.2)

8.7. TMC Maintenance Procedures (Section 5.8)

Routine maintenance to be performed by operators. Anything beyond that would be performed by contract or agency maintenance personnel.

8.7.1. Routine Maintenance (Section 5.8.1)

Typical daily checks, adjustments, and component exchange.

8.7.2. Preventative Maintenance (Section 5.8.2)

Scheduled by agency maintenance personnel or contractor.

8.7.3. Spare/Backup Equipment (Section 5.8.3)

Inventory of spare and backup equipment and listing of vendors and suppliers.

8.7.4. Emergency (Section 5.8.4)

Notification procedures for major failures.

8.7.5. Agency Maintenance (Section 5.8.5)

Listing of maintenance to be performed by agency personnel.

8.7.6. Contract Maintenance (Section 5.8.6)

Criteria for calling in contract maintenance, phone, fax, and pager listings and authorized agency personnel to authorize repairs.

8.8. System Operations Logs (Section 5.9)

Historical logging procedures (manual and automated) as determined by management within capability of specific system.

8.8.1. Incidents and Events (Section 5.9.1)

Planned and unplanned events, road closures, etc.

8.8.2. Operations (Section 5.9.2)

Operations periods, on-line/offline times, manual intervention, etc.

8.8.3. Maintenance (Section 5.9.3)

Malfunctions, outages, resolution of problem, etc.

8.8.4. Citizen Requests (Section 5.9.4)

Requests for service (e.g., signal timing, DMS displays).

8.9. System Reports (Section 5.10)

System evaluation operation parameters, etc.

8.10. Traffic Data Collection and Storage (Section 5.11)

Historical data, analyses, etc.

8.11. Risk Management (Section 5.12)

Guidance on what types of data to store and for how long in response to agency risk management policies.

8.12. System Documentation (Section 5.13)

Listing of available documentation and where it is stored or filed, procedures to update.

8.13. The Organizational Setting (Section 5.14)

The role of affiliated agencies in the operation of the transportation system.

8.13.1. Service Providers and Stakeholders (Section 5.14.1)

Missions, goals, functions, and services of affiliated agencies.

8.13.2. Agreements, Contracts, and Memoranda of Understanding (Section 5.14.2)

8.13.3. Advisory Functions of Related Organizations (Section 5.14.3)

8.14. Organizational Representation within the TMC (Section 5.15)

The manual should account for the physical presence as well as the level of operational functions that may be performed or the data and information that may be accessed.

8.14.1. Potential Agencies in TMC (Section 5.15.1)

8.14.2. Operating Agreements (Section 5.15.2)

8.14.3. Roles and Responsibilities (Section 5.15.3)

8.15. Performance Monitoring (Section 5.16)

8.15.1. Performance Measures (Section 5.16.2)

8.15.2. Other Aspects of Performance Measurement (Section 5.16.4)

- Data collection needs
- Establishing performance measurement thresholds
- Reporting performance measurement data

8.16. Summary of Life Cycle Timing and Resources

Table 8-1 summarizes when in the systems engineering life cycle each element of the inventory could be developed and what kinds of personnel resources could be engaged to help provide the information for those elements.

Table 8-1 Summary of Systems Life Cycle Timing and Resources for Content of a TMC Operations Manual

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources			
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles	
Inventory	5.2.1. Area of coverage	X					X			
	5.2.2. Functions	X					X			
	5.2.3. Services Provided	X					X			
	5.2.4. Field Located Traffic Control Devices	X	X			X	X		X	
	5.2.5. Highway Construction Plans			X					X	
	5.2.6. TMC Components	X	X						X	
	5.2.7. Stakeholders	X					X			
Daily Operations	5.3.1. Emergency and Other Contact Numbers	X				X	X		X	
	5.3.2. TMC Emergency Plan		X			X			X	
	5.3.3. General Policies	X		X				X	X	
	5.3.4. General System Operation	X	X				X		X	
Freeway System	Operational Concepts	5.4.1. Goals of the Traffic Management System	X					X		X
		5.4.2. Interagency and Inter-Jurisdictional Coordination	X					X		X
		5.4.3. Malfunction Response	X					X		X
		5.4.4. Traffic Monitoring	X					X		X
		5.4.5. Traffic Response	X					X		X
		5.4.6. Field Devices – Freeway Systems	X					X		X
	Operational Procedures	5.5.1. System Start-Up Procedures		X						X
		5.5.2. System Shut Down Procedures		X						X
		5.5.3. Operator Interface		X						X
		5.5.4. Incident Management Procedures		X						X

Table 8-1 Summary of Systems Life Cycle Timing and Resources for Content of a TMC Operations Manual (Cont.)

Category		Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
			Concept of Operations & Re-quirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Opera-tions Roles
Traffic Management System	Operational Concepts	5.6.1. Goals of the Traffic Signal Management System	X					X		X
		5.6.2. Interagency and Inter-Jurisdictional Coordination	X					X		X
		5.6.3. Control Area	X					X		X
		5.6.4. Traffic Signal Operations	X					X		X
		5.6.5. Agency Responsibilities in De-veloping Signal Timing	X					X		X
		5.6.6. Field Devices Traffic Signal Systems	X					X		X
	Operational Procedures	5.7.1. System Start-Up Procedures		X						X
		5.7.2. System Shut Down Procedures		X						X
		5.7.3. Operator Interface		X						X
		5.7.4. Incident Management Proce-dures		X						X
TMC Mainte-nance Proce-dures	5.8.1. Routine Maintenance		X			X			X	
	5.8.2. Preventative Maintenance		X			X			X	
	5.8.3. Spare/Backup Equipment		X			X			X	
	5.8.4. Emergency		X			X			X	
	5.8.5. Agency Maintenance		X			X			X	
	5.8.6. Contract Maintenance		X			X		X	X	
System Operation Logs	5.9.1. Incidents and Events		X			X			X	
	5.9.2. Operations		X			X			X	
	5.9.3. Maintenance		X			X			X	
	5.9.4. Citizen Requests		X			X			X	

Table 8-1 Summary of Systems Life Cycle Timing and Resources for Content of a TMC Operations Manual (Cont.)

Category	Handbook Section	Phase in Systems Engineering Process					Personnel Resources		
		Concept of Operations & Requirements	Design	Implementation & Integration	Testing & Verification	Operations	Planning & Change Agent Roles	Cross-Cutting Roles	Design, Procurement, & Operations Roles
	5.10. System Reports		X			X		X	
	5.11. Traffic Data Collection and Storage		X			X		X	
	5.12. Risk Management		X			X	X	X	
	5.13. System Documentation		X			X		X	
Other Organizations	Context	5.14.1. Service Providers and Stakeholders	X				X		
		5.14.2. Agreements, Contracts, and Memoranda of Understanding	X				X	X	
		5.14.3. Advisory Functions of Other Related Organizations	X				X		
	In the TMC	5.15.1. Potential Agencies in TMC	X				X		
		5.15.2. Operating Agreements	X				X	X	
		5.15.3. Roles and Responsibilities	X				X		
Performance	5.16.2. Performance Measures	X	X			X		X	
	5.16.4. Other Aspects of Performance Measurement	X	X			X		X	

