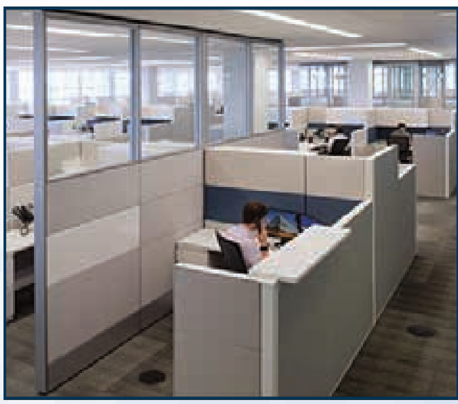
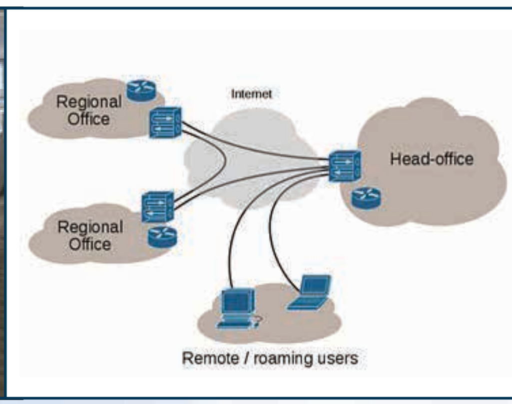
U.S. Department of Transportation
Federal Highway Administration

GUIDELINES FOR VIRTUAL TRANSPORTATION MANAGEMENT CENTER DEVELOPMENT





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16. Abstract

The purpose of project is to develop guidelines for the creation, implementation and operation of a Virtual Traffic Management Center (TMC). This guidebook is intended to serve as a detailed reference that addresses the concepts, methods, processes, tasks, techniques, and other related issues for practitioners to consider associated with planning and development for a virtual TMC. The guidebook describes the business planning process for developing a virtual TMC and provides guidance and procedures for addressing technical, operational and institutional issues such as data needs, communications, responsibilities, and agreements for collaborating remotely will be beneficial.

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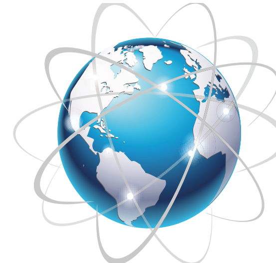


EXECUTIVE SUMMARY

The purpose of this document is to develop guidelines for the creation, implementation, and operation of a Virtual Traffic Management Center (VTMC). These guidelines identify the recommended procedures, roles, and responsibilities for planning and establishing a VTMC, as well as case studies highlighting transportation agencies that have gone or are considering going through this process.

It should be emphasized that the VTMC model or a hybrid virtual model is viable given the appropriate conditions, which include the right technical, institutional and political environments. It may not be a viable option for transportation agencies with existing Traffic Management Center (TMC) facilities; co-located with other entities; or with policies or procedures in place that prevent operators from working independently. However, this model may be a viable option and should be considered by transportation agencies looking to open a new TMC; merging two or more regional TMCs; monitoring rural areas; or wanting to enhance their back up or emergency operations.

What is a Virtual TMC?

Taking the definition of a TMC offered by the FHWA and fusing it with the computing world definition of "Virtual", the following is offered as the basic definition for "Virtual TMC":

A Virtual TMC is the function of monitoring, controlling, and managing the functional elements of a transportation management system through the use of computers and computer networks without being present at a physical nerve center or without the existence of such a physical nerve center. This includes the functions of monitoring, collecting, processing and fusing transportation system data; disseminating transportation information to outside entities; implementing control strategies that effect changes in the transportation system; and coordinating responses to traffic situations and incidents.

Current Practice

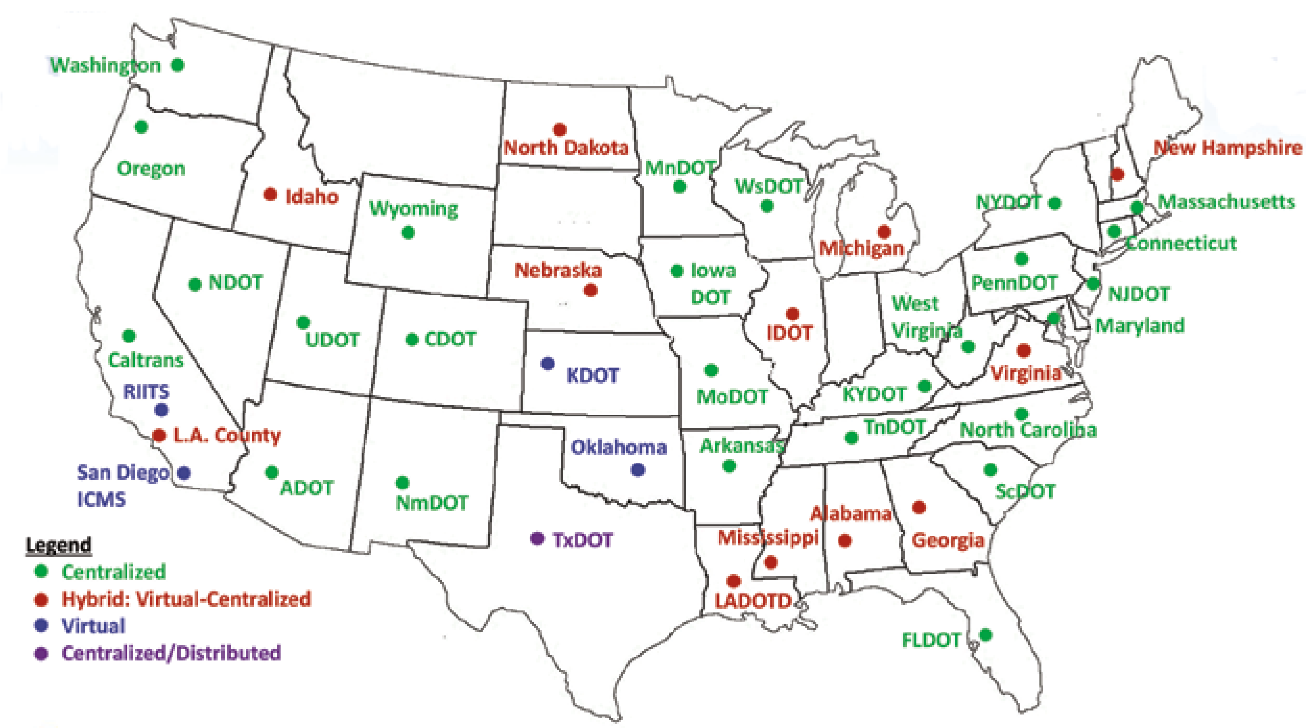
To achieve a better understanding of the current practices related to TMC Virtualization, various transportation agencies, including departments of transportation (DOT), were interviewed to determine their approaches to setting up and operating their facilities. All of the transportation agencies interviewed were entities known to have adopted Virtual TMC models, hybrid Virtual TMC models, or at least to have investigated Virtual TMCs as an option. Agencies that were contacted include: Alabama DOT, Los Angeles (LA) County, LA Metro, Michigan DOT, Minnesota DOT, New Hampshire DOT, Oregon DOT, San Diego Association of Governments (SANDAG), Oklahoma DOT and Kansas DOT, among others.

Types of TMCs

From the research conducted, TMC models can fall into four categories:

1. **Centralized** – In a centralized model, all systems reside in one location or datacenter (typically the TMC facility). This includes domain authentication services, email, applications, shared files and field devices. Remote sites can still have access using Thin Client devices and bandwidth friendly enablers (e.g. virtual private network (VPN) technology). Thin client refer to a network computer without a hard disk drive. Acting as a simple terminal to the server and require constant communication with the server as well.
2. **Distributed/Decentralized** – In this model, systems and staff reside in multiple locations/TMCs and certain functions or capabilities are distributed or shared between various centers. This arrangement provides agencies with the ability to maximize resources, increase efficiency, improve working relationships, and share costs. In this model, each site is mostly self-sustained, although some connectivity to the primary datacenter is required. However, each site is able to host its own email server, manage applications, control its internet access and host its own shared files. The TMC may have virtual control provided through the shared implementation of a wide-area network.
3. **Virtual** – Within this approach, the software and system application are available and are accessible from any location, so no physical TMC facility is necessary. There is still the need for physical communications to ITS field devices and between centers, but this is done in a virtual manner.
4. **Hybrid** – This is a combination of virtual and another model such as distributed or centralized. This can be a melding of performing certain functions in a centralized manner, as one example, and other functions as virtual. It also represents a model where a single large agency with multiple regions or districts elects to have one or two TMCs operate in some regions, but have other regions operate in a virtual manner without any TMC facility.

The map below provides a snapshot of the different models deployed throughout the United States. The research shows that the most common approached used is the Centralized Model, although there are Virtual TMC systems and several hybrid derivations.



Selecting the Virtual TMC Model

Implementation of a full Virtual TMC model or a hybrid model thereof requires various considerations to ensure it is the most suitable choice for a transportation agency or region. The table below outlines the advantages and disadvantageous of Virtual TMC operations followed by a series of questions that should be asked prior to deciding upon the Virtual TMC model.

Pros and Cons of the Virtual TMC Model

Advantages of Virtual TMCs	Disadvantages of Virtual TMCs
• **Capital cost savings** – Eliminates the need to construct TMC facilities which are large and more expensive to build compared to standard office space. • **Recurring Cost Savings** – TMC facilities require multiple recurring hardware and software maintenance contracts. • **Operate from any Location** – Virtual TMC operations require computer and software technologies that enable operations from anywhere. • **Staff Flexibility** – Staff can operate from anywhere including their homes during off peak and weekends. • **Staff Security** – In certain locations where staff's physical security is at risk, moving to a Virtual TMC model where staff is dispersed across multiple remote facilities can be an advantage. • **Multiagency Operations** – Virtual TMC operations is more conducive to regional multiagency operations.	• **Requires Broader Staff Capabilities** – Staff must be able to work independently and be knowledgeable of all SOPS, functions and operations. In a centralized model, tasks could be distributed to different staff more easily. • **Expanded/Revised Training Programs** – Operator training should be more extensive and comprehensive in this model. • **IT Security** – In the Virtual TMC Model, network security systems and policies will likely need to be extended. • **More Difficult Multi-staff Coordination** – Many agencies are dependent upon various staff being in the same physical. • **Existing Agency Agreements** – In many cases, there are existing agency agreements to share and operate facilities and systems together. • **Higher Computer Software and Systems Integration Costs** – To enable Virtual TMC operations, more complex and highly integrated software will be needed. • **Need for Physical Command Control Center** – Many agencies have the desire for command and control centers.

Here are some key questions to ask if you are considering a Virtual TMC:

- Are you thinking of building a TMC facility, but lack the necessary funding?
- Is there a lack of Operations and Engineering (O&E) resources to maintain ITS systems including TMCs?
- Are your existing TMCs facilities too costly to maintain?
- Is there a desire to start performing operations jointly with multiple agencies?
- Are your existing TMC applications integrated into a single platform?
- Are your existing TMC hardware and software systems conducive to Virtual TMC operations—e.g., web-based—or do we have a plan to convert them to this?
- Is there a desire to have operations staff dispersed across various physical locations?
- Does your agency support the use of web-based, virtual applications?

If the answer to most or all of these questions is yes, then Virtual TMC operations should be investigated as a possibility. This document provides guidelines and recommended action items/steps for agencies looking to entirely or partially virtualize their TMC operations.

1. INTRODUCTION

1.1. Purpose

A Transportation Management Center (TMC) acts as the nucleus for collecting, monitoring, verifying, and responding to traffic conditions often disseminating important information to other agencies and the public. Traditionally, a TMC encompasses a physical building, which may be part of a single agency or a multi-agency facility and managed by TMC operators and emergency responders (e.g., highway patrol). Nevertheless, with the introduction of newer communication, computing, and software technologies a physical TMC may no longer be the only solution. At this time, virtualized TMC operations are a reality and may be a viable alternative. Some agencies have adopted the Virtual TMC concept wholesale or have incorporated some portions of it into their operations, while other agencies are still investigating this notion.

The purpose of this document is to develop guidelines for the creation, implementation, and operation of a Virtual TMC. These guidelines identify the recommended processes, procedures, roles, and responsibilities for planning, implementing and operating a Virtual TMC. This report also presents case studies of agencies that have gone or are considering going through this process.

It should be emphasized that the Virtual TMC model or a hybrid virtual model is viable solution given the appropriate conditions, including suitable technical, institutional, and political environments. It may not be a viable option for agencies with existing TMC facilities, co-located with other entities, or with established policies that prevent operators from working independently. However, this model may be a viable option and should be considered by agencies looking to open a new TMC, merging two or more regional TMCs, monitoring rural areas, or wanting to enhance their emergency and back up operations. Ultimately, it is up to each agency to determine whether this model is right for them. This document provides guidelines and recommended action items for agencies looking to entirely or partially virtualize their TMC operations.

1.2. Intended Audience

The primary audiences for this document include:

- Agencies planning to implement, operate and maintain a TMC, and those considering partial or full functions of a Virtual TMC.
- Agencies currently operating a TMC and seeking to improve or expand their operations to include Virtual TMC functions.
- Agencies currently operating a TMC and planning to make operational changes in the near future.

1.3. Virtual TMC Related Definitions

1.3.1. Transportation Management Center (TMC)

The Federal Highway Administration (FHWA) defines a Traffic/Transportation Management Center as follows:

> *The Transportation Management Center (TMC) is the hub or nerve center of most freeway management systems. It is where the data about the freeway system is collected and processed, fused with other operational and control data, synthesized to produce "information," and distributed to stakeholders such as the media, other agencies, and the traveling public. TMC staff uses the information to monitor the operation of the freeway and to initiate control strategies that affect changes in the operation of the freeway network. It is also where agencies can coordinate their responses to traffic situations and incidents.*
>
> *The role of a TMC often goes beyond the freeway network and the particular responsible agency, functioning as the key technical and institutional hub to bring together the various jurisdictions, modal interests, and service providers to focus on the common goal of optimizing the performance of the entire surface transportation system. Because of its critical role in the successful operation of a freeway management system (and perhaps the broader surface transportation network), it is essential that the TMC be planned for, designed, commissioned and maintained to allow operators and other practitioners to control and manage the functional elements of the freeway management system, and possibly beyond.*[1]

This definition suggests that each TMC has its own features and organizational structure and operates in a unique setting appropriate to its geographical area, available technology, and jurisdictional needs. Clearly, this is a freeway-specific definition and there are TMCs that manage toll roads, arterial roadways, and transit systems, among others. Virtual TMC (VTMC) concepts can be applied to all these agencies and facilities.

1.3.2. Virtual TMC Definition

A definition of the word "virtual" is "being such in essence or effect though not formally recognized or admitted."[2] Other definitions in the context of the computing world include:

1. "Created, simulated, or carried on by means of a computer or computer network."
2. "……simulated by a computer systems as a convenient was to manage access to shared resources."
3. "Performing the functions of something that really is not there."

Taking the TMC definition from the previous section and fusing it with these definitions, the following is offered as the basic definition for Virtual TMC:

> *A Virtual TMC performs the function of monitoring, controlling, and managing the functional elements of a transportation management system through the use of computers and computer networks without having a presence at a physical nerve center or without the existence of such a physical nerve center. This includes monitoring, collecting, processing and fusing transportation system data; disseminating transportation information to outside entities; implementing control strategies that affect changes in the transportation system; and coordinating responses to traffic situations and incidents.*

1.3.3. Traffic Management Functions

Whether the TMC has a Virtual or a traditional setting, it will have a unique set of objectives, features, and defined organizational and operational structures based on its jurisdiction and subject to its needs. TMC activities will vary greatly depending on these factors. A VTMC may perform all or some of the "Traffic Management Functions" characteristic of a traditional TMC. These functions are described below and do not vary in the VTMC environment.

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1 FHWA, "Freeway Operations and Management - Transportation Management Centers" website, *http://ops.fhwa.dot.gov/freewaymgmt/trans_mgmnt.htm*; accessed November 5, 2013.

2 Merriam-Webster's dictionary

1.3.3.1. Typical TMC Functions

This section provides a brief overview of the most common functions supported by typical TMC operators as described the FHWA's TMC Operator Requirement and Positions Descriptions.[3]

The ability of the Virtual TMC to carry out the listed functions will depend on the scope of work for the center, the participation of partner agencies in the system's operations, the staffing model chosen for the center, etc.

Shown in Table 1 are the typical functions of a TMC and its relation to a Virtual TMC environment along with any possible constraints.

Table 1. Common TMC Functions

No.	Typical TMC Function	Description	Feasible in Virtual TMC Model	Observations
1	Provide travel information	Involves reporting highway conditions, delays, accidents, scheduled construction or other events, and preferred routes. The information may be disseminated through various means, including dynamic message signs, highway advisory radio, the Internet, and telephone traveler information systems	Yes	
2	Records management	Involves archiving and retrieving data about the operations and maintenance activities of the TMC. Activities include entering or recording data, generating and storing reports, and facilitating data warehousing.	Yes	
3	Congestion management	Involves identifying and responding to recurring congestion resulting from peak travel periods, as well as non-recurring congestion associated with incidents. Responses may include activating ramp meters, posting messages to dynamic message signs, traveler information sites (e.g. 511, wireless apps, etc.), HARs, adjusting signal timing plans among others.	Yes	
4	Failure management	Involves identifying, responding to, and repairing failures of transportation system-related field equipment.	Yes	Typically repairing failures would be responsibility of the field or maintenance crew.
5	Incident management	Involves detection, verification, response, and clearance of events including multi-car accidents, vehicle breakdowns, and accidents resulting from road debris or weather conditions.	Yes	
6	Special event management	Involves accommodating non-recurring events (such as sporting events, parades, motorcades, and construction) that are expected to have significant impact on the transportation system.	Yes	
7	Traffic flow monitoring	Involves viewing traffic data and video images in real time to evaluate traffic conditions for delays and hazards.	Yes	
8	Emergency management	Involves coordinating the response of emergency service providers (such as police, fire, EMS, and towing agencies) to emergency conditions (such as incidents, disabled vehicles, and signal malfunctions).	Yes	Depending on the systems the VTMC has in place and the operational setting for the VTMC.
9	Provide/coordinate service patrols	Involves identifying, verifying, and responding to requests for roadside assistance.	Yes	Depending on the systems the VTMC has in place.
10	Reversible and HOV lane management	Involves reconfiguring reversible lanes and HOV lanes, by manipulating gates and lane-use signals and visually verifying their status, to manage roadway capacity.	Yes	Depending on the systems the VTMC has in place. Highly likely it may require coordination with other staff/parties.
11	Traffic signal system management	Involves implementing appropriate traffic signal timing plans to optimize arterial street traffic flow, and responding to signal malfunction reports.	Yes	Highly likely to require coordination with Traffic Engineering Dept.

3 FHWA, *TMC Operator Requirements Position Descriptions*, unpublished draft report, December 2004.

No.	Typical TMC Function	Description	Feasible in Virtual TMC Model	Observations
12	Transit vehicle monitoring	Involves monitoring and evaluating transit vehicle operations to ensure schedule adherence and to identify and minimize delays.	Yes	
13	APTS system management	Involves monitoring and evaluating the performance of public transit vehicles and systems to improve system performance, and providing transit information to improve service to users.	Yes	
14	Environmental and Roadway Weather Information Systems (RWIS) monitoring	Involves monitoring weather related data (such as pavement temperature and surface conditions, visibility, and wind speed and direction) collected by remote sensors. The data are used to detect and forecast environmental conditions (such as icy roads or dense fog) that may affect travel on the roadway system.	Yes	
15	Over-height vehicle management	Involves the detection of and response to over-height vehicles to prevent accidents and damage to overhead structures.	Yes	
16	Rail crossing management	Involves monitoring railroad train operations and crossing control equipment such as signals and gates, and implementing appropriate response plans in the event of equipment malfunctions at crossings	Yes	Highly likely to require coordination with other staff/ agencies.

Furthermore, the National ITS Architecture provides a more detailed list of activities denoted in Table 2. Some of these activities may be difficult to perform in a virtual environment as they may require interaction and coordination with other groups within the same agency, external agencies, third-parties, etc.

Table 2. Services that a TMC May Perform[4]

List of Services	Feasible in Virtual TMC	Comments
Network surveillance	Yes	
Probe surveillance	Yes	
Surface street control	Yes	
Freeway control	Yes	
HOV lane management	Yes	
Traffic information dissemination	Yes	
Regional traffic control	Yes	
Traffic incident management system	Yes	
Traffic forecast and demand management	Yes	It needs support from Traffic Engineers
Electronic toll collection	No	Likely only monitoring and reporting
Emissions monitoring and management	Yes	
Virtual TMC and smart probe data	Yes	
Standard railroad grade crossing	No	Too complex of a process
Advanced railroad grade crossing	No	Too complex of a process
Railroad operations coordination	No	Too complex of a process
Parking facility management	No	Likely only monitoring and reporting
Regional parking management	No	Likely only monitoring and reporting
Reversible lane management	No	Requires extensive coordination and sophisticated systems
Speed monitoring	Yes	
Drawbridge management	No	Too complex of a process
Roadway closure management	Yes	
Transit vehicle tracking	Yes	

4 FHWA, Handbook for Developing a TMC Operations Manual, FHWA-HOP-06-015 (Washington, DC: November 2005). Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Handbook_TMC_Ops_Manual1.pdf*

List of Services	Feasible in Virtual TMC	Comments
Transit fixed-route operations	Yes	
Demand response transit operations	No	Requires coordination with others
Transit passenger and fare management	No	Requires coordination with others
Transit security	No	Requires coordination with others
Transit maintenance	No	Requires coordination with others
Multimodal coordination	No	Requires coordination with others. May be a much more complex system.
Transit traveler information	Yes	

The services mentioned above are accomplished by performing various "functions" described in Table 3.

Table 3. Functions Related to Services that a TMC May Perform

Functions Related to Services	Feasible in Virtual TMC	Comments
Barrier system management	No	Too complex of a system
Traffic surveillance data collection	Yes	
Highway-rail intersection (HRI) traffic management	No	Too complex of a system
Rail operations coordination	No	Requires additional coordination
System management safeguarding	Yes	
TMC environmental monitoring	Yes	
TMC evacuation support	No	Requires additional coordination
TMC for Automated Highway Systems (AHS)	Yes	
TMC freeway management	Yes	
TMC HOV lane management	Yes	
TMC incident detection	Yes	
TMC incident dispatch coordination/ communication	Yes	It will require proper systems and tools
TMC input to in-vehicle signing	No	
TMC multimodal coordination	No	Requires coordination with others. May be a much more complex system.
TMC multimodal crossing management	No	
TMC probe information collection	Yes	
TMC regional traffic control	Yes	
TMC reversible lane management	No	Too complex of a process
TMC signal control	No	Requires additional coordination
TMC speed monitoring	Yes	
TMC toll/parking coordination	No	
TMC traffic information dissemination	Yes	
TMC traffic network performance evaluation	Yes	
TMC work zone traffic management	Yes	
Traffic data collection	Yes	
Traffic maintenance	No	
Transit center security	No	
Transit evacuation support	No	
Transit garage operations	No	
Transit environmental monitoring	Yes	
Transit data collection	Yes	
Transit center tracking and dispatch	No	Requires additional coordination
Transit center para-transit operations	No	Requires additional coordination
Transit center multimodal coordination	No	
Transit center information services	No	

Functions Related to Services	Feasible in Virtual TMC	Comments
Transit garage maintenance	No	
Transit center fare and load management	No	

1.4. Choosing the Virtual TMC Model

The implementation of a full Virtual TMC model or a hybrid model thereof (which performs certain TMC functions in a virtual manner) requires a series of considerations to ensure it is the most suitable option for an agency or region.

This section presents information that can help agencies determine whether a Virtual TMC model is right for them. Table 4 outlines the advantages and disadvantageous of Virtual TMC model followed by a series of questions that should be asked prior to deciding upon the implementation of a VTMC.

Table 4. Pros and Cons of the Virtual TMC Model

Advantages of Virtual TMCs	Disadvantages of Virtual TMCs
• Capital cost savings – Eliminates the need to construct TMC facilities which are large and more expensive to build compared to standard office space. • Recurring Cost Savings – TMC facilities require multiple recurring hardware maintenance contracts to maintain video wall systems, UPS/Generator backup systems, special lighting and fire protection systems, etc. In addition, they require certain hardware systems to be fully replaced after a certain number of years; e.g., video walls. • Operate from any Location – Virtual TMC operations require computer and software technologies that enable operations from anywhere. This enables operations to still occur during emergency situations when a TMC building may need to be evacuated or when inclement weather makes commuting to physical buildings very difficult. • Staff Flexibility – With Virtual TMC operations, staff can operate from anywhere including their homes during off peak and weekends. Some agencies that have Virtual TMC capabilities allow such work location flexibility to their staff. • Staff Security – In certain locations where staff's physical security is at risk (e.g., at-risk government facilities), moving to a Virtual TMC model where staff are dispersed across multiple remote facilities can be an advantage. • Multiagency Operations – Virtual TMC operations is more conducive to regional multi-agency operations. Information sharing as well as shared device monitoring and control are more easily enabled through this model.	• Requires Broader Staff Capabilities – Staff must be able to work independently and be knowledgeable of all SOPS, functions and operations. In a centralized model, tasks could be distributed to different staff more easily. • Expanded/Revised Training Programs – Operator training should be more extensive and comprehensive in the model so remote operators understand all TMC functions, not just some. • IT Security – In the Virtual TMC Model, network security systems and policies will likely need to be extended. This will require more expensive hardware and software security systems. • More Difficult Multi-staff Coordination – Many agencies are dependent upon various staff being in the same physical location to interact; e.g., coordination between DOT and highway patrol staff during incidents. • Existing Agency Agreements – In many cases, there are existing agency agreements to share and operate facilities and systems together. • Higher Computer Software and Systems Integration Costs – To enable Virtual TMC operations, more complex and highly integrated software will be needed. • Need for Physical Command Control Center – Many agencies have the desire for command and control centers where many videos and applications can be displayed and viewed simultaneously on one common display. This will be lost in the Virtual TMC model.

Presented below are a number of key questions that agencies should ask themselves in order to help determine whether or not a Virtual TMC is a suitable option for their given environment.

- Are you thinking of building a TMC facility, but lack the necessary funding?
- Is there a lack of O&E resources to maintain ITS systems including TMCs?
- Are your existing TMCs facilities too costly to maintain/operate?
- Is there a desire to start performing operations jointly with multiple agencies?
- Are your existing TMC applications integrated into a single platform?
- Are your existing TMC hardware and software systems conducive to Virtual TMC operations, e.g. web-based or do we have a plan to convert them to this?
- Is there a desire to have operations staff dispersed across various physical locations?
- Does your agency support the use of web-based, virtual applications?

If the answer to most or all of these questions is yes, then Virtual TMC operations should be investigated as a possibility. If the answer to most of the questions is no, then the next set of questions may further assist an agency not entirely certain that a VTMC implementation is the best solution for them.

- Does your agency have existing TMC facilities in place?
- Is there long-term financial and institutional support to maintain these facilities?
- Are there institutional agreements in place to share TMC facilities?
- Is there a lack of multiagency agreements to jointly perform TMC functions?
- Does your agency have multiple separate applications used to perform TMC operations?
- Is the IT security policy in place that would prohibit Virtual TMC technology?
- Do you desire you TMC operations staff to physically sit together on one control center or facility?
- Are your existing agency TMC software applications thick-client or enterprise based applications?

If the answer to all or most of these questions is yes, then Virtual TMC operations may not be the best solution for that agency. However, if the answer to most of the above questions is “no,” then the agency should continue investigating the VTMC model. As an alternative any agency may also decide to launch a hybrid version of a Virtual TMC.

2. CURRENT TMC OPERATIONAL PRACTICES

2.1. TMC Deployment Models

This section provides a description of the industry's most common TMC types and models in the United States. There are four (4) typical models:

1. Centralized
2. Distributed
3. Virtual
4. Hybrid

It is common for TMCs to use a "hybrid" approach combining characteristics of two or more models. A large number of TMC in the United States have implemented the hybrid model.

2.1.1. Centralized

This model is usually managed by a single entity and it has straightforward lines of authority as well as established goals and objectives. Typically, the operational focus is based on local area issues, although coordination with neighboring agencies may still be necessary depending on existing inter-agency agreements. This approach can be located within the existing agency's facility and it can be staffed with in-house personnel. However, operations can also be outsourced under the supervision of the agency.

In a centralized model, all systems reside in one location or datacenter (typically the TMC facility). This includes domain authentication services, email, applications, shared files and field devices. Remote sites can still have access using Thin Client devices and bandwidth-friendly enables (e.g., virtual private network (VPN) technology). Benefits include lower capital and operational costs, greater data security (all data is stored in a secured datacenter), less backup complexity, co-location of all equipment (e.g., hardware) at one site, and minimized risk areas (e.g., internet access). The disadvantage of this model is that the remote's sites WAN connection could be a point of failure.

Typically, there are two implementation approaches:

- Single Centralized – this application is deployed in an overall region (e.g. Statewide)
- Multiple Centralized – this application is deployed in multiple regions, but each region oversees its own jurisdiction.

Figure 1 depicts a typical network architecture for this model.

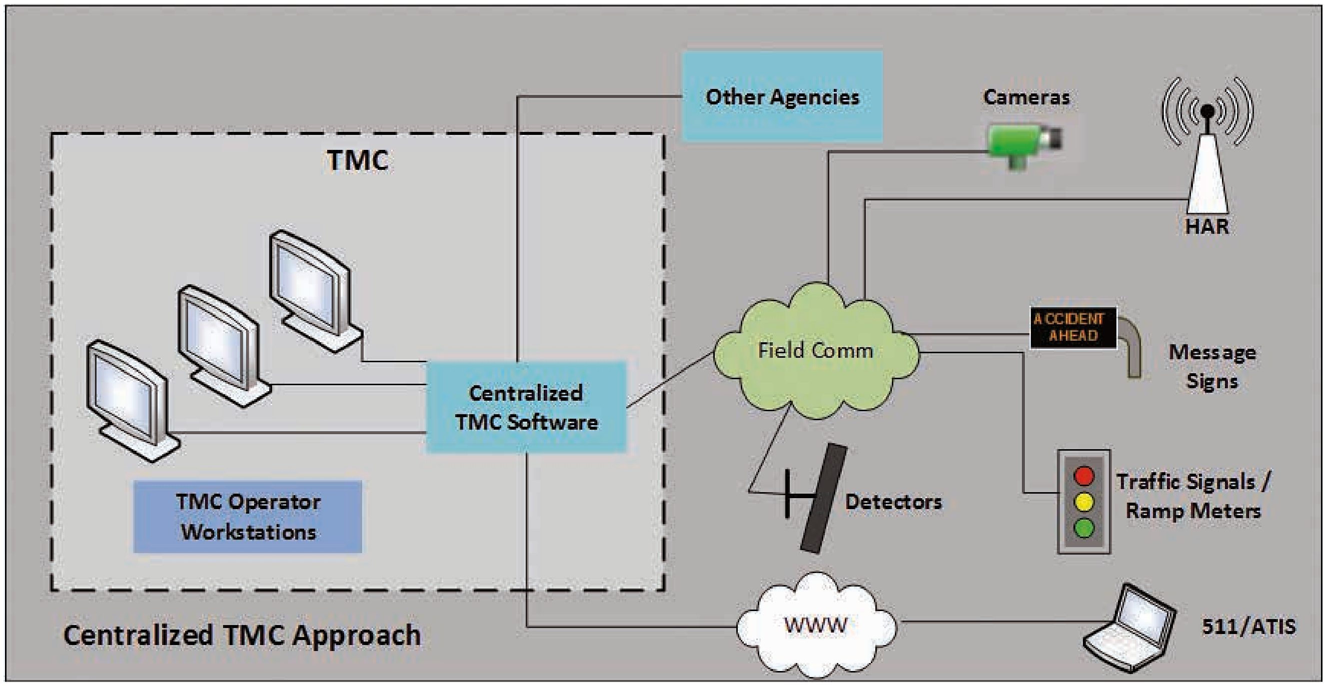

Figure 1. Graph. Centralized Approach

2.1.2. Distributed/Decentralized

This model is a joint program where various agencies reach agreement on policies and practices, structure, funding, staffing, asset sharing, and delineated roles for each agency. Generally, this operational model is applied to larger metropolitan areas that cross several jurisdictional boundaries.

In this model, systems and staff reside in multiple locations/TMCs and certain functions or capabilities are distributed or shared between various centers. This arrangement provides agencies with the ability to maximize resources, increase efficiency, improve working relationships, and share costs.

In this model, each site is mostly self-sustained, although some connectivity to the primary datacenter is required. However, each site is able to hosts its own email server, manage applications, control its internet access, and host its own shared files. The TMC may have virtual control provided through the shared implementation of a wide-area network (WAN). Localized management of signals and other traffic control elements ensures that the WAN is used for information and coordination rather than actual operations.

The benefit of this model is that there is no single point of failure as each site can survive on its own. The disadvantage of this model is cost as it requires additional hardware and software as well as support for each site.

Figure 2 depicts a typical network architecture for this model.

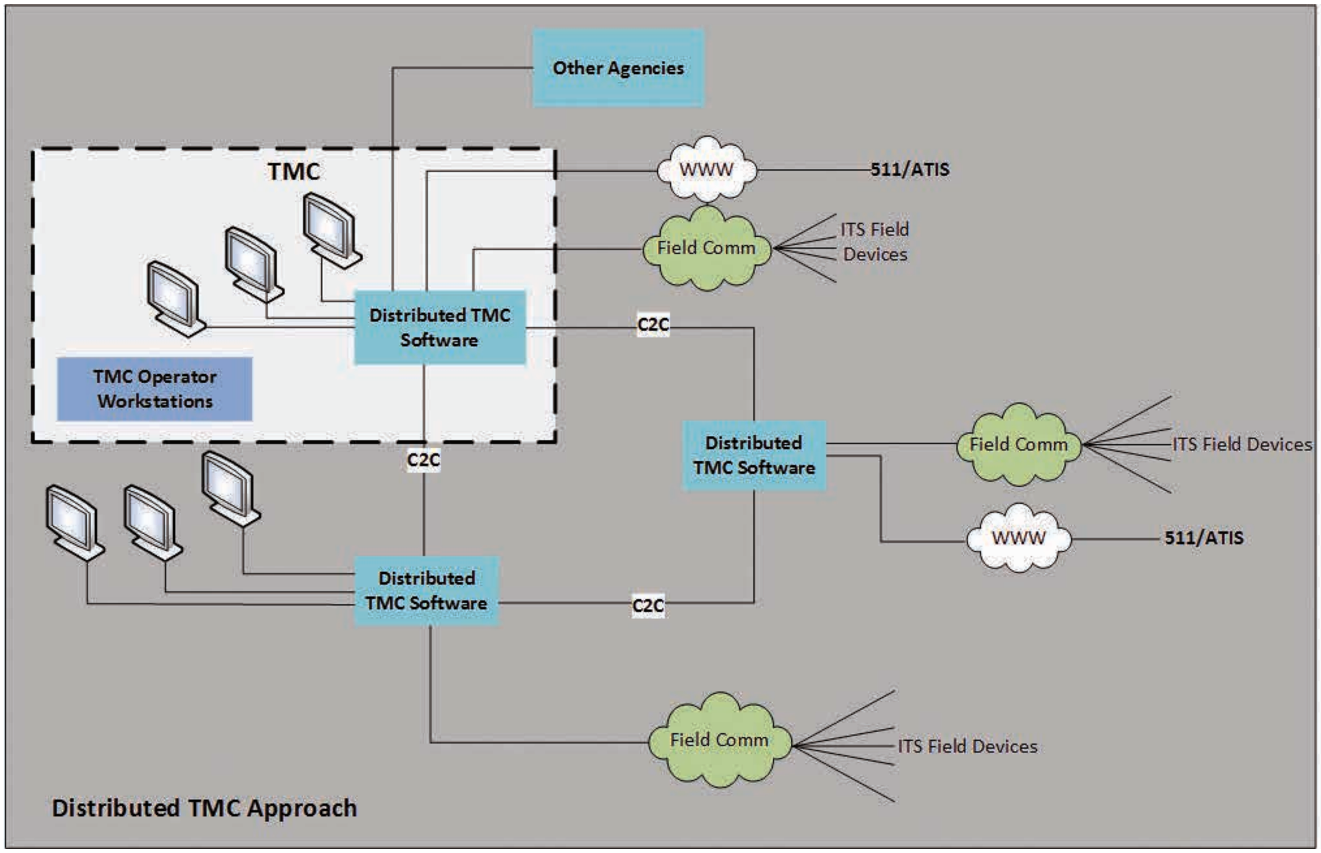

Figure 2. Graph. Distributed Approach

2.1.3. Virtual

This model may be applied in varying degrees to other operational models, or it may be deployed entirely on its own. Moreover, it needs to be supported with the appropriate ITS and communication infrastructure, and system security. If deployed on its own, the most common operational approaches include:

- Staffed and operated by a single entity; or
- Managed by a single entity with the operational support of partner agencies.

Depending on the jurisdiction, scope, operational approach and geographical area being covered, it may require extensive coordination and cooperation from participating agencies and stakeholders, as well as inter-agency agreements. Virtual access to the system may include both agency and interagency personnel.

Under this model, costs may be shared among the participating agencies or may be funded by a single entity.

Figure 3 provides a comparison of the Virtual TMC model alongside the two most common traditional models (Centralized and Distributed).

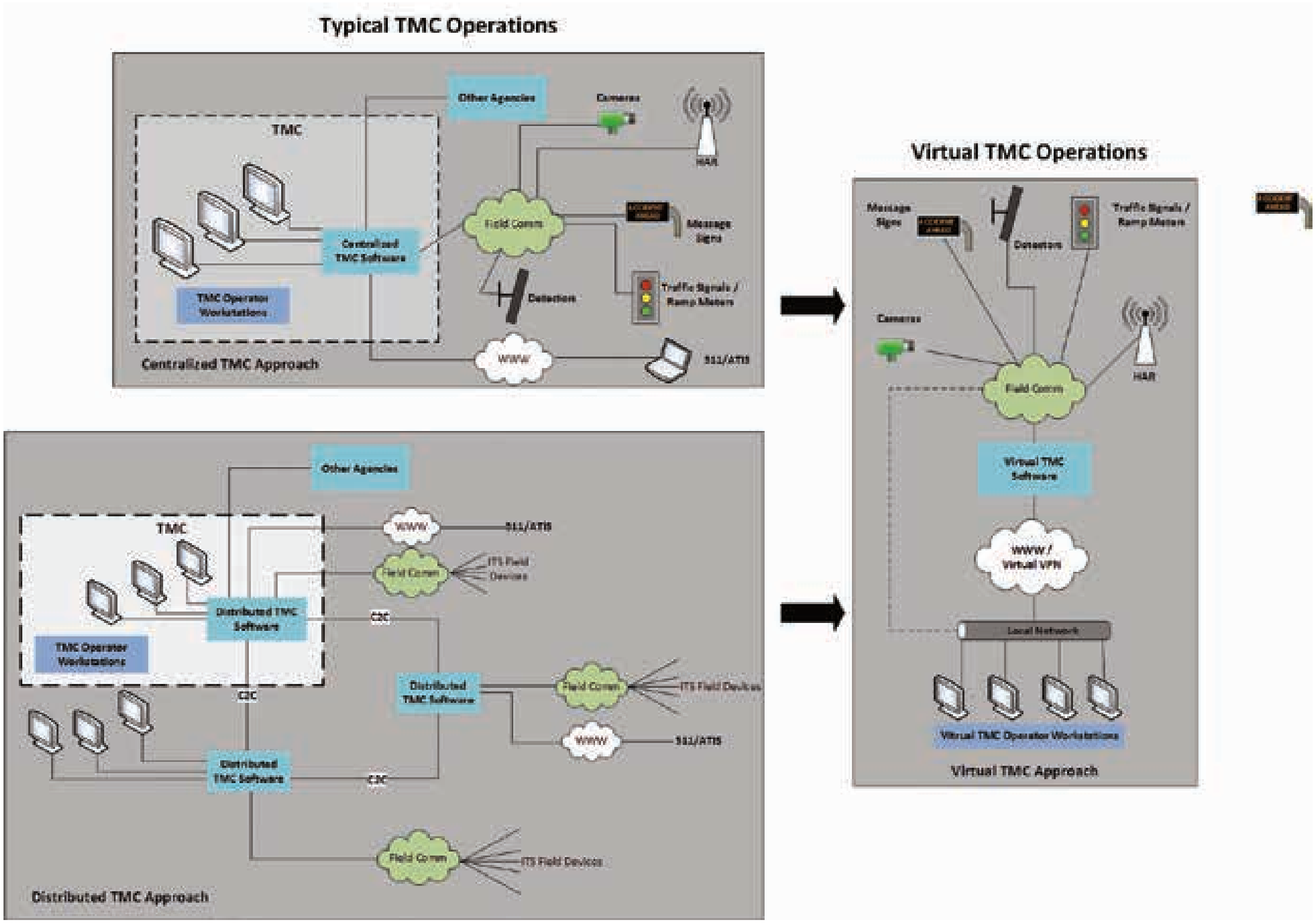

Figure 3. Graph. Model Comparison

2.1.4. Hybrid: Virtual

This model can be further divided into: Hybrid Centralized and Hybrid Distributed. The operational focus may cover an extended geographical area, which may include urban and rural regions.

In the Centralized version, all users are part of the same entity and share the same network. The main difference is that the network can be accessed via intranet or VPN. For example, District offices may be allowed to enter their own information (e.g. weather information collected from RWIS), manage their own events, etc.

In the Distributed version, the ATMS or any data input system is browser-based and accessible on the internet via Hypertext Transfer Protocol Secure (https) communication protocol. Users are able to log into the system from any place with internet connectivity. Access to the system will depend on privilege levels assigned to each user.

Currently, the majority of TMCs in North America have virtual capabilities. However, in most instances these have been established for Emergency Operations or as Backup Operations rather than as a stand-alone hybrid model.

In addition, typical TMCs are also managed based on their geographic area covered. The range and scope of the geographic service area of a traffic management center is dependent upon institutional, political, and economic considerations as well as the transportation management needs of the area.

Figure 4 depicts one of the hybrid models currently deployed in the United States.

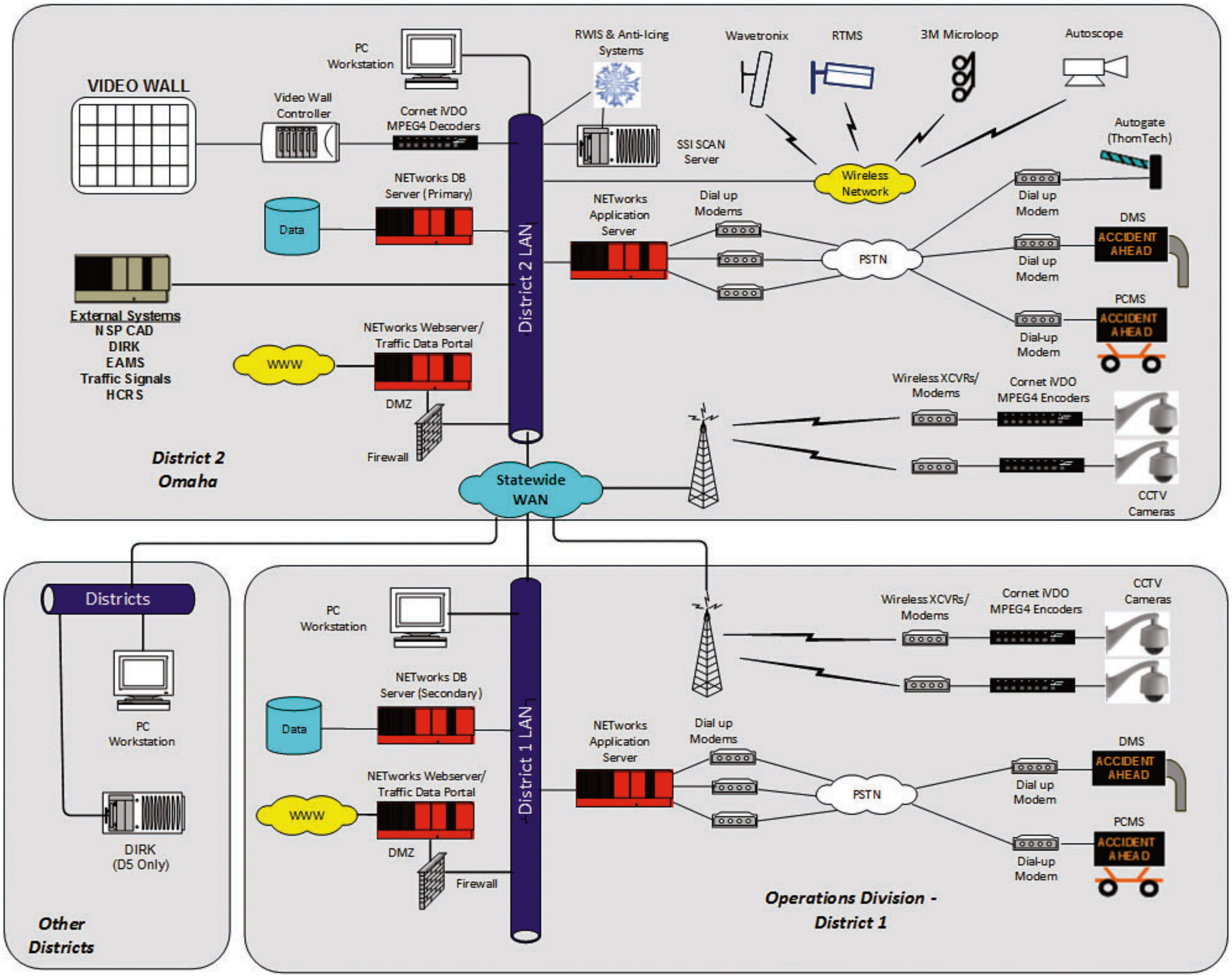

Figure 4. Graph. Hybrid: Virtual-Centralized[5]

Figure 5 depicts the other hybrid model currently deployed in the United States.

5 Nebraska Department of Roads (NDOR) District Operations Center Software Solution Deployment Plan, May 2007.

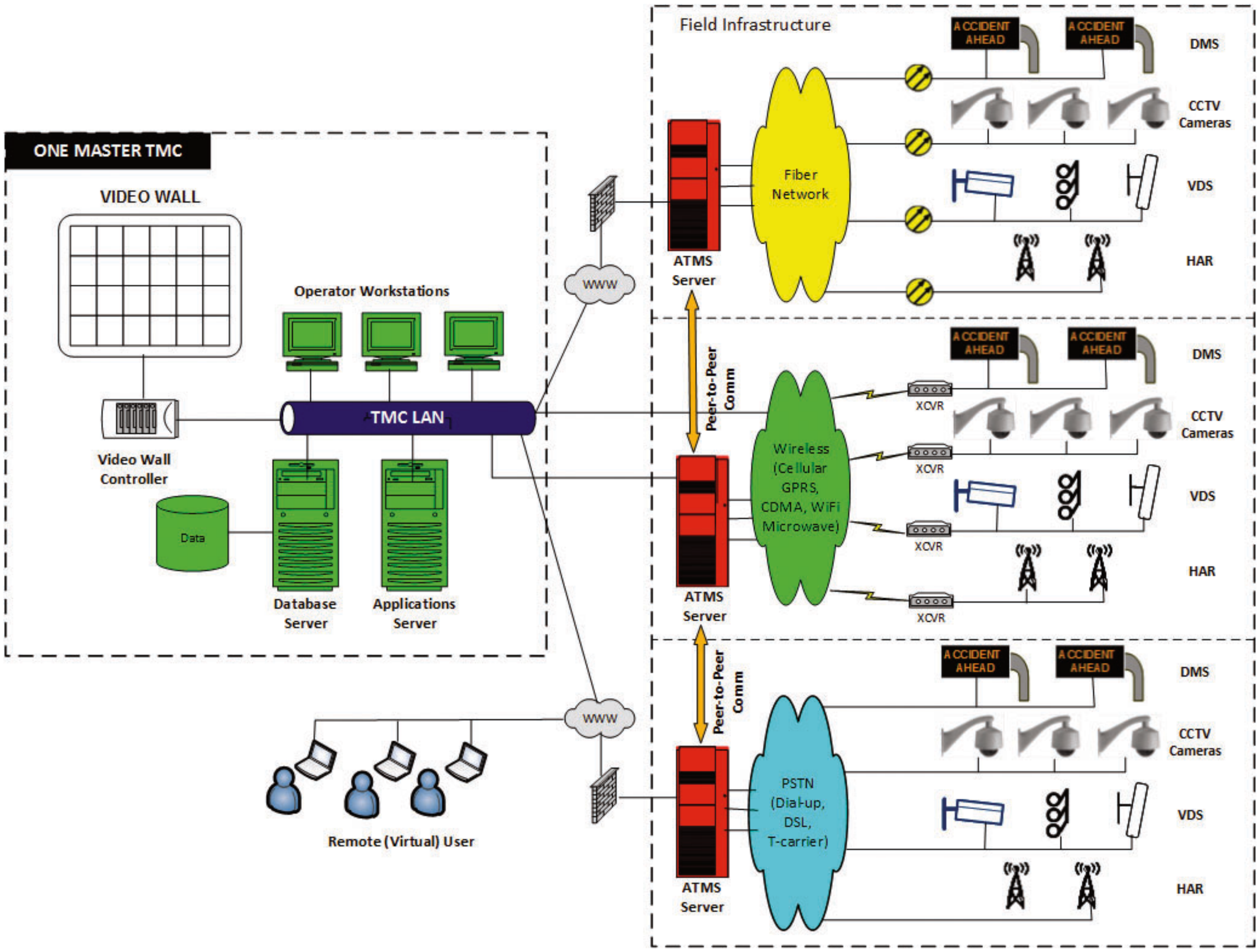

Figure 5. Graph. Hybrid: Virtual-Distributed

2.2. Geographic Area Covered[6]

As noted on the TMC Business Planning and Plans Handbook TMCs may serve single jurisdictions, multiple jurisdictions within a metropolitan area, a large region, or even an entire state. The following terminology is used when describing the various models:

- Jurisdiction – a city, county, or state;
- Agency – a transportation department, public safety department, or emergency management department; and
- Discipline – within a transportation agency, you might find a traffic engineering discipline, maintenance discipline, etc.

2.2.1. Single Jurisdiction TMC

Single-jurisdictional TMCs represent the least sophisticated business model arrangement. They serve a single city or county, typically are located in an office area of an existing facility such as a city hall or at the county department of transportation offices. In metropolitan areas with multiple jurisdictions, virtualization may help enable handoffs and coordination of operations with other TMCs through dedicated communications lines and networks.

Figure 6 depicts interaction among single jurisdiction, each responsible for their own ITS equipment (represented as circles in the figure below).

[6] FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005). Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

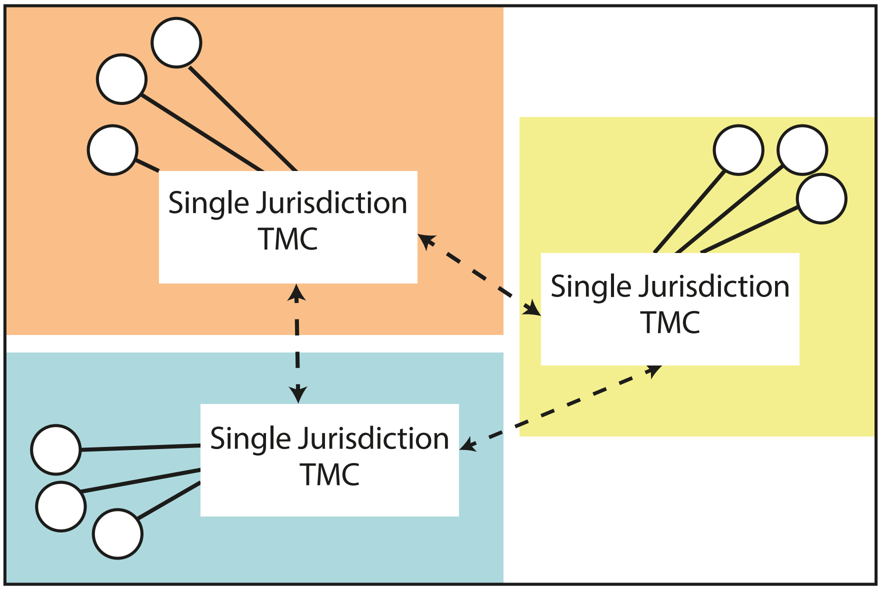

Figure 6. Graph. Illustration of Single-Jurisdiction TMCs[7]

2.2.2. Multiple Jurisdictions TMC

The multi-jurisdictional TMC controls ITS field elements in multiple jurisdictions (e.g. cities, counties), irrespective of political boundaries. Consequently, the number of miles of roadway, number of ITS elements, and the number of stakeholders is significantly larger than would be found in a single jurisdiction TMC arrangement.

Figure 7 depicts a TMC that controls ITS devices (represented as circles in the figure) and operates across political boundaries focusing on an entire metropolitan area.

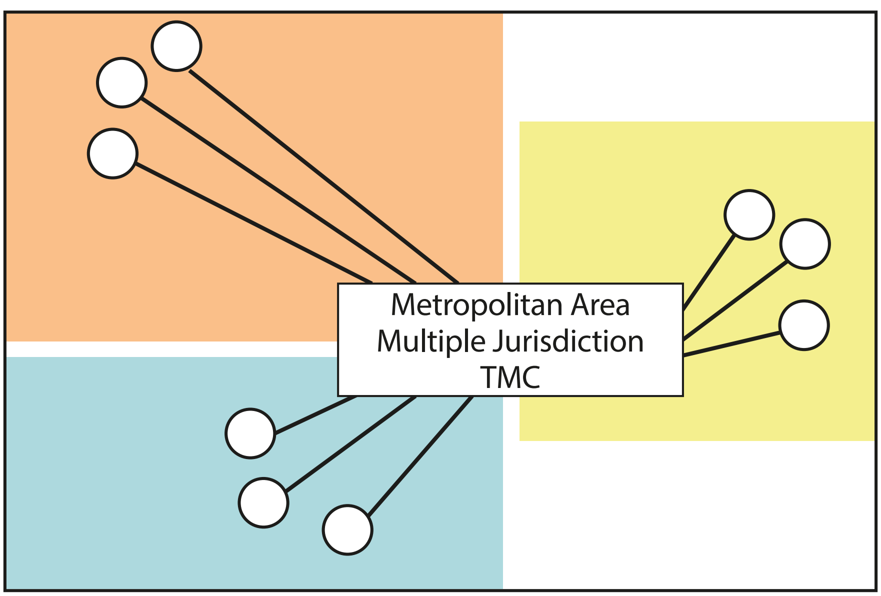

Figure 7. Graph. Illustration of a Multi-jurisdictional TMC[8]

7 FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005), p.4-3. Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

8 FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005), p.4-4. Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

2.2.3. Regional or District TMC

The regional or district TMC business model expands upon the multi-jurisdictional model in that it encompasses additional non-metropolitan areas such as county or state facilities outside of a metropolitan area, in addition to the multiple jurisdictions within the metropolitan area. The mission of a Regional or District TMC may include not only urban arterial traffic management, but also the operation and management of suburban, urban freeway, and rural highway and interstate facilities.

Figure 8 illustrates that the geographic area of a Regional or District Area may coincide with DOT districts, metropolitan planning areas, or other defined geographic boundaries.

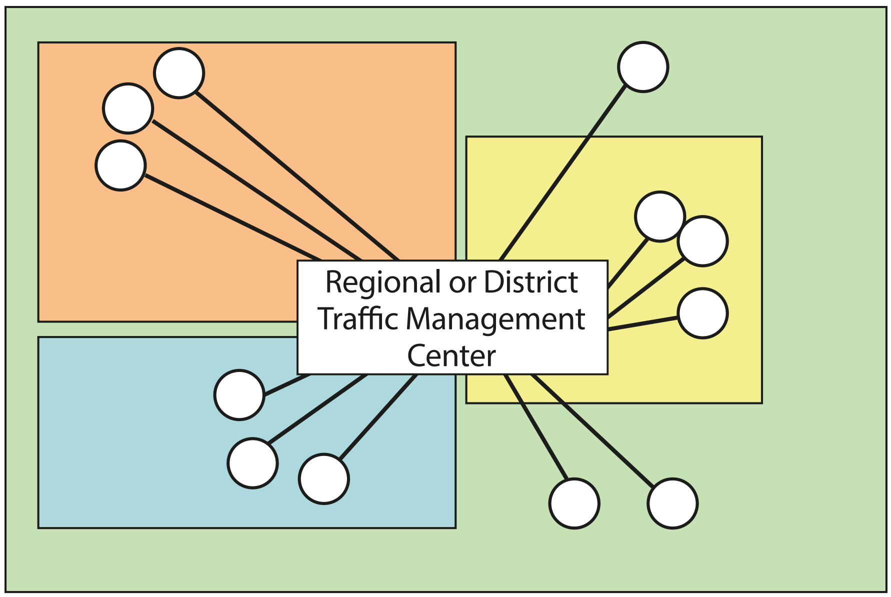

Figure 8. Graph. Illustration of a Regional or District TMC[9]

Virtualization of TMC functions benefits this model in particular by providing a means for mutual access to common systems and for remotely managing other systems (for instance rural systems that may not operate 24-7).

2.2.4. Statewide TMC

A statewide TMC is typically initiated by the State DOT, whose geographic service area encompasses the entire State. Some of these TMCs are operated by a single agency, while others have received participation from other state agencies such as the State Highway Patrol. A Statewide TMC can be implemented in a number of ways. The primary differentiator between the various alternatives is the level and scale of central control of the Statewide TMC. Typically, rural areas are monitored and managed by the Statewide TMC while metropolitan areas are under the supervision by Regional/District TMCs.

Figure 9 is an illustration of a statewide TMC that controls and monitors ITS devices statewide while a Regional TMC still has control over its own area.

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9 FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005), p.4-5. Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

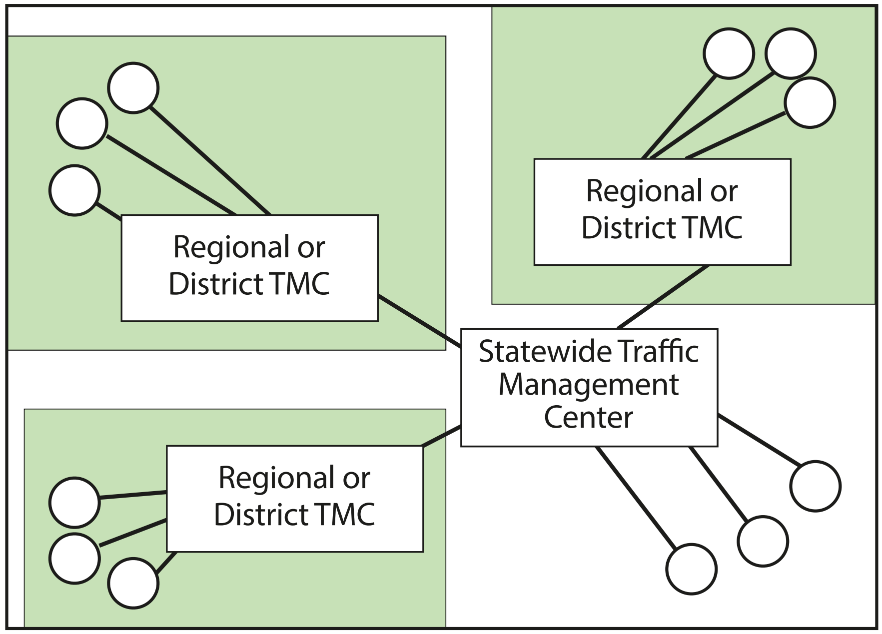

Figure 9. Graph. Illustration of a Statewide TMC[10]

2.3. Number and Type of Agencies Involved[11]

The number and type of agencies (such as a DOT, public works, or public safety agency) involved in the TMC significantly affects the functions and activities of the TMC. A number of different business models are available for TMCs relative to the number and types of agencies involved in the TMC planning and operation. Furthermore, multiple disciplines from a single agency may be participants in the TMC.

2.3.1. Single Agency TMC

The most common implementation of a TMC serves a single city, one county, or one state. The simplest of these single-jurisdictional TMCs, as described in the previous section, will likely include only a single agency or discipline within that jurisdiction. Typically, this would be the traffic engineering agency within a given city or county. Many of the same benefits that apply to a single jurisdiction TMC are applicable to the single-agency TMC model.

2.3.2. Multiple Transportation Agencies

A more sophisticated TMC model arises when transportation agencies from multiple jurisdictions come together to operate a single TMC. An example might be that the DOTs from two or more cities cooperatively join forces to sustain one TMC to handle both jurisdictions' transportation management needs. Such an arrangement may or may not include the police or emergency management personnel. Many of the benefits of the multiple-jurisdictional TMC are also applicable to the Multiple Transportation Agencies model.

2.3.3. Multiple Agencies and Disciplines

The Multiple Agencies and Disciplines TMC model is perhaps the most sophisticated, and as a result the most difficult to implement, but provides the highest potential payoff in terms of improved transportation operations throughout a region. Many of the same benefits of a multi-jurisdictional TMC model are also applicable to the multiple agencies and disciplines model.

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10 FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005), p.4-6. Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

11 FHWA, Transportation Management Center Business Planning and Plans Handbook (Washington, DC: 2005). Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

In this TMC business model, the transportation department, public safety department, emergency management department and transit department, or a combination of these agencies, shares a common facility. The agencies may be from the same jurisdiction, or from multiple jurisdictions. The most typical combination of these agencies includes the collocation of the transportation department and the public safety agency within a single TMC. Transportation and public safety are particularly complementary because of the overlap in their missions – to improve the safety of the transportation system, of which incident management is a core component. Logistically, the partner agencies are responsible for a common jurisdictional area. As an example, a State DOT could co-locate with the State Highway Patrol, while the city traffic engineering department co-locates with the local police department.

Historically, emergency management personnel (e.g., fire department) tend to be separate and only in rare instances are they known to co-locate with the transportation and public safety agencies. To help bridge this separation, more and more agencies are providing virtual connections between transportation and emergency management through integrated CAD systems and dedicated communications links so that critical information, including video images, can be shared. Multi-agency TMCs yield significant user, institutional, and system operations benefits.

2.4. Interview of Current Deployed Models

In order to achieve a better understanding of the current practices related to TMC Virtualization, various transportation agencies including DOTs were interviewed to determine their approaches to setting up and operating their facilities. Ten agencies were interviewed for this guidebook. The questionnaire supplied to them contained 18 questions which were used as input for the information shown in this report. The questions were organized into the following categories:

- General
- Traffic Management System (TMS) / System
- Operator Functions
- Virtual Capabilities
- Virtual – Cost Benefits
- Staffing
- Equipment – Operator Workstation
- Shared Operations
- Virtual Operations
- Virtual Implementation Challenges

Personnel at the following agencies were interviewed:

1. Alabama Department of Transportation (ALDOT)
2. Los Angeles County
3. Metro Regional Integration of ITS (RIITS)
4. Michigan Department of Transportation (MDOT)
5. Minnesota Department of Transportation (MnDOT)
6. New Hampshire Department of Transportation (NHDOT)
7. Oregon Department of Transportation (ODOT)
8. San Diego ICMS

A summary of the questionnaire responses are included in Appendix C.

2.5. Profile of the Agencies Reviewed

2.5.1. Alabama Department of Transportation

The Alabama Department of Transportation (ALDOT) is organized into nine geographic regions called Divisions, with a Central Office located in Montgomery.

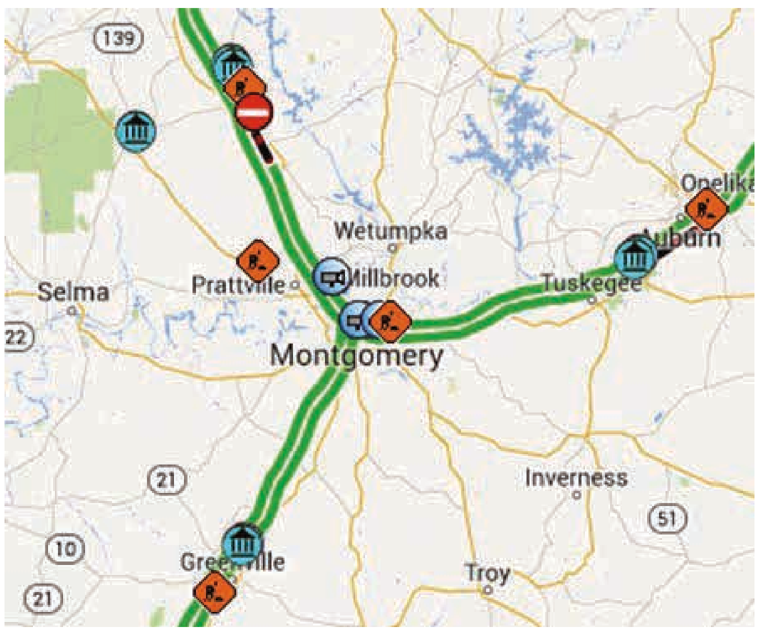
Deployment and Operations

There are 140 miles of Interstate Highways around the Montgomery Region. Currently, the traffic control center oversees 350 traffic signals and red light cameras plus 50-60 CCTVs.

ALDOT recently procured an ATMS system, which is browser-based and can be managed virtually. TMC operations staff and those with user privileges (e.g., supervisors, maintenance staff) will have the ability to perform all ATMS activities remotely. However, due to ALDOT's network security and rules the ATMS won't be accessible via VPN. The current VPN connection has a 22 minute delay and it needs to be upgraded.

Figure 10 shows a snapshot of ALDOT's traffic conditions in Montgomery County, which is available through the ALDOT's website.

Figure 10. Graph. Screen Capture from ALDOT Traffic Information and Cameras[12]



Initiatives

ALDOT is gearing up to open its new Statewide Regional Traffic Management Center (RTMC) in mid-2014. It is planned that the center would cover the road network for the entire state; however, during the initial launch only the Montgomery region and eight adjacent regions in the Southeast corner of the State will be covered. The TMC will operate from Monday-Friday 6am-6pm with morning and afternoon shifts.

At the opening of the RTMC, operations will not be shared or co-located with any other public agencies, although there is a possibility of doing so in the future with the Department of Public Safety and Highway Patrol, the latter operates 24/7. Operational sharing with the Highway Patrol may provide the RTMC the opportunity to operate around the clock.

The RTMC vision is to have an ATMS with virtual functionality in real time at a statewide level. The flexibility of

[12] Alabama Department of Transportation Traffic Information and Cameras. Available at: *http://alitsweb2.dot.state.al.us/its/*

ALDOT's ATMS system is that it can be operated remotely. This option may become available once the complete set of performance measures has been identified and coverage expands beyond the original 12 hrs. /day, 5 days/week.

Challenges

The biggest challenge that the RTMC faces is sharing the network with the rest of ALDOT, which requires authentication through the existing firewall. The ideal situation would be to have two separate networks, with one being for the exclusive use of the RTMC, since it has a set of needs that are distinct from those of the rest of the agency. Ideally, the separate network would allow for ISP service, and user identification/authorization would be made easier yet still be secure.

2.5.2. Los Angeles County

LA County operates signals for a number of cities and unincorporated cities within the county. The TMC is located in Alhambra and it operates Monday through Thursday from 7am to 5:30pm.

The Department is the hub for the Traffic Control System in the County. LA County also has a center-to-center connection to other cities, where they do not control those cities' signals, but have viewing capabilities and share data. Table 5 provides a snapshot of the number of cities participating in the program.

Table 5. LA County Overview

Traffic Control Systems	C2C	Intersections	Traffic Signals
15 cities	10 cities	670	1800

Deployment and Operations

The system in place is thick client-based with VPN access. It is in a virtual server platform with a terminal server setup. The system may be accessed remotely, although it is mainly used by maintenance crews and the cities that want access to it.

LA County has in place a substantial wireless radio network, which is monitored by their contractors, field maintenance crews, and the department's IT staff.

This is not a traditional TMC, and staff does not have the authority to make decisions regarding timing signals. If changes are needed, they must be approved first by the responsible staff at each agency. If LA County staff discovers an issues requiring immediate attention, operators contact the County Dispatch. In turn, County Dispatch notifies field crews. The agencies are also responsible for the maintenance of their system. However, in unincorporated areas operators can make changes to the signals based on their privileges at the TMC. Information is provided to operators by signal timing experts working on synchronization projects.

There are two agreements in place with each of the participating agencies: a VPN Access Agreement and a City Cooperative Agreement.

Challenges

Some of the challenges experienced at the beginning of the program were related to executing agreements with the cities and coordinating implementation with each agency's IT department.

2.5.3. Metro Regional Integration of ITS (RIITS)

The Los Angeles County Metropolitan Transportation Authority (Metro), sponsors the Metro Regional Integration of ITS (RIITS) network.[13] A number of agencies including Caltrans, City of Los Angeles Department of Transportation (LADOT), California Highway Patrol (CHP), Long Beach Transit (LBT), Foothill Transit (FHT) and Metro contribute information collected through their own Intelligent Transportation Systems to the network using the Los Angeles County Regional ITS Architecture and National ITS Standards. Table 6 shows the number of agencies (125) that participate in the RIITS program.

Table 6. RIITS User Numbers

Users	No. of User
LA County	88 agencies
Event Entry	30 agencies
Active Users (manual)	3 agencies
TOTAL # of agencies - 5 Counties: Los Angeles Orange, Ventura, Riverside and San Bernardino.	125 agencies

Deployment and Operations

The RIITS network supports information exchange in real-time between freeway, traffic, transit and emergency service agencies to improve management of the Los Angeles County transportation system and better serve the traveling public. RIITS also provides data to traveler information services of all kinds, which allows them to reach the widest possible audience.

RIITS is a unique system that combines the data of 125 agencies in the region. It is in essence the largest transportation system in the United States. The program ensures that agencies are able to provide their data to the system by advising each agency of the required hardware and software (e.g. networks, servers, applications (APIs)), and by providing training to IT staff.

Uptime for RIITS is 88 percent, although the system is currently being updated, and the new goal is to have RIITS up for 99.5 percent of the time.

RIITS does not operate as a traditional TMC; there are no RIITS operators. RIITS is rather a fully automated system (virtual) running 24/7. Each agency is responsible for providing its own data to RIITS. The system collects events, incidents, scheduled events, freeway performance, real-time transit, arterial traffic signals, and timing plans from all the agencies mentioned above. The information is collected for the counties of Los Angeles, Orange, Ventura, Riverside, and San Bernardino. The system belongs to Metro, but the data belongs to each provider.

RIITS is not a public facing system, the only component that has a Graphical User Interface (GUI) is the Event Entry section. The system is available through the internet but there is IP address security in place. It is configured to receive information from a number of pre-configured IP addresses. Event data entry does not reside at the same IP address where data is stored.

Agencies can choose to enter their data manually instead of using automation. The system can be accessed through a URL on the web or via a mobile application (event entry capability). Agencies that have signed up for manual entry have access to the system 24/7.

There are MOUs and Agency Agreements in place, as well as ISPS/Agency agreements.

Figure 11 depicts the network's architecture.

13 Los Angeles County Metropolitan Transportation Authority (Metro), "Regional Integration of Intelligent Transportation Systems" website. Available at: *www.riits.net*. Accessed April 6, 2014.

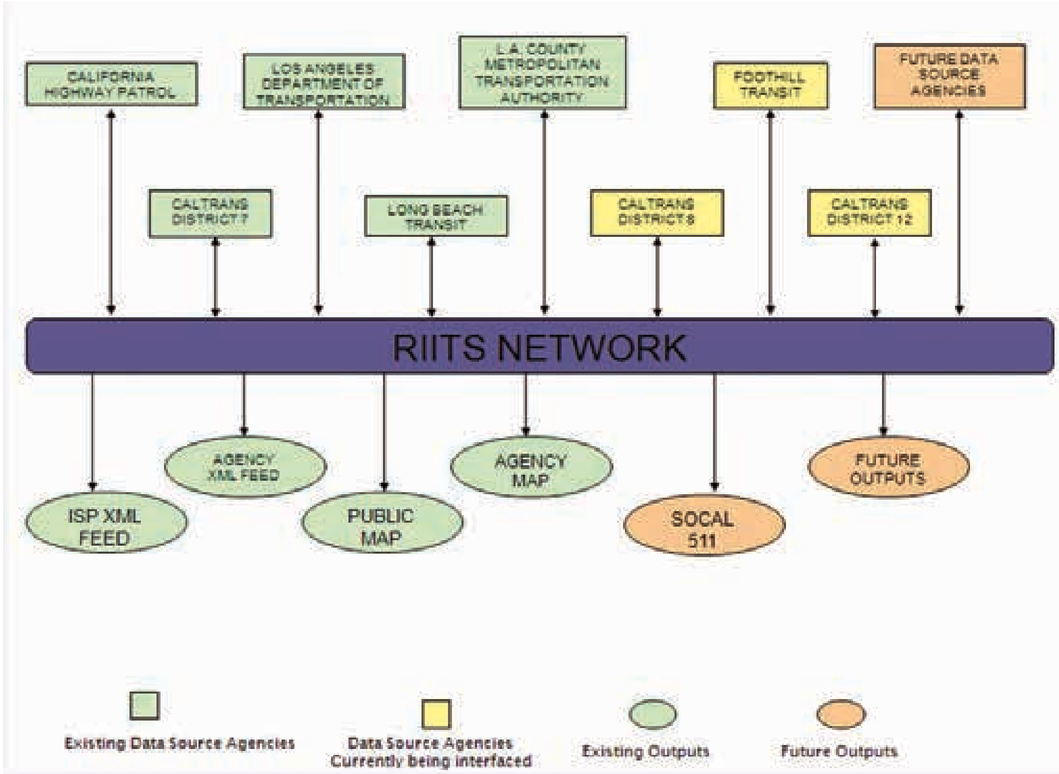


Figure 11. Graph. RIITS Network[14]

Figure 12 depicts the entire diagram of the network including the connection with other agencies.

[14] Los Angeles County Metropolitan Transportation Authority (Metro). Regional Integration of Intelligent Transportation Systems (RIITS) website. Available at: *www.riits.net* Accessed April 6, 2014.

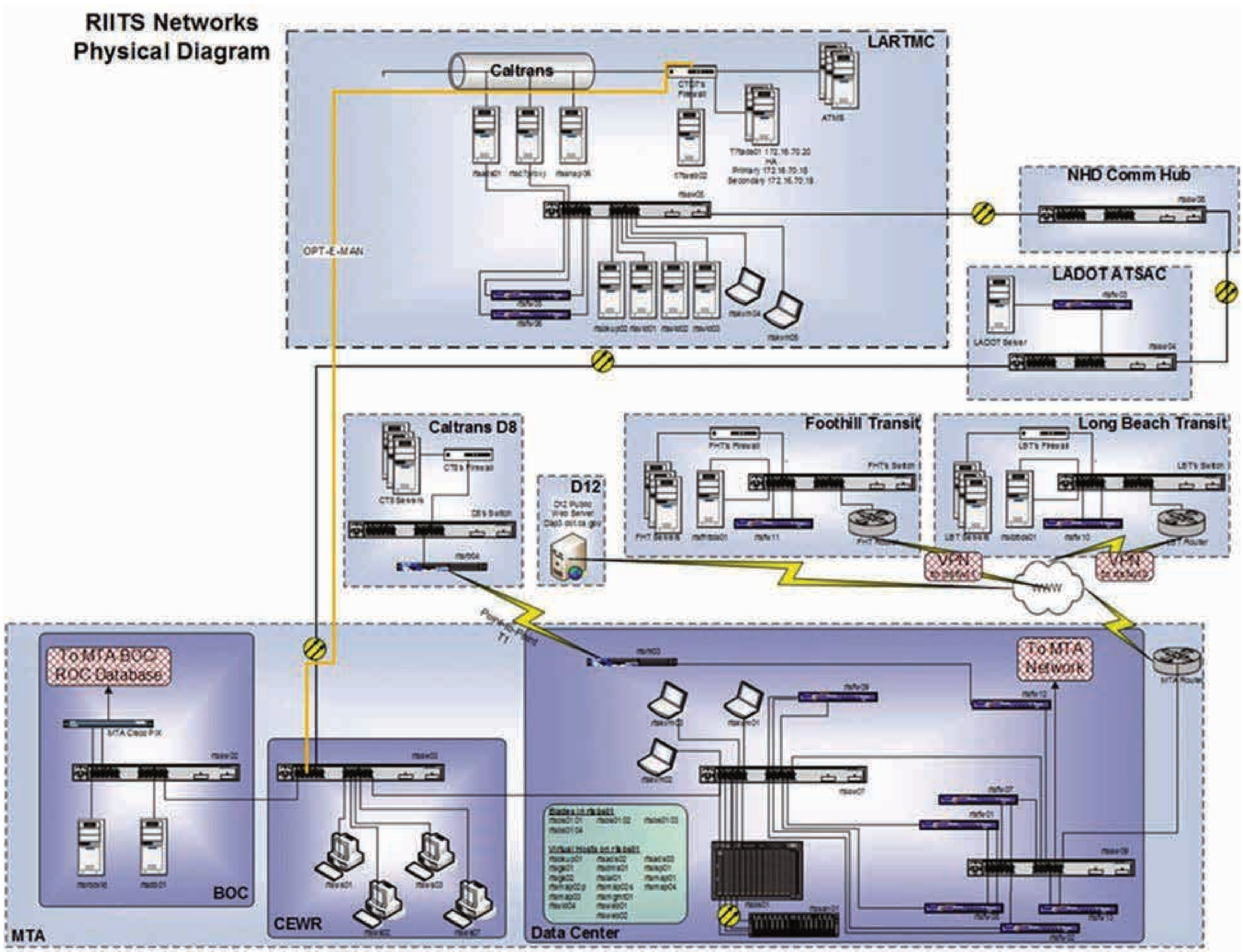


Figure 12. Graph. RIITS Networks Physical Diagram[15]

15 Los Angeles County Metropolitan Transportation Authority (Metro). RIITS Network Operations and Maintenance Manual. August 2014.

2.5.4. Michigan Department of Transportation

Deployment and Operations

The Michigan Department of Transportation (MDOT) has four TMCs in the state: the South Eastern Michigan Transportation Operations Center (SEMTOC) in the Detroit Metro Region, the Statewide Transportation Operations Center (STOC) in Lansing, the West Michigan Transportation Operations Center (WMTOC) in the greater Grand Rapids area, and the Blue Water Bridge (BWB) TOC. The SEMTOC and Statewide TOC operate 24/7, while the other two TOCs operate only during busy travel times.

The SEMTOC manages highway traffic in parts of the Metro Region (Wayne, Oakland, and Macomb counties). The West Michigan TOC manages highway traffic primarily within the region of Grand Rapids. The STOC manages traffic across the rest of the state.

MDOT is using a browser based ATMS system, which allows devices to be remotely monitored and managed. The ATMS is owned by MDOT, but it was developed and it is maintained by a contractor. The ATMS provides integrated control of DMS, CCTV and VDS, as well as integrated Event Management and Response Plans (for DMS and Notifications).

Michigan's TOCs coordinate response and disseminate information for activities on all MDOT-owned roadways. This includes urban, rural, and interstate facilities. There is coordination with other TOCs outside Michigan, and local TOCs within Michigan, but there are no formal agreements in place. The Michigan State Police dispatch and SEMTOC are co-located, and while they work together, there is no formal agreement in place for sharing information.

The staff at the TOC is contracted and allowed to work alone during overnight shifts. Access to the ATMS system is provided to TOC and MDOT staff. However, there are other users that have access to view information only. MDOT has formal data and video sharing agreements with various agencies and companies, including the National Weather Service (NWS), plus many media stations and other traffic information providers.

All centers cover over 1,247 freeway miles, 652 US route miles, and 171 State route miles. Operations staff mange 85 CCTVS (with plans to have about 130 more implemented by the end of 2014) and 190 DMSs. The network is monitored by TOC management.

Challenges

Some of the biggest challenges implementing virtual capabilities have been network integration and device communication issues.

2.5.5. Minnesota Department of Transportation

Deployment and Operations

The Minnesota Department of Transportation (MnDOT) has in place a Regional Transportation Management Center (RTMC) comprised of three functional areas all co-located at the center:

- Minnesota State Patrol Dispatch 24/7
- MnDOT Metro Maintenance Dispatch 24/7
- MnDOT Freeway Operations M-F, 4:30am - 10:00pm with limited weekend coverage.

MnDOT Metro Maintenance Dispatch and Freeway Operations staff cover the Twin Cities Metro Area. Freeway Operations covers urban freeways in the Twin Cities Metro Area. These roads are interstates, US routes, and State routes.

The Minnesota State Patrol Dispatch covers the northern 2/3 of the state including the Twin Cities Metro Area. In the Twin Cities, cameras and detection cover about 500 miles of freeways. The State Patrol has another dispatch center in Rochester for the southern 1/3 of the state.

There is an ATMS system in place called IRIS, which is open source software developed in-house by MnDOT. The TMC supports onsite and remote control of the CAD system, ramp meters, CCTVs, DMS and lane control devices (See Figure 13). IRIS also allows for streaming video from MnDOT's cameras and camera control. Even though the IRIS system allows for virtual capabilities, in practice MnDOT continues to maintain staffing at the RTMC. RTMC operators have remote access to IRIS, but at this time only supervisors use the system remotely.

Local media have IRIS access to cameras only and use the system to switch camera feeds.

The virtual capabilities could be utilized in an emergency should the RTMC be non-functional.

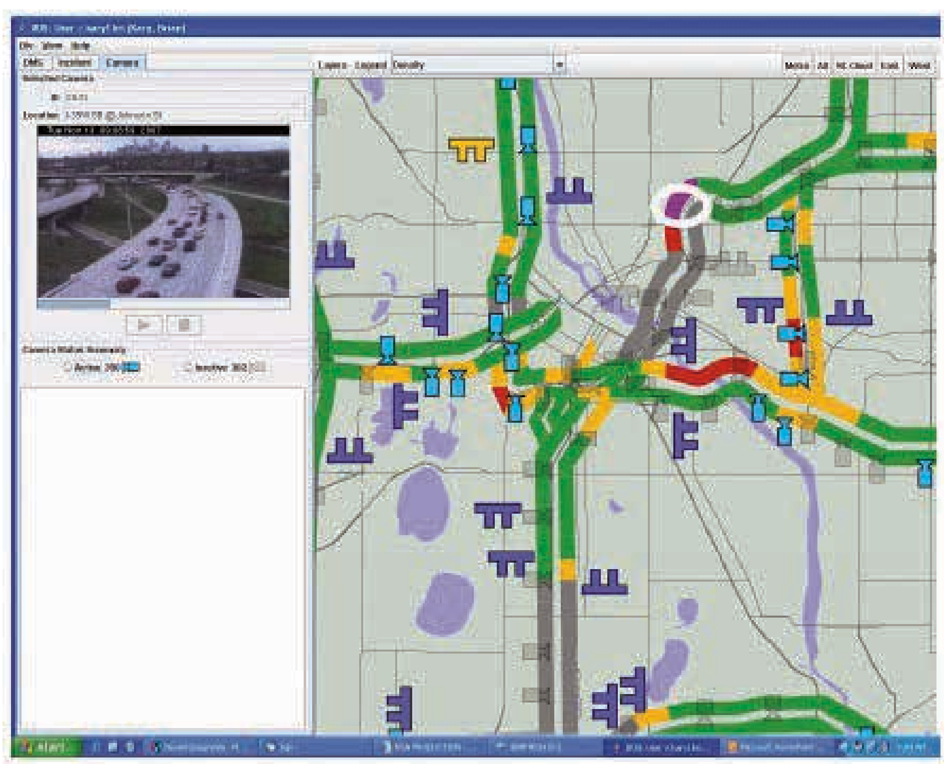


Figure 13. Graph. Screen Capture from the IRIS System Showing Interstate Congestion Levels[16]

[16] Starr, Ray. (2008). Mn/DOT IRIS Software [PP slide 7]. Retrieved from the National Rural ITS Conference: *http://www.nationalruralitsconference.org/downloads/Presentations08/MiniTraining_Open2.pdf*

2.5.6. New Hampshire Department of Transportation

Deployment and Operations

The New Hampshire Department of Transportation (NHDOT) has in place a 24/7 Statewide TMC. The TMC covers all NH routes throughout the state.

The TMC's scope includes functions that are atypical of a TMC, such as a statewide dispatch and call center that monitors environmental systems and manages construction work zones. The TMC is also responsible for maintenance dispatch operations and roadside assistance dispatching duties.

NHDOT has in place a browser-based ATMS system. District offices can access the ATMS only through the NHDOT VPN connection. All District Offices have been granted access to the ATMS with privileges to view other regions' information. At each District office one operator has access to input information into their Weather Module. District offices are open 24x7 from December to March, and weather data is input on the hourly basis. From April to November, the offices are open only during regular office hours and weather data is input five times per day.

Some of the servers are virtualized. Network monitoring is performed in house by the DOT's IT Department.

Figure 14. Graph. Screen Capture from New Hampshire DOT[17]

2.5.7. Oregon Department of Transportation

Deployment and Operations

The Oregon Department of Transportation (ODOT) has in place a 24/7 statewide TMC, which covers the Portland Metropolitan and surrounding counties, including part of Wheeler County.

The TMC scope of work includes monitoring and managing freeways, arterial roads and roads owned my ODOT. The TMC operates CCTVs on freeways and arterial roads, controls VMS, deploys traffic signals, monitors mountain passes and rural areas, and monitors a queue warning system, VSL, and travel time and curve warning systems (interchange between rural and urban area). In addition, operators also send traffic updates and notifications to various media outlets. TMC operation responsibilities also include dispatching Incident Response Vehicles to all freeways and some arterials in coordination with 911 to determine appropriate response plans.

ODOT has in place a browser-based ATMS system, which was developed by a private contractor with additional work being done to the system by ODOT and one of the local universities. The network and the system are monitored by ODOT's IT Department.

The ATMS has virtual capabilities including system access and system operations. At this time, only ODOT personnel have access to the system, including two District Offices. These users are connected to ODOT's network and do not require VPN access to manage the ATMS. However, designated personnel can view the system remotely. Remote connection is possible through VPN access.

The 911 system is not connected to the ATMS, but has shared access to the radio and CCTV feeds through the video switch. ODOT is working on a CAD interface.

[17] New Hampshire Department of Transportation Traffic Management Center. Available at: *http://www.nhtmc.com/*

Figure 15 below depicts the ODOT's Architecture Interconnects for Portland Area TMC operations.

Figure 15. Graph. ODOT's Architecture Interconnects for Portland Area TMC Operations[18]

2.5.8. San Diego ICMS

Deployment and Operations

The San Diego Association of Governments (SANDAG), United States Department of Transportation (USDOT) and the California Department of Transportation (Caltrans) deployed the San Diego I-15 Integrated Corridor Management System (ICMS). This ICMS is one of two integrated corridor projects in the United States.

The San Diego ICMS project is collaboration between SANDAG, local cities, and State and Federal transportation agencies to implement USDOT's vision that metropolitan areas can realize significant improvements in the efficient movement of people and goods through aggressive, proactive integration of existing infrastructure along major transportation corridors. It involves integration of technologies and concepts that have yet to be used in the United States. In San Diego, 13 agencies exchange data virtually through a data hub using a common application. The application is hosted in a third party data center. ICMS is a virtual system with no ICMS operators. The system is fully automated (virtual) and runs 24/7. Each agency provides data (input) and the system provides response plans (outputs) based on rules-based DSS, available assets, current and predicted traffic conditions and on-line Micro Simulation Analysis, as described in Figure 16 below.

[18] Oregon DOT System Architecture (Appendix C). *http://www.oregon.gov/ODOT/HWY/ITS/pdfs/itsdocuments/vastitsplan/appc_systems_architecture.pdf*

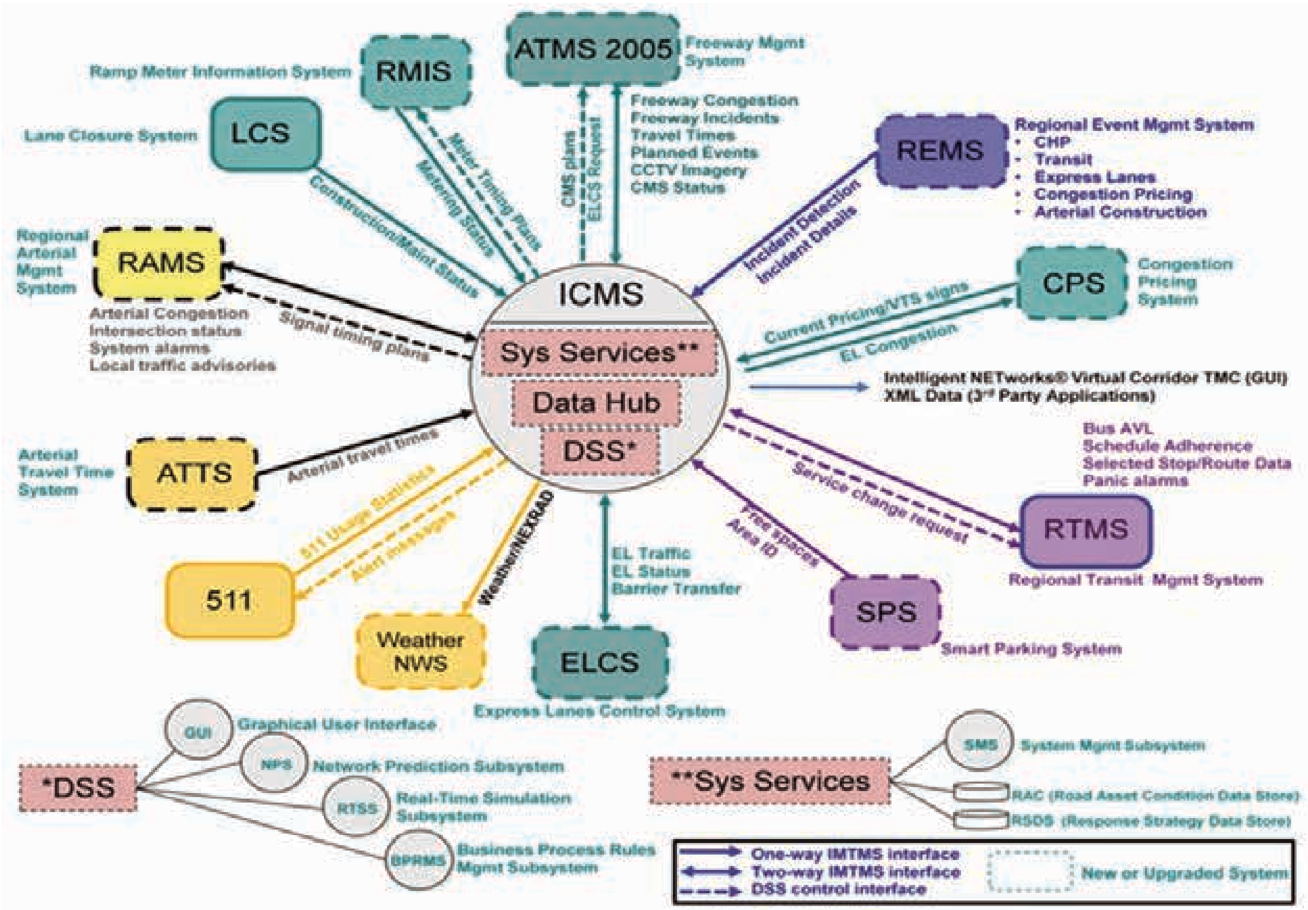


Figure 16. Graph. ICMS Inputs and Outputs[19]

Various Active Traffic Management (ATM) strategies were deployed to dynamically manage multiple facilities and modes along the corridor. These strategies include:

- Freeway coordinated adaptive ramp metering
- Signal coordination on arterials with freeway ramp metering
- Regional arterial management
- Real-time multimodal decision support
- Network traffic prediction
- On-line micro simulation analysis
- Real-time response strategy assessment
- En-route traveler information
- Pre-trip traveler information

Each agency's operators can now take proactive steps to prevent system breakdown using enhanced controls across multi-jurisdictional devices, such as traffic signals, ramp meters and dynamic message signs. This groundbreaking method of transportation management enhances mobility, improves goods movement, provides better accessibility to services, and enhances safety.

[19] San Diego Association of Governments (SANDAG). January 2014. ICMS System Architecture Document.

2.6. Current TMC Deployments

Figure 17 provides a snapshot of the different models deployed throughout the United States. The research shows that the most common approached used is the Centralized Model.

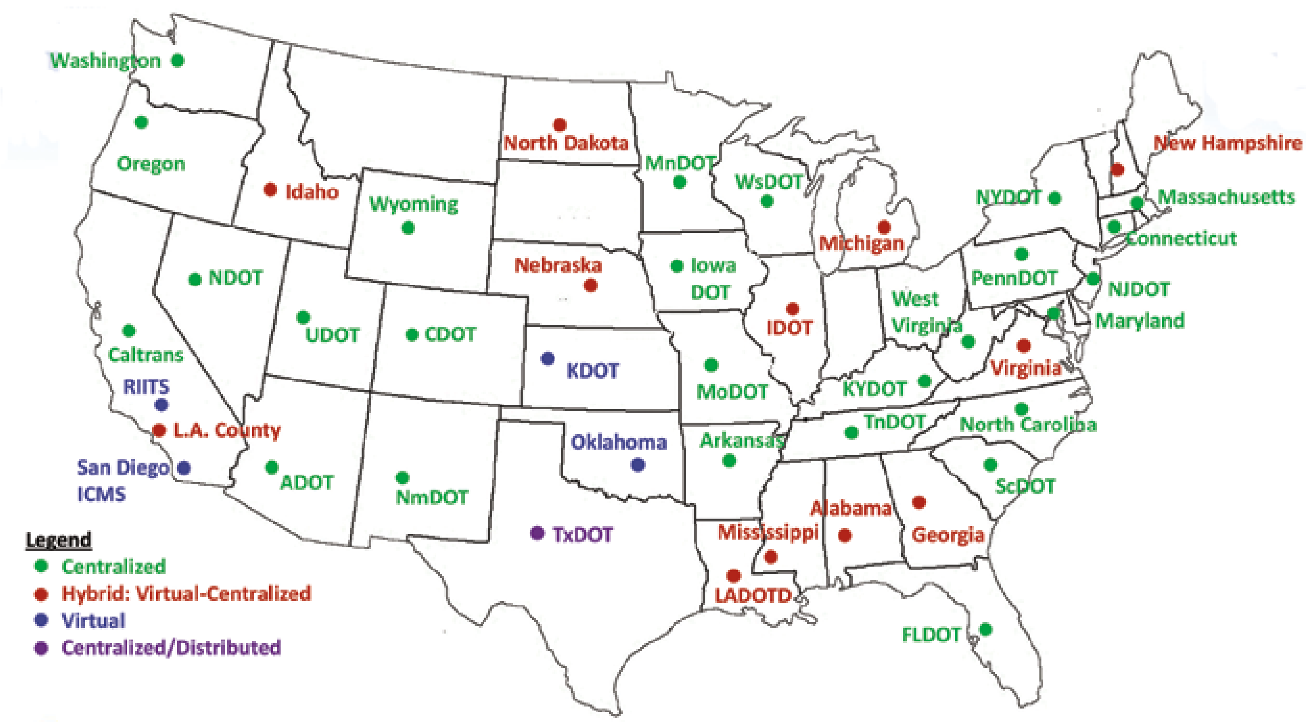


Figure 17. Graph. Map of Current US TMC Deployment Models

Table 7 shows the TMC model deployed by various agencies, as well as the geographic area covered at each TMC.

Table 7. Current US Deployment Models (based on above Map)

Agency/DOT	TMC Model				Geographic Area Covered			
	Centralized	Virtual	Hybrid	Centralized / Distributed	Single	Multiple	Region / District	Statewide
Alabama - ALDOT			●					☑
Arizona - ADOT	●							☑
Arkansas	●							☑
Caltrans	●						☑	
Colorado	●						☑	
Connecticut	●						☑	
Florida – FLDOT	●							☑
Georgia – GDOT			●					☑
Idaho – ITD			●					☑
Iowa DOT	●							☑
Kansas DOT		●				☑		
Kentucky - KYDOT	●							☑
LA County			●			☑		
Louisiana – LADOTD			●					☑
Maryland	●							☑
Massachusetts	●							☑
Michigan – MDOT			●				☑	
Minnesota – MnDOT			●			☑		☑
Mississippi DOT			●				☑	
Missouri – MoDOT	●						☑	
Nebraska DOT			●			☑		☑
Nevada	●					☑		
New Hampshire DOT			●			☑		☑
New Jersey DOT	●					☑	☑	
New Mexico	●							☑

Agency/DOT	TMC Model				Geographic Area Covered			
	Centralized	Virtual	Hybrid	Centralized / Distributed	Single	Multiple	Region / District	Statewide
New York	●						☑	
North Carolina	●							☑
North Dakota			●					☑
Oklahoma DOT		●						☑
Oregon – ODOT			●				☑	☑
PennDOT	●						☑	
RIITS (Metro)		●				☑		
San Diego ICMS		●				☑		
South Carolina – ScDOT	●							☑
Tennessee - TnDOT	●						☑	
Texas DOT				●			☑	
Utah DOT	●							☑
Virginia – VDOT			●				☑	
Washington - WSDOT	●						☑	
West Virginia	●						☑	
Wisconsin – WsDOT	●		●					☑
Wyoming	●							☑

● TMC Model (yes)

☑ Geography Type (yes)

3. VIRTUAL TMC IMPLEMENTATION GUIDELINES

This section presents a set of guidelines and considerations that aim to help in the implementation a Virtual TMC, keeping in mind that there are similar steps between implementing a Virtual TMC and a traditional TMC. Although the steps may be similar in both cases, the implementation and design approach will be different between the two. The main difference between both models is the absence of a main facility with a control room. Presented here is a list of steps that should be followed during the Virtual TMC implementation process, including the initial planning and design stages, system security and training program.

3.1. Virtual TMC Implementation Steps

Once the decision has been made to implement a Virtual TMC or hybrid derivation thereof, the following are the recommended steps that should be executed along with a description of each task that should be completed.

1. Develop Existing Systems and Needs Assessment

A description should be prepared for each system that will become virtualized. This includes the individual agency subsystems and any multi-agency connections, if the Virtual TMC deployment is to be a multi-agency model.

A high level needs assessment should be prepared to describe the following areas:

- Physical Communications
- Logical Communications
- Data and Information Needs
- Operational Needs
- Software System Needs

A high-level logical architecture should be prepared during this stage.

2. Develop Virtual TMC Concept of Operations

The Concept of Operations serves as the foundational document that addresses the who, what, when, where, why, and how for the new system. It should be accessible to all stakeholders in the system, regardless of their background or role in the system. High-level decision makers and Virtual TMC operators alike should find the document relevant and readable.

The Concept of Operations document is produced early in the requirements definition process to describe what the system will do (not how it will do it) and why (rationale). It should also define any critical, top-level performance requirements or objectives (stated either qualitatively or quantitatively) and system rationale.

The Concept of Operations document should present at a minimum:

- Identification of system stakeholders

- Definition of the high-level system
- Description of key sub-systems
- Identification and functions of user groups
- Description of the environment in which the system will operate

The Concept of Operations is also the critical initial component of the Systems Engineering approach to project development, which is recognized as the preferred method for facilitating the development, maintenance, refinement, and retirement of dynamic, large-scale systems consisting of both technical components (machines, information systems, etc.) and human components (users, stakeholders, etc.). The Systems Engineering method in the context of planning and developing Virtual TMCs. Figure 18 also known as The System Engineering "Vee" diagram illustrates the foundational role the Concept of Operation plays in the System Engineering life cycle. It defines goals and objectives, creates basis for defining functional requirements, helps to validate the finished system, and generally supports all other system engineering elements by providing a guiding vision for the system.

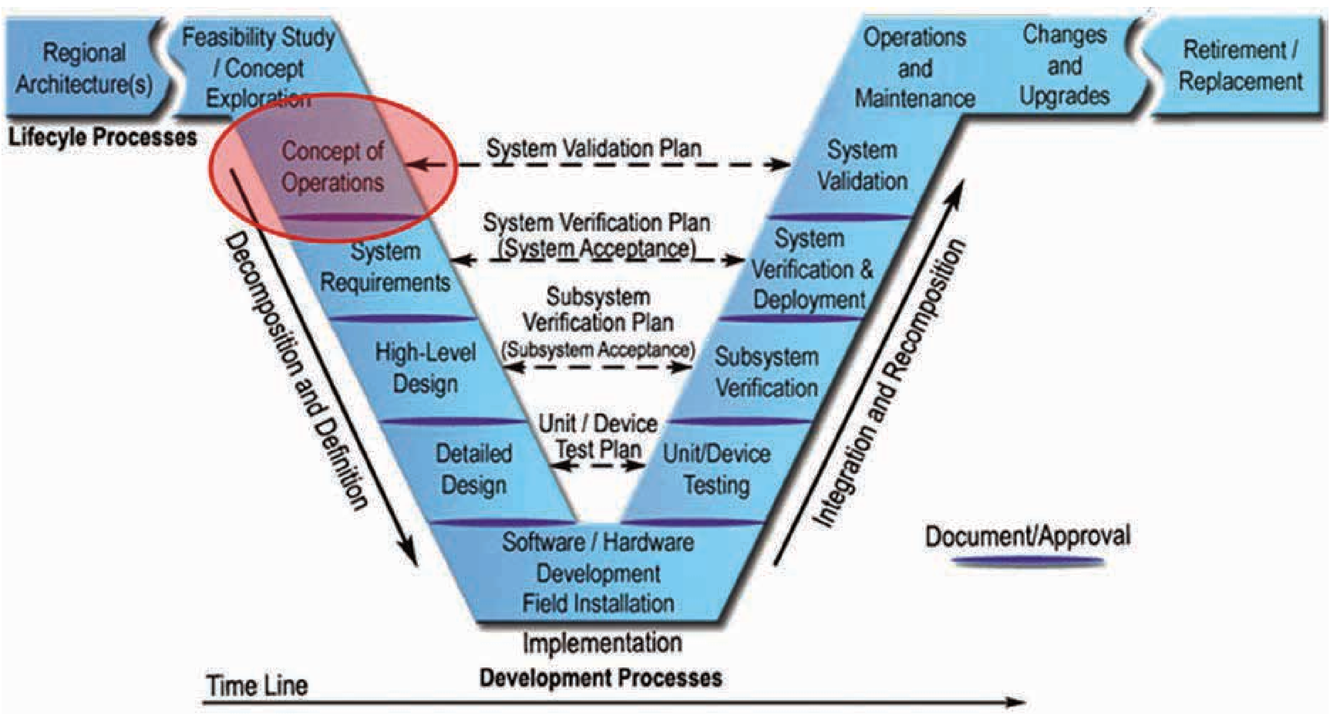


Figure 18. Graph. Business Plan Steps and Process. Concept of Operations in the System Engineering Development Context[20]

There are two standard frameworks commonly used in the ITS field to help develop concept of operations documents. The first is the Institute of Electrical and Electronics Engineers (IEEE) Standard 1362-1998 ("Concept of Operations IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document"). The second is the American National Standards Institute (ANSI) Standard ANSI/AIAA G-043-1992 ("Guide for the Preparation of Operational Concept Documents").

Both standards can be used to capture the operational characteristics of the Virtual TMC system adequately. However, the ANSI framework is more typically used when planning completely new systems whereas the IEEE framework tends to be used more for upgrades or modifications to existing systems.

ANSI/AIAA Standard G-043-1992

The ANSI/AIAA Concept of Operations standard recommends that a Concept of Operations Document "…describes

[20] FHWA, *Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals*. "Section 3.3.1 Overview of the "V" Model."

system characteristics from an operational perspective," and, for each stakeholder, answers the question, "What does it [the system] look like from my point of view?" The components of the standard are summarized below.

I. Scope – *An overview of the entire Concept of Operations*
   a. Outline the Contents of the Document
   b. Purpose for Implementing the System
   c. Highlight Major Objectives and Goals
   d. Identify the Intended Audience
   e. Set Boundaries on the Scope of the System
   f. Describe an Overarching Vision for the System

II. Referenced Documents – *resources used when developing the document*
   a. Business Planning Documents
   b. Concept of Operations for Related Systems
   c. Requirements for Related Systems
   d. Studies to Identify Operational Needs
   e. System Development Meeting Minutes

III. User-Oriented Operational Description – *system description from a user vantage point identifying how organization or system-specific goals and objectives are accomplished, including strategies, tactics, policies, and constraints.*
   a. User Activities
   b. Order of User Operations
   c. Operational Process Procedures
   d. Organizational/Personnel Structures

IV. Operational Needs – *details agency- and region-specific goals and objectives that will drive the requirements for the Virtual TMC system ("What is necessary for the agency or region that would complement and improve the existing system?")*

V. System Overview –*a high-level description of the interrelationships of key system components.*
   a. Scope
   b. Interfaces
   c. System Capabilities (Functions)
   d. Goals and Objectives

VI. *The Operational and Support Environments – describes the environment or "world" in which the system will operate.*
   a. Facilities
   b. Equipment
   c. Hardware
   d. Software

e. Personnel

f. Operational Procedures

g. Support Necessary to Operate the Deployed System

VII. Operational Scenarios – *Details how the new Virtual TMC system would impact their activities under differing conditions, ranging from normal conditions to stress and failure conditions. The operational scenario should tell different stories from perspectives of different user classes over a variety of circumstances.*

a. Included User's Perspectives

b. Variety of User Classes

c. Stress/Failure Scenarios

d. Multiple Circumstances

IEEE Standard 1362-1998

The IEEE Standard 1362-1998 identifies the minimal set of elements that should appear in all Concept of Operations documents. However, other elements may be incorporated by appending additional clauses or subclasses to the Concept of Operations document, by direct incorporation, or by reference to other supporting documents.

I. Scope – *What is the scope of the project, what is to be developed and documented?*

a. Identification

b. Document overview

c. System overview

II. Referenced documents

III. Current system or situation – *What is the current state of the practice related to applications or systems that may or may not be performing the functions expected from the Virtual TMC?*

a. Background, objectives, and scope

b. Operational policies and constraints

c. Description of the current system or situation

d. Modes of operation for the current system or situation

e. User classes and other involved personnel

f. Support environment

IV. Justification for and nature of changes – *Why does the Virtual TMC need to be developed and, at a high level, what will it do?*

a. Justification of changes

b. Description of desired changes

c. Priorities among changes

d. Changes considered but not included

V. Concepts for the proposed system – *Who are the users of the system, where will it be deployed, and under what constraints? What systems and subsystems are involved, how do they operate, when does the sequence of events occur within the Virtual TMC system?*

a. Background, objectives, and scope

b. Operational policies and constraints

c. Description of the proposed system

d. Modes of operation

e. User classes and other involved personnel

f. Support environment

VI. Operational scenarios – *What are the operational scenarios used to demonstrate the capabilities of the Virtual TMC?*

VII. Summary of impacts – *What operational impacts will the Virtual TMC have on the users, developers, and support organizations? What will the temporary impacts be on these system users as the new system is being developed, installed, and trained for?*

a. Operational impacts

b. Organizational impacts

c. Impacts during development

VIII. Analysis of the proposed system – *What improvements will be realized through the Virtual TMC? What disadvantages and trade-offs were considered?*

a. Summary of improvements

b. Disadvantages and limitations

c. Alternatives and trade-offs considered

3. Prepare Virtual TMC System Security Design

A secure and reliable Virtual TMC system will be made possible only through a long-term commitment to ongoing design, implementation, review, improvement and funding. However, early adoption of security best practices will greatly improve the effectiveness and resiliency of the system(s). At a minimum, VTMC stakeholders should consider the security measures listed below, in addition to the Secure System development Life Cycle guidelines provided in the following section. Organizations should also consider implementing an audit schedule for all VTMC systems by external agencies.

- **Layered Security:** Virtual TMC adoption poses unique security challenges created by complex, multi-location architecture, user mobility, and requirements to integrate and deploy a variety of systems and applications. To address these concerns, VTMC stakeholders must implement layered security methods including:
  - Deploy network and application firewalls providing technologies that prevent, detect, and respond to targeted threats in an adaptive manner.
  - Firewall functionality should also be deployed to provide additional layered security to protect critical devices within the Virtual TMC as well as to protect mobile devices that are placed directly onto external networks.
  - Principles of least-access should be implemented and enforced for the entire Virtual TMC infrastructure.
  - The National Institute of Standards and Technology (NIST) Special Publication 800-41 provides Guidelines regarding Firewalls and Firewall Policy which offers preliminary guidance when designing a Virtual TMC.
- **Secure Communications:** The Virtual TMC model mandates interconnected systems. Cryptography should be considered for all Virtual TMC communications both internal and external, and all data stores that are considered sensitive, provide high value, or are vulnerable to unauthorized disclosure. Encrypted communications between the Virtual TMC and remote operators, and traffic devices connected through

wireless networks are vulnerable to attack. Communications between a Virtual TMC and remote devices should be encrypted and secured. NIST Special Publication 800-21 provides guidance for implement Cryptography.

- **Log Management:** It is critical in the Virtual TMC environment to maintain an accurate record of all systems, security, and performance events. Security flaws and system failures have the potential to impact multiple agencies and public safety in significant ways. Centralized logging and reporting provides data on security trends, performance trends, and gives VTMC stakeholders the information needed to investigate any failures or prove compliance with any applicable regulations or mandates.
- **Consolidated System Logs:** System logs should be automatically consolidated to a centralized and secure location. Event log archives should match any mandates or regulations for data retention applicable to the VTMC.
- **Defined audit policies:** Stakeholders should define which system events should be recorded. A few examples include:
    - Operator login and logout: This should be recorded for all perimeter devices, systems, and applications within the VTMC infrastructure.
    - System performance metrics: Should be collected for all servers, storage devices, network devices, and field devices.
    - File, database, configuration changes: Should be collected for all servers, storage devices, network devices, and field devices.
    - Communications between all internal and external systems.
- **Defined alerts and notifications:** Define and configure alerts and notification for specific log events that will affect VTMC security or performance.
- **Defined and automated log analysis and reporting:** System logs are typically very large and it can be difficult to obtain and analyze important information. Developing improved reporting and analysis tools for the VTMC will provide more efficient analysis for TMC stakeholders.

  (NIST) Special Publication 800-53 provides guidelines for selecting and specifying security controls for information systems applicable to VTMC operations.
- **High-Availability Systems:** In the Virtual TMC model, high-availability systems may be significantly more important than in the traditional TMC. In a traditional TMC, operators may still be able to manage a subset of system assets when communication or system failures occur. In the VTMC model, system and communication failures could potentially prevent remote access to all TMC systems, leaving remote operators with no ability to address events until operations are restored.

Virtual TMC stakeholders should agree upon and commit to eliminating any single point of failure in the Virtual TMC model. Typically this includes:

- Resilient communication paths should be implemented
- High availability cluster server and application pools
- Active/passive or active/active network devices

In some instances it may not be practical or cost-effective to implement redundant communications, or active/passive traffic devices. In these cases replacement units and methods to efficiently restore operations should be considered and implemented.

4. Develop Virtual TMC Communications Architecture

There are various challenges associated with the concept of implementing Virtual TMCs and the implementation of effective communication systems is one of them. However, with the introduction of improved and modern communication technologies, concepts and the supporting network security systems, this challenge can be overcome with relative ease. As depicted in Figure 19, TMCs must communicate often with a multitude of ITS field elements via dedicated field communications in addition to a number of external systems via what is commonly called Center-to-Center (C2C) Communications.

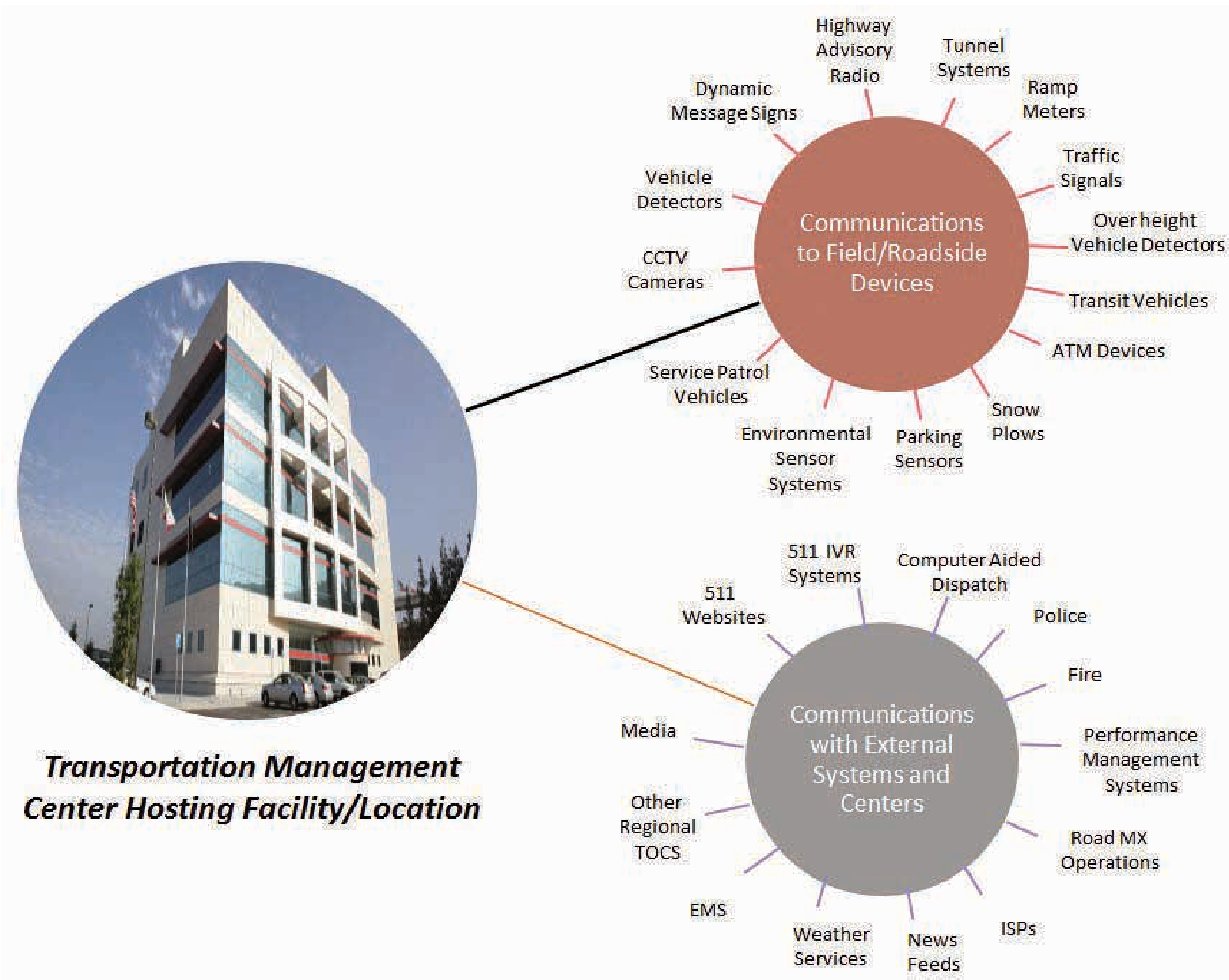


Figure 19. Graph. VTMS Communication Connections

The challenge with field communications is that a great many existing communication systems have been physically designed with the TMC (control center) being the nucleus of the system. This often includes physical hardline communications between the TMC buildings and the field infrastructure, e.g. spoke and wheel type architectures. These architectures must be updated to allow for a Virtual TMC model.

Table 8 provides a list of the various types of communications that can typically be encountered in a transportation management system. Each communication system type should be evaluated for how it should be modified for Virtual TMC operations. Although there is no physical facility or control room, the Virtual TMC servers and other equipment must still be hosted and be able to communicate with field devices.

Table 8. Field Communications.

Communication Method	Architecture/Technology	Typical ITS Field Devices
Fiber Optics	• Synchronous Optical Network (SONET) • GigaBit Ethernet • Frequency Division Multiplexing (FDM) • Time Division Multiplexing (TDM) • Asynchronous Transfer Mode (ATM)	• CCTV Cameras • Vehicle Detectors • Ramp Meters • Dynamic message Signs • ATM Devices • Tunnel Systems • Traffic Signals
Cellular Wireless	• Cellular Digital Packet Data (CDPD) • General Packet Radio Service (GPRS) • Code Division Multiple Access • WiMax • 1G, 2G, 2.5G, 3G, 4G, LTE	• Portable ITS Devices o Portable DMS o Portable HAR o Portable TMS o Portable HAR • Transit Vehicles, SSP Vehicles, Snow Plows • ESS • Traffic Signals
Microwave	• Licensed • Unlicensed • Spread Spectrum	• CCTV Cameras • Vehicle Detectors • Ramp Meters • Dynamic message Signs • ATM Devices
Satellite	• Direct Broadcast Satellite • Very Small Aperture Terminal	• CCTV Cameras
Radio	• Trunked Radio (APCO25, TETRA, etc.) • Spread Spectrum • ARDIS	• CCTV Cameras • SSP Vehicles • Police and Fire • Transit Vehicles
Leased Telecommunications	• POTS • T-1 • DS-0 • DS-1 • DS-3 • MPLS • Dial-up Telco (POTS)	• Vehicle Detectors • Traffic Signals • Dynamic message Signs • ESS • HAR • Parking Systems
Direct Cabling	• Twisted-Pair • Coaxial Cable	• Traffic Signals
Dedicated Short Range Communications (DSRC)	• 802.11 wireless LAN • Bluetooth • HIPERLAN • Infrared	• Connected Vehicles (V2V) and V2I) • Snow Plows • Transit Vehicles • Traffic Signals

Agencies must select one of three recommended paths or guidelines to implement C2F communications in the Virtual TMC Model:

1. Establish a C2F communication hub where remote virtual communications can be established using secure

communications (e.g., firewalls, web application firewalls, and VPN appliances).

2. Modify the C2F communications network to enable communications from any virtual position.

3. Establish a hosted TMC Model using hosted services.

Figure 20 represents one migration model. In this model, the existing C2F communication system can remain in place as long as remote secure communications can be established between this centralized location and the VTMC operators. In this model, a centralized TMC facility is not needed, but a communication hub or computer serving center is still in place.

A more ideal VTMC model is represented in Figure 21. In this model, the C2F communications network is established in a manner where no physical connections are made to any single facility; instead, more "openly accessible" means are established using secure methods. For example, 4G cellular communications provides acceptable bandwidth and can be used for most typical ITS field devices. In addition, other leased services such as Multiprotocol Label Switching (MPLS) can be used to enable communications from any location, as long as there is a central hub serving point. In this example, the communications with these devices is secured using password authentication and data encryption methods. Included within this architecture are the hosted computing services where the ATMS applications used by the VTMC operators can be accessed from any location where secure World Wide Web connections are available.

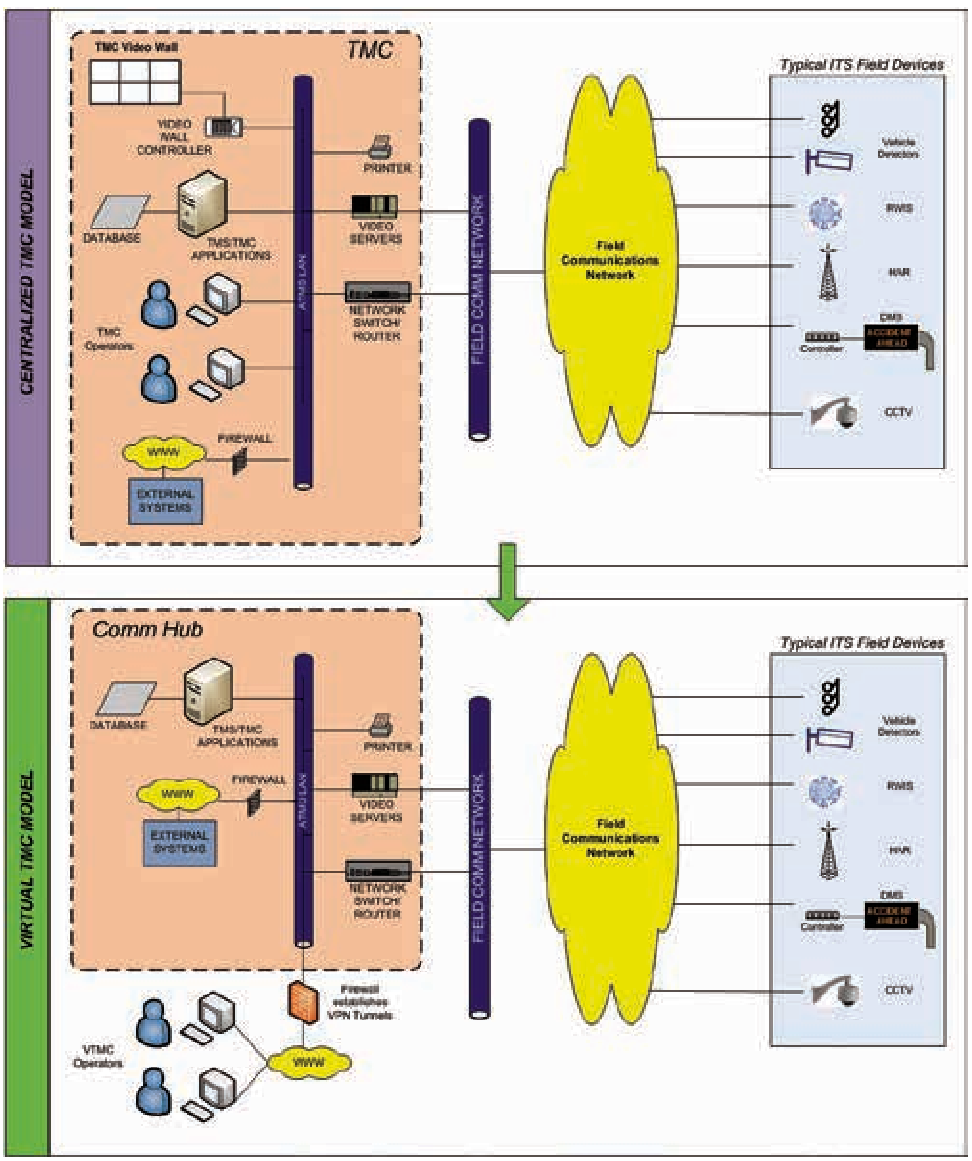


Figure 20. Graph. Hosted Virtual TMC

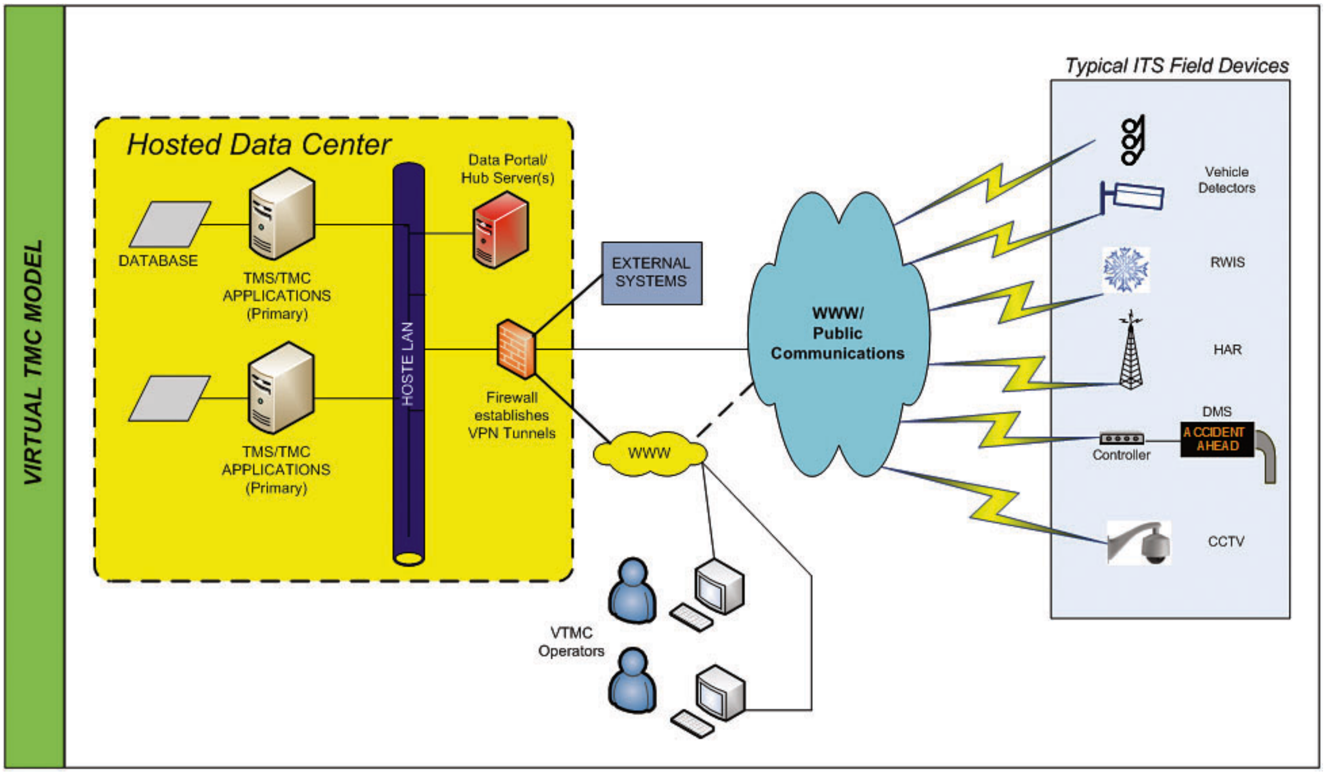


Figure 21. Graph. Virtual TMC Model

Establishing Center-to-Center (C2C) /External Communications for Virtual TMCs

When establishing a Virtual TMC model, whether it is single agency, multiagency or multiregional, a key aspect of the communications is how information transfer occurs between regions. This includes the methods for real-time operational data to be exchanged between operational entities (DOTs, counties, municipalities), emergency responders, traffic data feeds, computer aided dispatch systems, ISPs, and the media among others. The recommended method to do this is via a data hub, also referred to as a data gateway or portal. Figure 22 is one such example data gateway in which information is exchanged in a common manner between multiple agencies using standard methodologies and data formats.

This data gateway is essential a single location where all information that must be exchanged between agencies is shared. A typical example involves each agency "pushing" their data into this common location in a common format, e.g. using a TMDD standard, or the data is provided to the gateway and then converted into a common format for everyone to share. With this being in place any TMC, especially a virtual one, can obtain the information it needs to operate and in turn share its information with other agencies so they may also perform their multiagency operating functions.

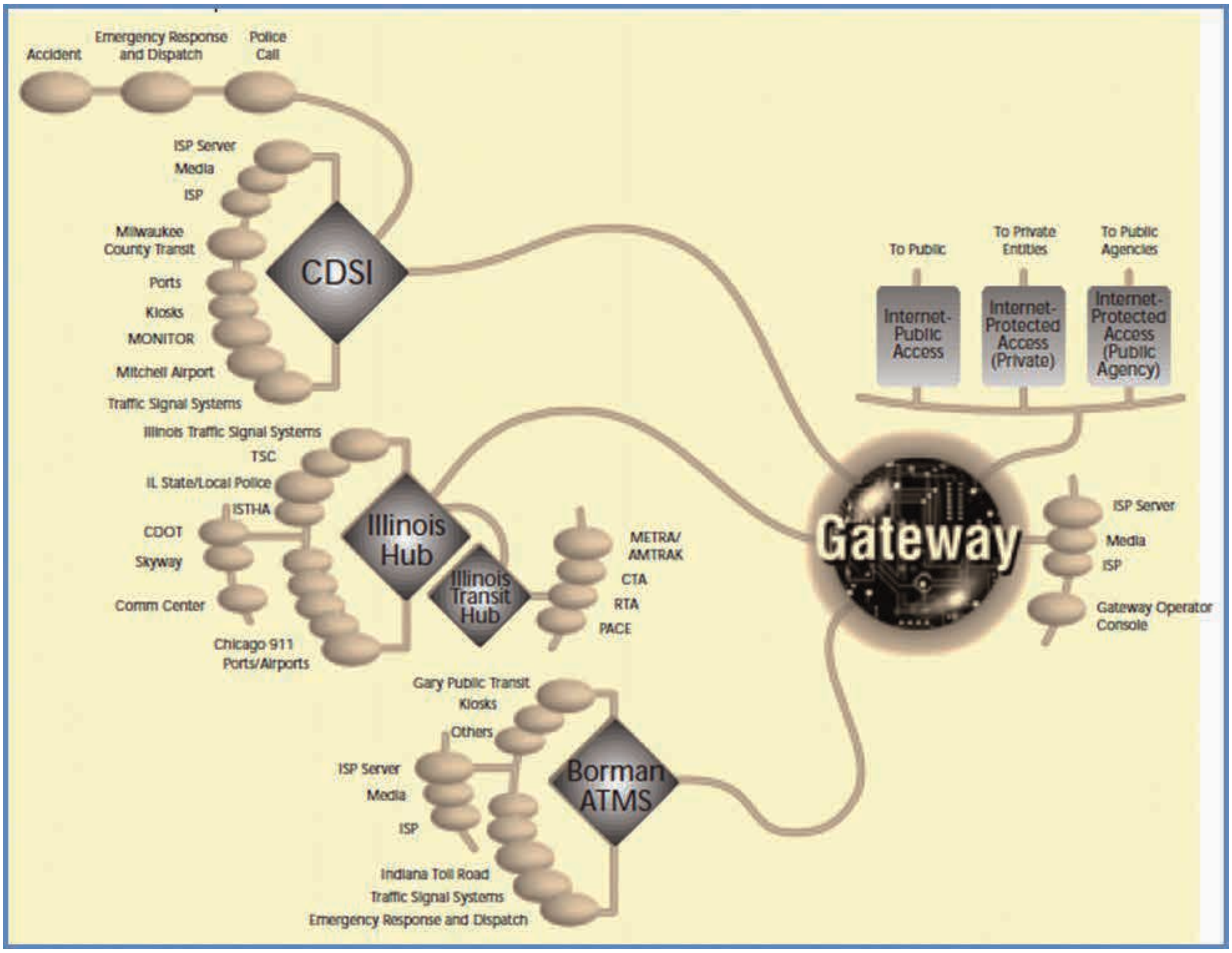


Figure 22. Graph. C2C Communication Hub or Gateway[21]

These data hubs should be created taking into account the common C2C standards used in the ITS market today:

- NTCIP 2306 – Application Profile for XML in ITS Center-to-Center Communications – This standard is the application Profile for XML Message Encoding and Transport in ITS Center-to-Center Communications (C2C XML). This standard allows transportation agencies and center managers the ability to specify and implement communications interfaces for transmitting information encoded in the Extensible Markup Language (XML) between their center and an external center.
- ITE TMDD 3.03 – Traffic Management Data Dictionary (TMDD) and Message Sets for External Traffic Management Center Communications (MS/ETMCC). This standard contains data elements for roadway links and for incidents and traffic-disruptive roadway events. The standard includes data elements for traffic control, ramp metering, traffic modeling, video camera control traffic, parking management, and weather forecasting as well as data elements related to detectors, actuated signal controllers, vehicle probes, and dynamic message signs. The standard also contains the message sets for communication between traffic management centers and other ITS centers, including information service providers, emergency management systems, missions management systems, and transit management systems.

[21] FHWA, *Regional ITS Architecture – Development, A Case Study - Gary-Chicago-Milwaukee ITS Priority Corridor*, FHWA-JPO-99-022/FTA-TRI-99-03 (Washington, DC: 1999).

5. Develop ATMS Implementation Plan

In order for a Virtual TMC to become a reality, either a common ATMS should be developed or the existing system(s) that are in place should be enhanced. Many ATMS solutions are designed as enterprise solutions or client-server type applications based around the use of a physical TMC facility and its communication networks. To implement Virtual TMC functions, an integrated solution, typically web-based and thin-client should be considered. This could be hosted by the agency or by a software-as-a-service (SaaS) model.

The ATMS Implementation plan should include the following components:

- ATMS Purpose
- Mission Statement
- ATMS Functionality Description
- Existing and Proposed ATMS Architectures
- Implementation Procedures/Steps
- Roles and responsibilities for executing the plan
- Implementation Schedule
- Costs

6. Develop Standard Operating Procedures

The TMC Standard Operating Procedures (SOPs) will need to be modified or developed to accommodate the new Virtual TMC model. Each of these SOPs should include the following:

- Virtual TMC Procedure Overview – Provides decryption of each individual procedure and its purpose.
- Area or Responsibility – Who is responsible for implementing this procedure given the new VTMC model; i.e., who is responsible for doing what.
- Procedure Steps – An actual description of the steps that will be followed in the new VTMC model.
- References – References to any other procedures that will be used in association with this specific Virtual TMC procedure.

7. Modify Staffing Plan

In the absence of a physical facility in a Virtual TMC scenario, there is still room to consider the implementation of additional or "hybridized" staffing models (i.e., combining features of more than one approach). Staffing will largely depend on the agency's needs and the scope of operations.

Currently, these are the most common staffing approaches for Virtual TMCs:

- Staffed and operated by the managing entity—no dedicated TMC staff, rather the entity staff also perform TMC functions.
- Staffed and operated by the managing entity—dedicated staff for TMC functions but not working in a typical physical TMC environment (i.e., staff working remotely).
- Managed by a single entity with the operational support of partner agencies.

The staffing plan should address each of these functions given the new Virtual TMC model, noting that several will have little or no modification to those that would be performed in a standard TMC model.

8. Develop Training Plan

Many traditional TMC training programs involve a classroom type setting. The training session is usually led by the system trainer and is accompanied by a PowerPoint presentation, specific manuals, and hands-on exercises.

Training sessions may take anywhere between 2 and 4 hours each and have 8-10 personnel in attendance. Usually a training session may be separated into different training sessions; operator and system administrators. System administrators participate in the operators training, as well as receiving a more detailed system training.

For Virtual TMCs, this training model needs to have some specific modifications. As described above, training sessions are tailored to the specific users (operators, maintenance, administrators). There are no clearly defined "roles and responsibilities" for a Virtual TMC operator. This TMC operator needs to be able to be an operator, an administrator, and a maintenance user. The training model for a Virtual TMC must be able to satisfy the flexible roles and responsibilities.

A training modification is for the combining roles and responsibilities into a single operator, or at least most of the common TMC functions. Many TMCs have multiple operators, who have specific regions or responsibilities (i.e. contact maintenance, coordinate with roadway work crews, etc.). With the Virtual TMCs, these responsibilities are now within a single operator. This operator needs to be able to handle any of the various operations. Therefore the training session has to detail all the responsibilities, no matter the designation (operator or administrator).

Another distinctive modification is the classroom setting. In a physical TMC, there are multiple, dedicated workstations, as well as a training room. This may not be the situation for the Virtual TMC. Classroom training could now be performed as a one-to-one training or as part of a teleconference (WebEx, join me, GoToMeeting, etc.) with multiple users. One-to-one training may not be cost or time effective, as the trainer must now perform the same training numerous times, rather than a single classroom session. A teleconference may be a more effective training tool for the Virtual TMC operators.

A useful training tool is the use of scenarios. Real-life examples allow the trainees, whether they are operators or administrators, to perform all actions needed for real-life scenario. Scenarios should include unplanned events with minor lane blockage, unplanned events with major lane blockage with injuries and fatalities, and responses to planned closures. Other scenarios should also include the more day-to-day activities, i.e. daily reports for events. Scenarios should also include the not so normal activities, i.e. the workstation has crashed or the internet connection has been lost. Training must include the actions that an operator needs to take to remain an active participant in the TMC operations.

Since an operator may be responsible for contacting other agencies, as well as making decisions in regards to notifying media personnel; training sessions and manuals must include the associated personnel. Again as part of the training sessions, information must be made available to allow the Virtual TMC operators to contact the necessary personnel. This list of personnel could be other agency contacts, maintenance contacts, and even IT personnel.

9. Perform Risk Assessment

In order to mitigate risks associated with establishing a Virtual TMC, it is important that each agency identifies, assesses, and evaluates risks associated with this model. With risk being defined as a "potential problem," the key is to identify the possible issues beforehand and prevent the actual issue from occurring by implementing mitigation steps, tasks, or plans designed to prevent the problem from actually occurring.

For the risks identified in the Risk Identification and Register (Table 3-2), each risk should be given two types of rankings:

1. Likelihood of Occurring, rated as:

   L = Low Likelihood

   M = Medium Likelihood

   H = High Likelihood

   E = Extreme Likelihood

   NA = Not Assessed or Not Applicable

2. Impact if issue becomes a reality

   L = Low Impact

   M = Medium Impact

   H = High Impact

   E = Extreme Impact

   NA = Not Assessed or Not Applicable

With a combined ranking of likelihood and risk together, Table 9 offers a potential grade for each risk, with a grade ranking of "A" requiring immediate attention, those with a "B" grade requiring secondary attention, and so forth.

Table 9. Risk Identification and Register

Rating for Likelihood and Seriousness of Each Risk			
L	Rated as low	E	Rated as extreme (used for seriousness only)
M	Rated as medium	NA	Not assessed
H	Rated as high		

Grade: Combined effect of likelihood/impact					
		Impact			
		Low	Medium	High	Extreme
Likelihood	Low	E	D	C	A
	Medium	D	C	B	A
	High	C	B	A	A

Recommended Actions for Grades of Risk	
Grade	Risk Actions
A	Actions to reduce the likelihood and seriousness to be identified and implemented as soon as the project commences.
B	Actions to reduce the likelihood and seriousness to be identified and appropriate actions implemented during project execution.
C	Actions to reduce the likelihood and seriousness to be identified and costs developed for possible action if funds permit.
D	To be noted – no action is needed unless grading increases over time.
E	To be noted – no action is needed unless grading increases over time.

Project Identification	
Project:	Virtual TMC
Client:	DOT XXXX
Project Manager:	John Doe, Project Manager
Project Scope:	Phase 1 Scope
Version/Date:	Version 1

Table 10 is a sample Virtual TMC risk table with some commonly anticipated risks that could be faced by an agency attempting to implement a Virtual or hybrid TMC solution.

Table 10. Risk Identification Matrix

PROJECT TASK	DESCRIPTION OF RISK	LIKELIHOOD	IMPACT	GRADE	CHANGE	ACTIONS/MITIGATION	RESP PARTY.	STATUS
All	Agency partners do not have common operational concept	High	High	A		Establish common multi-agency concept of operations		
All	Agency security policies do not allow for virtual tmc concepts to be deployed, e.G. Firewalls for multi-agency, multi tmc connections cannot be configured to enable vtmc operations	Medium	High	B		Review all agency security policies, review with it staff and obtain modifications or waivers as necessary.		
All	Center-to-field communication systems are not conducive for vtmc operations	High	Low	C		Review details of c2f communication architecture. Establish local communication node or server system. Reconfigure c2f network as necessary.		
All	Center-to-center communication system is not conducive for vtmc operations	High	Medium	B		Design common c2c communication gateway, portal or hub using agreed standard data exchange mechanism		
All	Operators are not trained for vtmc operational model	High	Medium	B		Establish a training program for virtual tmc operations. Implement training based upon agreed schedule		
All	Existing software management and tmc management tools are not designed for vtmc operations.	High	High	A		Execute systems engineering process to design or upgrade existing system tools to perform vtmc operational functions.		
All	Regional its architecture does not support vtmc model	High	Low	C		Begin process to update regional its architecture accordingly.		
All	Complete DOT IT Security Breach compromises the VTMC Network	Low	Extreme	A		Perform full security assessment and implement security measures and components to prevent such a complete breach.		

10. Develop Operations & Maintenance (O&M) Plan

An O&M plan for Virtual TMCs should be developed. This plan may be an enhancement to the existing TMC O&M Plan. It should include:

- A list of the hardware and software items that will be maintained
- How will these various systems be maintained
- Who will be responsible for the maintenance activities
- Descriptions of the routine maintenance
- Descriptions of preventive maintenance tasks
- Description of non-critical O&E activities
- How will emergency repairs be handled
- What spare parts will be kept and how will these stock piles be used and access
- A discussion of required service level agreements.

3.2. The Planning Process

3.2.1. Objectives

The planning process applies to agencies wanting to deploy a new center or agencies wanting to add new virtual functionality or virtual capabilities to their current operations. Its objective is to describe the process for developing, implementing and deploying a Virtual TMC or a TMC with virtual capabilities. Through this process agencies will need to:

1. Establish goals;
2. Address existing and potential issues and challenges;
3. Consider operational and technological capabilities;
4. Explore opportunities for improvement; and
5. Create Memoranda of Understanding (MOU) in the case of multi-jurisdictional operations or the partner agency support model.

3.2.2. Operational Considerations

When considering a new virtual deployment or the implementation of new virtual features, it is crucial to evaluate the agency's TMC requirements and needs, funding, communication infrastructure, and security protocols as well as the functions envisioned for the center. Operational considerations include, but are not limited to:

- Stakeholder Identification
- Coordination
- Staffing

3.2.2.1. Stakeholder Identification

Stakeholder identification will largely depend on a series of factors unique to the context of the Virtual TMC scope, including:

- The jurisdiction's road networks;

- The operating environment;
- The organizational structure; and
- The functions to be performed.

A thorough understanding of the future system or the system at hand will facilitate the identification of a wide variety of key players. Many stakeholder groups are easily identifiable in the early stages of system planning, while others are identified later in the process as the scope becomes more detailed.

The USDOT's 2005 report Developing and Using a Concept of Operations in Transportation Management aggregates survey results from transportation professionals and identifies several different classes of stakeholders. The most frequent categories of stakeholders cited were:

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

It is often effective to classify stakeholders into internal and external groups. Internal stakeholders are those individuals, groups and organizations that are considered within the scope of the system, and external stakeholders are those individuals, groups, and organizations that are outside the defined scope of the system but interact with the system. Identification of external stakeholders will become possible as the system definition continues.

Below in Table 11 are some general attributes of each class, identified in USDOT's 2005 Report on Developing and Using a Concept of Operations in Transportation Management:

Table 11. Attributes of Internal and External Stakeholders

Internal Stakeholders	External Stakeholders
• Within the primary organization(s) that is developing or operates the system • Play a significant role in system function • Are significantly affected by changes in system design and function	• Interact with the system but are outside the scope of the system • Play a secondary role in system function or are only affected by system function
Examples: • System engineers and architects • Operators • System users • Maintainers • Public Agencies (partners)	**Examples:** • Private entities • Media • Legal advisors • Technical advisors • Financial institutions

Stakeholders may be identified and should be included in all stages of the planning and the development processes.

Although the operational, organizational, and technological context of each Virtual TMC implementation will require a unique set of stakeholders, in general all projects will share the same categories of stakeholder groups. The ANSI

Concept of Operations standard identifies the following high-level categories of system implementation stakeholders:

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

As illustrated above, there is a wide range of entities that can and should be considered as stakeholders. It is important to take the necessary time to identify the right mix of stakeholders and to involve them early on in the Virtual TMC planning process. Early participation can build goodwill and trust among the stakeholders by making them feel that they are an important part of the development process.

3.2.2.2. Coordination

As discussed in USDOT's comprehensive 2005 report Developing and Using a Concept of Operations in Transportation Management, active participation among stakeholders is essential for the planning and deployment of a transportation management system. Due to the multi-jurisdictional and multi-system features often inherent to TMC virtualization, the coordination effort to involve the various stakeholders becomes particularly important to ensure their involvement.

One of the main causes cited for stakeholder non-participation or even hostility is when stakeholders do not feel like their mission or goals are being met. This is not to say that all parties necessarily have to agree on every aspect of the system, but stakeholders must not be made to feel that their major goals as an organization are being compromised by agreeing to some aspect of the system. Clearly, goal-alignment becomes increasingly difficult as the number and variety of stakeholders increases, but stakeholder consensus is necessary in order for the final system to gain acceptance and be used as designed.

3.2.2.3. Staffing

In the absence of a physical facility in a Virtual TMC scenario, there is still room to consider the use of additional or "hybridized" staffing models (i.e. combining features of more than one approach). Staffing will largely depend on the agency's needs and the scope of operations.

Currently, the most common staffing approaches for Virtual TMCs include:

- Staffed and operated by the managing entity—no dedicated TMC staff, rather entity staff also performs TMC functions.
- Staffed and operated by the managing entity—dedicated staff for TMC functions but not located in a typical physical TMC environment (e.g. staff working remotely)
- Managed by a single entity with the operational support of partner agencies.

Traditionally, the four models presented in this section apply to TMCs with physical facilities. However, these approaches can provide a useful framework for evaluating staffing options. Each model offers a range of ownership options, operational requirements, performance, and cost, and have been used in various settings nationally.

Model 1: Private Sector - Concession Operations

In this option, systems are contracted and privately owned, remaining in the contractor's ownership after the contract period. Operations are also contracted out, usually as part of the same system provision contract. The Contractor is responsible for the systems, staff, and for maintaining services through Service Level Contracts and performance monitoring.

Deployment Example: The Utah Department of Transportation 511 system is fully outsourced.

This model is viable in a traditional TMC approach, and it may not be applicable to a Virtual TMC scenario since the latter does not require typical TMC operations.

Model 2: Joint Private-Public Partnerships / Application Service Provider (ASP)

This option is similar to the Concession Operations, where systems are contracted, privately owned, and remain in the contractor's ownership after the contract period. The main difference is that the system is operated by in-house operations staff (public employees).

Deployment Examples: Washington State, New England states of Rhode Island, Vermont, and New Hampshire, Kansas, the Dakotas, Nevada and Montana.

This model is viable in a Virtual TMC scenario, since it uses in-house staff to operate the system. The system will need to meet the agency's security protocols.

Model 3: Private Sector - Contracted Operations

In this option, operations are contracted out to a Private Sector service provider. The Contractor is responsible for staff and for maintaining services through Service Level Contracts and performance monitoring.

Deployment Example: The Virginia Department of Transportation (VDOT) used contracted operations for its Regional TMCs.

This model is viable in a traditional TMC facility, but it may not be applicable to a Virtual TMC scenario.

Model 4: Public Operations

In this option, the system is publicly owned, and it may exist or it may be created as part of a separate contract. The system is operated by in-house operations staff in the TMC.

Deployment Example: Arizona's 511 system.

This model is viable in a Virtual TMC scenario, since it uses in-house staff to operate the system. Depending on the scope of work, it may not require full time staff.

Table 12 summarizes the high-level ownership and cost distinctions among the four deployment models:

Table 12. Staffing Models

Model	System Ownership	System Operation	Cost Focus	In Virtual TMC Model
1. Private Sector Concession Operations	Private Contractor to the Agency	Private	Operating	No
2. Joint Private-Public Partnership	Private Contractor to the Agency	Public	Operating	Yes
3. Contracted Operations	Public (Agency)	Private	Operating and/or Capital	No
4. Public Operations	Public (Agency)	Public	Capital	Yes

3.2.3. Organizational Considerations

3.2.3.1. Typical Virtual TMC Organizational Needs

This section discusses the common business processes and services typically supported by Virtual TMCs; roles, responsibilities, and capabilities; inter-agency collaboration; and programmatic integration.

As presented by USDOT in a 2004 presentation titled "A National Campaign for Improving Regional Transportation Operations," the following are key organizations related to planning may be applied to a Virtual TMC and must be considered in developing the Concept of Operations.

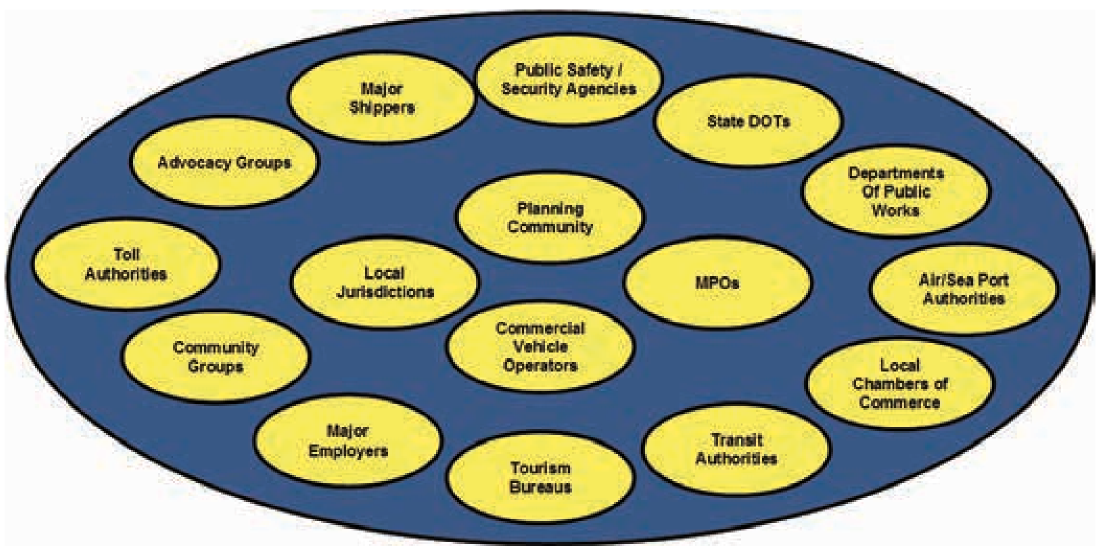


Figure 23. Graph. Key Organizations in Planning a TMC or Virtual TMC.[22]

Figure 23 above illustrates how a Virtual TMC relates to and provides a platform for a variety of other services. A Virtual TMC is highly likely to have links and synergies with other policies and services. Areas with particularly strong synergies include:

- **Safety and security:** video cameras play a key role within a TMC operation, which can be combined with improvements in safety and security management. A Virtual TMC deployment is especially well suited to supporting safety- and security-related video distribution owing to its distributed system architecture.
- **Incident management:** A Virtual TMC can be used to mitigate the impacts of incidents, reducing the effects of traffic collisions upon the overall transportation network flows and conditions.

22 USDOT, "A National Campaign for Improving Regional Transportation Operations," Presentation given at a special session of the National Association Working Group (NAWG), February 2004

- **Public transportation operations:** A Virtual TMC can be used to improve the movement of buses and other public transportation services that use the transportation network (e.g., by facilitating transit signal priority operations along bus routes).

3.2.3.2. Operational Coordination

This section addresses operational aspects that need to be implemented to achieve a more consistent, timely, and efficient incident response and management of large-scale events, including coordination with other agencies that affect TMC activities.

As presented by USDOT in a 2004 presentation titled A National Campaign for Improving Regional Transportation Operations, Figure 24 illustrates the key TMC functions that are relevant to planning a Virtual TMC.

Subjects that need to be addressed include:

1. Creating and reviewing operational policies and practices;
2. Addressing issues of common concern among the partner agencies;
3. Facilitating training, drills, and exercises;
4. Reviewing infrastructure (where applicable), maintenance, and other operational resource requirements; slated
5. Performing debriefings following major incidents; and
6. Proactively planning for major events and emergency scenarios.

It is important to promote peer-to-peer information exchange, open participation, and relationship building among the stakeholders.

Implementing effective regional transportation management and operations in a collaborative manner is a critical component of a Virtual TMC deployment to ensure that it supports and continues to support the various entities and services to which it's connected and performs the functions required of it.

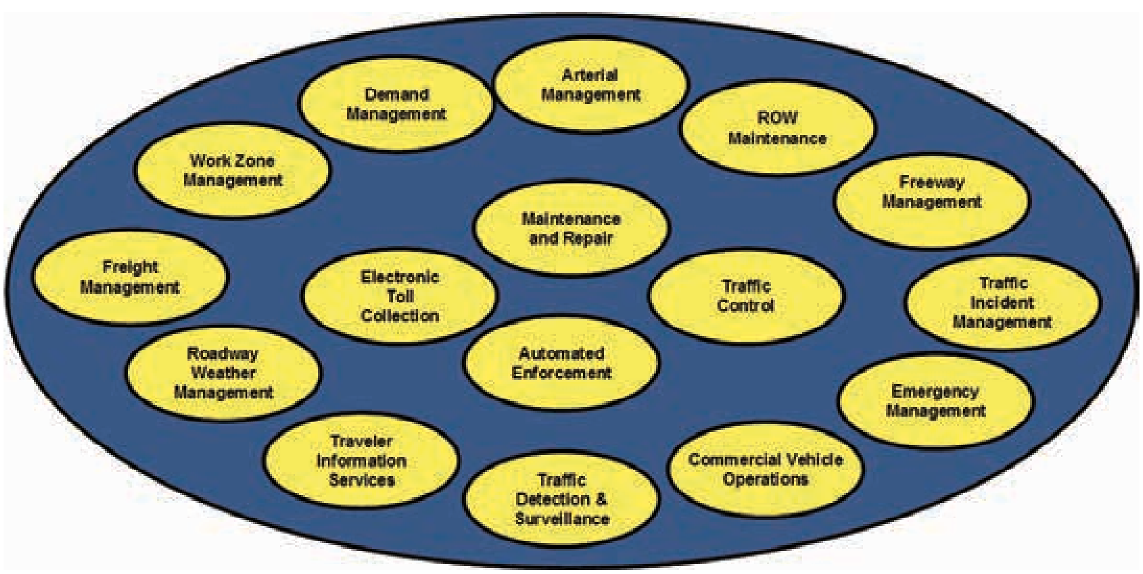


Figure 24. Graph. Key TMC Functions in Planning a Virtual TMC[23]

23 USDOT, "A National Campaign for Improving Regional Transportation Operations," Presentation given at a special session of the National Association Working Group (NAWG), February 2004.

One approach to facilitating such coordination is described in USDOT's 2011 Practitioner's Guide to Regional Concept for Transportation Operations. In this report, the USDOT highlights successful cases of regions using a Regional Concept of Transportation Operations (RCTO), a management tool used by planners and practitioners to define a strategic direction for improving regional transportation management and operations in a collaborative manner. The authors observed that successful implementations of RCTOs shared these common features:

- Strong and persistent leadership to guide the effort and maintain momentum for developing and implementing an RCTO.
- An iterative process for bringing participants into the RCTO process as the RCTO objectives are formulated and agreed to by all participating agencies.
- Leveraging and building upon existing relationships to gain support for an RCTO.
- Focusing on current or anticipated needs.

It was found that the RCTO process can be an effective mechanism for incorporating operations considerations into the planning process so that funds needed to implement operations strategies can be integrated into regional capital investment plans.

Figure 25 illustrates how an RCTO could be developed in three distinct phases. As shown, the motivation element is not created during the development of an RCTO. It is an issue observed by the partners that prompts the initiation of an RCTO and is then recorded. The first phase is largely driven by values and needs, and it consists of forming the operations objective, which establishes the desired outcome.

The second phase identifies possible approaches to achieving the operations objective and culminates in the selection of a particular course of action. The third phase translates the approach into more specific, tangible elements that guide joint or coordinated actions including system design, resource allocation, and interagency and multi-jurisdictional agreements.

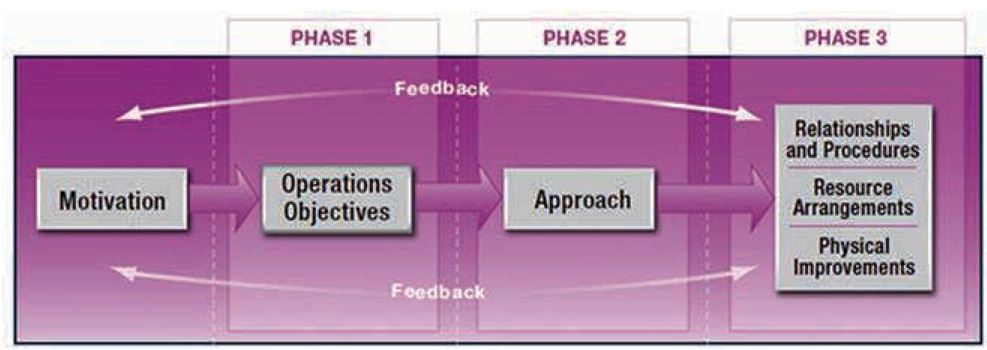


Figure 25. Graph. RTCO Development Phases[24]

The Practitioner Guide cited the example of the city of Tucson's use of an RCTO to improve its operational policies and practices related to arterial management operations, traveler information, and work zone management—all key focus areas of TMCs and Virtual TMCs. For each focus area, the RCTO team established operational objectives and agreed upon associated performance measures. Table 13 illustrates how the RCTO established the traveler information focus area.

24 USDOT's 2011 Practitioner's Guide to Regional Concept for Transportation, p. 2.

Table 13. Example of RTCO Focus Areas, Objectives and Measures[25]

RCTO Focus Area	Operations Objectives	Performance Measure
Traveler information *Motivation:* The stakeholders saw the need to coordinate traveler information systems in the region, reduce duplicative efforts, and make better use of the existing systems in disseminating information**.**	• Reduce traveler delay by improving the quality, quantity, accessibility, and use of multi-modal traveler information services in the region. • Improve the data management and storage of traveler information. • Educate roadway users to improve driver habits. • Provide current and accurate information to Tucson metropolitan area traveler information services (work zones, incidents, other closures).	• Number of calls placed to 511 telephone system from the Tucson metropolitan area and number of website hits for Tucson-specific travel information. • Number of events (incidents and planned events) that are entered into HCRS per year for the Tucson metropolitan area. • Number of media outlets using traveler information to distribute to the public

Another example specific to the incident management responsibilities of a TMC is the case of the Hampton Roads RCTO, which coordinated incident response operations among:

- Virginia State Police,
- Local fire and rescue,
- Local traffic engineers and public works staff,
- Local law enforcement,
- Environmental and hazardous materials (hazmat) staff,
- Local emergency medical services, and
- Members of the towing and recovery community.

In the 2½ years following the development of the RCTO, Hampton Roads RCTO participants from local and State DOTs, local and State public safety agencies, and the Hampton Roads Transportation Planning Organization continue to meet on a quarterly basis as the Hampton Roads RCTO subcommittee. Despite fluctuations in participation level and staff changes, the group continues to make progress on the actions identified in the RCTO. As of early 2011, a memorandum of understanding (MOU) was being developed to formalize the commitment of the agencies participating in the RCTO to collaboratively advance traffic incident management in the region.

Table 14 depicts an example approach for meeting the consensus incident management operations objectives.

Table 14. Sample Approaches for Meeting Operations Objectives[26]

Operations Objective	Approach
Increase Responder Safety	• Start a regional public awareness campaign concerning the “Slow Down, Move Over” law and the “Move It” law. • Encourage optimal lighting and traffic control equipment for secondary responder vehicles.
Decrease incident clearance times	• Implement the use of intermediate reference location signs. • Pursue the use of incentive based towing contracts or other innovative towing initiatives
Decrease secondary incident occurrences	• Provide Virginia Port Authority (VPA) and other regional entities information regarding major incidents in Hampton Roads. • Enhance the dissemination of incident-specific information to the motoring public.

25 USDOT’s 2011 Practitioner’s Guide to Regional Concept for Transportation, p. 12.

26 USDOT’s 2011 Practitioner’s Guide to Regional Concept for Transportation, p. 21

Operations Objective	Approach
Improve inter-agency communication during incidents	• Improve external and internal communication related to traffic incident management. • Explore the possibility of multiple agencies being co-located at the Hampton Roads Traffic Management Center (HRTMC).
Identify existing regional incident management resources and establish plan for inter-agency utilization and acquisition	• Conduct cross-agency training • Provide more total station equipment to be utilized in investigations
Establish a regional incident management pro-active and post-incident review consortium	• Hold meetings of the post-incident review consortium following any problematic incidents

Establishing an inter-agency coordination and planning process similar to the RCTO examples described above is good way to ensure that operational policies and practices are continually reviewed and improved, common concerns among partner agencies are addressed quickly and openly, and infrastructure, maintenance, personnel, and other operational requirements are regularly assessed.

3.2.3.3. Reporting Relationships

In an operational setting, communications occur for a number of purposes and at varying frequencies. It is important to establish well-defined project responsibilities, comprehensive system oversight, and clear communications and reporting structures as well as to explain the basis for work day and off-hour communications and identify where additional resources are needed, including:

- Management responsibilities and staff reporting;
- Meeting schedules and communications issues;
- Quality assurance;
- Problem resolution;
- Documentation and record keeping requirements;
- Routine reporting requirements;
- Implementation of timelines and procedures; and
- External communications with other agencies and the public.

3.2.3.4. Finding the Right Organizational Fit

Every Virtual TMC deployment will have its own unique functions and responsibilities. However, most will share some common elements. FHWA's 2004 Report on TMC Operator Requirements and Position Descriptions found that the most commonly referenced groups of functions applicable to Virtual TMC implementations include:

1. Traffic monitoring
2. Control of ITS devices
3. Maintenance, repair, and troubleshooting
4. Disseminate information
5. Personnel management (if appropriate)
6. Data analysis
7. Interface with media and public
8. Plan, recommend, and implement system, and procedural upgrades
9. Coordination with incident response agencies

10. Coordination with other local and regional transportation agencies

The following tables are adapted from FHWA's 2004 report on TMC Operator Requirements and Position Descriptions and are applicable to the skills and knowledge required of a Virtual TMC operator. However, due to the distributed nature of the Virtual TMC functional architecture, it is more likely that a particular resource will need to have greater knowledge and be required to do more tasks than his centralized TMC counterpart. For this reason, it is expected that the Virtual TMC operator will more often be in the Full Performance or Advanced categories rather than Entry Level.

Human Resources: Generic Activity Group 1

Monitors, classifies, assesses, and archives data and other inputs regarding traffic accidents, road surfaces, traffic density, weather, traffic signal operation/malfunctions, construction projects, major disasters, and special events to maintain constant awareness of traffic system operation.

	Entry Level	Full Performance	Advanced
Knowledge	• TMC metro area road system. • Use of Common language/ terms used to describe traffic conditions.	• Road locations that are critical to traffic safety and/ or traffic flow. • TMOT's manual, including policies and procedures. • Traffic system terminology. • Principles of technical traffic engineering (e.g. queuing, capacity).	• Traffic signal timing selection plans. • HAZMAT policies, procedures and codes. • Overheight vehicle control regulations and response plans. • Rail crossing traffic signal controls and response plans
Skills / Abilities	• Skill in visualizing map locations (i.e., map reading skill). • Skill in reading and listening to detailed or technical information. • Ability to communicate orally and in writing to provide information clearly and succinctly. • Ability to learn a body of material consisting of regulations, and /or procedures. • Demonstrated success in dealing with pressure	• Ability to analyze multiple source data from equipment and people under time pressure. • Ability to communicate effectively with transportation system audiences (e.g., police, highway helpers, public).	• Ability to interpret conflicting or ambiguous traffic incident/congestion information. • Ability to make a disciplined and timely assessment of information on potential for major disasters and emergencies.

Human Resources: Generic Activity Group 2

Selects, activates, and operates a variety of existing equipment and information systems, including computers, traffic signal timing plans, closed circuit cameras, dynamic message signs, two-way radios, ramp meters, traffic density detectors using various software. These systems are used to collect road and traffic information and transmit accurate and timely images, messages, or data on traffic conditions and incidents under the purview of the TMC, and are located at a workstation in a TMC. Notifies information systems support professionals about equipment or software performance problems and issues work orders.

	Entry Level	Full Performance	Advanced
Knowledge	• Computer equipment/ software with Microsoft Windows or equivalent systems.	• Software programs/ equipment capabilities and limitations used in TMC operated systems.	• Techniques to respond to and correct minor equipment/software performance problems.
Skills / Abilities	• Demonstrated general automation skill by use of moderately complex software used in spreadsheets, word processing, databases, or Internet applications. • Demonstrated ability to operate and integrate audio, video, or other moderately complex electronic equipment.	• Skill in operating software and equipment used by a TMC. • Ability to clearly communicate with ITS staff regarding how the equipment and software is performing.	• Ability to independently troubleshoot and correct minor performance problems with equipment and software. • Ability to train/mentor other operators about equipment and software capabilities. • Ability to recommend improvements to traffic information systems and network operations

Human Resources: Generic Activity Group 3

Evaluates data on the severity of traffic conditions and other factors affecting the traveling public and selects the appropriate response plan in order to ensure the best possible flow of traffic using TMC policies, procedures, and precedents. Takes the necessary steps to implement the response plan and ensures that the conditions and responses are recorded into the data system of the TMC. Track and evaluate performance measurement data for use in modifying operations or recommending traffic systems operational changes.

	Entry Level	Full Performance	Advanced
Knowledge	• English usage and grammar, demonstrated by successful completion of relevant high school courses. • In specific TMCs, conversational Spanish - - test or structured interview. • Mathematical concepts, demonstrated by successful completion of related high school courses in geometry, algebra or trigonometry.	• Principles of technical traffic engineering (e.g., queuing, capacity, etc.). • TMC operations manual including policies, precedent and procedures. • Intelligent transportation measuring systems (e.g., heuristic).	• HAZMAT policies, procedures, and codes. • Area emergency evacuation policies and procedures .

	Entry Level	Full Performance	Advanced
Skills / Abilities	• Ability to solve problems (e.g., demonstrated good judgment about career and life situations). • Demonstrated success in dealing with stressful situations. • Apply quantitative skills such as percentages, numerical ratios, and speed and distance formulas	• Ability to diagnose and assess the severity of traffic incidents. • Ability to develop and implement effective and disciplined response plans within established policies under time pressures. • Skill in timely and effectively addressing customer service needs.	• Ability to recognize when to override/modify automated system generated plan. • Ability to make timely and independent decisions to respond in unprecedented situations or major disasters (e.g., plane landing on highway, atypical HAZMAT spills). • Ability to independently develop traffic management plans for special events and/ or other areas of potentially chronic congestion. • Ability to independently evaluate meter queues and adjust timing of ramp meters. • Ability to recommend systems operational changes.

Human Resources: Generic Activity Group 4

Coordinates with or dispatches other traffic management personnel and organizations such as police, fire and rescue squads, emergency assistance personnel, transit services, highway patrol, or traffic signal repair crews to resolve traffic system problems or repair parts of the transportation management system. Participates in transportation planning activities as required.

	Entry Level	Full Performance	Advanced
Knowledge	• English grammar and usage, demonstrated by successful completion of relevant high school courses..	• Traffic management terminology	• Traffic management systems for arterial roads
Skills / Abilities	• Ability to speak / write in an understandable manner using detailed information or technical terms. • Ability to listen and understand detailed and technical information.	• Skill to communicate technical information clearly and succinctly to peers. • Ability to listen and understand detailed and technical information and apply solutions that are within established guidelines.	• Ability to independently resolve issues from the competing or conflicting needs or concerns of other traffic management entities. • Ability to represent the TMC at meetings to develop special events plans.

Human Resources: Generic Activity Group 5

Disseminate information to the public through message signs, advisory radio, web sites, and other media to improve the flow of traffic.

	Entry Level	Full Performance	Advanced
Knowledge	• English grammar and usage. • Conversational Spanish (optional to specific position where metropolitan area has large Spanish-speaking population)	• Traffic system terminology • Web site management	• Not applicable
Skills / Abilities	• Ability to speak and write succinctly.	• Ability to clearly communicate technical information in layman's terms. • Skill in displaying courtesy and sensitivity to the motorist and public needs.	• Not applicable.

3.2.3.5. Inter-Departmental and Inter-Agency Agreements

In a Virtual TMC it is critical to establish processes for agreements, formalize partnership with other departments and agencies and develop institutional arrangements and agreements.

Table 15 summarizes the key agreement content with content providers and other system partners:

Table 15. Inter-Agency Agreements

Entity	Agreement Content
Content Providers	Data Sharing Requirements Data Exchange Standards Data Quality Agreements System Interface Requirements Troubleshooting/Maintenance Cost Sharing
Adjacent Agencies/States	Agreement and standards to facilitate mutual data transfer Cost sharing agreement Standards for future integration
Marketing Partners Providers	Marketing/co-branding agreements Cost sharing agreements

Data sharing agreements will play a critical role in Virtual TMC implementations owing to the significant amount of data exchange in terms of both inputs and outputs that is involved with a virtual setup. Strong data sharing agreements should be drawn up between all parties during the implementation stage in order to ensure that there are no contractual breaches throughout the lifespan of the Virtual TMC. If data feeds are to be supplied by a private sector partner (e.g., Inrix traffic data), consideration needs to be given to how these data are paid for and also what level of return could be achieved through such investments.

3.2.4. Business Models for a Virtual TMC

3.2.4.1. Key Factors to Consider

In order to develop a Virtual TMC business plan, it is necessary first to consider how the Virtual TMC is organized and the functions it serves for the region. Such aspects define the TMC's business model.

In its 2005 *TMC Business Planning and Plans Handbook*[27] the FHWA identified several different types of

27 FHWA, *Transportation Management Center Business Planning and Plans Handbook* (Washington DC: 2005). Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

organizational and functional options for a TMC that factor into the business model. These options are applicable to virtualized TMC functionality as well. The key factors to consider when developing a business model for a Virtual TMC include:

- Functions or services provided;
- Geographic area covered;
- Number and types of agencies involved; and
- Operating mechanism.

The typical options for these factors are summarized in Table 16 and are discussed in greater detail in the following sub sections.

Table 16. Organizational and Functional Options for a VTMC

Geographic Area	Number and Type of Agencies	Operating Mechanism
• Single jurisdiction • Multiple jurisdictions • Regional/district • Statewide	• Single agency • Multiple agencies • Multiple agencies and disciplines	• Public sector operated (single agency) • Public sector operated (consortium) • Separate public sector operating entity • Public-private partnership • Contracted operation

Local and regional conditions, institutional arrangements, system capabilities, and needs will necessarily impact the design of any Virtual TMC implementation. However, the factors listed above will help establish at a high level the basic organizational, functional, and institutional relationships that comprise various options for structuring a Virtual TMC.

While virtualization of operations can benefit a number of the TMC business models summarized above, it is most beneficial when one or more of the following criteria apply:

1. Coordination and decision making in a group setting is rare;
2. System users do not have common needs for more developed functional shared facilities (e.g., emergency operations room, media room, etc.);
3. User groups require common information, but do not use this information directly for coordinating real-time decisions that are core of their operations. The information is instead more complementary in nature;
4. Visual or verbal access among user groups is of little or no value to the work being performed;
5. Due to the nature of the TMC (e.g., rural coverage area) there is no extended benefit for improved coordination and communications with other user groups;
6. There is no need to cross-train or back-fill positions, even in a temporary or casual capacity; or
7. Computer or communications equipment for different user group systems is sufficiently different, or carries enough security risks, that it cannot readily be integrated into one room or be maintained, repaired, or configured by common staff.

3.2.5. Planning for a Virtual TMC vs. a Centralized TMC

The implementation of a TMC, virtual or centralized, requires a broad set of criteria to be addressed during the planning stages. These criteria include the stakeholders' long-term vision and goals; objectives; relationships, roles, and responsibilities; functional needs; performance targets; infrastructure; technology; costs; and future needs.

Figure 26 depicts the process for developing a TMC Business Plan, which is applicable to both virtual and centralized environments.

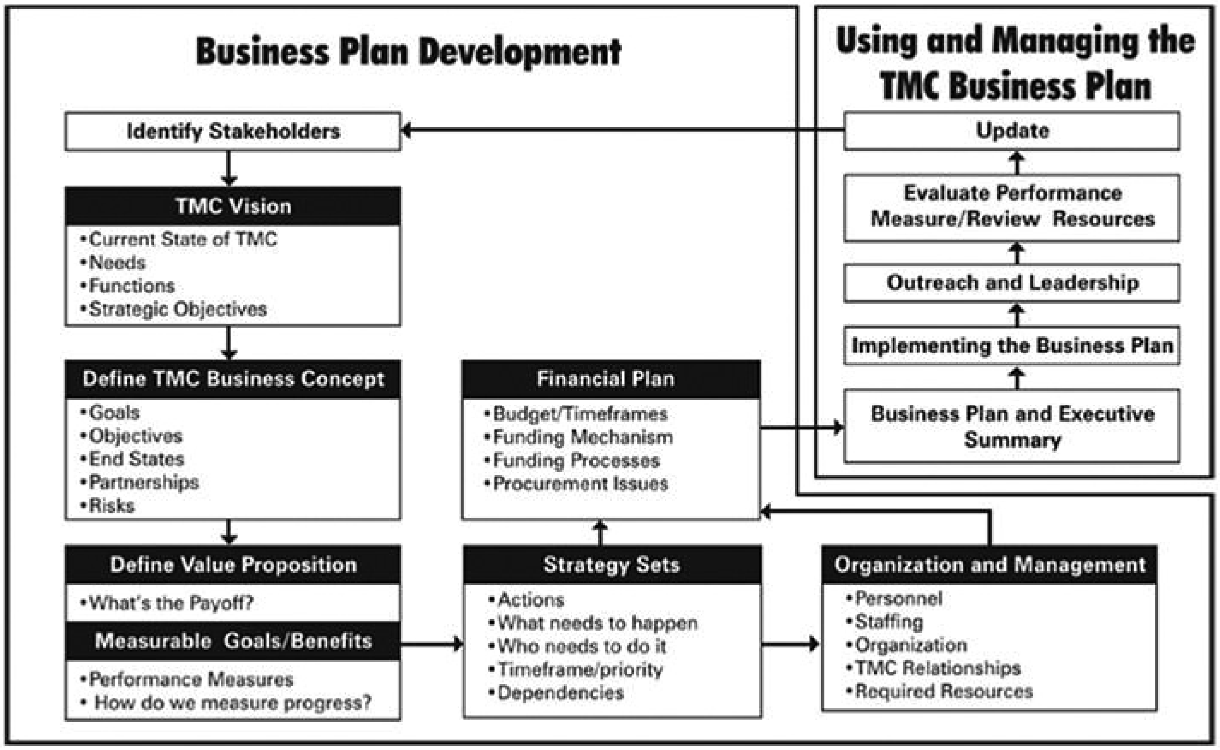


Figure 26. Graph. Business Plan Steps and Process[28]

Table 17 further expands upon the key components that should be contained in the Virtual TMC Business Plan.

Table 17. Virtual TMC Business Plan Core Components

VTMC Business Plan Core Component	Recommended Content and Focus
Identify Stakeholders	• Summarizes the key points of the Business Concept, Strategies, Partnerships, Organization and Financial Plan • Used as a tool to sell the Business Concept and Plan to high level agency managers, local and regional elected officials, and TMC partners
Define Business Concept	• Functions and description of key functions or needed functions • Strategic objectives, goals, future trends • Services – within the TMC and how the TMC relates or supports other agency operations and regional TMS, emergency management, safety, regional connectivity, information management, etc. • Vision and TMC description (current state, future end state) • Partnerships, including existing and desired or needed partners or alliances • Risks and dependencies
Define Value Proposition	• Define benefits and how they will be measured, how progress will be monitored and reported • Who benefits – who stands to benefit from achieving strategic objectives • The Value Proposition helps to market and 'sell' the Business Concept to target audience and decision makers

28 FHWA, *Transportation Management Center Business Planning and Plans Handbook*, "Chapter 1. Introduction and Overview." (Washington, DC: 2005). Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

VTMC Business Plan Core Component	Recommended Content and Focus
Strategy Sets	• Actions – What needs to happen (projects, implementations, changes or enhancements that need to occur) • Who is responsible (to lead, champion, produce, develop, implement or manage) • Timeframes and priorities • Dependencies
Financial Plan	• Budget and timeframes • Funding mechanisms • Funding processes • Procurement issues/requirements
Organization and Management	• Who owns, who manages, who participates • Personnel, staffing (numbers and types of staff, training and experience requirements, etc.) • Organization structure, chain of command, resource requirements • TMC relationships to external agencies, how it functions in the "bigger picture," and what are the critical agency relationships and partnerships

In addition, during the planning process, consideration should be given to current and future regional ITS programs and establish ITS processes to help define the Virtual TMC objectives. Figure 27 illustrates the relationship between ITS planning processes and the TMC business plan.

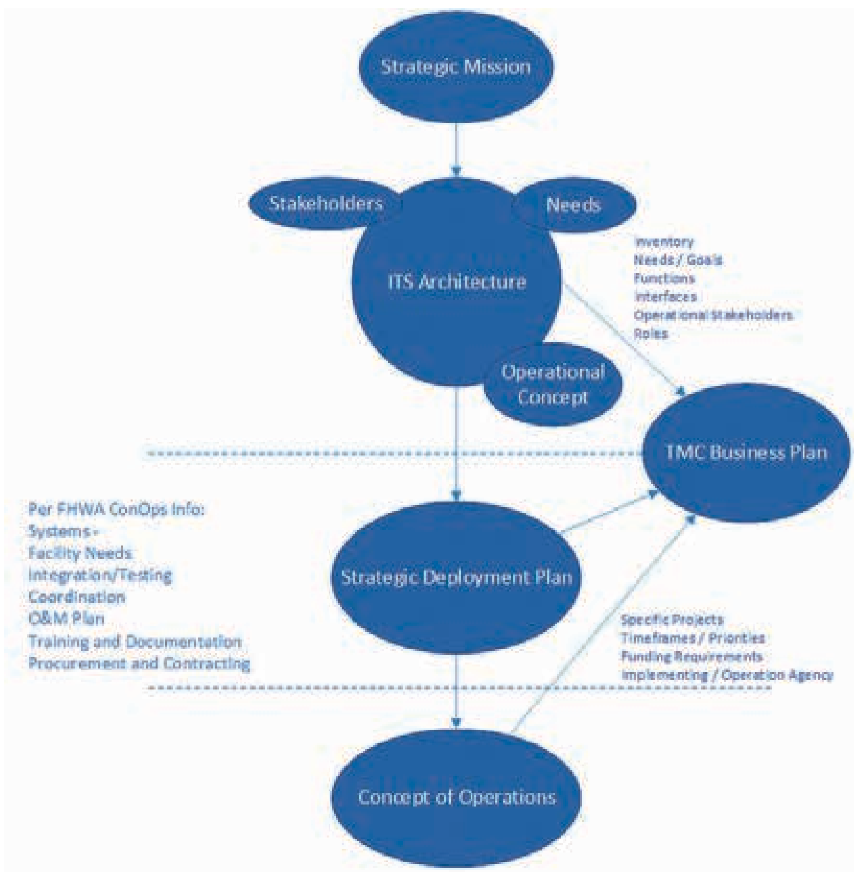


Figure 27. Graph. Relationship of the TMC Business Plan to other Plans and Processes[29]

It is important to align plans for a Virtual TMC deployment—including its funding—with the regional ITS architecture. The regional ITS architecture, as depicted in Figure 28, focuses on specific, measurable, and and

29 FHWA, *Transportation Management Center Business Planning and Plans Handbook,* "Figure 2-5. Relationship of ITS Planning Processes with the TMC Business Plan" (Washington, DC: 2005), p. 2-15. Available at: *http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/TMC_BPG_Final.pdf*

outcome-oriented objectives in the planning and operations of a Virtual TMC.

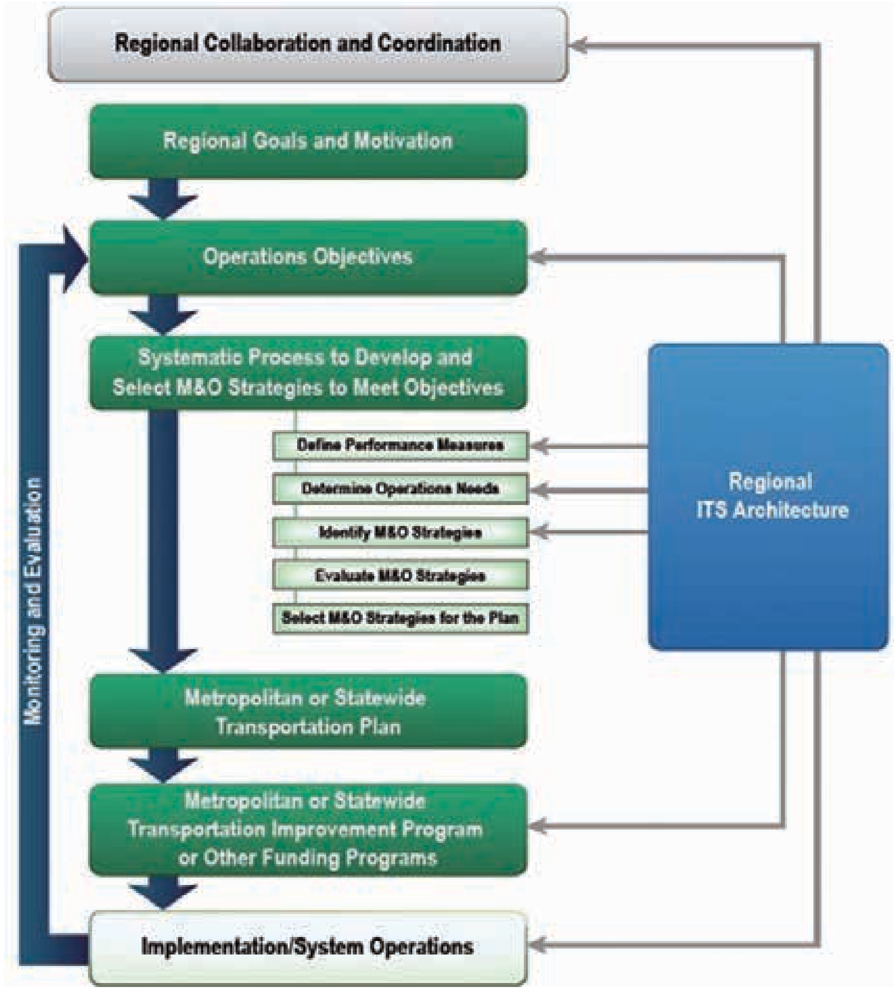


Figure 28. Graph. Regional ITS Architecture to Suppport Planning and Operations[30]

Following the National ITS Architecture

With the passage of the Transportation Equity Act for the 21st Century (TEA-21), ITS projects funded through the Highway Trust Fund were required to conform to the National ITS Architecture and applicable standards. Conformance with the National ITS Architecture was interpreted to mean using the National ITS Architecture to develop a regional ITS architecture and requiring all subsequent ITS projects to adhere to that regional architecture as well. The National ITS Architecture is to be used as a resource in the development of the regional ITS architecture (as discussed above), and the subsequent regional ITS architecture is to be on a scale commensurate with the scope of ITS investment within the region. (Refer to ***http://www.ops.fhwa.dot.gov/publications/tptms/handbook/chapter_3.htm*** for additional information.)

This legislation imposed the following requirements:

- All ITS projects funded by the Highway Trust Fund must be based on a systems engineering analysis on a scale commensurate with the project scope.
- Compliance with the regional ITS architecture must be in accordance with United States Department of Transportation (USDOT) oversight and Federal-aid procedures, similar to non-ITS projects.
- ITS projects funded by the Highway Trust Fund and the Mass Transit Account must conform to a regional architecture.

30 FHWA, *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer.* http://ops.fhwa.dot.gov/publications/fhwahop12001/index.htm

- Projects must use USDOT-adopted ITS Standards as appropriate.
- Regions currently implementing ITS projects must have a regional architecture in place in 4 years, while regions not currently implementing ITS projects must develop a regional ITS architecture within 4 years from the date the first ITS project advances to the final design.
- Major ITS projects should move forward based on a project-level architecture that is coordinated with the development of the regional ITS architecture.
- The concept of operations document should identify the roles and responsibilities of participating agencies and stakeholders for the regional ITS architecture developed for the TMS.

Figure 29 depicts the various systems, sub-systems, and interconnects that comprise the National ITS Architecture.

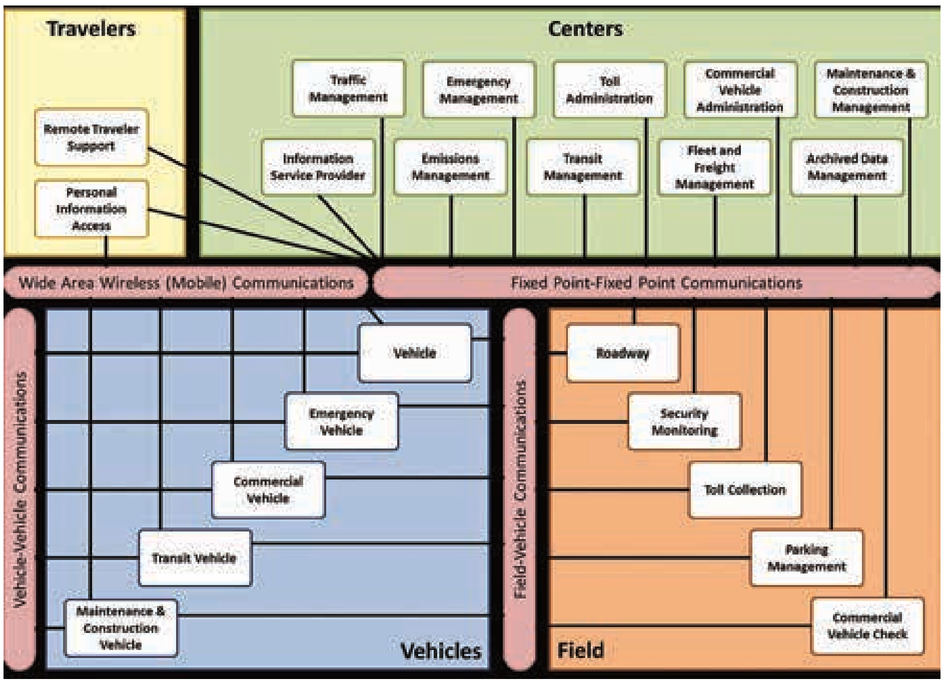


Figure 29. Graph. National ITS Architecture Interconnect Diagram[31]

The National ITS Architecture considers Traffic Management a Service Package Group containing numerous Service Packages designed to reflect the current definition of ITS and the evolving implementations of ITS. Service packages are defined by sets of equipment packages required to work together (typically across different subsystems) to deliver a given transportation service and the major architecture flows between them and other important external systems. In other words, they identify the pieces of the National ITS Architecture required to implement a service. Service packages are not intended to be tied to specific technologies, but of course depend on the current technology and product market in order to actually be implemented. As transportation needs evolve, technology advances, and new devices are developed, service packages may change and new service packages may be defined.

Although the National Architecture does not distinguish between a virtual and traditional TMC, all the identified Service Packages within the Traffic Management Service Package Group may be applicable to a Virtual TMC. As identified in the Key Concepts of the National ITS Architecture report (available at the link: ***http://www.iteris.com/itsarch/documents/*** keyconcepts/keyconcepts.pdf), these include:

- Network Surveillance
- Probe Surveillance

31 FHWA, ITS Architecture Implementation Program, "Figure 23 – National ITS Architecture – Sausage Diagram". *http://ops.fhwa.dot.gov/its_arch_imp/its-integration-ohio/section443.htm*

- Traffic Signal Control
- Traffic Metering
- HOV Lane Management
- Traffic Information Dissemination
- Regional Traffic Management
- Traffic Incident Management System
- Traffic Decision Support and Demand Management
- Electronic Toll Collection
- Emissions Monitoring and Management
- Roadside Lighting System Control
- Standard Railroad Grade Crossing
- Advanced Railroad Grade Crossing
- Railroad Operations Coordination
- Parking Facility Management
- Regional Parking Management
- Reversible Lane Management
- Speed Warning and Enforcement
- Drawbridge Management
- Roadway Closure Management
- Variable Speed Limits
- Dynamic Lane Management and Shoulder Use
- Dynamic Roadway Warning
- VMT Road User Payment
- Mixed Use Warning Systems

The National ITS Architecture also identifies communication and information-based standards. Such standards are especially relevant to a Virtual TMC, as its distributed architecture places a heavy emphasis on efficient and reliable communication. Among the pertinent national ITS standards development activities in process are the suite of standards being developed under the National Transportation Communications for ITS Protocol (NTCIP) effort. There are also a number of other existing communication and information-based standards that are applicable to ITS projects. The following list some of the applicable ITS standards with respect to data elements, message sets, and communication protocols.

Data elements:

- Traffic Management Data Dictionary (TMDD) - reference the Institute of Transportation Engineers (***www.ite.org/TMDD).***
- NTCIP standards for the communications with the various ITS devices such as traffic controllers, dynamic

message signs, environmental monitoring stations, CCTV cameras and switches, ramp controllers, etc. (reference ***www.ntcip.org***) and refer to document NTCIP 9001 for a guide to these standards.

- Advanced Traveler Information System (ATIS) data dictionary (SAE J2354).

Message sets:

- Transit Communication Interface Profile (TCIP) (APTA).
- Message Sets for External Traffic Management Center Communications (MS/ETMCC - now part of the ITE TMDD effort).
- Incident Management Message sets (IEEE-1512).
- Advanced Traveler Information System (ATIS) message sets (SAE J2354).

Communication protocols:

- National Transportation Communications for Intelligent Transportation Systems (ITS) Protocol (NTCIP). These protocols identify center-to-center and center-to-field communications protocols for a variety of media (e.g., analog telephone, Ethernet).

In addition to the ITS-specific standards involving communications data, messages, and protocols, existing and emerging standards are available for many ITS devices and/or their interfaces (e.g., signal controllers, video cameras, dynamic message signs, etc.). These standards can be reviewed and considered for incorporation into the Virtual TMC Project based on the appropriate engineering analyses.

3.2.6. Relevant Factors to Virtual TMC Planning

Other factors to consider in planning a Virtual TMC include:

- Virtual private networks (VPN) – Are they required to support agency IT guidelines or security preferences?
- Center-to-Center (C2C) systems – Which connections with other agencies are required and how technically will this be accomplished?
- CCTV and video feed sharing –Will video sharing be allowed and what technical solutions should be put in place if it is?
- Upgrade of field devices to current standards – Should the field communication network be upgraded to be more conducive to Virtual TMC Operations?
- Procurement of a common software application (e.g. ATMS system) to perform transportation management functions – Should new software packages be procured that better enable Virtual TMC Operations?
- Adequate levels of IT support. Support needs are likely to be greater than in a typical TMC setting – What kind or additional IT support may be required and how much?
- Well defined Memoranda of Understanding - Are any supplemental agreements between agencies needed (when a multiagency Virtual TMC model is being considered)?

3.2.7. Establishing a Core Management Team

Ensuring Key Stakeholder Representation

The implementation of a Virtual TMC requires a focused team to manage the project all the way from inception through the launch. This core management team should be answerable to and reflect the needs of the project's key stakeholders, including:

- **Public/agency authorities:** responsible for providing traffic management services and initiation of the project. These stakeholders are the driving force behind the Virtual TMC.
- **Virtual TMC operator:** responsible for providing the day-to-day Virtual TMC operations. Operators may be a public or private sector partner.
- **Emergency services:** key, highly-visible users of the Virtual TMC systems.
- **Private sector:** providing project support in various ways, from implementation (including ITS, materials, or personnel) or providing professional knowledge and expertise as a consultant.
- **Technical advisors:** responsible for providing expert technical advice and services as required.
- **Legal advisors**: responsible for providing legal advice, constructing contractual agreements, and continued legal support.

While the context of each Virtual TMC implementation is unique—each with different operational needs, institutional structures, and political environments—in all cases, it is critical to identify these key stakeholders and to bring them together around one table to ensure that the implemented project addresses the needs of the region.

Forming a Focused Core Project Team

It is important to ensure that the Virtual TMC project receives input from a variety of stakeholders, but the core project team itself should be small and focused in order to manage the project from inception through launch and to the full operation.

Since TMCs (and Virtual TMCs in particular) must rely on the integration of various technologies and data communication, it is important to establish an appropriate composition of partners in this core team with clear understanding of how each party will work within the management and administrative structure. This becomes especially important in public-private partnerships.

3.2.8. Implementing Data Storage and Archiving

Effective data management and data archiving for TMC and Virtual TMC operations is a critical component needed to improve coordinated operations and increase return on investment (ROI) for TMC projects. To maximize ROI for data storage and archiving it is recommended to initially approach data management through an agency and public benefit analysis as opposed to a typical functionality- and requirements-driven perspective.

In 2013 the Permanent Citizens Advisory Committee (PCAC) to New York City's Metropolitan Transportation Authority (MTA) provided several realized and projected benefits impacting internal and external stakeholders.[32] In one example the PCAC stated that data analytics can help management make improvements across a series of stations. A software program that captures data from multiple departments, for example, could reflect the total rider experience at each station by displaying multiple metrics like ridership, service frequency, wait assessment, maintenance, capital improvements, injuries, and crime. If these data were then presented in a uniform way through a medium like data visualization, management could quickly identify stations that need attention as well as highlight stations that are excelling in a comprehensive way.

32 E. Shannon, Permanent Citizens Advisory Committee to the MTA, (2013). Retrieved from "The MTA in the Age of Big Data" website: *www.pcac.org*.

Figure 30 illustrates typical benefits of applied transportation data.

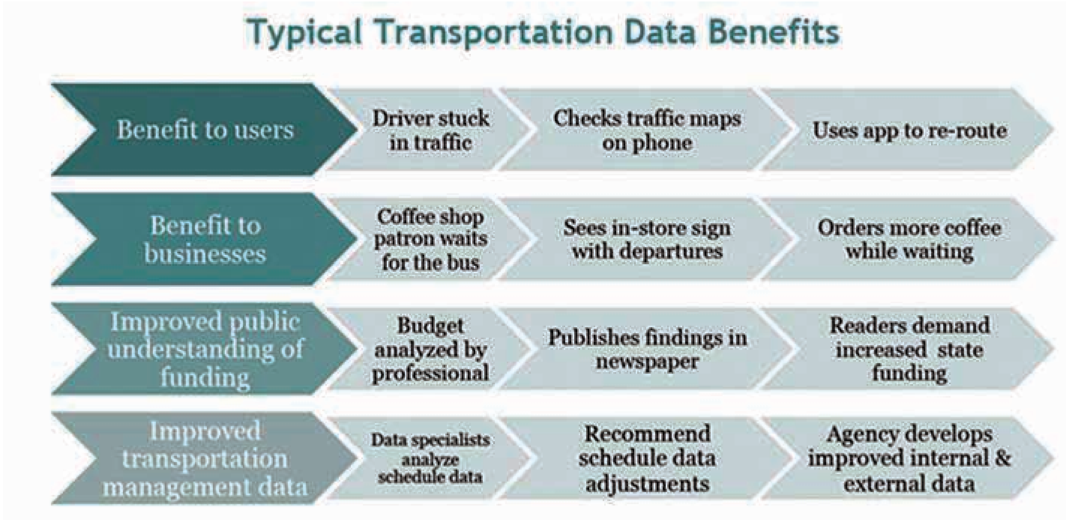


Figure 30. Graph. Typical Transportation Data Benefits[33]

The ability to collect and provide visual or analytical traffic data offers significant potential for improved services offered by traffic agencies. Once an agency has defined what data warehousing and analytical functions should be fulfilled by the system, the performance requirements and scalability for data storage and archiving can be evaluated more effectively.

The operational and functional requirements of a TMC data solution will dictate which agency data should be collected, and retention requirements for each data set. Typically storage requirements encompass diverse data types including:

- Congestion data (freeway and Arterial)
- Signal and Ramp Meter Status
- Vehicle Location Data
- Transit signal priority data
- Travel Time data
- DMS/CMS records
- Incident/Event Data
- Response plan data
- Environment data (ESS)
- CCTV Control Data
- CCTV Recordings

Many cloud hosting providers provide scalable storage for small and large data sets which are integrated with Business intelligence and visualization application platforms. This may be an attractive option for smaller agencies, multi-agency collaborations, or where long term usage and data size is not fully known.

Agencies that require on premise data warehousing due to security or functional requirements should be careful to select scalable storage and database solutions which can accommodate unexpected data growth and constantly

33 S. Kaufman, "Getting Started with Open Data," Informally published manuscript, Rudin Center for Transportation Policy and Management (New York: New York University, 2012).

evolving performance requirements.

For a large scale urban TMC, data storage capacity needs are typically in the range of 1 GB per week. A de facto guideline for TMC data storage is 13 months, although with the highly decreased cost of data storage drives, many years of data (e.g. 5 years or more of archived data) are now typically kept online for many TMC facilities, virtual or otherwise. The recommended data storage size for Virtual TMCs is 10 Terabytes to hold a minimum of 5- years of data.

3.2.9. Determining a Financial Model

Before determining the appropriate Financial Model to fund a Virtual TMC, a Financial Plan must be developed during the planning process. According to the TMC Business Planning and Plans Handbook, the Financial Plan "needs to address the TMC-specific funding requirements, and tie these requirements back to the Business Concept, Value Proposition, improvements required to develop the capabilities required, and the strategies and services needed to manage, operate, and maintain a TMC."

The Financial Plan is also the place where potential funding sources—typically Federal, State, and local—need to be identified. However, there may be opportunities to form Public-Private Partnerships (PPP) as well. Funding will largely depend on the Virtual TMC's jurisdiction, scope of services, functions, and coverage area. Traditionally, government funding has been provided for capital expenditure of new or renovated TMC facilities. There are a number of general funding programs available as shown in Table 18

Table 18. Available Funding Sources[34]

SUMMARY OF FUNDING SOURCES			
Funding Resources	Eligibility		Qualifying Conditions
	Capital Expenditures	Operating Expenditures	
National Highway System (NHS)	✓	✓	80/20 percent federal/local match with no time limit on operations
Surface Transportation Program (STP)	✓	✓	80/20 percent federal/local match within the initial project scope.
Interstate Maintenance (M)	✓	✓	90/10 percent federal/local match
Congestion Mitigation and Air Quality Improvement Program (CMAQ)	✓	✓	80/20 percent federal/local match for 2 years or longer if improvements are demonstrated.
SAFETEA/TEA-LU (TEA-21 Reauthorization)	✓	✓	
ITS Integration	✓	✓	50% federal integration funds 20% local funds 30% other federal or non-federal funds
National Corridor Planning and Development Program and Coordinated Border Infrastructure Program	✓	✓	80/20 percent federal/local match
State Funding	✓	✓	Criteria varies per program
Local Funding	✓	✓	Criteria varies per program
Moving Ahead for Progress in the 21st Century – MAP 21			Criteria varies per grant
TIGER Grants			Safety, economic complexity, state of good repair, livability and environmental sustainability
DOT Grants			Criteria varies per grant

34 FHWA, *Transportation Management Center Business Planning and Plans Handbook,* "Chapter 9. Financial Plan" (Washington, DC: 2005).

All of the programs listed above may become financial sources for the implementation and operation of Virtual TMCs. The programs are described in further detail below:

National Highway System (NHS) – Provides for capital and operating costs for traffic monitoring, management, and control facilities and programs. Funds provided on an 80/20 percent Federal/local match basis with no time limit for operations.

Surface Transportation Program (STP) – Provides for capital and operating costs for traffic monitoring, management, and control facilities and programs. Funds provided on an 80/20 percent Federal/local match basis within the initial project scope.

Congestion Mitigation and Air Quality Improvement Program (CMAQ) – Provides funds for the establishment or operation of a traffic monitoring, management, and control facility or program in nonattainment areas. Explicitly includes, as an eligible condition for funding, programs or projects that improve traffic flow. Funds are provided for O&M on an 80/20 percent Federal/local match basis for 2 years, or longer if the project demonstrates air quality improvement benefits on a continuing basis.

Interstate Maintenance – The Interstate Maintenance Program was created to provide funds to States to maintain previously completed sections of the Interstate System. Some states have used these funds for capital investments in Traffic Management Centers and operations that serve the Interstate System. Funds are provided on a 90/10 percent Federal/local match basis.

SAFETEA/TEALU (2004 Reauthorization Bill) – will also authorize several additional Federal funding mechanisms, which are available specifically to aid in the deployment and operation of ITS.

ITS Integration – This component of the ITS Deployment Program provides funding for activities necessary to integrate ITS infrastructure components that are either deployed (existing) or will be deployed with other sources of funds. This may include the integration of different ITS systems or subsystems (e.g., freeway management, arterial management, etc.) or the integration of ITS components across jurisdictions. Eligible activities include system design and integration, creation of data sharing/archiving capabilities, and deployment of components that support integration with systems outside of metropolitan areas. The ITS Integration Program can fund up to 50 percent of an integration project's costs with a minimum of 20 percent of the local match to come from non-federally derived sources. The other 30 percent match could come from other Federal funds or nonfederal funds.

The National Corridor Planning and Development Program and Coordinated Border Infrastructure Program – was established under Sections 1118 and 1119 of the Transportation Equity Act for the 21st Century (TEA21). The Coordinated Border Infrastructure Program aims to improve border infrastructure and transportation telecommunications to facilitate the safe and efficient movement of people and goods at or across the U.S.-Canada and the U.S.-Mexico borders. The National Corridor Planning and Development Program provides DOT authority to allocate dollars to states and metropolitan planning organizations (MPOs) for coordinated planning, design and construction of highway corridors. Criteria under which the Border Program project funding applications will be reviewed include reduction in travel time through a major international facility, potential for improvements in border crossing vehicle safety and cargo security, and the applicability of innovative techniques and technology to other border crossing facilities. The Federal share for projects funded through these programs is 80 percent (sliding scale applies).

The following section provides an overview of the most common Financial Models available.

Financial Models

Single Agency Funding – In this model one agency funds the entire implementation and operations costs. Under this model, the agency has full control and no interagency coordination is required. However, it makes the single agency responsible for obtaining all funding.

Deployment Example: INFORM, Long Island New York

Funding Allocation Based On TMC Utilization – In this model costs are shared amongst various agencies including operating costs for facilities, computer system and telecommunications. Agencies co-located in the facility pay a utilization cost based on shared resources used. Depending on the agreement, some agencies may share the cost of pooled personnel (e.g. IT support, building security). This model is used in some large TMCs.

Deployment Example: Regional Traffic Management Centre, British Columbia

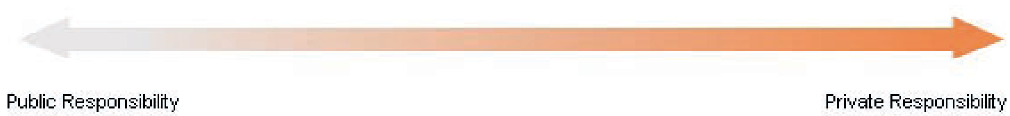
Funding Allocation Based on TMC Coverages – In this model, multiple agencies use one TMC, and cost is shared among the agencies based on the number of field devices in each jurisdiction that is sharing the TMC.

Deployment Example: FAST, Las Vegas Nevada

Funding from User Fees or Dues – This model largely depends on the nature of the TMC functions, and the services provided to end users (e.g., general public, transportation agencies, private entities) as it will be supported by user fees.

Deployment Example: TRANSCOM's Traffic Operations Center, New York and New Jersey.

Public-Private Partnerships (P3s) – This models involves a contractual agreement between a public agency and the private sector in the delivery of projects that can be mutually beneficial. In this collaboration it is crucial to identify each partner's responsibilities and budget sharing arrangements. This relationship is illustrated in Figure 31:



P3 Options					
New Build Facilities	Private Contract Fee Services	Design Build	Design Build Operate Maintain	Design Build Finance	Design Build Finance Operate Maintain Concession
Existing Facilities	O & M Concession				Long Term Lease Concession

Figure 31. Graph. Public-Private-Partnerships Options[35]

3.3. Security

The Virtual TMC (VTMC) model mandates a highly networked environment. This design may translate to a substantial increase in system exposure and potential risk when compared with a traditional TMC Model. This is especially true when the Virtual TMC model provides remote access to users and agencies through the internet, connecting to traffic devices over public networks, and interconnecting multiple agencies. A functional VTMC will require interfaces and possibly modifications to existing or planned ATMS systems. System security must be considered holistically for both VTMC and ATMS systems.

The potential impact to public safety and traffic operations which would be caused by an attack or availability failure of any Traffic Management System is very high. As such the security requirements between traditional TMCs and Virtual TMCs are similar. However, given the increased exposure to external risks presented by the Virtual TMC

35 Innovative P3 Program Delivery *http://www.fhwa.dot.gov/ipd/p3/defined/*

model, and risks associated with connection data system for multiple agencies, real consequences from security flaws are more likely to occur. Additional security measures will be needed to protect systems from external access, including robust firewalls, Intrusion detection systems, and encryption technologies. Stakeholders at each level of the agency must make a fundamental commitment to system security, from project initiation through end-of-life procedures.

The requirements for security each system will vary, it is therefore imperative that each agency or agencies agree upon a Risk Management process at project inception that will guide the creation of security requirements, and risk analysis throughout the project design and implementation. Risk Management and Defense in depth (RMDID), is a commonly used and well documented approach to system security which may benefit any agency seeking to improve or implement new security architecture. The following sections provides a high level path for implementing RMDID measures for Virtual Traffic Management Systems as part of the Systems development life-cycle (SDLC) guided through recommendations provided by The National Institute of Standards and Technology (NIST) 800 series publications. The NIST 800 series publications provide workable and cost-effective methods for optimizing the security of information technology (IT) systems and networks in a proactive manner.

Figure 32 demonstrates Key Risk Management tasks which should be addressed at each SDLC phase of a VTMC Project.[36,37] NIST SP 800 publications and additional reference documents which should be referenced during each phased of a Virtual TMC project development life-cycle are provided below.

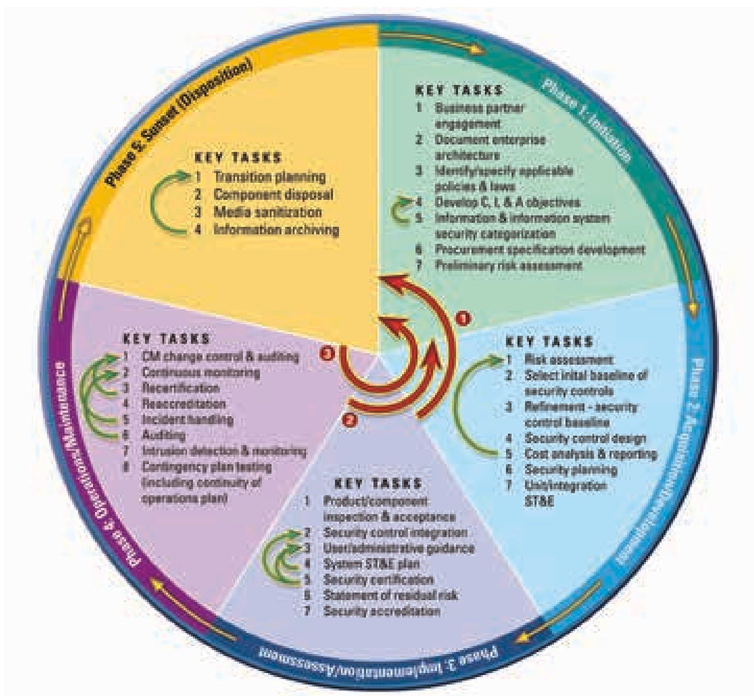


Figure 32. Graph. Project Development Life Cycle[38]

Risk Management Integration into SDLC

It is crucial that a security and risk management architecture is selected and implemented during the initial stages of any VTMC project. Risk Management measures must be balanced against agency requirements and cost limitations. Failure to address risks measured before procurement will have a significant impact on project budgets.

36 Computer Security Division, Information Technology Laboratory, National Institute of Standards and Technology. ITL bulleting the system development life cycle SDLC (NIST ITL SDLC) (n.d.). Retrieved from website: *http://csrc.nist.gov/publications/nistbul/april2009_system-development-life-cycle.pdf*

37 "Information Security System Development Life Cycle." *Ready.Gov.* N.p., 31 10 2011. Web. Retrieved from *http://www.ready.gov/document/information*-security-system-development-life-cycle on 10 Apr 2014.

38 National Institute of Standards and Technology. Information Security System Development Life Cycle. *http://www.ready.gov/sites/default/files/documents/files/IS_system_development_cycle.pdf*

Senior leaders and executives must be committed to making risk management a fundamental mission requirement. This top-level, executive commitment ensures that sufficient resources are available to develop and implement effective risk management for a Virtual TMC.[39]

Assignment of risk management responsibilities to senior leaders and executives should be completed at project inception.

Security planning should begin in the initiation phase with the identification of key security roles to be carried out during system development.

The information to be processed, transmitted, or stored should be identified and evaluated for security requirements, and all stakeholders should have a common understanding of the security considerations. Guidance is provided by NIST through two documents: NIST 800-60, Guide for Mapping Types of Information and Information Systems to Security categories (Revision 1), and FIPS 199, Standards for Security Categorization of Federal Information and Information Systems.

Beyond selection of key security roles and risk management process selection, the methods and depth of system security architecture will vary based upon project and agency requirements. The following reference documents provided by NIST SDLC may be adapted in whole or part by agencies when implementing a Virtual TMC system. Documents are available at ***http://csrc.nist.gov/publications/PubsSPs.html***#800-30

Phase 1

SDLC P1 Task	Reference Document
1	SP 800-35 Guide to Information Technology Security Services
1	SP 800-27 Engineering Principles for Information Technology Security (A Baseline for Achieving Security)
2	SP 800-47 Security Guide for Interconnecting Information Technology Systems
3	SP 800-14 Generally Accepted Principles and Practices for Securing Information Technology Systems
3	SP 800-12 An Introduction to Computer Security: The NIST Handbook
4,4	FIPS 199 Standards for Security Categorization of Federal Information Systems
4,5	SP 800-60 Guide for Mapping Types of Information and Information Systems to Security Categories
6	SP 800-36 Guide to Selecting Information Technology Security Products
6	SP 800-23 Guidelines to Federal Organizations on Security Assurance and Acquisition/Use of Tested/Evaluated Products
7	SP 800-30 Guide for Conducting Risk Assessments

Phase 2

SDLC P2 Task	Reference Document
1	SP 800-30 Risk Management Guide for Information Technology Systems
2	SP 800-53 Security Controls for Federal Information Systems
3	SP 800-53 Security Controls for Federal Information Systems
4	SP 800-36 Guide to Selecting Information Technology Security Products
4	SP 800-23 Guideline to Federal Organizations on Security Assurance and Acquisition / Use of Tested / Evaluated Products
5	SP 800-64 Security Considerations in the Information System Development Life Cycle
5	SP 800-36 Guide to Selecting Information Technology Security Products
6	SP 800-55 Security Metrics Guide for Information Technology Systems
7	Common Criteria; FIPS 140-2 Security Requirements for Cryptographic Modules

39 Computer Security Division Information Technology Laboratory National Institute of Standards and Technology. (n.d.). Managing Information Security Risk (NIST SP 800-39). Retrieved from website: *http://csrc.nist.gov/publications/nistpubs/800-39/SP800-39-final.pdf*

Phase 3

SDLC P3 Task	Reference Document
1	SP 800-64 Security Considerations in the Information System Development Life Cycle
1	SP 800-51 Use of the Common Vulnerabilities and Exposures (CVE) Vulnerability Naming Scheme
2	SP 800-64 Security Considerations in the Information System Development Life Cycle
3	SP 800-61 Computer Security Incident Handling Guide
3	SP 800-36 Guide to Selecting Information Technology Security Products
3	SP 800-35 Guide to Information Technology Security Services
3	SP 800-56 Recommendation Key Establishment Schemes
3	SP 800-57 Recommendation on Key Management
4	SP 800-55 Security Metrics Guide for Information Technology Systems
5	SP 800-37 Guide for the Security Certification and Accreditation of Federal Information Systems
5	SP 800-53A Guide for Assessing the Security Controls in Federal Information Systems
6	SP 800-37 Guide for the Security Certification and Accreditation of Federal Information Systems
7	SP 800-37 Guide for the Security Certification and Accreditation of Federal Information Systems

Phase 4

SDLC P4 Task	Reference Document
1	Handbook 150:2001, NVLAP Procedures and General Requirements
2	SP 800-26 Security Self-Assessment Guide for Information Technology Systems
3	SP 800-37 Guide for the Security Certification and Accreditation of Federal Information Systems
3	SP 800-53A Guide for Assessing the Security Controls in Federal Information Systems
4	SP 800-37 Guide for the Security Certification and Accreditation of Federal Information Systems
5	SP 800-61 Computer Security Incident Handling Guide
6	Handbook 150:2001, NVLAP Procedures and General Requirements
6	SP 800-55 Security Metrics Guide for Information Technology Systems
7	SP 800-61 Computer Security Incident Handling Guide
7	SP 800-31 Intrusion Detection Systems (IDS)
8	SP 800-34 Contingency Planning Guide for Information Technology Systems

Phase 5

SDLC P4 Task	Reference Document
1	SP 800-64 Security Considerations in the Information System Development Life Cycle
1	SP 800-35 Guide to Information Technology Security Services
3	SP 800-36 Guide to Selecting Information Technology Security Products
4	SP 800-14 Generally Accepted Principles and Practices for Securing Information Technology Systems
4	SP 800-12 An Introduction to Computer Security: the NIST Handbook

3.4. Developing a Training Program

3.4.1. Current TMC Training Practices

Many TMC training programs involve a classroom type setting. The training session is usually led by the system trainer and is accompanied by a PowerPoint presentation, specific manuals, and hands-on exercises.

Training sessions may take anywhere between 2 and 4 hours and have 8-10 personnel in attendance. Usually training may be separated into different sessions: one for operators and one for system administrators. System administrators participate in the operators' training as well as receiving more detailed system training.

3.4.2. How to Provide Training for Virtual TMCs

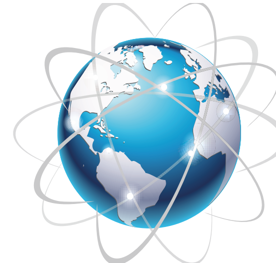
For Virtual TMCs, this training model needs to have some specific modifications. As described above, training sessions are tailored to the specific users (operators, maintenance, administrators). There are no clearly defined "roles and responsibilities" for a Virtual TMC operator. The TMC operator needs to be able to be an operator, an administrator, and a maintenance user. The training model for a Virtual TMC must be able to satisfy the flexible roles and responsibilities.

A training modification is for blurred roles and responsibilities. Many TMCs have multiple operators who have specific regions or responsibilities; i.e., contact maintenance, coordinate with roadway work crews, etc. With a Virtual TMC, these responsibilities reside within a single operator. This operator needs to be able to handle any of the various operations. Therefore the training session has to detail all the responsibilities, no matter the designation (operator or administrator).

Another distinctive modification is the classroom setting. In a physical TMC, there are multiple, dedicated workstations, as well as a training room. This may not be the situation for the Virtual TMC. Classroom training must now be performed as a one-to-one training or as part of a teleconference with multiple users. One-to-one training may not be cost or time effective, as the trainer must now perform the same training numerous times rather than in a single classroom session. A teleconference may be a more effective training tool for the Virtual TMC operators.

An effective training tool is the use of scenarios. Real-life examples allow the trainees, whether they are operators or administrators, to perform all actions needed for a real-life scenario. Scenarios should include unplanned events with minor lane blockage; unplanned events with major lane blockage, injuries, and fatalities; and responses to planned closures. Other scenarios should also include the more day-to-day activities, such as daily reports for events. Scenarios should also include the not-so-normal activities; e.g., the workstation has crashed or the internet connection has been lost. Training must include the actions that an operator needs to take to remain an active participant in the TMC operations.

Since an operator may be responsible for contacting other agencies as well as making decisions regarding notifying media personnel; training sessions and manuals must include the appropriate associated personnel from the media and other agencies. Again as part of the training sessions, information must be made available to allow the Virtual TMC operators to contact the necessary personnel. This list of personnel could be other agency contacts, maintenance contacts, and even IT personnel.



4. VIRTUAL TMC BENEFITS AND CHALLENGES

4.1. Benefits

There are a number of benefits for agencies considering the implementation of a Virtual TMC. These benefits can also extend to partner agencies (stakeholders) participating in the program. Some of the benefits include:

- Remote system accessibility – provides operators and other users with the ability to operate the system(s) by establishing a remote access connection from any location
- Shared control of the agency's existing (and future) ITS devices and data
- Data sharing/exchange among partner agencies
- Improved information collection and dissemination
- Software alignment across partner agencies – use of same software applications across partner agencies facilitates information sharing
- Ability for agencies to combine facility infrastructure and staffing resources to operate in a multi-agency coordinated manner
- Operations alignment across partner agencies - use of Standard Operating Procedures (SOPs) during multi-agency events facilitates integrated response
- Backup capabilities including systems and operations – anyone with appropriate privileges can access the system from anywhere
- Regional Stakeholder buy-in – improved cooperation and collaboration among partner agencies
- Improved communication among partner agencies. Coordinated response to multi-agency events
- Improved relationships with partner agencies
- Cost savings – capital and staffing cost savings may significantly lower in the Virtual TMC model vs. a traditional TMC
- Innovative approach that requires coordination and cooperation between agencies
- A Virtual TMC can be at the service of many agencies

Some of these benefits are discussed in more detail below.

4.1.1. Cost Savings

One of the most important factors in planning a TMC is accounting for the cost associated with its implementation and operations. Agencies have the laborious task of finding one or several sources of funding in order to build, operate, and maintain a Centralized TMC facility. For example, traditional deployment models require larger initial capital investments for the construction or remodeling of a facility. These costs include, but are not limited to:

- Capital Expenditures – facility planning and conceptual design. Cost to buy or lease the land, construction permits, civil infrastructure, utilities, landscaping, power supply, etc. The facility also needs to be equipped with the proper communication infrastructure, central system hardware, security systems, furnishings, etc.
- Staffing – eliminating operational redundancies, eliminating superfluous staff and administrative functions, sharing specialized personnel, coordinating efforts of staff, etc.
- Maintenance costs – staffing, building, supplies, utilities, replacement costs, etc.

There is available data on the costs for the construction of TMC facilities in various locations in the United States. It ranges from $3.5 million for a small 7500 square foot facility to $45 million for a multi-story 88,000 square foot building. From the data gathered, the average TMC cost is $10.6 million at an average size of 31,000 square feet, or $340 per square foot. For these TMCs, the ITS JPO Costs Database reported that operations and management (O&M) costs can range from $50,000 to $1.8 million for the TMC physical plant and from $55,000 to $1.3 million for TMC personnel.[40] Table 19 provides a further summary of costs

Table 19. TMC Operations and Management Costs

Type of TMC	Number of Personnel	Annual Physical Plant Operations Costs ($)	Annual Personnel Operations Costs ($)
Regional	27	1,838,823	1,278,100
Large	7	180,700	476,000
Medium	4	109,400	277,900
Small	1	46,900	53,600

Not a great deal of cost data or cost comparison data is available on the Virtual TMC model. One of the reasons cited by agencies that implemented virtual or hybrid virtual models was the reduction in capital costs for TMC facilities. Since TMCs require supplemental hardware maintenance and replacement associated with video walls, uninterruptible power supplies, generators, lighting, fire protection and other facility-related contingencies, it can be concluded these long-term life cycle costs will be reduced, likely significantly. There may be some additional network communication or IT costs associated with the Virtual TMC model, but this depends on the existing systems that the agencies already have in place. To some agencies, these costs could be higher but to others it could be no additional cost. Such recurring costs should be investigated on a case-by-case basis before the decision is made to implement the Virtual TMC model.

Other cost-saving factors include the integration of systems that can help create significant staffing efficiencies. Depending on the scope of work and the objectives of the Virtual TMC, there may be no need for dedicated operational staff. Existing agency staff may be responsible for monitoring and managing the system. In scenarios such as ICMS in San Diego or RIITS in Los Angeles, both systems can operate entirely on their own with no human interaction (not accounting for system health monitoring). The cost reduction in TMC personnel costs (e.g. salaries, benefits, overtime) including managers, supervisors and operators can be significant.

4.2. Challenges

There are a number of challenges for agencies to face when considering a Virtual TMC. These challenges are described in the following sections and include:

- Regional Stakeholder Buy-In

40 ITS Joint Program Office Costs Database

- Legacy System Migration/Updates
- Servicing Agreements
- Lines of Communication
- Security
- Risk Avoidance

4.2.1. Regional Stakeholder Buy-In

In a Virtual TMC setting it is crucial to build and establish relationships between regional stakeholders (e.g. local jurisdictions, local law enforcement, bordering states, state agencies, federal agencies, EMS, fire, transit) in order to improve communication and the ability to respond more efficiently to events, incidents and emergencies. Closer working relationships can lead to stronger interagency cooperation and more efficient responses to multi-agency events.

Regrettably, interagency relationships can sometimes be challenging because each agency has their own point of view on how issues need to be handled. Also, there may be certain unwillingness to change established practices.

Overcoming Stakeholder Conflicts

Sometimes, stakeholder goals will be in conflict, with no clear way for the system to address both. In such cases, a sort of horse-trading between the opposing stakeholders can be used to reach an agreement on the contentious issue.

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

Another example applicable to Virtual TMC project planning concerns jurisdictional control issues that can stall project planning discussions. In this example, Capital Wireless Integrated Network (CapWIN) was developing a system to share incident information between public safety and transportation agencies operating within metropolitan Washington, DC. Jurisdictional concerns were at the heart of the issues involving the development of the system. Stakeholders were forced to migrate from informal inter-organization arrangements to formal ones, which put a tremendous weight on defining, conceptually and legally, who would do what and when.

Presented below is a list of best practices for regional stakeholder buy-in.

Best Practices
Build and establish a network and relationships between agencies prior the handling of any incident.
Encourage staff interaction on both an assignment basis and casual basis.
Consider different approaches to problem-solving and routine activities. Be open to suggestions.
Foster cooperative joint operations by assessing situations in a group setting. Use scenario planning to build cooperation amongst stakeholder group.
Be willing to share information both formally and informally (e.g. phone calls, emails, CAD) as needed
Establish processes and procedures beforehand for incident response of a multi-agency event.
Consider fostering relationships with liaisons (e.g. police, fire)
Assign roles and responsibilities to each agency along with incident response priority levels.
Create and implement Standard Operating Procedures for multi-agency event response

4.2.2. Legacy Systems

There are some transportation agencies that have established TMCs and traffic management systems. For example, the Caltrans District 7 region has a co-located TMC with the highway patrol. This was a new building that was established primarily for the traffic management system. This building is less than 10 years old and for the agency to transition to a Virtual TMC is not the most cost effective option. Also the district has a robust traffic management system that is fairly current with the industry's technology.

A number of transportation agencies are reevaluating whether to move from a centralized TMC to the more Virtual TMC. A key factor in these discussions is the building where the TMCs are located. Is there enough space to "grow"? Is the building old (older than 10 years)? Will the building sustain new infrastructure technology if the traffic management system is replaced? These answers will enable the transportation agencies to make informed decisions about their TMCs and their next steps.

Another question that agencies are asking themselves is "Is my traffic management system up-to current technology standards?" If traffic management systems are current with the industry, then the cost effectiveness of transitioning to a newer system could be outweighed by the benefits of a Virtual TMC and a newer system. Therefore the agency's "legacy" system is the most effective tool for the transportation agency.

4.2.3. Servicing Agreements

The Virtual TMC operations workstation has crashed. Who does the operator contact for repair? If the Virtual TMC is located in a state office building, who is responsible for the TMC workstation? Is it the building IT department? Is it the transportation IT department? These are questions that influence the decisions of Virtual TMC versus the established TMCs.

In most established TMCs, there is a defined maintenance group. This group is responsible for maintaining the TMC equipment, including workstations, video wall equipment, server equipment, the TMC infrastructure communications equipment, etc. Yet for a Virtual TMC, who is responsible? Who does the operator contact when their workstation fails? Or the communications from the field has disappeared?

If the Virtual TMC is located in a transportation department or building, then it's a fairly easy decision to make. The transportation IT department could be the maintainers of the TMC equipment. But what about when the Virtual TMC is located in a different State building? Does the State IT department become the maintainers of the Virtual TMC workstation and the associated infrastructure equipment? These answers, again, are key to determining costs and making the decision whether to establish a Virtual TMC versus a physical one.

4.2.4. Lines of Communication

As discussed in the training section, staffing could be different in a Virtual TMC. Centralized TMCs have dedicated workstations with multiple operators. Each operator could be assigned a specific area of responsibility or region. Either way, these operators are communicating with the other operators face-to-face.

In a Virtual TMC, one (1) operator may perform multiple duties or all duties that may typically be assigned to multiple different staff in the standard physical TMC model. VTMC operators may be responsible for operations, as well as administrative duties and possibly maintenance duties. The Virtual TMC operator must be able to make decisions in a timely fashion, without having the ability to discuss the situation with other operations staff.

They are the sole contact point in unplanned events. The operators need to be able to monitor and control the event as well as contact the personnel needed to address the event (local agency, emergency responders), as well answer the questions from the local agencies and the transportation directors. The Virtual TMC operator must know who to contact in all situations. These contacts could include the following:

- Media relations personnel
- Maintenance personnel
- Emergency Operations personnel
- Local agency personnel
- Department IT personnel

Again, the Virtual TMC operator must be able to make quick decisions and perform multiple tasks quickly and efficiently.

4.2.5. Security

Many established TMCs require a specific security clearance to enter a TMC. Many TMCs that are co-located with highway patrol or other law enforcement agencies also have strict security, so an operations staff member may have to have multiple levels of security clearance to work in a TMC. But in the case of the Virtual TMC residing in a separate State building, there may be only a single level of security.

What about the TMC infrastructure equipment? Does it reside in a separate secure room? Is access to the traffic management system accessible only through a secure network connection? Where does that equipment reside? Again, similar to the servicing agreements, who is responsible for this equipment? What is their security level? Does the transportation IT personnel have a higher clearance than other state IT personnel?

These questions and answers all must be addressed when determining the cost effectiveness of a Virtual TMC versus a physical TMC.

4.2.6. Risk

There are different types and levels of risk with Virtual TMC operations and established TMC operations. Some of these risks have been discussed in the previous sections. These include:

- Maintenance of equipment (workstations, communications, etc.)
- Operations staff communications
- Legacy traffic management systems
- Security

Each type of Virtual TMC operation has its own level of risk. Do you provide additional security for a Virtual TMC residing in a state office building? Do you provide additional operations staff during peak hours? Or do you provide another area for an additional Virtual TMC workstation that can share the responsibilities? But if that is the option selected, how do the operators communicate? Is there a dedicated radio system for operations?

Again, the answers to these questions affect the cost effectiveness of a Virtual TMC.

5. CASE STUDIES

5.1. Oklahoma Department of Transportation

5.1.1. Background

The Oklahoma Department of Transportation (ODOT) has deployed a full Virtual TMC. ODOT considered implementing an integrated, multi-agency, centralized TMC, but it was not feasible due to the costs associated with building, operating, and maintaining such a facility. As a result, ODOT in partnership with the University of Oklahoma Intelligent Transportation Systems Laboratory designed a low-cost, distributed, Virtual TMC using commercial off-the-shelf (COTS) desktop computers and an open source GIS mapping software.

The Virtual TMC consists of a geographically distributed fault-tolerant network of desktops referred to as ITS Pathfinder or ITS consoles, which are capable of controlling ITS devices visible on the statewide private ITS network.

ODOT provides stakeholder agencies with ITS consoles along with multiple channel Voice over Internet Protocol (VoIP) capability to allow interagency voice communications. In rural areas where fiber optic capability is not available, ITS consoles with limited multi-channel video capability can still be deployed provided that there is an Internet connection capable of supporting a secure VPN.

5.1.2. Architectural Overview[41]

The network backbone consists of a Virtual Local Area Network (VLAN) implemented over a dedicated Gigabit Ethernet (GigE) network which enables connectivity between the ODOT Headquarters in Oklahoma City and ODOT Division offices around the State. The statewide private ITS fiber optic network covers most of the State.

Under normal conditions where the network is fully connected, all ITS Consoles maintain a common database that fully describes the state of all devices connected to the network, including lists of all mutually visible ITS consoles. Control is fully distributed and the system is fault-tolerant in the sense that in case of partial or catastrophic network failures, any group of connected consoles can continue to function and continue to control and manage all ITS resources visible within their group. Throughout the outage, database update messages destined for consoles that are not currently visible are queued until network connectivity is re-established.

41 Distributed ITS Control and the Oklahoma Virtual TMC white paper – October 2, 2009.

The main design philosophy is that any sufficiently privileged operator can be logged into any console at any time and can control/utilize all ITS resources currently visible to that console. Figure 33 illustrates ODOT's ITS network.

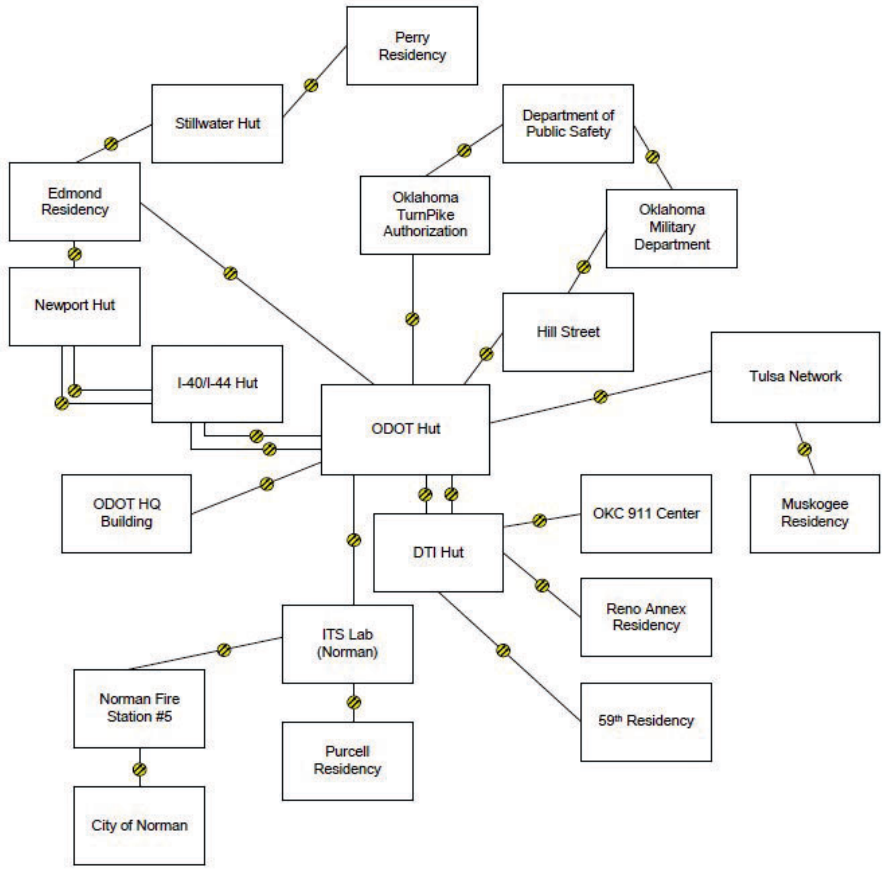


Figure 33. Graph. Distributed Topology of the Oklahoma ITS Network[42]

5.1.3. Deployment and Operations

The ODOT Virtual TMC model is managed by ODOT personnel, but there is no dedicated staff assigned to operate the system nor does ODOT have a TMC. Instead, the system is operated jointly with partner agencies.

Currently, there are 45 agencies participating in this endeavor. ODOT has in place a Memorandum of Understanding (MOU) with each agency. The MOU covers roles and responsibilities, policies and procedures, priorities, "do's" and "don'ts," as well as guidelines for incidents, weather, amber alerts, and appropriate public service announcements.

There are 200 miles of statewide coverage with ITS devices. Most of the devices are located within the Oklahoma City, Tulsa, and Lawton and McAllister areas.

The ITS Pathfinder/ITS Consoles consists of various protocols including CCTVs, DMS, RWIS, traffic sensors, and event management, which are integrated into a single system.

ITS Consoles are currently deployed around the State in locations including, but not limited to:

- 911 centers, Department of Public Safety, the Oklahoma Highway Patrol, municipal government agencies, and regional associations of municipal governments and various ODOT departments.
- The residences of appointed ODOT managers, where they can access and control ITS devices by connecting to an ITS console through an ISP provided device if the appropriate security hardware is installed on their PC.

42 Distributed ITS Control and the Oklahoma Virtual TMC white paper – October 2, 2009.

There are approximately 75-100 deployed ITS consoles protected by a solid firewall system built using Private Internet eXchange (PIX) and data encryption.

ODOT monitors, maintains and supports the system and also provides training to all partner agencies on an ongoing basis. User privileges are set up by ODOT personnel.

5.1.4. Lessons Learned

From the development of the concept of operations to the maintenance of the Virtual TMC, ODOT has had strong support from upper management. Upper management understands the level of effort and the costs associated with deploying a Virtual TMC. This has proven to be a tremendous benefit for this endeavor, illustrating the need for agency support as a prerequisite to establishing a viable Virtual TMC.

In addition, ODOT's long-term partnership with Oklahoma University has allowed the agency to benefit from cutting edge technology, although there is some vulnerability to risk since ODOT is a pioneer in this area.

Another lesson is to use inter-agency MOUs, which in ODOT's case have promoted a good rapport amongst ODOT's partner agencies. This has led to trust and the establishment of lasting relationships, and has proven to be one of the reasons for the success of the Virtual TMC.

5.2. Idaho Department of Transportation

5.2.1. Background

In 2006, the Interagency Regional Operations Center (IROC) was initiated by numerous agencies in Idaho to develop a concept and high-level design of a co-located facility. The goal of the effort was to bring multiple agencies under one roof to manage and respond to incidents and emergencies. However, the implementation of that facility has not materialized yet. As a result, in 2012 the Idaho Transportation Department's (ITD) commissioned a feasibility study to examine existing systems and conduct a needs assessment prior to moving forward with the implementation of a virtual operations center network. The aim of this virtual network initiative is to promote collaboration amongst agencies and allow them to share information.

ITD defines its vision as follows:

> *The goal of this virtual TMC concept is to establish a standardized approach to systems used statewide that support traffic and incident management. This includes ITD providing the foundation of their ATMS system to transportation departments and public safety departments throughout the state to leverage their device control/operations to create an integrated environment statewide controlled by permissions. This includes the potential in the future for creating a standardized approach to CAD systems and their operations with the idea of information and cost sharing across state, county, and city partners, which local public safety and sheriff's offices could take advantage of with this shared/integrated system over time.*[43]

5.2.2. Virtual TMC Initiatives

In 2012, ITD also procured an Advanced Transportation Management System (ATMS) to manage the region's transportation system. With this initiative, ITD is offering the ATMS system to partner agencies as a centralized system for ITS device and operational system management and control. The aim is to share data and video with other agencies to enhance their operations and better manage the transportation system.

ITD developed a formal agreement for the connection to and use of their ATMS system. Agencies (e.g., transportation, public safety) or media outlets can request access to the ATMS system to view information based on privileges granted

43 Idaho Transportation Department, *Statewide Implementation Plan*, Final Report, January 2013.

by ITD.

Under the virtual network environment, agencies would have access to streaming video of the transportation network (both freeway and arterial), DMS messages, data archives, incident reporting, event management, and weather conditions data.

ITD connection requirements include both Direct and Not Direct connection to their ATMS system.

- Direct Connection – via direct fiber or wireless network.
- Not Direct Connection – Connection to ITD intranet via external internet browser or VPN. Figure 34 shows the types of connection to the system that are available.

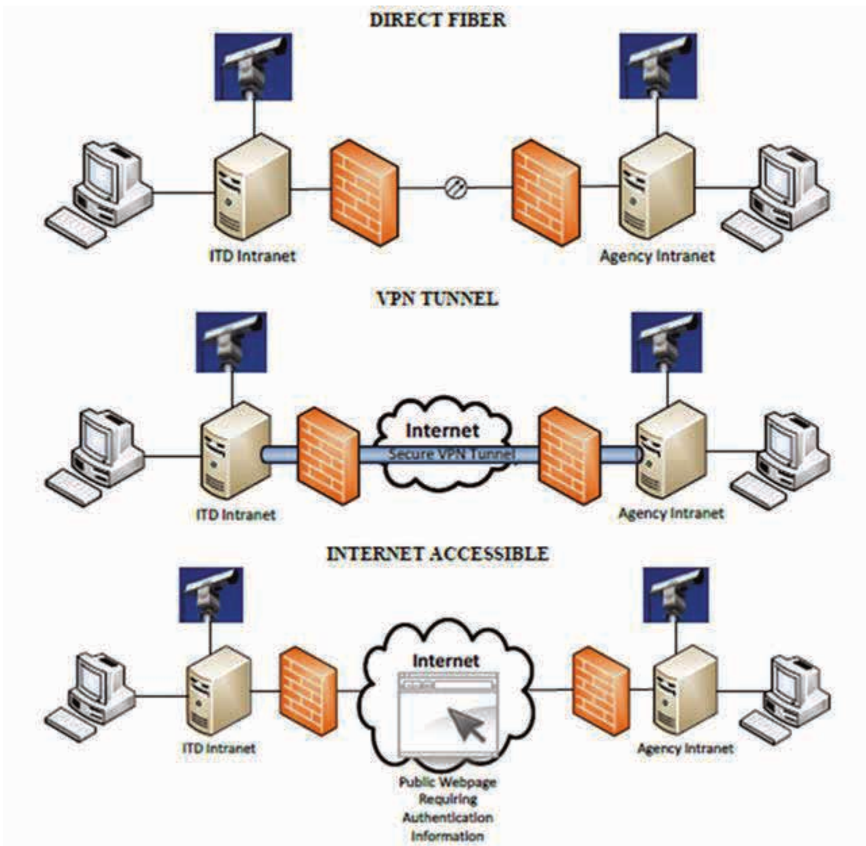


Figure 34. Graph. Agency Connection Types (to the ATMS)[44]

5.2.3. Deployment and Operations

The ITD TMC is co-located with Idaho's Police Dispatch. The TMC is responsible for monitoring and managing US Routes, State Routes and Intestate Routes throughout the State.

TMC personnel are contracted by the Department of Health and Welfare, which overlooks the Emergency Management Services (EMS) Bureau. In essence, TMC staff is EMS staff. Therefore, TMC personnel perform other functions unrelated to transportation management (e.g., dispatching medical personnel). The TMC supports operation of CCTVs, DMS, HAR, RWIS, a 511 system, and data archival of reports.

ITD is operating a browser-based ATMS system, which can be managed remotely. There are six District Offices with access to the ATMS system. District Offices are able to manage systems within their own jurisdictions (e.g., CCTV, DMS), but only have viewing privileges of other District offices. Each office has a Traffic Engineer and System Operations Engineer with access to the ATMS. However, only EMS staff has access to operate the entire ATMS system.

44 Idaho Transportation Department, *Statewide Implementation Plan*, Final Report, "Figure 5. Agency Connection Types" (January 2013).

In the event of an emergency, personnel have the ability to take over each other's operations, but at this time training is needed. There have not been any drills or workshops to determine the exact process and circumstances of when this could occur.

The TMC network is monitored by the State Communication Center, which is the System Administrator for ITD. The ATMS is also monitored by the ATMS contractor. The ATMS system is only accessible on the intranet or over VPN. VPN privileges are reserved for System Administrators and the ATMS contractor.

At this time, ITD has MOUs in place with the State Police, 911 (Kootenai County) and the Sheriff's Department. ITD is looking at establishing agreements with WSDOT for the eastern part of the State as well as with media outlets.

The biggest challenge for ITD is bureaucracy, so establishing partnerships and agreements with the counties has been challenging. It appears that there is hesitation from other agencies and government offices in joining ITD's virtual network.

5.3. Nebraska Department of Roads

5.3.1. Background

Nebraska Department of Roads (NDOR) has eight Districts. There are seven District Operation Centers and one Statewide Operations Center in Lincoln, District 1. All centers are responsible for monitoring and managing incidents on interstate freeways and State highways. The centers do not oversee county roads, rural highways, or city streets.

5.3.2. Virtual Initiatives

Currently, the NDOR is working towards establishing agreements with the City of Omaha and the City of Lincoln to view their CCTV and DMS, as well as to access any other ITS devices. In addition, there are ongoing talks with Iowa DOT and Wyoming DOT about sharing their camera feeds. As this time, firewalls pose the biggest technical issue among the agencies.

Nebraska's vision is to move toward one Operation Center in District 2 (Omaha), which oversees the largest urban area in the region, and one statewide center. Ideally, NDOR will also move towards a full browser-based ATMS.

The Statewide Center has been built and was opened in April 2014.

5.3.3. Deployment and Operations

Each of the eight Districts manages its own region as well as supporting other Districts' operations as needed. Only District 1 (Lincoln) and District 2 (Omaha) have full-time TMC staff and operate 24x7 during emergencies. All other Districts are staffed by Nebraska Department of Roads employees, who have other duties within the Department of Roads, and operate normal business hours.

NDOR is operating an ATMS system, which has a browser-based module called Highways Condition Reporting. Part of the system can be managed remotely via VPN, allowing staff to report incidents. Hierarchy and privileges have been established in the ATMS system, which allows authorized staff to cover other regions' functions.

The ATMS supports the operation of CCTV, automated gates, DMS, speed information, and RWIS.

5.3.4. The ATMS System

One of NDOR's primary goals of their ITS deployment was to enable one-common integrated system application called the District Operations Center Software System (DOC SS) that performs the following key functions:

- Acts as the nucleus for incident and traffic management across the state by integrating all of the key functions used across all Nebraska districts
- Via a simple web-based application, allows all applicable NDOR staff to monitor the roadway, enter new roadway information and control key ITS field devices via any personal computer with an internet browser
- Provide interfaces for monitoring and control of ITS field infrastructure via the established ITS communications infrastructure. ITS field devices include:
  - o Full Motion CCTV Cameras
  - o Snapshot CCTV cameras (at weather stations)
  - o Dynamic Message signs (DMS)
  - o Portable Dynamic Message Signs (PDMS)
  - o Environmental Sensor Stations (ESS)
  - o Vehicle Detection Sensors (VDS)
  - o Mainline and Ramp Gate Control Systems (near future)
  - o Anti-Icing Systems (near future)
- Provide interfaces with other key external systems including:
  - o Highway Conditions Reporting System (HCRS) – System for entering and maintaining all roadway conditions information.
  - o Intelligent Notification System – System for automated notification of staff via page, text message, e-mail, phone and fax regarding key events such as major accidents.
  - o Enterprise Asset Management System (EAMS) – Used to manage state-owned assets (e.g. field cabinets, light poles, guard rail, etc.) and information regarding their maintenance.
  - o Nebraska Service Patrol Computer Aided Dispatch (NSPCAD) – Monitors activities of Nebraska's Highway Patrol.
  - o Maintenance Decision Support System (MDSS) – Used to monitor locations of maintenance vehicles such as snow plows using Automatic Vehicle Location (AVL) technology.

The end result is that the DOC SS allows all systems associated with incident or traffic management to be accessible to all NDOR employees, wherever they are, from one single software application.

The end result of the initial system deployment is depicted in Figure 35. The DOC SS installation is a distributed, fault-tolerant, and redundant architecture which involves the installation of three (3) PC servers in District 2 DOC and three (3) servers at the Computer Operations Room at the NDOR Headquarters. All servers run the Microsoft Windows Operating System (OS). Three of the servers in one district act as the primary servers with the second set in the other district acting as secondary or backup. This redundant configuration allows for the 99.5% uptime requirement. In the event anything happens to a server at the primary location, the secondary server acts as a backup. Should one DOC lose power or become inoperable for any reason, the secondary DOC assumes control via connection to the IP field network. Districts 3 through 8 do not contain any dedicated DOC SS servers. Only PC workstations with statewide WAN access are required.

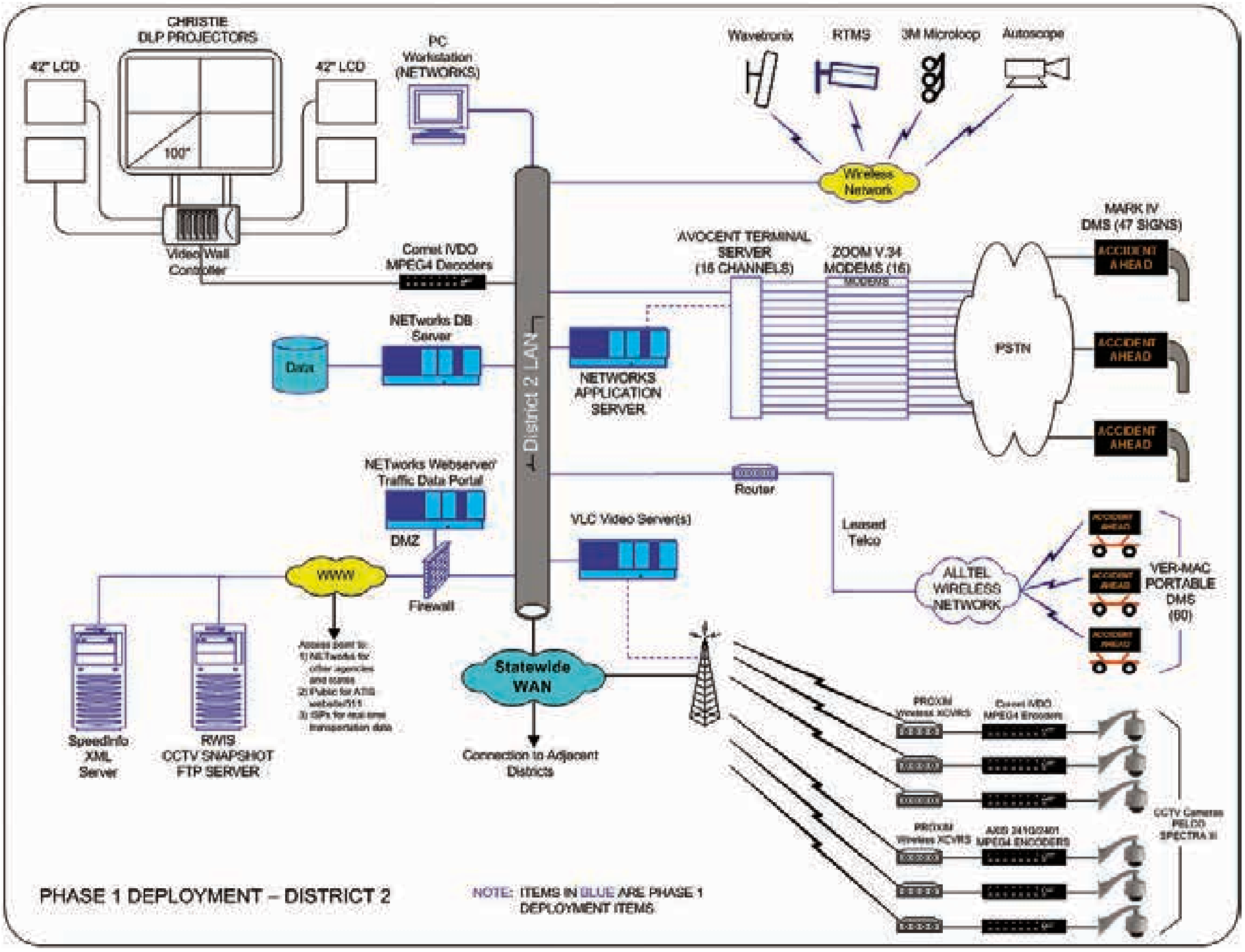


Figure 35. Graph. NDOR ATMS Deployment Diagram[45]

5.4. Kansas Department of Transportation

5.4.1. Background

Kansas Department of Transportation (KDOT) conducted a study to evaluate various TMC deployment options. KDOT determined that it would be viable to deploy a Virtual TMC due to the reduced cost of neither staffing nor maintaining a typical TMC building, as well as the rural nature of the state. The cost of providing traveler information over DMSs was significantly reduced with the chosen model. The only additional cost to KDOT is staff sharing for one workstation at the Wichita 911 center. In this instance, both agencies share the cost for the dedicated workstation.

5.4.2. Architectural Overview

The Virtual TMC software is hosted on KDOT thin client servers, and it is an off-the-shelf software coined MIST. There is one central database for MIST and for all field equipment. There are six Districts, each with 2 to 4 area offices, all offices have access to the central database.

In addition the KDOT ITS unit, area supervisors and engineers are able to use the system through VPN. VPN access is granted to users upon approval. On average there are 30-40 users using the system throughout the day.

5.4.3. Deployment and Operations

KDOT operates the system 8am - 5pm. Kansas City Scout and Missouri DOT (jointly) have access and operate the

45 Nebraska Department of Roads (NDOR) District Operations Center Software Solution Deployment Plan, May 2007

system after hours, both agencies operate 24x7. Scout manages messages statewide.

Each District is responsible for monitoring their own CCTVs and managing their own DMS signs. CCTVs are checked daily, there are only 60 CCTVs statewide and they are on average 30 miles apart. The Wichita and Tapioca areas have speed detection (VDS), CCTVs and DMS.

There are SOPs in place for each District and for backup operations.

Weather events can affect the state at any time and are of great concern since interstates can be significantly affected (e.g. complete closures). Therefore, KDOT has staff on standby 24x7. Primary system operators include maintenance supervisors and area engineers, and there are no dispatching activities for EMS.

System training is provided to 911 operators in Wichita and other KDOT staff by KDOT engineers.

Figure 36 depicts travel information provided to travels via Kansas Traveler Information website.

Figure 36. Graph. Screenshot from KanDrive[46]

5.4.4. Lessons Learned

The biggest challenge during the implementation of the Virtual TMC was related to KDOT own in-house network policies including the ban use of multi-cast video, bandwidth restrictions, network policies, challenges implementing new technology across the network, and appointing the right staff to manage the network switches and video. The IT department in KDOT did all the work and the system has been in operations since 2008.

46 Kansas Department of Transportation Traveler Information website: *http://511.ksdot.org/KanRoadPublic/Default.aspx?BrowserDetect=Yes*

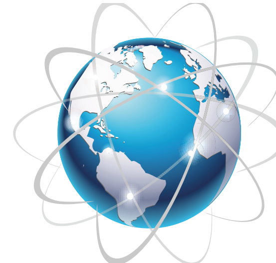
APPENDIX A: RESOURCES, NOTES, AND REFERENCES

This document has been developed based on the information gathered from the following key documents:

1. US Department of Transportation Federal Highway Administration, *Freeway Management and Operations Handbook*, FHWA-OP-04-003 (Washington, DC: 2003).
2. US Department of Transportation Federal highway Administration, *Handbook for Developing a Traffic Management Center (TMC) Operations Manual*, FHWA-HOP-06-015 (Washington, DC: 2005).
3. US Department of Transportation Federal Highway Administration, *Transportation Management System Performance, Monitoring, Evaluation and Reporting*, FHWA-HOP-07-124 (Washington, DC: 2005).
4. US Department of Transportation Federal Highway Administration, *Developing and Using a Concept of Operations in Transportation Management Systems,* FHWA-HOP-07-001 (Washington, DC: 2005).
5. US Department of Transportation Federal Highway Administration, *Guidelines for TMC Traffic Management Operations Technician Staff Development,* FHWA-OP-03-071 (McLean, VA: 2002) ***http://tmcpfs.ops.fhwa.dot.gov/cfprojects/uploaded_files/Guidelines%20for%20TMC%20TMOT%20Staff%20Development.doc***
6. US Department of Transportation, Federal Highway Administration, *The Regional Concept for Transportation Operations: The Blueprint for Action*, FHWA-HOP-07-112 (Washington, DC: 2007).
7. US Department of Transportation, Federal Highway Administration, *Designing for Transportation Management and Operations: A Primer*, FHWA-HOP-13-013 (Washington, DC: 2013).
8. US Department of Transportation, Federal Highway Administration, *Applying a Regional ITS Architecture to Support Planning for Operations: A Primer*, FHWA-HOP-12-001 (Washington, DC: 2012)
9. US Department of Transportation Federal Highway Administration, *TMC Operator Requirements and Position Descriptions*, (Washington DC: 2004).
10. Texas Department of Transportation Research and Technology Implementation Office, *Development of Guidelines for Data Access for Texas TMCs*, FHWA/TX-06/0-5213-1 (Austin, TX: 2007).
11. Washington State Department of Transportation, *The Gray Notebook – Performance Reporting*, (WS: 2013)
12. US Department of Transportation Federal Highway Administration, *The Regional Concept*

for Transportation Operations: A Practitioner's Guide, FWHA-HOP-11-032, (Washington, DC: 2011)

13. Mouchel, "Managed Motorways All Lane running Concept of Operations v2.0", Highways Agency, UK (August 2013) **http://www.highways.gov.uk/knowledge/publications/managed**-motorways-all-lane-running-documents/
14. US Department of Transportation Federal Highway Administration, *Transportation Management Concept of Operation*s, FHWA-JPO-99-020 (Washington, DC: 1999)
15. "Auckland | NZ Transport Agency – Auckland Joint Traffic Operations Centre," Updated September 12, 2012, **http://www.nzta.govt.nz/planning/nltp-2012-2015/auckland.html**
16. "ITS International – Virtual traffic management centers, a new direction in traffic monitoring," *ITS International* June 2011, **http://www.itsinternational.com/categories/utc/features/virtual**-traffic-management-centres-a-new-direction-in-traffic-monitoring/
17. Stacy Unholz, Atkins, Virtual Traffic Management: Distributing the Function, Reaping the Benefit– ITS Alaska, April 2012
18. New York Department of Transportation, *Joint Traffic Operations Center*, – White Paper by John M. Tipaldo Ph.D., P.E. (New York 2006)
19. Basel H. Kilani, Ekasit Vorakitolan, Joseph P. Havlicek, Monte P. Tull, and Alan R. Stevenson, *Peer-based Communication for a distributed, Virtual Traffic Management Center* – White Paper, (Washington DC: 2011) **http://www.hotnsour.ou.edu/joebob/PdfPubs/KilaniITSC2011.pdf**
20. Basel H. Kilani, Ekasit Vorakitolan, Joseph P. Havlicek, Monte P. Tull, and Alan R. Stevenson, *Distributed ITS Control and the Oklahoma Virtual TMC* – White Paper, (St. Louis, MO: October 2009) **http://www.hotnsour.ou.edu/joebob/PdfPubs/KilaniITSC09.pdf**
21. US Department of Transportation Federal Highway Administration, *Impacts of Technology Advancements of Transportation Management Center Operations*, FHWA-HOP-13-008 (Washington, DC: 2013).
22. US Department of Transportation Federal Highway Administration, *Regional, Statewide, and Multi-State TMC Concept of Operations and Requirements*, FHWA-HOP-07-122 (Washington, DC: 2007).
23. Shirley Radack, *The System Development Life Cycle* (SDLC), National Institute of Standards and Technology **http://csrc.nist.gov/publications/nistbul/april2009_system-development-life-cycle.pdf**
24. National Institute of Standards and Technology, *Information Security System Development Life Cycle*. Updated October 31, 2011, **http://www.ready.gov/document/information**-security-system-development-life-cycle
25. Kimley-Horn and Associates Inc., *Virtual Operations Center Network Feasibility Study* (Idaho: 2012)
26. Kimley-Horn and Associates Inc., Statewide *ATMS Implementation Plan* (Idaho: 2013)



APPENDIX B: ACRONYMS

Acronym	Definition	Acronym	Definition
AID	Automated Incident Detection	M	Miles
ALDOT	Alabama Department of Transportation	MDOT	Michigan Department of Transportation
ATIS	Advanced Traveler Information Systems	MnDOT	Minnesota Department of Transportation
ATM	Asynchronous Transfer Mode	MOUs	Memorandums of Understanding
ATMS	Advanced Traffic Management System	MPLS	MultiProtocol Label Switching
C2C	Center-to-Center	NHDOT	New Hampshire Department of Transportation
C2F	Center-to-Field	NIST	National Institute of Standards and Technology
CAD	Computer Aided Dispatch	NIST	National Institute of Standards and Technology
CapWIN	Capital Wireless Integrated Network	ODOT	Oregon Department of Transportation
CCTV	Closed Circuit Television	P3s	Public-Private Partnerships
CDPD	Cellular Digital Packet Data	RCTO	Regional Concept for Transportation Operations
CMS	Changeable Message Signs	RIITS	Regional Integration of ITS
ConOps	Concept of Operations	RMDID	Risk Management and Defense In Depth
DMS	Dynamic Message Sign	RTMC	Regional Traffic Management Center
DOT	Department of Transportation	RWIS	Road Weather Information System
EM	Emergency Management	SDLC	Systems Development Life-Cycle
EMS	Emergency Medical Services	SOC	State Operations Center
EOC	Emergency Operations Center	SONET	Synchronous Optical Network
ESS	Environmental Sensor Station	SOPs	Standard Operating Procedures
FDM	Frequency Division Multiplexing	TDM	Time Division Multiplexing
FHWA	Federal Highway Administration	TMC	Transportation Management Center
FIPS	Federal Information Processing Standard	TMS	Transportation Management System
GDOT	Georgia Department of Transportation	TOC	Traffic Operations Center
GPRS	General Packet Radio Service	TxDOT	Texas Department of Transportation
HAR	Highway Advisory Radio	USDOT	United States Department of Transportation
HRTMC	Hampton Roads Transportation Management Center	VDS	Vehicle Detector Station
ICMS	Integrated Corridor Management Systems	VMS	Variable Message Sign
ISP	Internet Service Provider	VPA	Virginia Port Authority
ITD	Idaho Transportation Department	VSP	Virginia State Police
ITS	Intelligent Transportation Systems	VTMC	Virtual Transportation Management Center
KSA	Knowledge, skill and ability	WSDOT	Washington Department of Transportation

APPENDIX C: AGENCY QUESTIONNAIRE RESPONSES

Alabama DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	N	Hours of operation are M-F, 6am - 6pm with morning and afternoon shifts.	The Center is not opened yet, as Alabama DOT is gearing to launch it over the next few months. Currently, Maintenance staff is operation the ATMS during rush hours: 6:30am-8:30am and 4:00pm-6:00pm
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		It is envisioned that it will be Statewide coverage. At this time, only the Montgomery Region will be covered and eight adjacent regions (SE corner of the State)	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		140 miles of interstate highways around the Montgomery Region	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.		At this time the City of Montgomery has a TTC for the Metropolitan Area (50-60 CCTVs). The new TMC will have access to the signal operations. At this time, there are no agreements written up but they may be needed in the near future.	City of Montgomery has 350 traffic signals and red light cameras
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Y	New ATMS, deploying it for 80% of the Montgomery region, 15-20% in Mobile and to be deployed for Birmingham	
6	TMS / System	Is the TMS/System property of the government or privately own?		It belongs to the State of Alabama	
7	TMS / System	Whose TMS/System do you use?		Delcan's iNET ATMS. Going live with 16 modules: Map, EM, C2C, Reporting, CCTV, DMS, HAR, IAD, DVS, ATIS, Travel Times, and Response Plan.	ALDOT is building a ATIS website and a mobile app
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y		
b		Incident Detection: TMS or other System	Y		
c		Incident Response: TMS or other System	Y	This will be launched in the next 30 days: DMS, Travel Times and Response Plans	
d		Do operators contact 911 or other emergency services?	N		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	Y	Only the maintenance crews.	
f		Other. Please briefly provided details.	N/A		

Alabama DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.	Y	All activities can be performed remotely, but they will not be done remotely due to the current IT Network Security and the Network rules. VPN takes approximately 22 minutes so it is not an option.	ALDOT Chief Information Office (CIO) is aware that an upgrade is needed for VPN to work, or new rules are needed to support virtual functions for the TMC.
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	Y	The ATMS is browser based	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N		
12	Staffing	Is TMC staff government or contracted?		The staff will be contracted for the next 3-5 years. In Alabama all government contracts are valid for 12 months, with the option of 2-4 renewals.	The contract has not been awarded yet. ALDOT is in the process of posting the RFP.
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).		Operators won't be allowed to work alone, with the exception of major events. In this instance, operators will take direct orders from management on how to proceed with the event.	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		All of the equipment mentioned, plus a 2 way department radio. Radio dispatch is only for maintenance crews dispatching.	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	N	Not at this time, but there is a possibility it will happen in the future due to financial reasons. ALDOT is also looking to share operational information with the Department of Public Safety - Hwy Patrol, which has communication dispatch 24/7. This operational sharing may bring the TMC the opportunity to operate 24x7.	ALDOT Chief Information Office (CIO) is aware that an upgrade is needed for VPN to work, or new rules are needed to support virtual functions for the TMC.
16	Shared Operations	Are there aspects of your operations that are atypical/ unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		In Mobile there are three tunnels and a ferry. Their monitoring will need to become part of the Statewide ATMS.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			

Alabama DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
a		Who has access to operate the TMS/System virtually/ remotely?		Supervisors for Operations and Maintenance will have access, as well as Upper Management personnel, all within the Regional Traffic Management Center (RTMC). As well, as the Program Manager.	The Vision is to have full virtual functionality in real time at the RTMC level. This is the reason a browser based ATMS was chosen. This flexibility would translate in the ability to use/operate CCTVs and initiate Response Plans. This option may be available in the future once there are set Performance Measures and coverage expands beyond the 12hr/ day - 5days/week.
b		How is the TMS/System accessed?		The ATMS is web based	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?			
d		How is the network monitored and who is responsible for monitoring it?		It is ALDOT's network.	
e		How do you handle security issues for users that are not part of your secure private network?	N/A	It won't happen at the start of operations.	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	N/A		
18	Virtual - Challenges Challenges	What have been some of the challenges you had implementing Virtual capabilities?	Y	It is challenging to share the network with the rest of ALDOT. The ideal situation would be to have a separate network for the RTMC to allow for ISP service, user identification/authorization. The biggest challenge at this time is authentication through the existing fire wall.	

Idaho DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	Yes		
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Statewide. Collocated with Idaho Police Dispatch.	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		US routes, State Routes and Inter-state routes	

Idaho DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	No	Emergency Management Services (EMS) covers the entire state and it has dual relationships for other agencies.	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Yes		
6	TMS / System	Is the TMS/System property of the government or privately own?		Contracted out by the Department of Health & Welfare which overlooks the Emergency Management Services Bureau	
7	TMS / System	Whose TMS/System do you use?		Delcan - iNET and Condition Acquisition Reporting System (CARS) 511 - C2C module; DMS; HAR; CCTV; Map; RWIS (Visala); Data Archiving Reports	Integration of 3 Data Platforms: 511, RWIS and iNET is foreseen in the next couple of years. CARS 511 feeds iNET but there is bi-directional information exchange. RWIS feeds into 511.
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System		Report from DOT and Law Enforcement	
b		Incident Detection: TMS or other System	Yes	using Bluetooth technology; no automatic detection in the system	
c		Incident Response: TMS or other System	Yes	DMS Manually	
d		Do operators contact 911 or other emergency services?	Yes	Dispatch from EM Services; life lie - helicopter evacuation	
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	Yes	Dispatch of Maintenance and Medical personnel	
f		Other. Please briefly provided details.		HAR, calls intake - system records all calls, no email. Calls and s/w use policy in place.	
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.	Yes	All of them can be done remotely.	State Police was consolidated into 2 Centres with Fail Over capacity. This capability allows the District Offices (6) to sign up to iNET to operate e/o's equipment.
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	Yes	Due to privileges at this time, District Offices are only able to view other jurisdiction information and manage their own.	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	No	Kimley-Horn did a study in 2006 for the physical building only (not operations).	

Idaho DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
12	Staffing	Is TMC staff government or contracted?		Government	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	No	24x7 - there is always a Supervisor	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, telephone, hands-free headsets, radio dispatch, AM/FM radio, radio microwave system which communicate to handheld radios for maintenance crews	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	Yes	District can take over each other operations.	Training is needed to take each other's operations - currently no drills or workshops have been done to practice.
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?	No		
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?		All six (6) District Offices can view/use CCTVS and DMS signs within the jurisdiction. / Each District has a System Traffic Engineer & a System Operations Engineer. Only the EMS staff can operate the entire system. District Offices can view others but only operate their own.	
b		How is the TMS/System accessed?		Browser based	
c		What type of devices are supported by your TMS/System and managed by your staff/other agencies?		CCTVs, DMSs, RWIS (106) for 511, HAR	
d		How is the network monitored and who is responsible for monitoring it?		State Comm Center - System Administrator for Idaho DOT (ITD); ITD and Delcan (Contractor)	
e		How do you handle security issues for users that are not part of your secure private network?		The system is only accessible on the intranet or VPN. VPN access is reserved for System Administrators and Contractor (Delcan)	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	Yes	Dispatch Manual - policies for DMS and HAR, as well as Message Library. There are MOUs with the Police and Agreements with largest cities	MOU with Police (Northern State) and 911 (Kootenai County) and the Sheriff. Also looking to establish agreements with WashDOT for the Eastern part of the State, as well as TV stations.
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?	Yes	The State is rural in nature - congestions is not a big issue but theis re-occurring congestion. There is a lot of bureaucracy with the Counties (ATA County) and partnerships have been challenging. ATA controls the signals of State Routes going back to District Offices.	Others doing similar work include: Washington to Wisconsin Pool Fund for Statewide Centers. They are looking at Wyoming Center (Montana, North and South Dakotas). North-West-Passage.

Kansas DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7		There is no physical TMC. KDOT has a Virtual TMC in place that is managed by KDOT staff during business hours, and by Kansas City Scout and Missouri DOT after hours.	There is one central database for MIST and for all field equipment. There are six Districts, each with 2 to 4 area offices, all offices have access to the central database.
	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Statewide. Collocated with Idaho Police Dispatch.	
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Statewide	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		Urban, rural and Interstate roads	
		Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Yes		
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.		Yes, agreement with 911 Center in Wichita, Kansas City Scout and Missouri TMC for after-hours coverage	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Yes	Yes	Integration of 3 Data Platforms: 511, RWIS and iNET is foreseen in the next couple of years. CARS 511 feeds iNET but there is bi-directional information exchange. RWIS feeds into 511.
		What activities are performed by operators?			
6	TMS / System	Is the TMS/System property of the government or privately own?		Kansas owns it but private consultant developed it	
7	TMS / System	Whose TMS/System do you use?		Schneider, system is called MIST	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Yes		
b		Incident Detection: TMS or other System		Only via cameras and some VDS in the urban areas	
c		Incident Response: TMS or other System	Yes		
d		Do operators contact 911 or other emergency services?	Yes	It varies depending on who is running the sytem	
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	No		
f		Other. Please briefly provided details.	N/A		

Kansas DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.	Yes		
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	Yes		
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	Yes	It was financially feasible to have a Virtual TMC and not to carry the costs of a physical facility (TMS) and dedicated TMC staff	The cost of providing traveler information over DMSs was significantly reduced with the chosen model. The only additional cost to KDOT is staff sharing for one workstation at the Wichita 911 center. In this instance, both agencies share the cost for the dedicated workstation.
12	Staffing	Is TMC staff government or contracted?		Government, most activities are carried out by KDOT staff	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	Yes		
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		It depends on who is operating the system	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	Yes	The Wichita 911 center	
16	Shared Operations	Are there aspects of your operations that are atypical/ unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?			
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/ remotely?		KDOT operates the system 8am - 5pm. Kansas City Scout and Missouri DOT (jointly) have access and operate the system after hours, both agencies operate 24x7. Scout manages messages statewide.	Primary system operators include maintenance supervisors and area engineers, and there are no dispatching activities for EMS.
b		How is the TMS/System accessed?		The Virtual TMC software is hosted on KDOT thin client servers and via VPN for those users connecting remotely.	

Kansas DOT					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		CCTVS, DMS, VDS	
d		How is the network monitored and who is responsible for monitoring it?		KDOT IT department monitors and maintains it	
e		How do you handle security issues for users that are not part of your secure private network?		Private network	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	Yes	There are SOPs in place for each District and for backup operations.	
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		The biggest challenge during the implementation of the Virtual TMC was related to KDOT own in-house network policies including the ban use of multi-cast video, bandwidth restrictions, network policies, challenges implementing new technology across the network, and appointing the right staff to manage the network switches and video. The IT department in KDOT did all the work and the system has been in operations since 2008.	

Los Angeles DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	N	We operate M-Th (our Department works a 4/40 schedule) from 7 am - 5:30 pm.	Own signals in incorporated area; maintain traffic signals for a number of agencies - connected to their system. The "bosses" have an issue with timing approval for signals. Maintenance and operation is on their own, approval needed for change of timing signals. / Concept designs for signals with various levels of controls. Hosted city signals = HUB for Traffic Control System.
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Traffic signals in the unincorporated and various Cities in Los Angeles County.	C-2-C for other cities. No control and viewing capabilities, just data exchange. Cities on traffic control system - 15; cities on C-2-C - ten cities; 670 intersections; 1800 traffic signals maintained of which 800 are in the unincorporated cities.
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		Urban	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.		Yes, we execute agreements with all cities that are a part of our traffic control system. The intent of the agreements are to clarify the roles and responsibilities of operating the system.	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?		Yes - a traffic signal system. No incident detection.	
6	TMS / System	Is the TMS/System property of the government or privately own?		It is a proprietary system.	
7	TMS / System	Whose TMS/System do you use?		Kimley Horn's KITS. Plus C-2-C.	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	N		
b		Incident Detection: TMS or other System	N		
c		Incident Response: TMS or other System	N		
d		Do operators contact 911 or other emergency services?	N		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	N	If we discover an issue requiring immediate attention, we contact our County dispatch to notify the field crews.	Two divisions: systems operators; maintenance crew & telephone operators (first point of contact for Department of Public Works).
f		Other. Please briefly provided details.	N/A		

Los Angeles DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.	Y	We have remote access capabilities into the system, although it is primarily used by our field crews.	Thick client with VPN access into it. All in a Virtual Server Platform, terminal server set up. Remote access into the system: consultant, maintenance crew and the cities who want access to it.
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?			Maintenance are connected through fiber; consultants are HQ in Phoenix, and cities/ Counties.
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?			Yes. Agreements but no charge to any city. Original idea was to provide own workstation and communication to the cities, switched to having cities access the System and terminal server for all remote sessions.
12	Staffing	Is TMC staff government or contracted?		Government.	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).		If operators work off hours, they are paid overtime. This only occurs when necessary, i.e., to deal with a particular situation.	For incorporated areas, operators can change it based on privileges at the TMC in Alhambra. Synchronization projects, signal timing experts.
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, telephone.	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	Y	We have workstations also installed at our signal maintenance yard. We host traffic signals for other agencies, and they are provided with remote access.	No access by law enforcement, transit or freeways. Everyone is traffic signal expert.
16	Shared Operations	Are there aspects of your operations that are atypical/ unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		We are the only agency in LA County which operates traffic signals for other cities.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/ remotely?	Y		
b		How is the TMS/System accessed?		VPN access, and we use terminal servers.	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		Traffic signals, CCTV	video wall
d		How is the network monitored and who is responsible for monitoring it?		LA County is responsible for the network. We have a substantial wireless radio network and that is monitored by our contractor and field maintenance crews. Our Department's IT staff also monitors the communication.	Wireless radio - part of network; staff does it; signal staff = LA County

Los Angeles DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
e		How do you handle security issues for users that are not part of your secure private network?		See above - we have VPN access - so it is restricted.	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?		Yes, we require a confidentiality agreement be executed. I will provide a copy.	Outreach from LA County to cities. Cities were given the choice to have their own system.
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		We relied on our IT Department. It seemed to go fairly easily.	Issues getting cities to execute agreements; issues getting cities to coordinate with their IT department; sometimes not often issues with cities requiring support that have their own system.

Michigan DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7		MDOT has four TOCs. Our Southeast Michigan TOC and our statewide TOC operate 24/7. The West Michigan TOC and the BWB only maintain operations during busy travel times.	SEMTOC provides after hour services for BWB coverage area, and STOC provides after hour services for WMTOC coverage area so our entire network is managed and operated 24/7
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		BWB - devices within influence of the Blue Water Bridge on I-94 and I-69, WMTOC - all of Grand Region which is the greater Grand Rapids area, SEMTOC - all of Metro Region which is the greater Detroit area, STOC - all other areas statewide	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		Michigan's TOCs provide coordination of response and information dissemination for activities on all MDOT owned roadways. This includes urban, rural and interstate.	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.		We coordinate with other TOCs outside Michigan, and local TOCs within Michigan, but no formal agreements exist. We do have formal agreement with Michigan State Police due to co-location of MSP at the SEMTOC.	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?		MDOT uses ATMS	

Michigan DOT					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
6	TMS / System	Is the TMS/System property of the government or privately own?		Government "owned" but privately developed and maintained under contract with MDOT	
7	TMS / System	Whose TMS/System do you use?		Delcan	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System		incidents monitored using cameras where we have them, speed data where we have it, and always communication with first responders/dispatch	
b		Incident Detection: TMS or other System		Incidents detected in a variety of ways, camera, speed data, dispatch notification, freeway courtesy patrol, website responses, e-mail, etc.	
c		Incident Response: TMS or other System		Incident response is tracked in our ATMS software	
d		Do operators contact 911 or other emergency services?	Yes		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	Yes	There is freeway courtesy patrol in the greater Detroit and greater Ann Arbor areas. SEMTOC dispatches for Detroit area and STOC dispatches for Ann Arbor area.	
f		Other. Please briefly provided details.			•Call MDOT first responder, •Maintain phone contact with local dispatch center, •Check cameras for visual coverage, •Send e-mail notification to internal and external customers•Post incidents to MiDrive via LCAR, •Send messages to DMS , •Twitter updates, •Dispatch Freeway Courtesy Patrol, •Monitor Traffic Conditions and post updates, •Coordinate with other TOCs , Monitor MiDrive, Perform Device Checks, Submit Work Orders, Plan for upcoming special events, Monitor weather patterns, Complete incident packets, Monitor cameras Monitor police scanners, Compile data and generate reports for performance measure tracking
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.		Our ATMS software is web based so all devices can be controlled from anywhere.	

Michigan DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?			
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?			
12	Staffing	Is TMC staff government or contracted?		TMC staff is contracted	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).		Yes, our overnight operators are often alone in the control room at STOC. SEMTOC always has MSP present due to dispatch co-location, but they may only have one SEMTOC operator present at times.	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, telephone, hands free headset, 800 MHz radio, pager, smart phone, television, video wall	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?		SEMTOC is co-located with MSP dispatch	
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		The vast geographic coverage area of the STOC seems to be unusual.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?		specific MDOT employees and STOC operations contract employees	
b		How is the TMS/System accessed?		web based	
c		What type of devices are supported by your TMS/System and managed by your staff/other agencies?		DMS, detectors, cameras, limited ESS monitoring, PCMS, truck parking	
d		How is the network monitored and who is responsible for monitoring it?		Network monitored by TOC management	
e		How do you handle security issues for users that are not part of your secure private network?		Users that are not MDOT or TOC contract employees are only given view access.	

Michigan DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?		All TOCs have SOPs	
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		device communication issues and network integration	

Minnesota DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	Y	The Regional Transportation Management Center (RTMC) comprises of 3 functional areas that have different hours of coverage. - Minnesota State Patrol Dispatch 24/7 - MnDOT Metro Maintenance Dispatch 24/7 - MnDOT Freeway Operations M-F, 4:30 AM - 10:00 PM, limited weekend coverage. Duties transferred to Metro Maintenance Dispatch in off-hours.	
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		MnDOT Metro Maintenance Dispatch and Freeway Operations Staff cover the Twin Cities Metro Area. Minnesota State Patrol Dispatch covers the northern 2/3 of the state including the Twin Cities Metro Area. State Patrol has another dispatch center in Rochester for the southern 1/3 of the state.	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		Freeway Operations covers urban freeways in the Twin Cities Metro Area. These roads are either interstate, US hwy, or State Hwy	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	N		
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?		Cameras and detection cover about 500 miles of freeways in the Twin Cities	

Minnesota DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
6	TMS / System	Is the TMS/System property of the government or privately own?		Government owned	
7	TMS / System	Whose TMS/System do you use?		IRIS which is an open source software developed in-house by MnDOT	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y	Monitor incidents on camera	
b		Incident Detection: TMS or other System	Y	Some incidents detected on camera but most are detected through 911 calls.	
c		Incident Response: TMS or other System	Y	Freeway Operations staff deploy CMS, lane control and dispatch freeway service patrol vehicles	
d		Do operators contact 911 or other emergency services?	Y	Co-located with State Patrol Dispatch. Direct dial line between Freeway Operations and State Patrol Dispatch	
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	Y	Freeway Operations Staff dispatch freeway service patrol vehicles to all types of incidents.	
f		Other. Please briefly provided details.			
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.	Y	Through our IRIS software, we can remotely control our ramp meters, DMS, and lane control devices. IRIS also allows for streaming video from our cameras and camera control. Dispatch of Freeway Service Patrols would require access to portable radios.	
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	N	Although our IRIS system allows for virtual capabilities, in practice we continue to maintain staffing at our center. The virtual capabilities could be utilized in an emergency should the RTMC be non-functional.	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N		
12	Staffing	Is TMC staff government or contracted?		Government staffed	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	Y	Since there are 3 functional areas in the RTMC, operators are never completely alone, however, the Freeway Operations section and Maintenance Dispatch may have only one person within their functional areas.	

Minnesota DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, telephone, radio dispatch council, TMS (IRIS), Computer Aided Dispatch (CAD), hands-free headsets, scanner	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?		As noted above, Freeway Operations is co-located with Maintenance Dispatch and State Patrol	
16	Shared Operations	Are there aspects of your operations that are atypical/ unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?			
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/ remotely?		All operators have remove access to IRIS, however, only supervisors use it. Local media have IRIS access to cameras only and use IRIS to switch camera feeds.	
b		How is the TMS/System accessed?		IRIS is a Java based application that can be accessed online.	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		CMS, detection, ramp meters, gate arms, cameras, lane control signals	
d		How is the network monitored and who is responsible for monitoring it?		MnDOT has two IT staff that monitor the TMS network and IRIS system.	
e		How do you handle security issues for users that are not part of your secure private network?			
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	N		
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?	N		

Nebraska DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7		In transition. 8 Districts. District Operation Centers (TMCs) in each District except to a Statewide Ops Center in Lincoln. Step like process working with 1 of the Districts. / District 2 and Omaha are 24/7 - it is situational based. / Also during the summer. NOT 365. Only run 24x7 during emergencies - center is staff when needed. District 1 (Lincoln) and District 2 (Omaha) have full-time TMC staff. Other Districts do not have full time as staff have other duties within DOT.	District 2 remains open. Biggest urban (metropolitan one) and a Statewide. The vision is to move to 1 Centre plus 1 Statewide. The TMC physically exists. Open on April 21st.
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		District covers their own area. They can support other Districts. Hierchachy established in iNET for covering other functions in other Districts (privilage based).	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		All interstate freeways, highways in the State. No county roads or rural highways. No city streets.	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.		Currently only informal agreements. Working towards with City of Omaha and Lincoln to view their CCTVS, DMS, etc.	There are firewall issues, Iowa DOT and Wyoming DOT in talks to share their feeds.
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?		ATMS - Networks (Delcan) - view and control CCTVS, automated gates, DMS, speed info centres and RWIS.	Event mangement throught Highway Condition Reporting System. It is URS enginerring, but it feeds Networks which feeds the website and 511.
6	TMS / System	Is the TMS/System property of the government or privately own?		Developed by consultants.	
7	TMS / System	Whose TMS/System do you use?		Delcan and URS.	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y		
b		Incident Detection: TMS or other System		Most incidents are detected through Dispatch and Public.	911 is called and notification is received from law enforcement side. Verbal communication. No CAD integration.
c		Incident Response: TMS or other System	Y		
d		Do operators contact 911 or other emergency services?	Y		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?		3 programs in the State - Motorist Assistance Program. In Omaha, 1 in Lincoln and 1 in Grand Island. Volunteer based - NDOR State patrol and private patroled. Each has a route during the week / peak hours / services provided include assistance to stranded motorist, water, gas. Program in place for about 15 years.	Operators and Volunteers talk on the phone.

Nebraska DOT					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
f		Other. Please briefly provided details.	Y	There are radios within the TMC to communicate with Mainteance Crews.	Depending on District, direct communication depends on the District (e.g. highway stripping). There is def a connection between operators and maitnenace crews.
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.		Networks is not web based; Highways Condition Reporitng is web-based. Operators can VPN into the sytem if needed.	Very infrequent and on as needed basis only. T
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones . If not, are there any initiatives to implement Virtual capabilities in the future and which ones?		Networks is not web based; Highways Condition Reporitng is web-based. Operators can VPN into the sytem if needed. / condition reporting - web based category is used frequently by field personnel. Entering information from laptop / home.	Road Condition Reporting - accessible. Events entered in the system./
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?		They want an ATMS system that is web based.	They hope to get to a situation where the ATMS is web-based and a hybrid situation especially for rural areas.
12	Staffing	Is TMC staff government or contracted?		Government	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	Y	overnight or weekends. Situations when operators work alone.	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		radios, pcs	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?		It depends on events - always in cooridation with other States. Coordinated with Wyomming on snow event. Coordiation with Kansas, Missouri, South Dakota, Iowa and Wyomming especially at all the crossings (bridges).	
16	Shared Operations	Are there aspects of your operations that are atypical/ unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		Gates on ramps located in 4 locations and planning to expand to all districts; District 2 is collocated with State Patrol; Anti-icing systems.	Gates used for weather events or incidents to stop traffic to enter the highway. Automated Gates. It is due to resource issues.
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/ remotely?			
b		How is the TMS/System accessed?			
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?			

Nebraska DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
d		How is the network monitored and who is responsible for monitoring it?			
e		How do you handle security issues for users that are not part of your secure private network?			
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?			
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?			

New Hampshire DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	Y		
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Statewide	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		We cover all NH routes on a statewide basis.	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	N	We are responsible on a stateside basis - so we are not compartmentalized into regions.	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Y	We use an ATMS system at our TMC	
6	TMS / System	Is the TMS/System property of the government or privately own?		Designed by a private vendor but procured through federal funding and it is state owned.	
7	TMS / System	Whose TMS/System do you use?		Contractor (iNET – Delcan)	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System		TMS	
b		Incident Detection: TMS or other System		Other system	
c		Incident Response: TMS or other System		TMS	
d		Do operators contact 911 or other emergency services?	N		

New Hampshire DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	Y	We run statewide maintenance dispatch operations so we run the roadside assistance as well as basic dispatching duties.	
f		Other. Please briefly provided details.	N/A		
9	Virtual	Can any of these activities be performed virtually/remotely? Please specify which ones.	Y	The ATMS is browser based. All District Offices can access and have privileges to view other regions, but they cannot operate. Not until Incident Detection is an automatic feed into a system.	
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones. If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	Y	Some of our servers are virtualized. Also, the ATMS is browser based and District offices have access to input information into the Weather Module. District offices are open 24x7 from December to March, where weather data is input on the hourly basis. From April-Nov, the offices are opened only during the day (office hours) and data is input 5 times/day.	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N	There is no report that I am aware of.	
12	Staffing	Is TMC staff government or contracted?		Government staff	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	Y	There are certain times when there are no supervisors present.	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		All mentioned	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	N		
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?	Y	We perform operations that are atypical of TMC. We are a statewide dispatch and call center, we monitor environmental systems and manage construction work zone system.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?		To the virtually component in the District offices, one operator is granted access to the system to input weather data.	
b		How is the TMS/System accessed?		If accessed remotely, it is done through a VPN connection.	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		Servers	
d		How is the network monitored and who is responsible for monitoring it?		Monitored by our IT department	

New Hampshire DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
e		How do you handle security issues for users that are not part of your secure private network?		Through VPN access	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	N		
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?	N/A		

Oklahoma DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	N		
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Entire State.	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)			
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.			
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?		Software is an open source GIS mapping software, there are UI for events and incidents and locate them on the map. All in one s/w - cctvs, dms, event management. All protocols are integrated into the system.	ITS Pathfinder or ITS Console. Worked with the University of Oklahoma work together to integrate software and field devices. Joint partnerships. Contract for 12 years.
6	TMS / System	Is the TMS/System property of the government or privately own?		Privilege owner and in house created	Field maintenance personnel has access to the ITS console. They do a lot weather monitoring. Department of Public Safety notifies field maintenance personnel. Public Affairs has a console, Traffic Division gets it, the ITS group since they are maintaining.

Oklahoma DOT					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
7	TMS / System	Whose TMS/System do you use?		OU and ODOT.	No 511 website - info being to ODOT website.
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y	VDS, RWIS - both connected to it. Speeds on the map are color coded. Based on color they determine if there is an incident - bc of speed slowdown.	Red, yellow (normal congestions during peak hours). All agencies can view the camera feeds. Users able to tell who is operating the camera (name and telephone given).
b		Incident Detection: TMS or other System	Y		
c		Incident Response: TMS or other System	Y	Module to log incidents, it will populate incidents (accidents, road construction). No track on what lanes are closed.	
d		Do operators contact 911 or other emergency services?			
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?		no roadside assistance program	
f		Other. Please briefly provided details.			
9	Virtual	Can any of these activities be performed virtually/ remotely? Please specify which ones.		Virtual from day 1. Close network - everyone operates it from the closed network. It can be remote into the private network (VPN) access. Granted only to certain personnel.	
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones. If not, are there any initiatives to implement Virtual capabilities in the future and which ones?		100% virtual. ODOT provides is own maintenance and support. HOT phone is used in case of emergencies outside of business hours. System can be operated remotely. Very good partnership among agencies to make sure everything is taking care off to provide safe environment.	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?		The virtual operations would be less expensive to build a physical building to house everyone. Partnerships agreements and info was being delivered from ODOT. Training is provided to agencies - 1on1 or small classrooms.	DPS - 911 and dispatch operators. Training done by ODOT while user privileges get set up.
12	Staffing	Is TMC staff government or contracted?		Staffed by government staff. No contract out.	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	n/a	Multiple task for staffing.	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, internet access or direct close network access. 75-100 different terminals out there. Plug into ODOTs network, everyone has a user ID and passwords. Weather, DMS access, CCTV, Travel Times, etc. Everything that a responder needs. It doesn't have any other programs, internet (fire blocked).	It is a closed system

Oklahoma DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	Y		
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		Pretty typical in regards to weather and traffic conditions.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?			
b		How is the TMS/System accessed?			
c		What type of devices are supported by your TMS/System and managed by your staff/other agencies?			
d		How is the network monitored and who is responsible for monitoring it?		ODOT monitors the closed network: devices, security, staff with OU	
e		How do you handle security issues for users that are not part of your secure private network?		User privilege based to access close network - Google Authentication is being used. Random generated - changes every 90 secs. It needs to be used if users are going to VPN.	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and urpose of the documents. Is there a copy a report/document that can be shared for this study?	Yes	Policies and procedures - priorities, dos and don't; incidents, weather, amber alerts; national campaigns. SOPS and MOUs outlining guidelines of what they can/can't do, roles and responsibilities of what they can do.	
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		support from upper management in the concept of operations - it was a tremendous benefit; long-term partnership with OU - it meant that they had to understand it was worthwhile and costly to have that relationship; pros of OU is cutting edge but also puts them out on the limb; implementation has been easy - 7 undergrads - 7 graduate students working at the same time; close to 40 students that have worked; Wiki system is being used to document changes, protocols, integration with devices (allows for continuity in the handoff)	for bugs and issues - reports to ITS staff; every 2 weeks report and call with OU for bugs and problems (e.g. push codes, push updates);

Oregon DOT

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	Y		Interviewed Dennis - Regional Traffic Engineer / Manager ITS Program
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		Portland Metropolitan and surrounding counties, including part of Wheeler County.	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		Freeways, arterial roads = roads owned my ODOT. There are CCTVs in arterials and freeways. Monitoring of all freeways and some arterials depending on location.	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	N		
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Y		
6	TMS / System	Is the TMS/System property of the government or privately own?		Government	
7	TMS / System	Whose TMS/System do you use?		Also some work being done by the local University and some by ODOT	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y		
b		Incident Detection: TMS or other System	Y	Display on video wall. The existing system is automated but it generates too many false alarms. Operators look at cameras.	
c		Incident Response: TMS or other System	Y		
d		Do operators contact 911 or other emergency services?	Y	It depends who detects the problem. 911 dispatches police and fire.	
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?		TMC operators dispatch Incident Response Vehicles to all freeways and some arterials. Response Vehicles can work together with 911 to determine a response plan.	
f		Other. Please briefly provided details.	Y	operators look at VMSs; CCTVs; send notifications to media outlets and radio stations; look at Trimet Terminal information (feed from CCTVs)	
9	Virtual	Can any of these activities be performed virtually/remotely? Please specify which ones.	Y	Virtual collocation with City of Portland for system and video. TMC staff works with the City on arterial incidents. Each District Office also has access to operate the system. Designated personnel can view the system remotely.	

Oregon DOT					
No.	**Function**	**Survey Questions**	**Y/N**	**Response**	**Other/Comments**
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones. If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	Y	System access and system operations	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N		
12	Staffing	Is TMC staff government or contracted?		It is government employed.	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	Y	1 person per shift	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		PC, PC control of radio system, phones, keyboards for cameras, radio (high-low frequency);	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?		System - CCTVs - City of Portland (operate); Trimet (just feed) and 911 (operation control of cameras)	
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?	Y	Rural monitoring, mountain pass, VMS control, deployment of traffic signals, ramp metering, queue warning system and variable speed limits, travel time, curve warning system (interchange in urban area and rural area)	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?		ODOT personnel has access to the system, as well as the two (2) District Offices. Everyone is connected to ODOT's network.	
b		How is the TMS/System accessed?		Remote connection - VPN access and in house through the ODOT network	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		CCTVs, VMSs, Queue Warning, Variable Speed Limits. It uses various modules of the iNET. Also RWIS sensors in some areas.	
d		How is the network monitored and who is responsible for monitoring it?		monitored in-house by the IT department	
e		How do you handle security issues for users that are not part of your secure private network?		911 is not connected into the system. There is share access to radio and CCTV feeds and the only connection is to the Video Switch. ODOT working on CAD.	

Oregon DOT					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	No	the system works by accessing the ODOT network only	
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?	N/A		

Regional Integration of ITS (RIITS)					
No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7	Y	there is no operations center for RIITS, it is an automated system running but it runs 24x7	24x7 staff for the facility: contractor maintains the system and there is 24x7 regular, preventive and emergency maintenance.
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		5 Counties: Riverside, LA, Orange, Ventura and San Bernardino.	The system collects events: accidents, scheduled; freeway performance; arterial - traffic signals, timing plans and real-time transit.
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		It covers freeways and arterials.	
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	Y	1. MOU to share transportation data and 2. User Agreements - agency and access to enter data manually and receive data. 3, Data Sharing with private companies (e.g. Google, SigAlert, Media) = ISP agreement / liability	
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Y	There is detection system: automated and manually. Events in RIITS can be entered manually.	
6	TMS / System	Is the TMS/System property of the government or privately own?		The system belongs to the government (Metro), but the data is owned by the source agency.	System, administration and knowledge
7	TMS / System	Whose TMS/System do you use?		Custom-built by Delcan. Delcan owns the sw that "talks" to the agencies.	
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	N/A		
b		Incident Detection: TMS or other System	N/A		

Regional Integration of ITS (RIITS)

No.	Function	Survey Questions	Y/N	Response	Other/Comments
c		Incident Response: TMS or other System	N/A		
d		Do operators contact 911 or other emergency services?	N/A		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?	N/A		
f		Other. Please briefly provided details.		There are no RIITS Operators - each agency is responsible for providing their own data to RIITS.	It is not a public facing system, the only component that is public facing is the Event Entry.
9	Virtual	Can any of these activities be performed virtually/remotely? Please specify which ones.	Y	URL is accessible on the web and via mobile app (event entry capability).	
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones. If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	N	There are no operations - the system operates virtually already.	
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N		
12	Staffing	Is TMC staff government or contracted?		Government - Administration; Maintenance - Contracted	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).		Agencies have access to the system 24x7	
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		Equipment needed for RIITS: networks, servers, applications (APIs) and it is provided to agencies	
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?		Share data only within RIITS and agencies	Training is paid by RIITS and dependent on what agencies need to automate data
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		It is a unique system b/c it combines the data of 125 agencies in the region. RIITS is one of the largest transportation systems in the US - 88 agencies in LA County (cities); 125 agencies in the region - includes cities, SCAG, Caltrans (D7, D8, D12), OCTA. It combines data from freeways, arterials, traffic signals and timing plans.	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			

Regional Integration of ITS (RIITS)

No.	Function	Survey Questions	Y/N	Response	Other/Comments
a		Who has access to operate the TMS/System virtually/ remotely?		Agencies that are users (125) have access and can enter events. 30 agencies have access including Metro Bus Operational Control. Currently, there are 3 active users. Contractor (Delcan) has access. Management has viewing privileges.	
b		How is the TMS/System accessed?		URL	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?	N/A		
d		How is the network monitored and who is responsible for monitoring it?		Automated but it is monitored by contractor (Delcan). Uptime is 88% with the goal to have it up at 99.5%. Currently upgrading the system.	
e		How do you handle security issues for users that are not part of your secure private network?		The system is connected to the internet but there is IP address security in place. The system is configured to receive information only from a # of IP addresses to receive data. Event Entry data does not reside at the same IP address that overall data. There have been no breaches.	
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	Y	There are MOUs and Agency Agreements in place, as well as ISPS/Agencies.	
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		There is no ops money to help operate a TMC; the system needs more people to run/maintain the system.	

San Diego ICMS

No.	Function	Survey Questions	Y/N	Response	Other/Comments
1	General	Does the center operate 24x7? If not, please provide the operating hours and explain why operation are not 24x7		CALTRANS = Yes Local Cities = No Transit Operator = Yes	
2	General	What is the geographical coverage area? (i.e. District, Statewide, etc.)		San Diego Region	
3	General	What types of roads do you cover? (i.e. urban, rural, interstate, etc.)		All	

San Diego ICMS

No.	Function	Survey Questions	Y/N	Response	Other/Comments
4	General	If, it covers various regions. Are there any inter-agency agreements or joint partnerships in place? If so, please list types.	NA		
5	TMS / System	Is there Traffic Management System (TMS) or other System(s) in place for detection, monitoring and response?	Y		
6	TMS / System	Is the TMS/System property of the government or privately own?		Shared	
7	TMS / System	Whose TMS/System do you use?	NA		
8	Operator - Functions	What activities are performed by operators?			
a		Incident Monitoring: TMS or other System	Y		
b		Incident Detection: TMS or other System	Y		
c		Incident Response: TMS or other System	Y		
d		Do operators contact 911 or other emergency services?	Y		
e		Do operators dispatch, i.e. roadside assistance, maintenance? If, yes, please explain the nature of the dispatch, i.e. standalone or agency roadside assistance program?		Both variants exist	
f		Other. Please briefly provided details.	NA		
9	Virtual	Can any of these activities be performed virtually/remotely? Please specify which ones.	NA		
10	Virtual	Does your agency have any Virtual capabilities related to your TMC Operations? If so, list which ones. If not, are there any initiatives to implement Virtual capabilities in the future and which ones?	NA		
11	Virtual - Cost-Benefit	Has your agency done a Cost-Benefit analysis on Virtual Operations? If so, is there a copy of the report that can be shared for this study?	N		
12	Staffing	Is TMC staff government or contracted?		Government	
13	Staffing	Are operators allowed to work on their own? Overnight? Weekends? If not, please list the reason(s).	NA		
14	Equipment - Workstation	What equipment do operators need to perform their work? e.g. PC, telephone, hands-free headsets, radio dispatch, AM/FM radio?		All listed	

San Diego ICMS

No.	Function	Survey Questions	Y/N	Response	Other/Comments
15	Shared Operations	Are operations shared with other centers/agencies? If yes, under what circumstances? And with which centers?	N		
16	Shared Operations	Are there aspects of your operations that are atypical/unique compared to other centers within the same tier of operation, e.g., region, city, etc. If so, what are they?		ICM	
17	Virtual - Operations	Please answer the following questions if your agency has implemented/is in the process of implementing Virtual TMC Operations			
a		Who has access to operate the TMS/System virtually/remotely?		Regional Stakeholders	
b		How is the TMS/System accessed?		Remotely	
c		What type of devices are supported by your TMS/ System and managed by your staff/other agencies?		ITS devices	
d		How is the network monitored and who is responsible for monitoring it?	NA		
e		How do you handle security issues for users that are not part of your secure private network?	NA		
f		Are there documents/protocols/operating procedures in place for working virtually/remotely? e.g. ConOps, SOPs, Memorandums of Understanding (MoUs). If yes, please outline type and purpose of the documents. Is there a copy a report/document that can be shared for this study?	NA		
18	Virtual - Challenges	What have been some of the challenges you had implementing Virtual capabilities?		None	

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