

Model Systems Engineering Documents for Dynamic Message Sign (DMS) Systems

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GLOSSARY

Beacon	An external device that directs light in one direction and flashes. The device is intended to increase a driver's attention to a message.
BOS	Blank Out Sign - A type of DMS that has the capability to show a blank message or one fixed message.
Central Computer	A computer system that operates as a control source for one or more signs in the signage system. A computer/server that is host to its signs, also referred to as the host or central computer. The signage system may be controlled by central computers installed in more than one location. Or, it may be a remotely located central computer capable of managing the operation of one or more signs.
CFR	Code of Federal Regulations
CMS	Changeable Message Sign - A sign that is capable of displaying one of two or more predefined messages, or a blank message.
COTS	Commercially available Off-The-Shelf. This is an FAR term defining a non-developmental item of supply that is both commercial and sold in substantial quantities in the commercial marketplace, and that can be procured or utilized under government contract in precisely the same form as available to the general public.
DMS	Dynamic Message Sign - Any sign system that can change the message presented to the viewer such as VMS, CMS and BOS. It includes the following major components: sign face, sign housing, controller, and, if present, the controller cabinet.
DMS Controller	A device used to control and monitor the operations of a sign. It can have a variety of control interfaces, such as a local control panel, a local field programming terminal, or a central computer.
DMS Management System	See Central Computer.
Dynamic Message Sign (DMS) System	The overall system that manages DMS to convey information to the traveling public. The software communicates with the DMS in the field from a central location such as a TMC/TOC.
External Device	A component that is not normally considered part of a DMS, but is connected to the DMS by some interface.

FAR	Federal Acquisition Regulation
Field Programming Terminal	A portable computer running maintenance software. It can communicate with a sign controller, control activation of the sign, and perform diagnostics on the controller.
ITS	Intelligent Transportation System
Low-bid	Contract awarded to the “lowest responsible bidder”. Bid is based on a complete set of plans and specifications that precisely defines the facilities to be built.
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
PIF	Public Interest Finding
Real-time	Activity that occurs simultaneously with or very soon after an event. For example, real-time control involves taking action based on measurements immediately after the measurement is completed.
RFI	Request For Information
RFP	Request For Proposal
RFQ	Request For Qualifications
Specification	The project-specific detailed requirements for a DMS to be purchased by an agency or a statement by a manufacturer defining the detailed features provided by the DMS.
TMC	Transportation or Traffic Management Center - The location of the DMS Management System central computer and equipment which allows operations staff to monitor and manage traffic through roadside field devices (e.g. vehicle detectors, VMS, etc.).
TOC	Transportation or Traffic Operations Center – See TMC

EXECUTIVE SUMMARY

This guidance document for procuring Dynamic Message Sign (DMS) Systems is part of a series of Model Systems Engineering Documents. The model systems engineering documents provide a framework for agencies to clearly articulate their needs, and specify succinct and comprehensive system requirements to guide the procurement and implementation of Intelligent Transportation Systems (ITS). Target procurements include those projects that:

- Cannot reasonably afford development of systems engineering documents from scratch.
- Make selections from existing device and software products in the market, rather than supporting new product or software development.

These model documents make it possible for agencies to develop meaningful systems engineering documents that will effectively support procurements and reduce risk for smaller, more routine ITS implementation projects.

Using these documents will support an agency's compliance with 23CFR940.11.

PART OF AN ITS IMPLEMENTATION PROCESS

A DMS implementation project will be part of an overall ITS implementation strategy to support the agency's operations planning. The user will be able to identify the goals, objectives and activities from those planning efforts to select the appropriate needs within the Model Concept of Operations.

During the project phase, this Concept of Operations will support documentation of system requirements to a level of detail necessary for clarity during a DMS system procurement. Verification and Validation will confirm that the system fulfills the requirements and successfully meets the agency's needs. Demonstrably meeting needs ensures that the agency will attain the operations objectives driving the project.

WHAT THE USER WILL DO

The user will review sample statements that reflect each of the agency's needs related to their operations objectives. Following this guidance, the user will tailor these sample statements to address specific situations. Selecting and tailoring user needs in the Concept of Operations will link to a set of clear and concise requirements. This guidance leads the user to develop the following systems engineering documents:

- Concept of Operation.
- System Requirements.
- Verification Plan.
- Validation Plan.

PROCUREMENT SUPPORT

DMS systems procured using traditional low-bid processes impose an unnecessary risk on project success. A number of studies and experience has demonstrated that Intelligent Transportation Systems, including DMS systems are complex and require sufficient integration and customization that are difficult to anticipate and manage effectively within a low-bid process. This guidance includes a discussion of procurement processes that make effective use of systems engineering documents to minimize project risk and comply with Federal procurement regulations.

When Federal funds are involved in a project, the systems engineering documents are subject to review by the appropriate Federal Highway Administration (FHWA) Division Office, and must follow State procedures as determined between the FHWA Division office and the State transportation agency.

CHAPTER 1. CONCEPT OF USE

PURPOSE

The primary objective of this Dynamic Message Sign (DMS) Systems Concept of Use (COU) is to describe how the Systems Engineering (SE) Model Documents can guide the deployment of a DMS system ensuring the procured and deployed DMS system is successfully meeting the user needs of the stakeholders who will be using the DMS system to convey information to the traveling public. The purpose of the SE Model Documents is to guide the user through the process of developing systems engineering documents for definition and procurement of a DMS system. The DMS system may be a brand new deployment or an expansion of an existing system.

The Model Systems Engineering Documents for DMS Systems are intended for projects with the following characteristics:

- Relatively small, such that the project budget cannot be reasonably expected to fund systems engineering document development from scratch.
- Constrained to existing products in the market. The model documents are not intended to provide the detail necessary to support new significant software development.
- Applications of DMS already well-defined in the transportation industry.

Agencies building large projects with custom software development or innovative applications will need to perform more detailed custom systems engineering, though these documents may provide an effective and time-saving starting point for that effort.

The reference architecture for a DMS System along with the scope of the DMS Model Systems Engineering Documents is shown in Figure 1.

As shown in Figure 1, the scope of the DMS Model SE documents comprises the DMS Management System, the DMS Controller, DMS Field Device or sign, as well as an optional Field Programming Terminal and optional External Devices. The interfaces crossing the dashed line are between the DMS Management System and the User, the DMS Management System and External Systems and between the Optional External Devices and External Systems.

The DMS Management System is comprised of the server side processing and is connected to one or more DMS Controllers. Each DMS Controller is connected to one or more DMS Field Devices or “Signs”. An optional Field Programming Terminal, either provided with the DMS Controller or a separate computer, allows field access to the DMS Controller to mimic the commands from a DMS Management System. Optional external device(s) connect to the DMS Controller and provide additional indicators and/or sensors involved with the DMS Field Device. Interfacing with the DMS Management System is the User and other External Systems. It is possible for an External System to also communicate with the optional External Devices.

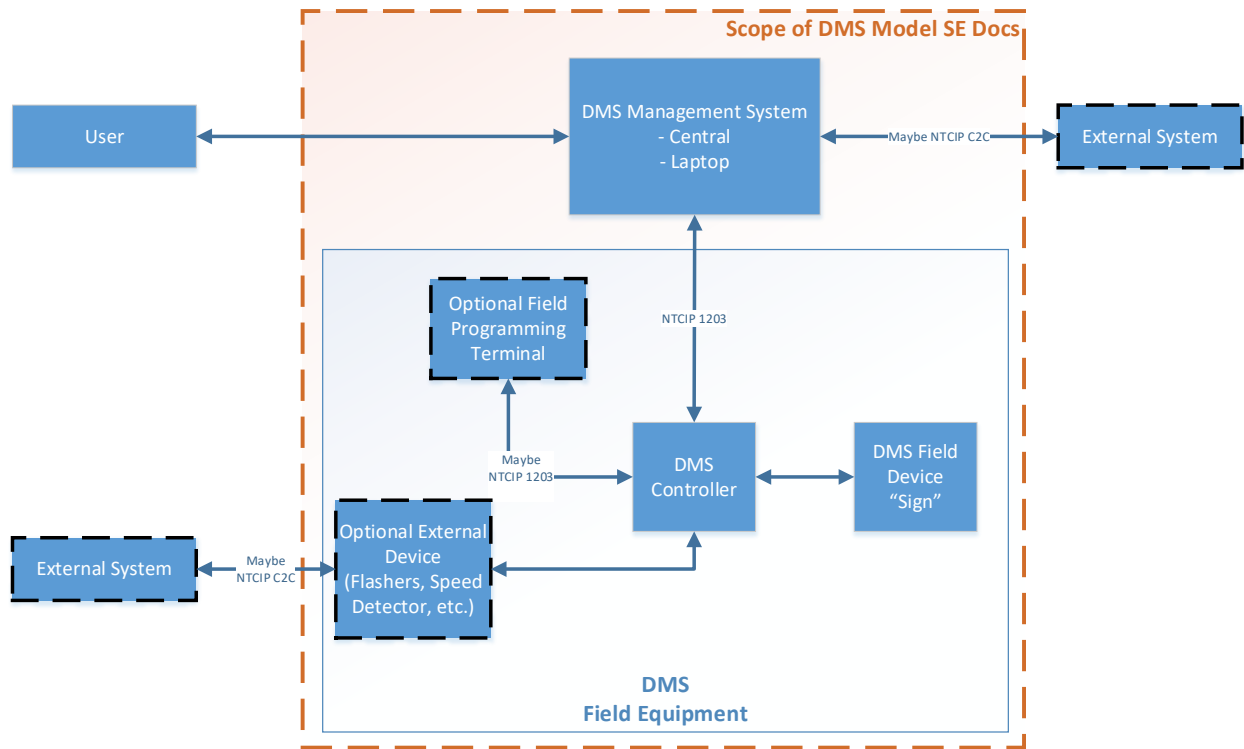


Figure 1. Reference Architecture for a DMS System with the scope of the DMS Model SE Documents

PROCESS

The target audience for this COU includes transportation agencies needing to procure relatively small-scale DMS systems by following a standardized systems engineering process without the need to hire a consultant. The COU will help an agency align their processes, operations and needs with the DMS System Engineering Model Documents, allowing the tailoring of the model document content.

This process will lead to a set of user needs, requirements, verification plan and validation plan to support a successful procurement of a DMS system. A successful procurement results in a DMS system that not only meets the agency’s needs but also provides a basis for ensuring that the procured system meets its advertised capabilities.

The overall framework for the set of SE Model Documents is depicted in Figure 2 below.

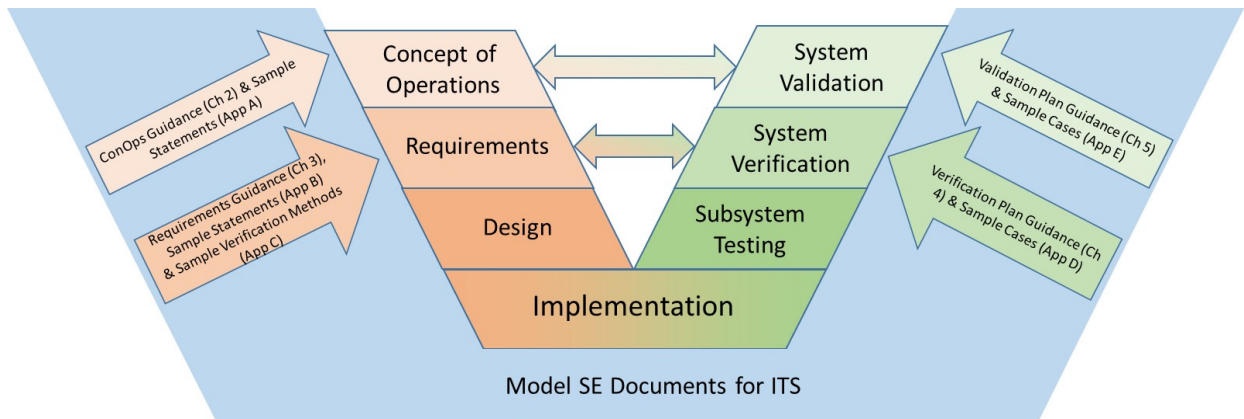


Figure 2. Concept of Use Process for SE Model Documents

The DMS SE Model Documents begin with creating a Concept of Operations capturing typical representative *use cases*, and operational scenarios involving DMS systems. Use cases capture the system *actors* and activities in order to accomplish a specific purpose. An actor defines a role, which may be filled by a person, a group of people, or an external system. The actors form the foundation for the definition of the users of the system and are critical to the high-level use cases, operational scenarios and user needs. Operational scenarios provide examples in narrative form of how those users, activities and systems work together in actual practice.

The ensuing analysis of the use cases, and operational scenarios lead directly to draft user needs (all embodied in the *Concept of Operations*), and the beginning of system validation cases validating the user needs documented in the Validation Plan. The user needs drive the definition of the requirements and the requirements verification methods (residing in the Requirements document) and a requirements Verification Plan. These have been previously reviewed and validated by operational DMS Subject Matter Experts (SMEs). The DMS SE Model Documents walk the user through the process of selecting and tailoring the pertinent use cases and operational scenarios in order to arrive at a set of user needs. Since the systems engineering process is being used, there is forward and backward traceability between the resulting user needs and the requirements. The verification plan and the requirements verification methods are directly traceable back to the requirements being verified. Correspondingly, the validation plan is directly traceable back to the user needs being validated.

The DMS Model Systems Engineering Documents will provide an agency with a means to describe their existing and planned DMS system operations using substantive systems engineering products. In particular, the user will tailor the needs and requirements provided in the model. The process will provide meaningful systems engineering support for a DMS procurement with far less effort than developing systems engineering documents from scratch. The user will still be expected to understand their processes in applying a DMS system to solve their transportation management problems, but the model documents will provide guidance to the user to help them do so.

CONCEPT OF OPERATIONS

The first product of the application of the model documents will be a *Concept of Operations* for a DMS system. The Concept of Operations (ConOps) is written from the perspective of the system operator, and it establishes the activities of the user in solving the transportation management problem at hand, using DMS, as the basis for defining and defending requirements. The primary audience for the ConOps includes stakeholders who will participate in the operation of the system or be directly affected by it. The ConOps is responsible for capturing the stakeholder needs and expectations in a manner that is easily understandable to the stakeholder community, so that the stakeholder community can be confident that it properly models what they will do.

The needs and expectations must be defined succinctly enough to determine what functions the proposed system must be capable of fulfilling. Stakeholders who may play a role in tailoring or reviewing the ConOps may include system operators, maintenance staff, system managers, administrators, decision-makers, elected officials, and other non-technical readers. Every element of the subsequent documents in the project, including the requirements, verification plan, designs, test procedures and processes and validation plan, must be able to be traced to statements of user need in the Concept of Operation. Ultimately, the ConOps describes how the agency will use the system, and in that manner could be considered a prototype for an operating policy and procedure. It is the basis for validating (via the Validation Plan) the system when delivered to ensure that the system is acceptable, with “acceptable” being defined as fulfilling all the *user needs*. The guidance for the Concept of Operations can be found in Chapter 2 of this guidance document.

REQUIREMENTS DOCUMENT

After the ConOps is defined, corresponding system requirements are captured in the DMS System Requirements Document. The requirements document targets technical staff, system users, system designers and vendors. The ConOps describes what the users will do, and the requirements define what the system must do. Each of the requirements listed in this document must be linked to a corresponding need described in the ConOps. Every need in the ConOps must be linked to one or more requirements in the Requirements Document. The forward and backward traceability between needs and requirements makes it possible to define needed requirements during procurement, and to defend requirements if they are challenged during procurement. The Requirements Document becomes the principal systems engineering document during the procurement process, providing the basis for selection, progress verification, (in some cases) payment, and system acceptance.

Once the user has selected and defined their user needs, the SE Model Documents provide system requirements that are linked to those user needs. The guidance in the model documents will assist agency users in tailoring the model needs and requirements as needed, including any needed iteration between needs and requirements. During tailoring, you will need to iterate between needs and requirements to ensure that they remain traceable and consistent. Traceability ensures that each need is fully represented in the requirements, and each requirement is fully driven by needs. Consistency ensures that what the requirements require will satisfy the user needs to which they are traced. Once all the needs and requirements are tailored to the specific

project, and checked for traceability and consistency, both the ConOps and the Requirements documents will be complete and correct.

The DMS Systems Requirement Document does not define the design of the system, nor does it determine what technologies to use or how to implement them. This document sets the technical criteria that will be used to evaluate design and technology choices. It is the basis for verifying (via the Verification Plan) the system during design and when delivered to ensure that the system is acceptable, with “acceptable” being defined as fulfilling all the *requirements*. The recommended approach is to have an Acceptance Test of the procured system based on the system requirements. The guidance for the Requirements Document can be found in Chapter 3 of this guidance document.

VERIFICATION PLAN

This leads to the third document that the user will develop using the Model Documents, the DMS System Verification Plan. The Verification Plan is responsible for defining the verification testing that will demonstrate fulfillment of requirements. The target audience for this document is the same as for the Requirements document. Generally, the implementing contractor will be responsible to fulfill the requirements. The Verification Plan describes the general verification effort including verification cases with corresponding requirements being fulfilled, including the method by which that determination will be made. It is critical that all requirements are verified within the scope of the Verification Plan. This is best done by tracing each requirement into a verification case and eventually into appropriate steps in the verification procedures. The Model Documents provide a direct mapping of verification cases to the requirements. The user simply needs to extract and tailor the corresponding verification cases related to the chosen set of requirements.

The Verification Plan does *not* describe detailed procedures for testing the DMS System. It is typical that the system developer/supplier/vendor will develop the verification test procedures that will map to the verification plan as part of the procurement process. The specific steps of a verification test procedure require a knowledge of the specific software and hardware technology that will be implemented. The guidance for the Verification Plan can be found in Chapter 4 of this guidance document.

VALIDATION PLAN

The fourth document that the user will develop using the Model Documents is the DMS System Validation Plan. The Validation Plan is responsible for defining the validation testing that will demonstrate that the system meets the user needs. The target audience for this document is the same as for the Concept of Operations (ConOps) document. Generally, the implementing contractor will *not* be responsible for validation. The Validation Plan describes the general validation effort including validation cases with corresponding user needs being fulfilled. The Model Documents provide a direct mapping of validation cases to the user needs categories. The user simply needs to extract and tailor the corresponding validation cases related to the chosen set of user needs.

The Validation Plan does *not* describe detailed procedures for validation testing of the DMS System. Typically, once the DMS System has been accepted, the users of the system will validate if the system meets their user needs according to the Validation Plan and subsequent validation procedures. The guidance for the Validation Plan can be found in Chapter 5 of this guidance document.

PROCUREMENT

Finally, the guidance within the model documents includes a general discussion of procurement approaches, and how the products of the systems engineering process support various procurement processes. The guidance for procurement can be found in Chapter 6 of this guidance document.

ASSEMBLING YOUR DOCUMENTS

The finished product of your efforts will be several systems engineering documents. In order to successfully prepare these documents, you will need to take the following steps:

1. Read this document completely.
2. Begin to prepare the Concept of Operations. Establish chapters in accordance with the Concept of Operations template. While you are free to format the document to suit your needs, the template follows the outline suggested in American National Standards Institute (ANSI) standard G-043-1992. As an alternative, you may simply take the table of sample statements and check those statements you wish to include.
3. Following the instructions in this document, copy and edit relevant statements from the Table of Sample Statements for the Concept of Operations. Depending on how you answer each question in the guidance, select and edit each Concept of Operations statement.
4. Some sections of the Concept of Operations require you to write appropriate text in accordance with the instructions contained in this document.
5. Each statement in the Concept of Operations table has a unique identifier. The needs statements (Chapter 4) each refer to at least one relevant System Requirement that should be considered to support the need statement. Each Concept of Operations statement also contains a reference to the relevant section of this Guidance Document.
6. Begin to prepare the System Requirements. Establish chapters in accordance with the System Requirements template. As an alternative, you may choose to include the System Requirements as an appendix to the Concept of Operations. In this case, you may simply take the table of sample statements and check those statements you wish to include.
7. For each need statement used from the Concept of Operations table, identify the System Requirements that are linked. Copy and edit each relevant requirement into the System

Requirements document. Note that whenever you pick a “child” requirement, you should also select its “parent” requirement.

8. If you describe needs in the Concept of Operations that are not covered by these sample statements, then you must either also create new requirements related to those needs, or take separate actions to support those needs if they do not lead to system requirement.
9. Prepare the Verification Plan. Establish chapters in accordance with the Verification Plan template. There is a suggested verification method for each System Requirement. Each high-level System Requirement also has an associated verification case name and description to get you started. Note that every System Requirement requires a verification test, which you will need to define to suit your situation.
10. Prepare the Validation Plan. Establish chapters in accordance with the Validation Plan template. Note that every need expressed in the Concept of Operations requires a corresponding validation test, which you will need to define to suit your situation. If you define performance measurement in your requirements, some validation may be provided by the new system, while some may require separate off-line tests.

SUMMARY

In summary, the DMS System Model Documents will provide documentation templates that will guide the user through the selection and insertion of applicable user needs, requirements, verification cases and validation cases that are consistent with each other. The Model Documents will provide guidance to the user on selecting operational DMS system capabilities that fit within the use cases and operational scenarios. The focus of this guidance is to develop documents that will enable the agency to successfully procure a DMS system that is currently available in the product market. It should be stressed that the responsibility for preparation of these DMS Systems Engineering documents rests entirely with the procuring agency.

CHAPTER 2. CONCEPT OF OPERATIONS GUIDANCE

The Model Concept of Operations can be found in Appendix A. The chapters of the Model Concept of Operations, which are described in the sections below, follow a standard outline for concepts of operation established by the American National Standards Institute (ANSI/AIAA-G-043). There are competing standardized outlines for concepts of operations, but the ANSI outline was determined to be the most appropriate for infrastructure construction projects that established new capabilities.

While the layout of the Concept of Operations described in this guidance will provide a logical flow for the intended readers, it is generally not prepared in this sequence. As practical traffic engineers, it is generally preferable to describe at an early stage the operational scenarios envisioned by the system users/operators. After initially describing the limitations of the existing system, you should describe all the situations in which you expect the system to provide benefit, and how you expect the system to operate in each situation. After describing the operational scenarios, you will then be in a position to better describe the specific system and user needs, the alternative strategies considered and why they were discarded, and the envisioned system. Then you will be able to revise the operational scenarios so they are consistent with the statements of needs and provide clear examples of the expected operation.

The Concept of Operations will be organized in the following chapters, following the structure recommended in ANSI G-043-1992:

1. Scope.
2. Referenced documents.
3. User-Oriented operational description.
4. Operational needs.
5. System overview.
6. Operational environment.
7. Support environment.
8. Operational scenarios.

Once you have completed the Concept of Operation, use this checklist to confirm that all critical information has been included:

- Is the reason for developing or procuring the system clearly stated?
- Are all the stakeholders identified and their anticipated roles described? This should include anyone who will operate, maintain, build, manage, use, or otherwise be affected by the system.
- Are alternative operational approaches (such as maintaining the current system capabilities or no system, as appropriate to your situation) described and the selected approach justified?

- Is the external environment described? Does it include required interfaces to existing systems, both internal and external to your agency?
- Is the support environment described? Does it include maintenance?
- Is the operational environment described?
- Are there clear and complete descriptions of normal operational scenarios?
- Are there clear and complete descriptions of maintenance and failure scenarios?
- Do the scenarios include the viewpoints of all involved stakeholders? Do they make it clear who is doing what?
- Are all constraints on the system identified?

SCOPE (CHAPTER 1 OF THE CONOPS DOCUMENT)

The first product of the application of the model documents will be a Concept of Operations for a DMS system. The Concept of Operations (ConOps) is written from the perspective of the system user/operator, and it establishes the activities of the user in solving the transportation management problem at hand, using DMS, as the basis for defining and defending requirements. The primary audience for the ConOps includes stakeholders who will participate in the operation of the system or be directly affected by it. The ConOps is responsible for capturing the stakeholder needs and expectations in a manner that is easily understandable to the stakeholder community, so that the stakeholder community can be confident that it properly models what they will do.

The needs and expectations must be defined succinctly enough to determine what functions the proposed system must be capable of fulfilling. Stakeholders who may play a role in tailoring or reviewing the ConOps may include system users/operators, maintenance staff, system managers, administrators, decision-makers, elected officials, and other non-technical readers. Every element of the subsequent documents in the project, including the requirements, verification plan, designs, and test procedures and processes, must be able to be traced to statements of user need in the Concept of Operation. Ultimately, the ConOps describes how the agency will use the system, and in that manner could be considered a prototype for an operating policy and procedure.

Document Purpose and Scope

The first part of this chapter is a short statement of the purpose and scope of this document. This will briefly describe contents, intention, and audience. Sample statements that may be used in this chapter are contained in the Concept of Operations sample statements table in Appendix A. These statements should be customized to explicitly apply to your situation. One or two paragraphs will normally suffice.

Project Purpose and Scope

The second part of this chapter gives a brief overview of the purpose and scope of the system to be built. It includes a high-level description; describes what area will be covered by the project; and identifies which agencies will be involved, either directly or through interfaces. Sample statements that may be used in this chapter are contained in the Concept of Operations Sample Statements table. These statements should be customized to explicitly describe your project. One or two paragraphs will usually suffice. This section should be written late in the process, after the envisioned system has been described. It will be a brief summary to introduce the reader to the proposed system.

Procurement

The final section of this chapter will be a brief discussion of the proposed procurement process. The method of procurement should be determined early in this process, because it will have an impact on the format and content of the system requirements document. See Chapter 6 of this Model SE Document for DMS Systems document for additional information.

REFERENCED DOCUMENTS (CHAPTER 2 OF THE CONOPS DOCUMENT)

This chapter is a place to list any supporting documentation and other resources that are useful in understanding the operations of the system. This could include any documentation of current operations and any strategic plans that drive the goals of the system under development. In particular, it should include documents that define the overall goals and objectives of your agency that will be supported by the DMS System. This includes local and regional transportation program and policy documents and relevant inter-agency, management and labor agreements and memoranda of understanding. It should reference the applicable statewide and/or regional ITS Architecture(s) and include relevant codes and standards, such as ANSI, Institute of Electrical and Electronics Engineers (IEEE), National Transportation Communications for Intelligent Transportation System Protocol (NTCIP), National Electrical Manufacturers Association (NEMA), Code of Federal Regulations (CFR) and National Electrical Code (NEC). It should also include references to detailed documentation of any required interfaces to other systems such as an Integrated Corridor Management (ICM) system. However, do not treat this as a bibliography. Only include documents that are referenced directly in the Concept of Operation. Sample statements that may be used in this section are contained in the Concept of Operations sample statements table (Appendix A).

USER-ORIENTED OPERATIONAL DESCRIPTION (CHAPTER 3 OF THE CONOPS DOCUMENT)

This chapter describes the operational problem to be solved and how a DMS System helps the agency solve it. This is where we define the use cases related to application areas. When the use cases are selected in Chapter 3, it will guide you to which groups of user needs you need to select in Chapter 4, User Needs.

General Actors

The general actors represent the various roles and systems that interact with the DMS System. Each actor represents a role, a user can have multiple roles and there can be multiple for the same type of actor. For example, a DMS System Maintainer and a DMS System User could be the same person or they could be different people.

Use Cases

Use cases capture the high-level typical interactions between an actor and a computer system. A use case needs to address a discrete goal of the actor/user. Besides the common use cases of system support (e.g., configuration, maintenance, etc.) the DMS System use cases give the system operator the ability to better judge a transportation-related situation.

OPERATIONAL NEEDS (CHAPTER 4 OF THE CONOPS DOCUMENT)

In order to effectively manage the surface transportation system, operators need to be able to see the current conditions in order to detect problems, verify problems and ensure proper mitigation of the problems through various transportation management operations. A DMS System provides the operators with ability to inform the traveling public with a variety of information. This information can include advisory information such as incidents, road closures, estimated travel times, as well as regulatory information such as speed limits and available high occupancy vehicle (HOV) lane access requirements.

This chapter captures the stakeholder (including actual user/operator) needs and expectations answering the question “Why is a DMS System Needed?” which sets the foundation for the system requirements. The stakeholder needs and expectations must be defined in a manner that is easily understandable to the stakeholder community, so that the stakeholder community can be confident that it properly models what they will do.

Each high-level grouping of user needs in Chapter Four of Appendix A includes the statement “Choose the user needs in this group if you chose [any on this list of use cases] in Chapter Three”. This is how the user needs relate back to the use cases. In most cases, the user needs were categorized specifically by their corresponding use case.

Some user needs and their corresponding system requirements will require additional specification and tailoring to the DMS System environment. The user needs indicate where this is necessary by square brackets “[specify]”.

ENVISIONED DMS SYSTEM OVERVIEW (CHAPTER 5 OF THE CONOPS DOCUMENT)

This chapter is an overview of the envisioned DMS system. It is a high-level description that will describe the main features and capabilities and the scope of its coverage. You should describe its conceptual architecture at a block diagram level with a high-level data flow diagram. This should not show design details. This description should reflect the needs that are described in the previous chapter.

It should illustrate, either graphically or in words, each of the following categories of needs that are relevant:

- Network characteristics.
- Type of DMS System operations.
- Interfaces to other systems (if any).
- A good way of illustrating the system is to draw out the activities undertaken by stakeholders in a particular situation, and highlight those that are anticipated to be augmented with the operation of the DMS System. An example of such a diagram, based on the typical physical architecture in NTCIP 1203 and generated from RAD-IT, is illustrated in Figure 3.

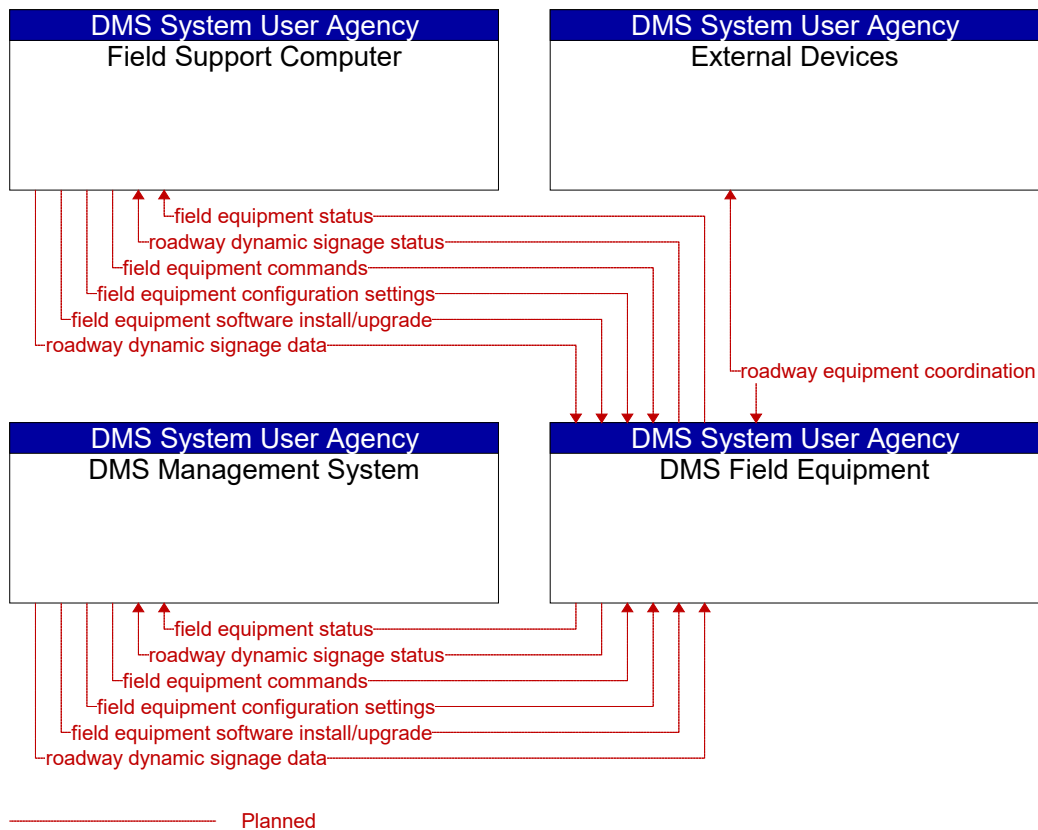


Figure 3. High-Level Representative DMS System Project Architecture Diagram

Each interface between ITS elements in the architecture diagram can have multiple communications standards associated with it. Using the Systems Engineering Tool for Intelligent Transportation (SET-IT) tool and converting the DMS System Project Architecture results in a set of standardized communication protocol stacks for each triple (source element, information flow and destination element). An example of one of these communication protocol stack diagrams is shown in 4. The entire set of standardized communication protocol diagrams for each interface can be found in Appendix F.

NTCIP-SMTP		
roadway dynamic signage data		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 4. Communications Protocol Standards Example for the NTCIP-SMTP Triple of DMS Management System → roadway dynamic signage data → DMS Field Equipment based on the DMS System Project Architecture Diagram

DMS SYSTEM OPERATIONAL ENVIRONMENT (CHAPTER 6 OF THE CONOPS DOCUMENT)

This chapter describes both the operational environment and the physical environment within which the DMS System will operate.

Operational Environment

Describe the stakeholders. These should include all existing stakeholders who have an influence on the operation of the proposed DMS System. This will include Traffic Management Center (TMC) operations staff, and staff of other agencies whose operation and duties may be affected by the envisioned DMS System.

The activities related to DMS System operation should be described, such as configuration, DMS sign characteristics, DMS message characteristics, system performance monitoring, and inter-agency staff interactions.

The organizational structure should be described, highlighting any changes from the existing arrangements that are envisioned. An overview of the qualifications and experience of personnel should be presented along with clear definition of any roles and responsibilities that would be undertaken by contractors, vendors, consultants and staff of other agencies.

Sample statements that may be used in this section are contained in the Concept of Operations sample statements table (Appendix A).

Physical Environment

This section describes the facilities within which equipment and personnel will be housed, additional furniture and equipment that will be required, new computing hardware and software that will be required, operational procedures for operating the system and any additional support that will be need.

For example, describe whether the equipment will be located in a TMC, at City Hall, at the corporation yard or signal shop and/or in the field. Will field equipment need to be field hardened or located within an air-conditioned environment? Will existing power supplies be adequate or will additional service, UPS and battery backups be required?

Will the operators be on duty or available 24/7 or during limited hours? Describe their required experience, skills and additional training needs.

Sample statements that may be used in this section are contained in the Concept of Operations sample statements table (Appendix A).

DMS SYSTEM SUPPORT ENVIRONMENT (CHAPTER 7 OF THE CONOPS DOCUMENT)

This chapter describes the current and planned physical support environment. Describe what support equipment, personnel, training and procedures currently existing, and explain those that need to be acquired or implemented.

Describe any additional test equipment and repair tools that will be needed to support DMS System operation. Where will test equipment be located?

Describe additional staff or contractors who will not be involved in the day-to-day operations of the system, but will be needed to support the operators and maintenance staff. This should include staff from the system vendor and/or consultants, who will provide additional on-going training, periodically audit the system setup and performance and support expansion of the system in the future.

Where multiple agencies are involved, describe the support that will be provided by or to other agencies. This should include any existing or proposed memoranda of understanding or

operations and maintenance agreements that will affect the DMS System, or will need to be modified to include reference to the DMS System. This may include modifying the policies and procedures of those agencies in addition to developing new policies and procedures within your agency.

Sample statements that may be used in this chapter are contained in the Concept of Operations sample statements table (Appendix A).

PROPOSED OPERATIONAL SCENARIOS USING A DMS SYSTEM (CHAPTER 8 OF THE CONOPS DOCUMENT)

The purpose of this chapter of the Concept of Operations document is to provide examples that illustrate how the system will be expected to operate and interface with the operators in typical circumstances. It is not intended to comprehensively describe the operation under all conditions. It is intended to illustrate to vendors, managers and decision-makers alike how you see your objectives being met by the system. This description is practically oriented and takes into account the practical limitations of available systems, which you expect to be live with. It should not be a description of how you would like some imagined system to operate with no regard for the practical limitation of candidate systems.

Each statement in a scenario should relate to a user need, although not all needs will be further described in a scenario. The statements in the description of each scenario do not directly generate requirements. Requirements are only generated from needs. The scenarios in the Concept of Operations sample statements table (Appendix A) simply provide examples of how the system meets some of the needs.

Once you have written the scenarios, if you are not satisfied that they describe an operation that will be adequate, you should then review your needs statements. If you wish to describe elements of the proposed operation that are not described by needs, then additional needs should be enunciated.

CHAPTER 3. SYSTEM REQUIREMENTS GUIDANCE

The model System Requirements can be found in Appendices B and C. Appendix B lists the requirements with backward traceability to the needs, and Appendix C shows the method by which each requirement can be verified. The sections below describe the typical outline of a *standard* requirements document, as described by International Organization of Standardization (ISO) /IEEE 29148:2011(E). For the projects targeted by these model documents, all of these sections may not be necessary, or are adequately covered in the Concept of Operations. We include them here for general information and context. The parts of the outline that are critical, however, include Chapters 3 and 4 of the IEEE outline, which include the requirements and verification methods. For this reason, the numbering for the functional requirements listed in Appendices B and C start with a “3.1”. This numbering approach is an artifact of the standardized numbering.

The chapters required for the System Requirements document are:

1. Scope of System or Sub-system.
2. References.
3. Requirements.
4. Verification Methods.
5. Supporting Documentation.
6. Traceability Matrix.
7. Glossary.

This document sets the technical scope of the system to be built. It is the basis for verifying (via the Verification Plan) the system and sub-systems when delivered.

This document must be tailored to your project. All DMS system projects need a set of requirements defining what will be provided by the vendor. You will need to decide how extensively to document these requirements. One convenient way to gauge how many requirements to write and/or how much detail to have in the requirements document is to start at the finish line. The following should be asked when starting at the top level of the system:

- What are all the functions needed in order to demonstrate to the agency that the system is doing what it is expected to do?
- How well does the system need to perform the required functions?
- Under what conditions does the system need to operate?

Each of these tests will need a set of requirements. This is done for the system and the sub-systems. For simple systems, one or two pages of requirements may be sufficient to fully define what the system is to do. In more complex systems, this could be 10 to 20 pages, or even more.

Another factor that drives the number of requirements and depth of detail that needs to be written is the extent to which commercially available products are used. These products have their own specifications. For many requirements, it may be sufficient to reference the existing product specifications after the requirements have been carefully reviewed. For example, the DMS

systems that are on the market have sufficient documentation to demonstrate that most requirements are fulfilled. The additional requirements would be for any modifications or enhancements needed. However, great care must be taken when referencing existing commercial product specifications to ensure the wording does not unnecessarily or unintentionally limit compliance to a single system when more than one is capable of fulfilling the requirements.

When choosing from available products, your requirements do not need to be as detailed as they would be when developing a new system. This document applies only to the former situation. If your needs lead you to decide that new software must be developed, the project will be of sufficient scope and risk to warrant a more detailed and customized system engineering process than is provided by these model documents.

Once the requirements document has been completed, use this checklist to confirm that all critical information has been included.

- Is there a definition of all the major system functions?
- With each function of the system, is there a set of requirements that describes: what the function does, and under what conditions (e.g., environmental, reliability, and availability)?
- Are all terms, definitions, and acronyms defined?
- Are all supporting documents such as standards, concept of operations, and others referenced?
- Does each requirement have a link (traceability) to a higher-level requirement of a user-specified need or scenario?
- Is each requirement concise, verifiable, clear, feasible, necessary, unambiguous, and technology (vendor) independent?
- Are all technology dependent requirements identified as constraints?
- Does each requirement have a method of verification defined?
- Does each requirement trace to a verification case?

SCOPE OF SYSTEM OR SUB-SYSTEM (CHAPTER 1 OF THE REQUIREMENTS DOCUMENT)

This chapter is a brief overview of the system and statement of the purpose of this document. Briefly describe the contents, intention and audience for this document. Summarize the history of system development, the proposed operation, and maintenance. Identify the project stakeholders, acquiring agency, users and support agencies. Identify current and planned operating sites.

REFERENCES (CHAPTER 2 OF THE REQUIREMENTS DOCUMENT)

This chapter identifies all standards, policies, laws, the Concept of Operations document, concept exploration documents and other reference material that are needed to support the requirements.

REQUIREMENTS (CHAPTER 3 OF THE REQUIREMENTS DOCUMENT)

This chapter lists all the requirements necessary to define the proposed DMS System. Each requirement should be clear and concise, verifiable, feasible, necessary, unambiguous and technology independent. Each requirement should have a single statement. DO NOT use terms such as "and", "but", "except" and other modifiers that combine more than one thought into a single requirement.

In general, each of the sample requirements falls into one of the following categories, although they are not expected to be organized in this manner:

- Functional Requirements (What the system shall do).
- Constraints (e.g., Technology, design, tools, and/or standards).

Sample requirements that may be used in the Requirements document are included in the System Requirements samples table (Appendix B). Each of these is directly related to one or more statements of need in the Concept of Operation.

Some of the requirements and their corresponding user needs will require additional specification and tailoring to the DMS System environment. The requirements indicate where this is necessary by square brackets “[specify]”.

VERIFICATION METHODS (CHAPTER 4 OF THE REQUIREMENTS DOCUMENT)

In this chapter, identify one of the following methods of verification for each requirement.

- Demonstration is used for a requirement that the system can demonstrate without external test equipment.
- Test is used for a requirement that requires some external piece of test equipment (such as logic analyzer or voltmeter).
- Analyze is used for a requirement that is met indirectly through a logical conclusion or mathematical analysis of a result. For example, algorithms for congestion: the designer may need to show that the requirement is met through the analysis of count and occupancy calculations in software or firmware.
- Inspection is used for verification through a visual comparison. For example, quality of welding may be done through a visual comparison against an in-house standard.

Suggested verification methods that may be used in the Requirements document are included in the Suggested Requirements Verification Methods table (Appendix C). Do not describe how,

when or where the verification will be performed. This is separately covered in the Verification Plan document.

SUPPORTING DOCUMENTATION (CHAPTER 5 OF THE REQUIREMENTS DOCUMENT)

This optional chapter is a catchall for anything that may add to the understanding of the Requirements and cannot be logically located elsewhere. Examples of supporting documents include: diagrams, analysis, memos, stakeholders contact list and published documents related to similar projects.

TRACEABILITY MATRIX (CHAPTER 6 OF THE REQUIREMENTS DOCUMENT)

This is a table that traces the requirements in this document to the needs expressed in the Concept of Operation. Every requirement *must* support *at least one* user need.

GLOSSARY (CHAPTER 7 OF THE REQUIREMENTS DOCUMENT)

This is a standard glossary of terms unique to the project.

CHAPTER 4. VERIFICATION PLAN GUIDANCE

The model Verification Plan can be found in Appendix D. The chapters required for the Verification Plan are:

1. Purpose of Document.
2. Scope of Project.
3. Referenced Documents.
4. Conducting Verification.
5. Verification Identification.

This verification plan describes the activity of verifying that the system being built satisfies all the requirements set out in the requirements documents.

The verification documents will include:

- A plan to initially lay out the specific verification effort.
- The verification plan that defines the detailed mapping of the requirements to verification cases.
- A report on the results of the Verification activities.

To ensure that all requirements are verified by this activity, trace each requirement into a verification case, then trace this in turn into a step in the Verification procedure.

The Verification Plan does not need to include verification procedures. These may be prepared by the vendor, but must be reviewed by the agency to ensure each verification case will be tested and appropriate results recorded. In relatively simple cases, the vendor may prepare both the Verification Plan and the procedures. In this situation, the agency must ensure that each requirement is mapped to at least one verification case.

Preparation of a stand-alone verification plan is strongly advised if:

- The system is complex.
- There are several separate verification activities being performed on the system.
- Multiple deployment sites are involved.
- Multiple stakeholders have to be satisfied.

There is also the question of how comprehensive to make the verification effort. It is impossible to validate all possible combinations of actions under all possible operational situations. A good rule of thumb is: if it was important enough to write down as a requirement, then it should be

verified, at least once. In-process¹ verification performed on the needs and requirements will help ensure that the correct requirements are being verified.

Once the verification plan is completed, use the following checklist to ensure all critical information has been included.

- Does the Verification Plan answer all the questions of who, what, where, and when?
- Does the Verification Plan make clear what needs to happen if a failure is encountered?
- Does the Verification Plan document the configuration of the hardware, software?
- Are all requirements traced to a verification case?

PURPOSE OF THE DOCUMENT (CHAPTER 1 OF THE VERIFICATION PLAN DOCUMENT)

This section identifies the type of verification activity to be performed within this Verification Plan. For instance, this activity may validate the entire system, a sub-system, the deployment at a site, a burn-in, or any other verification activity called for in the Verification Plan.

SCOPE OF PROJECT (CHAPTER 2 OF THE VERIFICATION PLAN DOCUMENT)

This section gives a brief description of the planned project and the purpose of the system to be built. This section also describes the environment in which the project operates. It identifies the organization structures that encompass all stakeholders. It also gives a brief description of the role to be played by each stakeholder. This includes ad hoc and existing management work groups and multi-disciplinary technical teams that should be formed to support the project.

REFERENCED DOCUMENTS (CHAPTER 3 OF THE VERIFICATION PLAN DOCUMENT)

This is a list of all documents used in the preparation of this Verification Plan. This usually includes the Project Plan, (if one was written), and the applicable Requirements Documents. Reference to other documents, such as descriptions of external systems, standards, a Concept of Operations, and manuals may also be included.

CONDUCTING VERIFICATION (CHAPTER 4 OF THE VERIFICATION PLAN DOCUMENT)

This section provides details on how verification is accomplished. It defines: who does the verification; when and where it is to be done; the responsibilities of each participant before, during, and after verification; the deployed hardware and software configuration; and the documents to be prepared as a record of the verification activity.

¹ In-process verification is reviewing the needs and requirements during the definition stage by the stakeholders to ensure that all the needs have been identified and traced to the appropriate requirements and have been reviewed for completeness for each of the needs.

This section also defines how anomalies are to be handled (that is, what to do when an unexpected situation or a failure occurs during verification).

In general, the following information should be included in this section:

- A description of the participating organizations and personnel and identification of their roles and responsibilities. This may include for example, a verification conductor, verification recorder, operators, and/or engineering support.
- Identification of the location of the verification effort, that is, the place, or places, where the verification must be observed.
- The deployed hardware and software configuration for all of the verification cases, including hardware and software under verification and any supporting equipment, software, or external systems. Several configurations may be necessary.
- Identification of the documents to be prepared to support the verification, including Verification Procedures, a Verification Report and descriptions of special equipment and software.
- Details of the actual conduct of verification, including:
 - Notification of participants.
 - Emphasis on the management role of the verification conductor.
 - Procedures for approving last minute changes to the procedures.
 - The processes for handling a failure, including recording of critical information, determination of whether to stop the verification, restart, or skip a procedure, resolution of the cause of a failure (e.g. fix the software, reset the system, and/or change the requirements), and determination of the re-verification activities necessary as a result of the failure.

VERIFICATION IDENTIFICATION (CHAPTER 5 OF THE VERIFICATION PLAN DOCUMENT)

This section identifies the specific verification cases to be performed. A verification case is a logical grouping of functions and performance criteria (all from the Requirements Document) that are to be verified together. For instance, a specific verification case may cover all the control capabilities to be provided for control of the DMS System. There may be several individual requirements that define this capability, and they all are verified in one case. The actual grouping of requirements into a verification case is arbitrary; however, the grouping is usually based on the grouping of functional requirements in the Requirements Document. They should be related and easily combined into a reasonable set of procedure actions. Suggested verification cases that may be used in the Verification Plan document are included in the Verification Plan Sample Cases table (Appendix D).

Each case should contain at least the following information:

- A description name and a reference number.
- A description of the objective of the verification case, usually taken from the wording of the requirement, to aid the reader understanding the scope of the case.
- A complete list of requirements to be verified or traceability to the requirements in the requirements document. Since each requirement has a unique number, they can be accurately and conveniently referenced without repetition.
- Any data to be recorded or noted during verification, such as expected results of a step. Other data, such as a recording of a digital message sent to an external system, may be required to validate the performance of the system.
- A statement of the pass/fail criteria. Often this is just a statement that the system operates per the requirement.
- A description of the verification configuration. That is a list of the hardware and software items needed for verification and how they should be connected (in most cases this is the deployed system configuration). Often, the same configuration is used for several verification cases.
- A list of any other important assumptions and constraints necessary to conduct the verification case.

Each verification case in Appendix D corresponds to the same name of a section of requirements in Section 3 of the Requirements model document. The details of each verification case will need to be added as the system is further defined.

CHAPTER 5. VALIDATION PLAN GUIDANCE

The model Validation Plan can be found in Appendix E. The chapters required for the Validation Plan document are:

1. Purpose of Document.
2. Scope of Project.
3. Referenced Documents.
4. Conducting Validation.
5. Validation Identification.

This document describes the activity of validation that the system being built meets the user needs and scenarios developed in the concept of operations. The validation documents will generally include three levels of validation documents:

- A plan to initially lay out the specific validation effort.
- The user's/operator's manual and/or a validation plan that defines the detailed operational procedures.
- A report on the results of the validation activities.

To ensure user needs and scenarios are validated by this activity, trace each need and scenario into a validation case, then into appropriate steps in the validation procedure.

A separate Validation Plan and procedures may be minimal for the simplest projects, especially where the system is commercially available and does not involve any custom software development, and where the agency staff have a very clear understanding of the purpose of the system. Preparation of a validation plan is strongly advised if:

- The system is more complex.
- There are several separate validation activities.
- Multiple deployment sites are involved.
- Multiple stakeholders have to be satisfied.

There is also the question of how comprehensive to make the validation effort. It is impossible to validate all possible combinations of actions under all possible operational situations. A good rule of thumb is: if it was important enough to write down as a need or scenario, then it should be validated, at least once. This may not, for example, validate all possible failure mode conditions or all possible incident scenarios. In-process² validation performed on the needs will help ensure that end-to-end validation of the system will meet the stakeholder needs.

² In-process validation is reviewing the needs and requirements during the definition stage by the stakeholders to ensure that all the needs have been identified and traced to the appropriate requirements and have been reviewed for completeness for each of the needs.

Once the Validation Plan has been prepared, use this checklist to ensure all critical information has been included.

- Does the Validation Plan answer all the questions of who, what, where, and when?
- Does the Validation Plan make clear what needs to happen if an unexpected situation or a failure is encountered?
- Does the Validation Plan document the configuration of the hardware and software?
- Are all applicable needs and scenarios traced to a validation case?

PURPOSE OF THE DOCUMENT (CHAPTER 1 OF THE VALIDATION PLAN DOCUMENT)

This section identifies the type of validation activity to be performed within this Validation Plan. For instance, this activity may validate the entire system, a sub-system, the deployment at a site, a burn-in, or any other validation activity called for in the Program Plan or in the SEMP.

SCOPE OF PROJECT (CHAPTER 2 OF THE VALIDATION PLAN DOCUMENT)

This section gives a brief description of the planned project and the purpose of the system to be built. Special emphasis is placed on the project's user needs and issues that must be addressed and validated.

This section also describes the environment in which the project operates. It identifies the organization structures that encompass all stakeholders. It also gives a brief description of the role to be played by each stakeholder. This includes ad hoc and existing management work groups and multi-disciplinary technical teams that should be formed to support the project.

REFERENCED DOCUMENTS (CHAPTER 3 OF THE VALIDATION PLAN DOCUMENT)

This is a list of all documents used in the preparation of this Validation Plan. This usually includes the Project Plan, (if one was written), and the applicable Requirements Documents. Reference to other documents, such as descriptions of external systems, standards, a Concept of Operations, and manuals may also be included.

CONDUCTING VALIDATION (CHAPTER 4 OF THE VALIDATION PLAN DOCUMENT)

This section provides details on how validation is accomplished. It defines: who does the validation; when and where it is to be done; the responsibilities of each participant before, during, and after validation; the deployed hardware and software configuration; and the documents to be prepared as a record of the validation activity.

This section also defines how anomalies are to be handled (that is, what to do when an unexpected situation or a failure occurs during validation).

In general, the following information should be included in this section:

- A description of the participating organizations and personnel and identification of their roles and responsibilities. This may include for example, a validation conductor, validation recorder, operators, and/or engineering support.
- Identification of the location of the validation effort, that is, the place, or places, where the validation must be observed.
- The deployed hardware and software configuration for all of the validation cases, including hardware and software under validation and any supporting equipment, software, or external systems. Several configurations may be necessary.
- Identification of the documents to be prepared to support the validation, including Validation Procedures, a Validation Report and descriptions of special equipment and software.
- Details of the actual conduct of validation, including:
 - Notification of participants.
 - Emphasis on the management role of the validation conductor.
 - Procedures for approving last minute changes to the procedures.
 - The processes for handling a failure, including recording of critical information, determination of whether to stop the validation, restart, or skip a procedure, resolution of the cause of a failure (e.g. fix the software, reset the system, and/or change the requirements), and determination of the re-validation activities necessary as a result of the failure.

VALIDATION IDENTIFICATION (CHAPTER 5 OF THE VALIDATION PLAN DOCUMENT)

This section identifies the specific validation cases to be performed. A validation case is a logical grouping of functions and performance criteria (all from the Concept of Operations Document) that are to be validated together. For instance, a specific validation case may cover DMS System user permissions by the DMS System Manager. There may be several individual user needs that define this capability, and they all are validated in one case. The actual grouping of user needs into a case is arbitrary; however, the grouping is usually based on the grouping of user needs and the operational scenarios in the Concept of Operations. They should be related and easily combined into a reasonable set of procedure actions. Suggested validation cases that may be used in the Validation Plan document are included in the Validation Plan Sample Cases table (Appendix E).

Each case should contain at least the following information:

- A description name and a reference number.

- A description of the objective of the validation case, usually taken from the wording of the user need and/or scenario, to aid the reader understanding the scope of the case.
- A complete list of user needs and scenarios to be validated. For ease of tracing of user needs and scenarios into the Validation Plan and other documents, the user needs and scenarios are given numbers, so they can be accurately and conveniently referenced without repetition.
- Any data to be recorded or noted during validation, such as expected results of a step. Other data, such as a recording of a digital message sent to an external system, may be required to validate the performance of the system.
- A statement of the pass/fail criteria. Often this is just a statement that the system operates per the user need or scenario.
- A description of the validation configuration. That is a list of the hardware and software items needed for validation and how they should be connected (in most cases this is the deployed system configuration). Often, the same configuration is used for several validation cases.
- A list of any other important assumptions and constraints necessary to conduct the validation case.

Each validation case in Appendix E corresponds to the same name of a section of user needs in Section 4 of the ConOps model document. The applicable operational scenarios defined in section 8 of the ConOps are referenced in each validation case. The details of each validation case will need to be added as the system is further defined.

CHAPTER 6. PURCHASING A SYSTEM USING SYSTEMS ENGINEERING DOCUMENTS

TRADITIONAL APPROACHES ARE RISKY FOR TECHNOLOGY PROJECTS

Most agencies purchase systems by first exploring the marketplace to identify which technologies and products have the features they want, and then work from the sample specifications provided by the vendors of those technologies and products. They prepare plans and specifications, and then go out for bid. They then select the lowest responsible bidder, but they determine whether a bidder is responsible based on reputation or product affiliation. The bidder receives the contract, and then as part of mobilization, provides a material submittal, which includes product cut sheets describing what materials they intend to provide on the project.

For technology projects, prospective bidders select system and product providers based on cost or standing relationship, and usually require those providers to provide technical information needed to support the bid, and materials to include in the submittal.

The agency usually accepts the submittal unless it points to technologies and products different from what they had explored. If the contractor proposed a different provider, a negotiation begins where the contractor and the agency eventually come to an agreement.

The basis of the selection of the contractor and the contractor's providers is based mostly on cost. The acceptance of those providers is negotiated based on preferences, rather than on objective evaluation.

The problem emerges during implementation and testing, when the agency first has access to the supplied systems and products. At that point, they are able to see things not visible during market research, and the difference between what they have bought and what they are receiving come into focus. Those differences exist because their product selection (or the contractor's selection) did not actually do what they needed it to do, and as acceptance testing wears on, the agency comes to understand their needs and requirements more clearly.

Only two possibilities exist for resolving unmet emerging requirements: Either the agency sets those requirements aside (and does without), or the contractor and providers exceed their expected costs by modifying their product. Usually, both of these occur, and the outcome for the agency is that the system is more expensive than expected and less useful than needed. Even if the agency succeeds in requiring the contractor to absorb those extra costs, it is difficult to say that the project is as successful as it could have been.

One might call this the "consumer reports" approach, where we make choices based on testimonials, short demonstrations, and advertising claims. The process is shown in Figure 5.

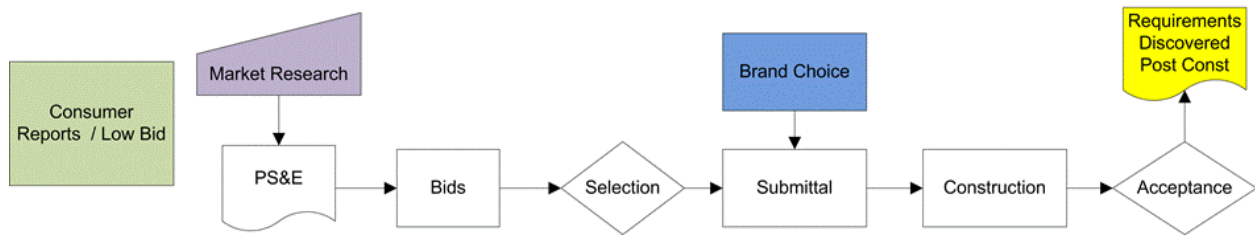


Figure 5. Consumer Reports acquisition approach.

This process follows the traditional approach used for highway construction, and works reasonably well when all the requirements are clearly understood and documented before the acquisition process begins. When the requirements are not clearly understood beforehand, they will be discovered during the project, but after money has been spent and often too late to fulfill them completely.

REDUCING RISK USING REQUIREMENTS

With well-documented requirements in hand, the agency can still use the low-bid process. But the requirements have a specific effect at several key milestones of the project, and shown in Figure 6.

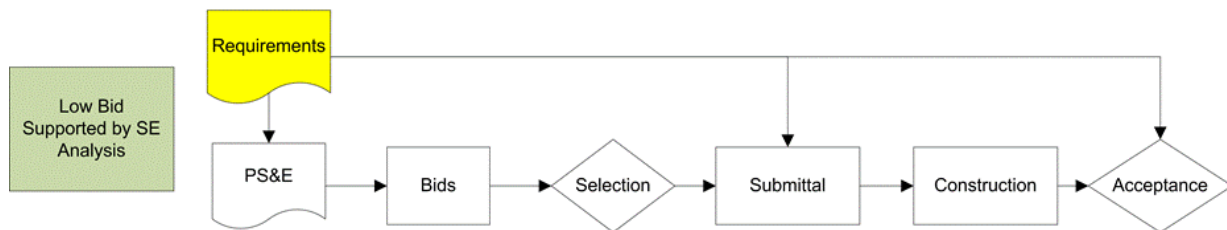


Figure 6. Low-bid process supported by requirements.

Firstly, requirements developed before design can be used to evaluate design choices, and to provide a means by which the designer can know and demonstrate, by applying the Verification Plan to the design, that the design is complete and correct. This gives the agency a reason to have more confidence in the design documents.

Secondly, because the requirements will be included in the bid documents, the bidder has a basis for selecting technology and product providers. If a provider falls short later in the process, the contractor cannot claim that the requirements emerged after bidding, as is often the case with the first approach. This reduces the likelihood of the contractor making a poor choice and having to correct it at his expense during implementation.

Thirdly, the requirements give the agency a means of evaluating the materials submittal explicitly, without having to depend completely on brand reputation, testimonials, or sales activities. The agency should include a requirement in the Special Provisions governing the materials submittal, requiring the contractor to provide a detailed explanation of how the

proposed material supply will fulfill each contract. This is, in essence, a pass through the Verification Plan. The agency can assess the materials submittal with much greater clarity and with much more leverage with the contractor if requirements are not fulfilled as expected.

Finally, the requirements provide a direct means of assessing work progress, and of determining when the system can be accepted.

REDUCING RISK FURTHER BY USING REQUIREMENTS FOR SELECTION

Agencies often believe that Federally funded projects require a competitive-bid selection process. This is the case only for infrastructure construction, and does not apply to the acquisition of software systems. Software systems, like engineering services, can be acquired using a technical selection process based on a proposal. This process, when applied to Federal acquisitions, is called the Best Value approach, because the selection of the most technically competent propose provides the best value even if they do not have the lowest price. In most States, this process is exactly the same as an engineering services acquisition, where cost is negotiated after making a technical selection. This process is shown in Figure 7, below.

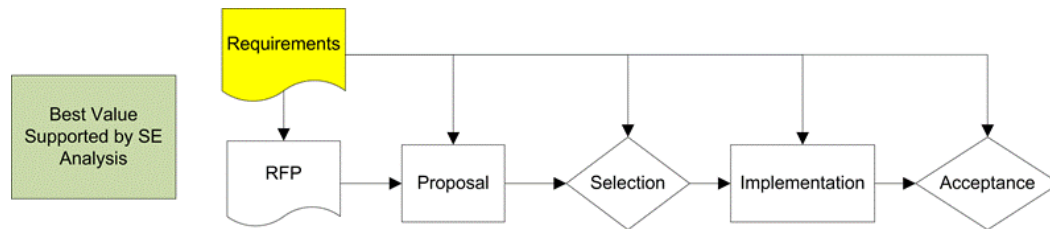


Figure 7. RFP-based technical selection acquisition process.

In this process, the documented requirements are included in the request for proposals (RFP). The instructions to the proposers request that they provide a detailed explanation of how their proposed approach fulfills each contract. The RFP should include the Concept of Operations, the Requirements, and the Verification Plan. The proposal will then be the proposer's written verification of their proposed approach.

The agency can then select the system that most closely fulfills their most important requirements. Even when none of the proposers fulfill all the requirements, agencies are able to make a reasoned and informed selection based on their needs.

The benefit this process offers over the previous process is that agencies can verify requirements fulfillment as the basis for selection, rather than after selection. This minimizes the risk of choosing the wrong provider.

SOLE-SOURCE ACQUISITIONS

According to Title 23 of the Code of Federal Regulations, Section 635, paragraph 411 (23 CFR 635.411), federally funded projects must be competitively acquired. However, there are exceptions, which include:

1. The State DOT certifies that there is no competing product that meets the specification. In a requirements-led process, this can be demonstrated by providing a requirements analysis that shows that only one product fulfills all the requirements.
2. The State DOT certifies that the product is necessary for synchronization with existing installations. This is usually not appropriate for adaptive signal control systems that are the first such being acquired by an agency. However, there are cases where it does apply. Justification for synchronization will be easier if the system to which the new system must be compatible was competitively acquired using a requirements-led process.
3. The FHWA finds, on being presented with sufficient justification that acquiring the technology is in the public interest even though there are other products or systems that also fulfill the requirements. These are known as public interest findings, and are in the public record, and thus must be carefully justified and evaluated.
4. The acquisition is made for experimental purposes, on a small scale. The scale should be small enough so that if the experiment fails, it can be discarded without unreasonable loss. The agency should also provide an experimental plan identifying the gap in knowledge that the acquisition would fill, the way in which the acquisition will fill it, and the way in which the evaluation will be made to determine the results of the experiment. Generally, such experimental projects are used to help an agency understand what they will do with a new technology, to provide the necessary education to support a realistic concept of operations. Experiments should not be made to verify products (i.e., to determine that they fulfill requirements). That sort of experimentation should be done using a pilot project, as discussed in the next section.

Systems installed on an experimental basis should not be expanded to a full implementation using synchronization to justify a sole-source acquisition. Doing so circumvents the meaning of the regulation and may not withstand an audit. At some point, either technical or price competition will be required without a public interest finding. Only a public interest finding can authorize sole-source acquisitions when more than one available product fulfills the requirements.

SERVICES AND INFRASTRUCTURE

The RFP-based approach only works for software and services, and can only include hardware that is incidental to those acquisitions. For example, the computers on which the software runs will usually be considered incidental. However, physical infrastructure, including, for example, communications conduit and cable, pull boxes, traffic controller foundations and cabinet installations, and so on, must be competitively bid. Many ITS implementations include software, integration services, and infrastructure construction. For these projects, the best approach is to separate the software and services from the infrastructure construction, and contract them separately, using separate processes. The software and services can follow the RFP-based approach and the construction can be contracted by low bid.

Figure 8 shows a complex project where systems services and infrastructure construction are divided into separate tracks. The project is further complicated by having a first pilot phase,

which allows the agency to confirm that they fully understand their needs and requirements, and have documented them completely and correctly.

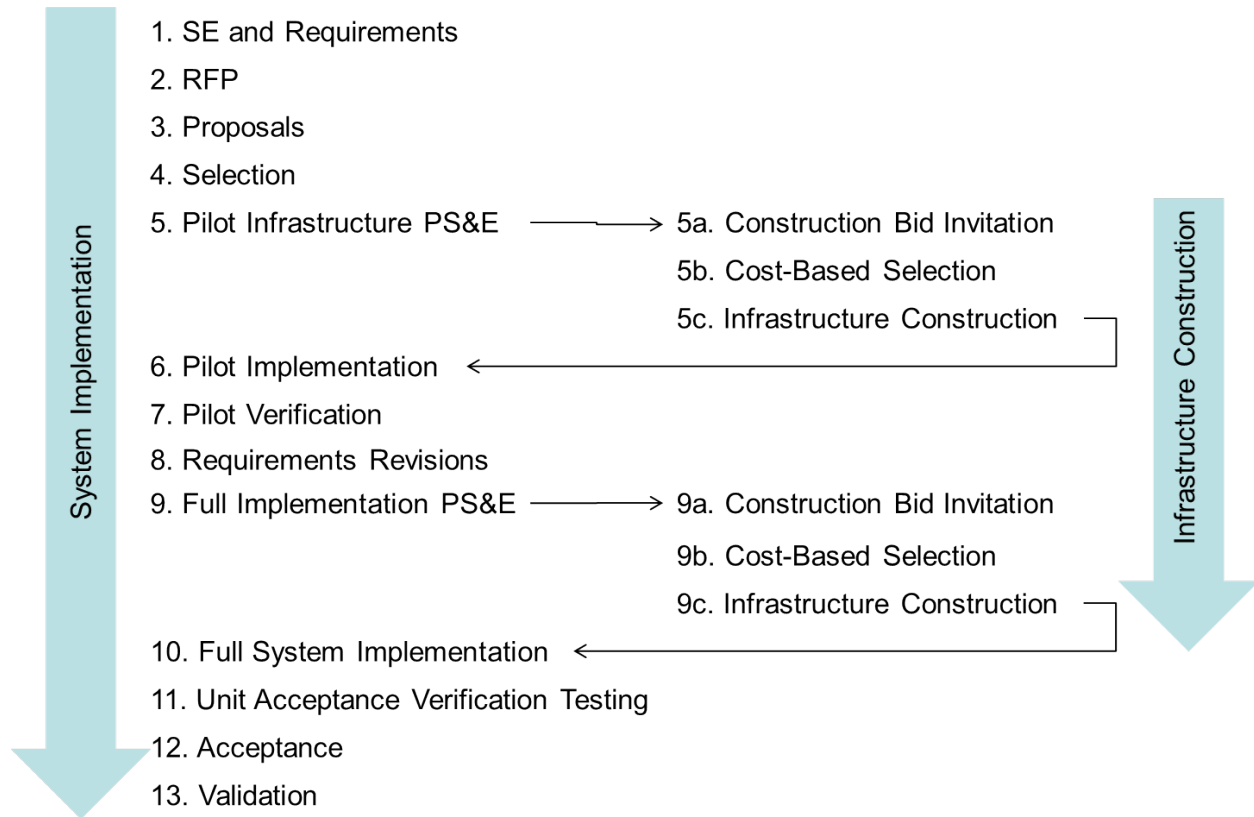


Figure 8. Complex project with both system services and infrastructure, and both pilot and full implementation phases.

In this process, the concept of operations and requirements documents are completed first, and then used as the basis for a request for proposals. The agency evaluates proposals and selects a system provider based on verification of the proposed approach against the requirements. The system provider then assists the agency in developing the design and specifications for the required physical infrastructure, which is then acquired using a conventional cost-based selection process.

The agency will verify the pilot phase of construction and system services against the requirements. In so doing, the agency will discover any deficiencies in the initial concept of operations and requirements documents, and will correct those documents as the basis for implementing the full system. The infrastructure component of the full system is then awarded to a contractor based on bid price. After implementation, the agency will verify final system against requirements, and once the implementation fulfills all requirements, the agency can accept it.

System providers usually have experience with acquisitions that separate services from infrastructure construction, and will build the cost of waiting for the completion of infrastructure construction into their negotiated price. The process should be fully identified in the initial RFP.

APPENDIX A: CONCEPT OF OPERATIONS TABLE OF SAMPLE STATEMENTS

ConOps Reference Number	ConOps Sample Statements
1	Chapter 1: Scope
1.1	Document Purpose and Scope
1.1-1	The scope of this document covers the consideration of a DMS System for use within [describe the agency and/or geographic area covered by this consideration].
1.1-2	This document describes and provides a rationale for the expected operations of the proposed DMS System.
1.1-3	It documents the outcome of stakeholder discussions and consensus building that has been undertaken to ensure that the system that is implemented is operationally feasible and has the support of stakeholders.
1.1-4	The intended audience of this document includes: system operators, remote system operators, administrators, decision-makers, elected officials, other nontechnical readers and other stakeholders who will share the operation of the system or be directly affected by it.
1.2	Project Purpose and Scope
1.2-1	A DMS System provides transportation system managers with a tool to convey information to the traveling public.
1.2-2	The purpose of having a DMS System is to provide the traveling public with actionable information affecting the transportation network. The information can be advisory in nature such as road closures, traffic congestion, estimated travel times and weather watches/warnings/alerts. The information can also be regulatory in nature such as speed limits, lane controls, amber alert, mandatory detour information, hurricane evacuation and High Occupancy Vehicle (HOV) lane access requirements.

ConOps Reference Number	ConOps Sample Statements
1.2-3	This project will allow [specify agency name] to convey information affecting the transportation network [summarize briefly the types of sign content expected].
1.2-4	Other agencies [specify which agencies] will be able to access the DMS System to view messages on the signs.
1.2-5	Other agencies [specify which agencies] will be able to access the DMS System to place messages on the signs.
1.2-6	The DMS System will be integrated with [name other systems, such as a traffic management software system].
1.3	Procurement
1.3-1	The DMS System will be procured using [Edit this or choose alternative statement].
1.3-1.1	a combination of best value procurement for software and system integration services, and low-bid procurement for equipment and construction services.
1.3-1.2	a best value procurement process based on responses to a request for proposals.
1.3-1.3	a low-bid process based on detailed plans and technical specifications.
1.3-2	A request for qualifications (RFQ) will be issued to all potential vendors. Responses will be used to develop a short list of suitable systems and a request for proposals (RFP) will be issued to those vendors. The selected system will be the one that provides the best value, subject to financial and schedule constraints.
1.3-3	Field equipment (parts and labor) will be procured using a low-bid process based on detailed plans and technical specifications.
1.3-4	A detailed procurement plan will be prepared after the system requirements have been determined.

ConOps Reference Number	ConOps Sample Statements
2	Chapter 2: Referenced Documents
2-1	The following documents have been used in the preparation of this Concept of Operations and stakeholder discussions. Some of these documents provide policy guidance for DMS System operation in this area, some are standards with which the system must comply, while others report the conclusions of discussions, workshops and other research used to define the needs of the project and subsequently identify project requirements.
2-1.1	<p>References Specific to the DMS System Locations</p> <ul style="list-style-type: none"> * Business Planning / Strategic Planning Documents for relevant agencies * Concept of Operations for related agency/facility-specific systems * Requirements of related systems * Studies identifying operational needs * Regional ITS Architecture documents * Planning studies and Master Plans * Transportation Improvement Programs (TIP) * Long Range Transportation Plans

ConOps Reference Number	ConOps Sample Statements
2-1.2	<p>Systems Engineering</p> <ul style="list-style-type: none"> * “Systems Engineering Guidebook for ITS”, California Department of Transportation, Division of Research & Innovation, Version 3.0, <http://www.fhwa.dot.gov/cadiv/segb/> * "Systems Engineering for Intelligent Transportation Systems, An Introduction for Transportation Professionals", http://ops.fhwa.dot.gov/publications/seitsguide/index.htm * “Developing Functional Requirements for ITS Projects”, Mitretek Systems, April 2002 * "Developing and Using a Concept of Operations in Transportation Management System, FHWA TMC Pooled-Fund Study (http://tmcdfs.ops.fhwa.dot.gov/cfprojects/new_detail.cfm?id=38&new=0)
2-1.3	DMS Systems Insert any DMS Systems used as a reference here.
2-1.4	<p>ITS, Operations, Architecture, Other</p> <ul style="list-style-type: none"> * 23 CFR parts 655 and 940, Intelligent Transportation System Architecture and Standards * Regional ITS Architecture Guidance Document; “Developing, Using, and Maintaining an ITS Architecture for your Region; National ITS Architecture Team; October, 2001
2-1.5	<p>NTCIP</p> <ul style="list-style-type: none"> * NTCIP 1203 – NTCIP Objects for Dynamic Message Signs (Version used for reference with these model documents is v03A-SE.06) * List other applicable NTCIP standards

ConOps Reference Number	ConOps Sample Statements
2-1.6	<p>NEMA</p> <ul style="list-style-type: none"> * NEMA TS 4-2016
2-1.7	<p>Procurement</p> <ul style="list-style-type: none"> * NCHRP 560: <http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_560.pdf> * Special Experimental Project 14 (SEP 14): <http://www.fhwa.dot.gov/programadmin/contracts/sep_a.cfm> * The Road to Successful ITS Software Acquisition: <http://www.fhwa.dot.gov/publications/research/operations/its/98036/rdsuccessvol2.pdf>
3	Chapter 3: User-Oriented Operational Description
3.1	The Existing Situation and Limitations of the Existing System
3.1-1	[Explain how the lack of or inadequacy of DMS is preventing achieving transportation management operational objectives. Describe the problem to be solved by deploying DMS technologies.]
3.2	Vision, Goals, and Objectives for the Proposed System
3.2-1	The agencies vision, goals and objectives for the proposed system are: [extract a summary from relevant planning documents. If planning documents do not provide vision, goals and objectives for the role of DMS in transportation management, summarize that role here].
3.3	Strategies to be Applied by the Improved System

ConOps Reference Number	ConOps Sample Statements
3.3-1	A set of use cases describe the strategies applied for a new or improved DMS System. The use cases defined in chapter three provide the framework for the user needs defined in chapter four of this document.
3.3.1	General Actors
3.3.1-1	The general actors listed below represent the various roles and systems that interact with the DMS System. Each actor represents a role, a user can have multiple roles and there can be multiple for the same type of actor. For example, a DMS System Maintainer and a DMS System User could be the same person or they could be different people.
3.3.1.1	DMS System Owner
3.3.1.1-1	The agency or organization that owns the system and sets policy for its use is represented by the DMS System Owner actor.
3.3.1.2	DMS System Manager
3.3.1.2-1	This actor represents the role of an operator of the DMS system. The DMS System Manager is expected to have full control of the system. The DMS System Manager assigns DMS System Users and DMS System Maintainers their system permissions and capabilities.
3.3.1.3	DMS System User
3.3.1.3-1	DMS System Users are granted access to the system for various duties, including viewing, controlling, and configuring the system, as configured by the DMS System Manager. Users may be local or remote, but have access to the system controlling the camera in question. A DMS System User also includes external systems such as an ATMS (Advanced Traffic Management System) whose users aren't identified as users of the DMS System. It is left up to the ATMS for example to control the access of the ATMS users.

ConOps Reference Number	ConOps Sample Statements
3.3.1.4	DMS System Maintainer
3.3.1.4-1	This actor represents the role of a maintainer of the DMS System responsible for diagnosing and testing the DMS System.
3.3.1.5	DMS System Designer
3.3.1.5-1	The DMS System Designer actor represents the role of the designer of the DMS System taking into account overall system requirements and constraints.
3.3.1.6	Traveling Public
3.3.1.6-1	This actor represents the role of the traveling public viewing the sign face of the DMS Field Equipment including any DMS Field Equipment External Devices such as beacons.
3.3.2	Use Cases
3.3.2-1	Use cases capture the high-level typical interactions between a user and a computer system. A user case needs to address a discrete goal of the user. Besides the common use cases of system support (e.g., configuration, maintenance, etc.) the DMS Management System use cases give the system operator the ability to convey actionable information to travelers.
3.3.2.1	Configuring the DMS Management System
3.3.2.1-1	The DMS System Manager configures the DMS Management System to control system access by other users (DMS System User and DMS System Maintainer).

ConOps Reference Number	ConOps Sample Statements
3.3.2.1-2	Various users will have different access to the DMS Management System capabilities such as viewing messages on signs, placing messages on signs, running system diagnostics and testing.
3.3.2.1-3	The DMS System Manger will set each user's permissions to access these capabilities.
3.3.2.1-4	The DMS System Manager configures the DMS Management System to arbitrate competing user requests for DMS Management System access such as particular DMS.
3.3.2.1-5	The DMS System Owner specifies the number of users to be accommodated by the DMS Management System at any one time based on DMS system design.
3.3.2.1-6	The DMS System User determines the DMS Field Equipment characteristics and capabilities.
3.3.2.1-7	The DMS System User manages the DMS Field Equipment fonts, graphics, and brightness level thresholds.
3.3.2.2	Monitoring DMS Field Equipment
3.3.2.2-1	For general DMS Field Equipment monitoring, the DMS System User interacts with the DMS Management System to determine what message is currently displayed on the sign face.
3.3.2.2-2	The DMS System User uses the DMS Management System to relinquish monitoring of a DMS Field Equipment.
3.3.2.3	Controlling DMS Field Equipment
3.3.2.3-1	The DMS System User uses the DMS Management System to place information on or remove information from the sign face to convey proper information to travelers.
3.3.2.3-2	The DMS System User uses the DMS Management System to define and store sign messages.

ConOps Reference Number	ConOps Sample Statements
3.3.2.3-3	The DMS System User uses the DMS Management System to remove any messages displayed on a sign.
3.3.2.3-4	The DMS System User uses the DMS Management System to prioritize particular sign messages.
3.3.2.3-5	The DMS System User uses the DMS Management System to schedule the display of particular stored sign messages.
3.3.2.3-6	The DMS System User uses the DMS Management System to activate and display a previously defined message to be displayed on the sign face.
3.3.2.3.1	The priority of the sign message to be displayed will take into account the priority of the currently displayed sign message.
3.3.2.3.2	The DMS System User will specify the desired duration of the message to be displayed.
3.3.2.3.3	The DMS System User uses the DMS Management System to specify which message should be displayed when certain non-scheduled events occur, such as loss of communication or loss of power.
3.3.2.3.4	The DMS System User uses the DMS Management System to control the sign brightness either directly or through an automated algorithm.
3.3.2.4	Controlling External Devices
3.3.2.4-1	The DMS System User uses the DMS Management System's auxiliary ports on the sign controller to control external devices, such as High Occupancy Vehicle (HOV) Lane Gates.
3.3.2.5	Logging DMS Management System Data

ConOps Reference Number	ConOps Sample Statements
3.3.2.5-1	The DMS System Maintainer specifies what DMS Management System events are logged.
3.3.2.5-2	The DMS System Maintainer specifies the size and timeframe of the DMS Management System's log.
3.3.2.5-3	The DMS System Maintainer accesses the log of the DMS Management System to review it.
3.3.2.5-4	The DMS System Maintainer accesses the log of the DMS Management System to review diagnostic and alarms.
3.3.2.6	Maintaining the DMS Management System
3.3.2.6-1	The DMS System Maintainer maintains the DMS Management System by performing and testing all DMS capabilities both locally and remotely.
3.3.2.6-2	The DMS System Maintainer maintains the DMS Management System by performing remote updates of the DMS firmware and DMS system software.
3.3.2.6-3	The DMS System Maintainer can remotely reset the sign controller to attempt to recover from a software failure.
3.3.2.6-4	The DMS System Maintainer can enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.
3.3.2.7	Determining DMS Field Equipment Siting
3.3.2.7-1	The DMS System Designer will specify the DMS Field Equipment siting characteristics taking into account best placement for traveler decisions based on actionable information and system maintenance requirements.
3.3.2.8	Interfaces

ConOps Reference Number	ConOps Sample Statements
3.3.2.8-1	The DMS System User interfaces with DMS Field Equipment from different manufacturers within the DMS Management System.
3.3.2.8-2	The DMS System Maintainer replaces DMS Field Equipment from different manufacturers within the DMS Management System.
3.3.2.8-3	The DMS System Designer specifies different DMS Field Equipment interface standards within the DMS Management System.
3.3.2.8-4	The DMS System Designer specifies the existing DMS interfaces in order to integrate new DMS Field Equipment into an existing DMS Management System.
3.3.2.8-5	The DMS System Designer specifies the existing DMS Field Equipment interfaces in order to integrate a new DMS Management System with existing DMS Field Equipment.
3.3.2.9	Failure Management
3.3.2.9-1	The DMS System User detects a suspected system failure, runs the system diagnostics and refers the issue to the DMS System Maintainer.
3.3.2.9-2	The DMS System User detects a suspected communications failure, runs the communication diagnostics and refers the issue to the DMS System Maintainer.
3.4	Alternative Strategies Considered

ConOps Reference Number	ConOps Sample Statements
3.4-1	<p>Agencies use DMS to provide facility-specific information to travelers in real time, to achieve a spatial diversion of demand away from a temporal bottleneck, or to provide the traveler with information needed in response to specific real-time scenarios that require textual presentation (such as for AMBER alerts) that do not require the use of a hand-held device while driving. Other traveler information technologies may also emerge in the future that will attain the objective of providing facility-specific information in real time. Highway advisory radio attains the objective of providing more detailed information beyond what can be represented on DMS, but usually requires a DMS to trigger a traveler to tune to the HAR frequency. The operational purpose of DMS has been established in the planning documents (if available) referenced in Chapter 2. Operational alternatives have been considered during the planning of this project. Some operational choices for types of signs and overall characteristics are made in this document, based on the needs identified in Chapter 4. These include, for example, the use of permanent versus portable DMS, variable versus fixed or changeable messaging, associated external devices, overall system architecture, and so on. Technological alternatives for dynamic message signs will be considered during the design stage of this project, in response to the Requirements.</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4	Chapter 4: Operational Needs	
4-1	<p>Note: There is a wide variety of DMS Field Equipment available in the marketplace. The user needs listed below contain features that are not applicable to all DMS Field Equipment. The DMS Management System may need to accommodate one or more of these DMS Field Equipment variations. [The user of these Model System Engineering Documents must categorize the DMS Field Equipment according to several key characteristics prior to determining which user needs, and by extension requirements, are mandatory for a particular deployment. The DMS Field Equipment characteristics include DMS Field Equipment Type, Portable or Fixed DMS Field Equipment, DMS Field Equipment Technology, DMS Field Equipment Display Matrix Configuration and DMS Field Equipment External Devices.]</p>	
4.1	Control Access to DMS Management System (Choose the user needs in this group if you chose the Configuring the DMS Management System use case in Chapter Three)	3.1.1 Access Control
4.1.1	The DMS System Manager needs access to the DMS Management System.	3.1.1.1 The DMS Management System shall enforce access control of all users.
4.1.1.1	The DMS System Manager needs access for DMS Management System configuration.	3.1.1.1 The DMS Management System shall enforce access control of all users.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.1.1.1.1	The DMS System Manager needs to configure DMS System User access.	3.1.1.2 The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Users.
4.1.1.1.2	The DMS System Manager needs to configure DMS System Maintainer access.	3.1.1.3 The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Maintainers.
4.1.1.2	The DMS System Manager needs access to the DMS Management System to select DMS Field Equipment.	3.1.1.4 The DMS Management System shall allow the DMS System Manager to select the DMS Field Equipment.
4.1.1.3	The DMS System Manager needs access to the DMS Management System to control DMS Field Equipment.	3.1.1.5 The DMS Management System shall allow the DMS System Manager to control the DMS Field Equipment.
4.1.1.4	The DMS System Manager needs access to the DMS Management System to control external devices.	3.1.1.6 The DMS Management System shall allow the DMS System Manager to control external devices attached to the DMS Controller.
4.1.1.5	The DMS System Manager needs access to the DMS Management System logged data.	3.1.1.7 The DMS Management System shall allow the DMS System Manager to access its logged data.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.1.2	The DMS System User needs access to the DMS Management System as configured by the DMS System Manager.	3.1.1.8 The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System User.
4.1.2.1	The DMS System User needs access to the DMS Management System to select DMS Field Equipment.	3.1.1.9 The DMS Management System shall allow the DMS System User to select DMS Field Equipment.
4.1.2.2	The DMS System User needs access to the DMS Management System to control DMS Field Equipment.	3.1.1.10 The DMS Management System shall allow the DMS System User to control DMS Field Equipment.
4.1.2.3	The DMS System User needs access to the DMS Management System to control external devices.	3.1.1.11 The DMS Management System shall allow the DMS System User to control external devices. 3.1.1.11.1 The DMS Management System shall control external devices such as flashers or beacons when directed by the DMS System User. Note: Agency policy may dictate when flashers and/or beacons may be used (e.g., lane blockage only). 3.1.1.11.2 The DMS Management System shall allow the DMS System User to specify automatically including flashers or beacons based on message type.
4.1.3	The DMS System Maintainer needs access to the DMS Management System as configured by the DMS System Manager.	3.1.1.12 The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System Maintainer.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.1.3.1	The DMS System Maintainer needs access to the DMS Management System to select DMS Field Equipment.	3.1.1.13 The DMS Management System shall allow the DMS System Maintainer to select DMS Field Equipment.
4.1.3.2	The DMS System Maintainer needs access to the DMS Management System to control DMS Field Equipment.	3.1.1.14 The DMS Management System shall allow the DMS System Maintainer to control DMS Field Equipment.
4.1.3.3	The DMS System Maintainer needs access to the DMS Management System to control external devices.	3.1.1.15 The DMS Management System shall allow the DMS System Maintainer to control external devices.
4.1.3.4	The DMS System Maintainer needs access to the DMS Management System to run system diagnostics and testing.	3.1.1.16 The DMS Management System shall allow the DMS System Maintainer to run system diagnostics and testing.
4.1.3.5	The DMS System Maintainer needs access to the DMS Management System to repair it.	3.1.1.17 The DMS Management System shall provide access to the DMS System Maintainer to repair it.
4.1.3.6	The DMS System Manager needs to organize DMS System Users into groups.	3.1.1.18 The DMS Management System shall organize DMS System Users into groups. 3.1.1.18.1 Membership in the group shall be defined by the DMS System Manager.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.1.3.6.1	The DMS System Manager needs to specify named groups of DMS System Users and place those users in the group.	3.1.1.18.1.1 The DMS Management System shall allow the DMS System Manager to specify named user groups and place those users in the group.
4.1.3.6.2	The DMS System Manager needs to specify which signs will be shared by individual or groups of users.	3.1.1.18.1.2 The DMS Management System shall allow the DMS System Manager to specify which signs will be shared with individual users or user groups.
4.1.3.6.3	The DMS System Manager needs to specify which users or groups of users can access the archived logged data.	3.1.1.18.1.3 The DMS Management System shall allow the DMS System Manager to specify which individual users or user groups can access the archived logged data.
4.1.3.7	The DMS System Manager needs to protect the integrity of archived and logged data.	3.1.1.18.2 The DMS Management System shall assign which signs are shared by individual users or groups of users.
4.1.3.8	The DMS System Manager needs to specify which users or groups of users can access the archived logged data.	3.1.1.18.3 Access to archived data shall be assigned by the DMS System Manager to users or groups.
4.1.3.9	The DMS System Manager needs to protect the integrity of archived and logged data.	3.1.1.19 The DMS Management System shall not allow archived data to be altered.
4.2	Configure DMS Management System (Choose the user needs in this group if you chose the Configuring the DMS Management System use case in Chapter Three)	3.1.2 Configure DMS Management System

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.1	The DMS System Manager needs to configure the DMS Management System data logging parameters.	3.1.2.1 The DMS Management System shall allow the DMS System Manager to configure the DMS Management System data logging parameters.
4.2.2	The DMS System Manager needs to accommodate [specify] users with access to the DMS Management System. [This may be further defined by type of user and their bandwidth consumption.]	3.1.2.2 The DMS System Management System shall accommodate [specify number] users at different physically accessed terminals as configured by the DMS System Manager. 3.1.2.3 The DMS System Management System shall accommodate [specify types of] users as configured by the DMS System Manager.
4.2.3	The DMS System Manager needs to configure the system to arbitrate competing requests for access, including providing automatic timeouts, transfer of access, and other DMS Field Equipment user access issues. [Describe the desired operation, and choose the requirements relevant to the desired operation. Options: DMS Field Equipment ownership, last user control, first-come-first-served, etc.]	3.1.2.4 The DMS System Management System shall arbitrate competing requests for access, including providing automatic timeouts, transfer of access, and other DMS Field Equipment user access issues as configured by the DMS System Manager. [Describe the desired operation, and choose the requirements relevant to the desired operation. Options: DMS Field Equipment ownership, last user control, first-come-first-served, etc.]
4.2.4	Managing DMS Field Equipment Configuration	

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.4.1	<p>The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.</p>	<p>3.1.2.6.1 The DMS Management System shall determine the identity of the DMS Field Equipment based on a DMS System User request.</p> <p>3.1.2.6.2 The DMS Management System shall determine the sign type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign) based on a DMS System User request.</p> <p>3.1.2.6.3 The DMS Management System shall determine the sign technology (mostly LED) based on a DMS System User request.</p> <p>3.1.2.6.4 The DMS Management System shall determine the manufacturer based on a DMS System User request.</p> <p>3.1.2.6.5 The DMS Management System shall determine the model and version number for both hardware and software elements based on a DMS System User request.</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.4.2	The DMS System User needs to determine the sign display characteristics of the DMS Field Equipment in order to determine if a given message can be displayed on the sign.	<p>3.1.2.6.6 The DMS Management System shall tell the DMS System User if an entered message can be displayed on a given sign.</p> <p>3.1.2.6.7 The DMS Management System shall limit the sign types available to the DMS System User based on a given message and different sign display capabilities.</p> <p>3.1.2.6.8 The DMS Management System shall manage variations in a given message to be displayed on signs with different capabilities.</p>
4.2.4.3	The DMS System User needs to define and edit the appearance of fonts used to display messages on DMS Field Equipment throughout the DMS Management System.	<p>3.1.2.6.9 The DMS Management System shall allow the DMS System User to define and edit the appearance of fonts (i.e., type, color and size) used to display messages on DMS Field Equipment throughout the DMS Management System.</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.4.4	<p>The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.</p>	<p>3.1.2.6.10 The DMS Management System shall allow the DMS System User to define the appearance of graphics used to for display on DMS Field Equipment for later use.</p> <p>3.1.2.6.11 The DMS Management System shall allow the DMS System User to edit vendor supplied graphics.</p> <p>3.1.2.6.12 The DMS Management System shall allow import of graphics generated independently by the DMS System User.</p> <p>3.1.2.6.13 The DMS Management System shall allow the DMS System User to manage existing graphics.</p> <p>3.1.2.6.14 The DMS Management System shall allow the DMS System User to determine the graphics storage capabilities throughout the DMS Management System.</p> <p>3.1.2.6.15 The DMS Management System shall assist the DMS System User in determining which graphics are compatible with each sign type.</p>
4.2.4.5	<p>The DMS System User needs to configure when the DMS Field Equipment may automatically switch between brightness levels based on changing lighting conditions.</p>	<p>3.1.2.6.16 The DMS Management System shall allow the DMS System User to configure when the DMS Field Equipment may automatically switch between brightness levels based on changing lighting conditions.</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.4.6	The DMS System User needs to configure the speed limit applicable to the location of the DMS Field Equipment.	3.1.2.6.17 The DMS Management System shall allow the DMS System User to configure the speed limit applicable to the location of the DMS Field Equipment. Note: this requirement is typically for portable DMS Field Equipment that act a speed warning signs.
4.2.4.7	The DMS System User needs to configure the threshold when the fuel in a generator powering a DMS Field Equipment is considered low. This is typically only for Portable DMS Field Equipment that use generators.	3.1.2.6.18 The DMS Management System shall allow the DMS System User to configure the threshold when the fuel in a generator powering a DMS Field Equipment is considered low. Note: this requirement is typically only for portable DMS Field Equipment that use generators.
4.2.5	Managing DMS Messages	
4.2.5.1	The DMS System Manager needs to configure message priority for each DMS.	3.1.2.5.1 The DMS Management System shall allow the DMS System Manager to configure message priority for each DMS. 3.1.2.5.3 The DMS Field Equipment shall display the message with the highest priority or the message with the latest start time if at the same priority as the message being displayed.
4.2.5.2	The DMS System User needs to create schedules assigning messages to particular DMS according to a start time, duration and message priority.	3.1.2.5.2 The DMS Management System shall allow the DMS System User to create schedules assigning messages to particular DMS according to a start time, duration and message priority.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.2.5.3	The DMS System User needs to be able to override the currently displayed message on a DMS.	3.1.2.5.4 The DMS Management System shall give the highest priority to messages being manually engaged by the DMS System User.
4.3	Monitoring DMS (Choose the user needs in this group if you chose the Monitoring DMS Field Equipment use case in Chapter Three)	3.1.3 Monitoring DMS Field Equipment
4.3.1	The DMS System User needs to select which DMS Field Equipment to view the current message displayed on the sign face.	3.1.3.1 The DMS Management System shall allow the DMS System User to select which DMS Field Equipment to view the current message displayed on the sign face.
4.3.2	The DMS System Manager needs to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site).	3.1.3.2 The DMS Management System shall allow the DMS System Manager to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site). 3.1.3.3 The DMS Management System performance monitoring shall conform, at a minimum, to NEMA TS 4-2016.
4.4	Controlling DMS (Choose the user needs in this group if you chose the Controlling DMS Field Equipment use case in Chapter Three)	3.1.4 Controlling DMS Field Equipment
4.4.1	The DMS System User needs to control the DMS Field Equipment from both remote and local locations.	3.1.4.1 The DMS Management System shall allow the DMS System User control of the DMS Field Equipment from both remote and local locations.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.4.2	DMS System Users need to be prevented from interfering with one another for simultaneous control of a DMS Field Equipment.	3.1.4.2 DMS Management System shall prevent DMS System Users from interfering with one another for simultaneous control of a DMS Field Equipment.
4.4.3	Controlling the DMS Field Equipment Sign Face	3.1.4.3 Controlling the DMS Field Equipment Sign Face
4.4.3.1	The DMS System User needs to be able to activate a stored message to be displayed on the sign face.	3.1.4.3.1 The DMS Management System User shall activate a stored message to be displayed on the sign face upon request of a DMS System User.
4.4.3.2	The DMS System User needs to specify the duration for the display of the activated message including its relative priority in order to possibly override the currently displayed message.	3.1.4.3.2 The DMS Management System shall allow the DMS System User to specify the duration for the display of the activated message including its relative priority in order to possibly override the currently displayed message.
4.4.3.3	The DMS System User needs to prioritize messages.	3.1.4.3.3 The DMS Management System shall allow the DMS System User to prioritize messages.
4.4.3.4	The DMS System User needs to create a message and modify its format and content.	3.1.4.3.4 The DMS Management System shall allow the DMS System User to create a message and modify its format and content.
4.4.3.4.1	The DMS System User needs to uniquely identify a message.	3.1.4.3.4.1 The DMS Management System shall allow the DMS System User to uniquely identify a message.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.4.3.4.2	The DMS System User needs to ensure that a message is complete.	3.1.4.3.4.2 The DMS Management System shall assist the DMS System User in ensuring that a message is complete by viewing it in WYSIWYG (What You See Is What You Get) format.
4.4.3.4.3	The DMS System User needs to develop an approved word list including standardized abbreviations.	3.1.4.3.4.3 The DMS Management System shall allow the DMS System User to develop an approved word list including standardized abbreviations.
4.4.3.4.4	The DMS System User needs to use the approved word list in developing a message.	3.1.4.3.4.4 The DMS Management System shall recommend words and abbreviations from the approved word list to the DMS System User.
4.4.3.4.5	The DMS System User needs to ensure that a message does not have offensive language.	3.1.4.3.4.5 The DMS Management System shall assist the DMS System User in ensuring that the message does not contain offensive language.
4.4.3.4.6	The DMS System User needs to define the exact contents of the message to be displayed on the sign face.	3.1.4.3.4.6 The DMS Management System shall assist the DMS System User in defining the exact contents of the message to be displayed on the sign face.
4.4.3.4.7	The DMS System User needs to define if the display of a message activates beacons. [Specify if supported]	3.1.4.3.4.7 The DMS Management System shall provide the capability for the DMS System User to define if the display of a message activates beacons. [Specify if supported]

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.4.3.5	The DMS System User needs to store a newly created or modified message in a library of messages.	3.1.4.3.5 The DMS Management System shall store a newly created or modified message by the DMS System User in a library of messages.
4.4.3.6	The DMS System User needs to blank or remove any messages displayed on a sign.	3.1.4.3.6 The DMS Management System shall blank or remove any messages displayed on a sign upon request by the DMS System User.
4.4.3.7	The DMS System User needs to schedule when messages are displayed on DMS Field Equipment. These are the stored messages that are displayed unless overridden by a manually activated message.	3.1.4.3.7 The DMS Management System shall allow the DMS System User to schedule when messages are displayed on DMS Field Equipment. These are the stored messages that are displayed unless overridden by a manually activated message.
4.4.3.7.1	The DMS System User needs to set a series of times when a stored message, including a blank message, will be activated.	3.1.4.3.7.1 The DMS Management System shall allow the DMS System User to set a series of times when a stored message, including a blank message, will be activated.
4.4.3.8	The DMS System User needs to set which message will be displayed when certain non-scheduled events occur such as loss of communications or power.	3.1.4.3.8 The DMS Management System shall allow the DMS System User to set which message will be displayed when certain non-scheduled events occur such as loss of communications or power.
4.4.3.9	The DMS System User needs to directly control the sign brightness.	3.1.4.3.9 The DMS Management System shall allow the DMS System User to directly control the sign brightness.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.4.3.10	The DMS System User needs to configure automated algorithms that can adjust brightness levels based on the ambient light levels.	3.1.4.3.10 The DMS Management System shall allow the DMS System User to configure automated algorithms that can adjust brightness levels based on the ambient light levels.
4.5	Controlling External Devices	3.1.5 Controlling External Devices
4.5.1	The DMS System User needs to control external devices through the auxiliary ports of the sign controller.	3.1.5.1 The DMS Management System shall allow the DMS System User to control external devices through the auxiliary ports of the sign controller.
4.5.1.1	The DMS System User needs to control High Occupancy Vehicle (HOV) Lane Gates attached to the DMS Field Equipment.	3.1.5.1.1 The DMS Management System shall allow the DMS System User to control High Occupancy Vehicle (HOV) Lane Gates attached to the DMS Field Equipment.
4.5.1.2	The DMS System User needs to control Beacons attached to the DMS Field Equipment.	3.1.5.1.2 The DMS Management System shall allow the DMS System User to control Beacons attached to the DMS Field Equipment.
4.5.1.3	The DMS System User needs to configure and monitor any speed detectors attached to the DMS Field Equipment.	3.1.5.1.3 The DMS Management System shall allow the DMS System User to monitor any speed detectors attached to the DMS Field Equipment. 3.1.5.1.4 The DMS Field Equipment shall detect speed and display speed threshold limits with detected speed.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.5.1.4	The DMS System User needs to configure, monitor and control environmental sensors attached to the DMS Field Equipment.	3.1.5.1.5 The DMS Management System shall allow the DMS System User to monitor and control environmental sensors attached to the DMS Field Equipment. 3.1.5.1.6 The DMS Field Equipment shall detect environmental conditions and display environmental conditions.
4.5.1.5	The DMS System User needs to control other external devices. [Specify other types of external devices]]	3.1.5.1.7 The DMS Management System shall allow the DMS System User to control other external devices. [Specify other types of external devices]
4.6	DMS Management System Logging (Choose the user needs in this group if you chose the Logging DMS Management System Data use case in Chapter Three)	3.1.6 DMS Management System Logging
4.6.1	The DMS System Maintainer needs to access and review the DMS Management System log(s).	3.1.6.1 The DMS Management System shall allow the DMS System Maintainer access to the DMS Management System log(s).
4.6.2	The DMS System Maintainer needs to specify what DMS Management System events are logged.	3.1.6.2 The DMS Management System shall allow the DMS System Maintainer to specify what DMS Management System events are logged.
4.6.3	The DMS System Maintainer needs to specify, for each log, the log size and/or duration for the DMS Management System.	3.1.6.3 The DMS Management System shall allow the DMS System Maintainer to specify, for each log, the log size and/or duration for the DMS Management System.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.6.4	The DMS System Maintainer needs to access and review a history (log) of the following diagnostic information [specify] and alarms [specify] for a period of [specify] days.	3.1.6.4 The DMS Management System shall allow the DMS System Maintainer to access and review a history (log) of the following diagnostic information [specify] and alarms [specify] for a period of [specify] days.
4.7	DMS Management System Maintenance (Choose the user needs in this group if you chose the Maintaining the DMS Management System use case in Chapter Three)	3.1.7 DMS Management System Maintenance
4.7.1	The DMS System Maintainer needs to maintain DMS Management System operations.	3.1.7.1 The DMS Management System operations shall be maintainable by the DMS System Maintainer.
4.7.1.1	The DMS System User needs durable equipment. [Add descriptions of what this means]	3.1.7.1.1 The DMS Field Equipment shall be durable to support operations. [Specify description of what this means]
4.7.1.2	The DMS System User needs equipment designed for environmental conditions.	3.1.7.1.2 The DMS Field Equipment shall conform to the environmental conditions specified in NEMA TS 4-2016. [Description needs to include conditions under which the equipment will be operated. Reference NEMA TS 4-2016. Does it need to withstand rain? Inundation? High-pressure hose-down? High wind? High (or low) temperatures? IPC67? IEC 60529? NEMA (Type R, Type X, etc.)? Ground cabinets versus signs.]
4.7.1.3	The DMS System Maintainer needs serviceable field equipment.	3.1.7.1.3 The DMS Field Equipment shall be serviceable. [Specify how to access for maintenance, crane, bucket truck, requirements for maintainer to be protected by elements]

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.1.4	The DMS System Maintainer needs to have access to replacement parts for the life of the system [specified period of time].	3.1.7.1.4 The DMS Field Equipment shall have readily available replacement parts for the life of the system [specified period of time].
4.7.1.5	The DMS System Maintainer needs to remotely test devices via IP protocol.	3.1.7.1.5 The DMS Management System shall allow the DMS System Maintainer to remotely test DMS Field Equipment via IP protocol.
4.7.1.6	The DMS System Maintainer needs diagnostic information that the DMS Field Equipment collects about itself at the direction of the Maintainer.	3.1.7.1.6 The DMS Management System shall provide diagnostic information via NTCIP 1203 protocols that the DMS Field Equipment collects about itself, defined in Section 9 of NEMA TS4-2016 at the direction of the DMS System Maintainer.
4.7.1.7	The DMS System Maintainer needs to enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.	3.1.7.1.7 The DMS Management System shall allow the DMS System Maintainer to enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.1.8	<p>The DMS System Maintainer needs the following failure conditions to trigger alarms visible to the DMS System User. [It is only necessary for the DMS Field Equipment to support information about capabilities actually present in the DMS Field Equipment. For example, a matrix sign does not provide the drum-rotor status items, and a drum sign does not provide the pixel status items.]</p> <ul style="list-style-type: none"> a. Power Sources b. Power Supplies c. Lamps d. Pixels e. Light Level Sensors f. Sign Controller g. Temperature Sensors h. Humidity i. Internal Environmental Systems (Fans and/or Heaters) j. Drum Sign Rotors k. External Device Errors 	<p>3.1.7.1.8</p> <p>The DMS Management System shall allow the DMS System Maintainer to troubleshoot the following failure conditions to trigger alarms visible to the DMS System User. [It is only necessary for the DMS Field Equipment to support information about capabilities actually present in the DMS Field Equipment. For example, a matrix sign does not provide the drum-rotor status items, and a drum sign does not provide the pixel status items.]</p> <ul style="list-style-type: none"> a. Power Sources b. Power Supplies c. Lamps d. Pixels e. Light Level Sensors f. Sign Controller g. Temperature Sensors h. Humidity i. Internal Environmental Systems (Fans and/or Heaters) j. Drum Sign Rotors k. External Device Errors
4.7.1.9	<p>The DMS System Maintainer needs to obtain detailed information about a reported warning or error condition within a subsystem (detailed-level diagnostics).</p>	<p>3.1.7.1.9</p> <p>The DMS Management System shall allow the DMS System Maintainer to obtain detailed information about a reported warning or error condition within a subsystem (detailed-level diagnostics).</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.1.10	The DMS System User needs to monitor errors associated with defining or activating a particular message.	3.1.7.1.10 The DMS Management System shall allow the DMS System User to monitor errors associated with defining or activating a particular message.
4.7.1.11	The DMS System Maintainer needs to monitor the temperature and humidity within the sign housing and control cabinet.	3.1.7.1.11 The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the sign housing. [Reference NEMA TS 4-2016] 3.1.7.1.12 The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the control cabinet. [Reference NEMA TS 4-2016] 3.1.7.1.13 The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the sign housing. [Reference NEMA TS 4-2016] 3.1.7.1.14 The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the control cabinet. [Reference NEMA TS 4-2016]
4.7.1.12	The DMS System Maintainer needs to monitor for any errors related to the attached external devices to the DMS Field Equipment. [Specify external devices.]	3.1.7.1.15 The DMS Management System shall allow the DMS System Maintainer to monitor for any errors related to the attached external devices to the DMS Field Equipment. [Specify external devices.]

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.1.13	The DMS System Maintainer needs to monitor the status (opened, closed) of the doors to the sign housing and control cabinet.	<p>3.1.7.1.16 The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the sign housing.</p> <p>3.1.7.1.17 The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the control cabinet.</p>
4.7.1.14	The DMS System Maintainer needs to monitor whether the DMS Field Equipment controller software is operating properly through the use of watchdog timers.	<p>3.1.7.1.18 The DMS Management System shall allow the DMS System Maintainer to monitor whether the DMS Field Equipment controller software is operating properly through the use of watchdog timers. [Reference NEMA TS 4-2016]</p>
4.7.1.15	The DMS System Maintainer needs to monitor the automatic display of a blank message when diagnostics detect that too many pixels are non-operational or that the light outputs are faulty.	<p>3.1.7.1.19 The DMS Management System shall allow the DMS System Maintainer to monitor the automatic display of a blank message when diagnostics detect that too many pixels are non-operational or that the light outputs are faulty. [Reference NEMA TS 4-2016]</p>
4.7.1.16	The DMS System Maintainer needs to monitor the source of power that is being used to operate the DMS sign face.	<p>3.1.7.1.20 The DMS Management System shall allow the DMS System Maintainer to monitor the source of power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.1.17	The DMS System Maintainer needs to monitor the voltage level of the power that is being used to operate the DMS sign face.	3.1.7.1.21 The DMS Management System shall allow the DMS System Maintainer to monitor the voltage level of the power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]
4.7.1.18	The DMS System Maintainer needs to monitor the level of fuel within the tank of a generator that is being used to operate the DMS Field Equipment.	3.1.7.1.22 The DMS Management System shall allow the DMS System Maintainer to monitor the level of fuel within the tank of a generator that is being used to operate the DMS Field Equipment.
4.7.1.19	The DMS System Maintainer needs to monitor the engine RPM when a generator is being used to operate the DMS Field Equipment.	3.1.7.1.23 The DMS Management System shall allow the DMS System Maintainer to monitor the engine RPM when a generator is being used to operate the DMS Field Equipment.
4.7.1.20	The DMS System Maintainer needs to run a complete diagnostic test and review the results.	3.1.7.1.24 The DMS Management System shall allow the DMS System Maintainer to run complete diagnostics and store the results for review.
4.7.2	The DMS Field Equipment in a DMS Management System need to be uniquely identifiable and locatable.	3.1.7.2 The DMS Field Equipment connected with a DMS Management System shall be uniquely identifiable. 3.1.7.3 The DMS Field Equipment connected with a DMS Management System shall be locatable.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.7.3	The DMS System Maintainer needs to have safe access to DMS Field Equipment locations for maintenance.	3.1.7.4 The DMS Management System shall be designed by the DMS System Designer to provide the DMS System Maintainer with safe access to DMS Field Equipment locations for maintenance.
4.7.4	The DMS System Maintainer needs to update DMS Field Equipment controller software and firmware remotely.	3.1.7.5 The DMS Management System shall provide the DMS System Maintainer with the ability to remotely update DMS Field Equipment controller software and firmware.
4.8	DMS Field Equipment Characteristics (Choose the user needs in this group if you chose the Determining DMS Field Equipment Siting use case in Chapter Three)	3.1.8 DMS Field Equipment Characteristics
4.8.1	The Traveling Public needs to read messages on the sign face in reduced visibility conditions.	3.1.8.1 The DMS Management System shall provide the capability for the Traveling Public to read messages on the sign face in reduced visibility conditions. Note: Reference the NEMA TS 4 viewing cone.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.8.2	<p>The DMS System User needs to store the following information in the DMS Management System:</p> <ul style="list-style-type: none"> * DMS Field Equipment Owner * DMS Field Equipment Unique Identifier * DMS Field Equipment Descriptive Name * DMS Field Equipment Location (physical, part of a corridor) * DMS Field Equipment Type * DMS Field Equipment Technology * DMS Field Equipment Display Matrix Configuration * DMS Field Equipment Fixed versus Portable * [Specify other DMS Field Equipment characteristics] 	<p>3.1.8.2</p> <p>The DMS Management System shall allow the DMS System User to store the following information in the DMS Management System:</p> <ul style="list-style-type: none"> * DMS Field Equipment Owner * DMS Field Equipment Unique Identifier * DMS Field Equipment Text Description [Specify number of characters of text] * DMS Field Equipment Location (physical, part of a corridor) * DMS Field Equipment Type (Blank Out Sign (BOS), Changeable Message Sign (CMS), or Variable Message Sign (VMS) as defined in NTCIP 1203) * DMS Field Equipment Technology (Fiber Optic, Light Emitting Diode (LED), Flip disk or shutter, Lamp Matrix, or Drum) * DMS Field Equipment Display Matrix Configuration (No Matrix (i.e., not a pixel matrix sign), Matrix Sign, Full Matrix, Line Matrix or Character Matrix) * DMS Field Equipment Fixed versus Portable * [Specify other DMS Field Equipment characteristics]
4.9	<p>DMS Field Equipment Siting (Choose the user needs in this group if you chose the Determining DMS Field Equipment Siting use case in Chapter Three)</p>	<p>3.1.9</p> <p>DMS Field Equipment Siting</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.9.1	The DMS System Designer needs to place the DMS Field Equipment at locations that provide travelers with actionable information to support the agency's operational objectives.	<p>3.1.9.1 The DMS Field Equipment shall be placed by the DMS System Designer at locations that provide travelers with actionable information to support the agency's operational objectives.</p> <p>3.1.9.2 The DMS Field Equipment sign placement shall conform, at a minimum, to NEMA TS 4-2016.</p>
4.9.2	The DMS System Designer needs to have DMS Field Equipment siting take into account maintenance needs. [specify]	3.1.9.3 The DMS Field Equipment siting by the DMS System Designer shall take into account maintenance needs. [specify]
4.10	Interfaces (Choose the user needs in this group if you chose the Interfaces use case in Chapter Three)	3.1.10 Interfaces
4.10.1	The DMS System User needs to interface with DMS Field Equipment from different manufacturers within the same system, while satisfying all the user needs. [specify what DMS Field Equipment are being used]	3.1.10.1 The DMS Management System shall interface with DMS Field Equipment from different manufacturers within the same system in accordance with NTCIP 1203v03 or later at a minimum. [specify NTCIP 1203 mandatory requirements and what optional requirements needed, and what DMS Field Equipment are being used]
4.10.2	The DMS System Maintainer needs to replace DMS Field Equipment with DMS Field Equipment from different manufacturers.	3.1.10.2 The DMS Management System shall support the replacement by the DMS System Maintainer of existing DMS Field Equipment with DMS Field Equipment from different manufacturers. [specify existing system interface in accordance with NTCIP 1203].

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.10.3	The DMS System Designer needs to integrate new DMS Field Equipment with the existing DMS Management System [specify existing system interface].	3.1.10.3 The DMS Management System shall be designed to support the integration of new DMS Field Equipment with the existing DMS Management System [specify existing system interface in accordance with NTCIP 1203].
4.10.4	The DMS System Designer needs to accommodate existing communications interfaces [specify].	3.1.10.4 The DMS Management System shall be designed to accommodate existing communications interfaces [specify].
4.10.5	The DMS System Designer needs to follow agency IT policies. [specify]	3.1.10.5 The DMS Management System shall be designed based on agency IT policies [specify].

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.10.6	The DMS System Designer needs to design the DMS Management System interface definitions to comply (mandatory and specify optional) with the latest version of NTCIP 1203.	<p>3.1.10.1 The DMS Management System shall interface with DMS Field Equipment from different manufacturers within the same system in accordance with NTCIP 1203v03 or later at a minimum. [specify NTCIP 1203 mandatory requirements and what optional requirements needed, and what DMS Field Equipment are being used]</p> <p>3.1.10.2 The DMS Management System shall support the replacement by the DMS System Maintainer of existing DMS Field Equipment with DMS Field Equipment from different manufacturers. [specify existing system interface in accordance with NTCIP 1203].</p> <p>3.1.10.3 The DMS Management System shall be designed to support the integration of new DMS Field Equipment with the existing DMS Management System [specify existing system interface in accordance with NTCIP 1203].</p>
4.11	DMS Management System Performance	<p>3.1.11 DMS Management System Performance</p>
4.11.1	The DMS System Owner needs to accommodate [specify] users at any one time.	<p>3.1.11.1 The DMS Management System shall accommodate [specify] users at any one time.</p>
4.11.2	The DMS System Owner needs the DMS Management System to accommodate a minimum of [specify] signs.	<p>3.1.11.2 The DMS Management System shall accommodate a minimum of [specify] signs.</p>

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.11.3	The DMS System User needs to receive confirmation that a new message is placed on the DMS Field Equipment within [specify] seconds.	3.1.11.3 The DMS Management System shall provide confirmation that a new message is placed on the DMS Field Equipment within [specify] seconds.
4.12	Fault Management	3.1.12 Fault Management
4.12.1	The DMS System User needs to detect suspected system faults.	3.1.12.1 The DMS Management System shall detect suspected system faults and report them to the DMS System User.
4.12.2	The DMS System User needs to run diagnostics for suspected system faults.	3.1.12.2 The DMS Management System shall allow the DMS System User to run diagnostics for suspected system faults.
4.12.3	The DMS System User needs to log and report suspected system faults to the DMS System Maintainer.	3.1.12.3 The DMS Management System shall allow the DMS System User to log and report suspected system faults to the DMS System Maintainer.
4.12.4	The DMS System User needs to detect suspected communications faults.	3.1.12.4 The DMS Management System shall detect suspected communications faults and report them to the DMS System User.
4.12.5	The DMS System User needs to run diagnostics for suspected communications faults.	3.1.12.5 The DMS Management System shall allow the DMS System User to run diagnostics for suspected communications faults.

ConOps Reference Number	ConOps Sample Statement	System Requirements
4.12.6	The DMS System User needs to log and report suspected communications faults to the DMS System Maintainer.	3.1.12.6 The DMS Management System shall allow the DMS System User to log and report suspected communications faults to the DMS System Maintainer.
4.12.7	The DMS System Maintainer needs to know what is causing a DMS system fault by viewing the message display.	3.1.12.7 The DMS Field Equipment shall display a user defined indication of the following conditions: <ul style="list-style-type: none"> · Communications fault · [specify other faults] [Specify the specific indicators to be used, e.g., *, 1, +, - at a specific position on the sign display]

ConOps Reference Number	ConOps Sample Statements
5	Chapter 5: Envisioned DMS System Overview
5.1	Operational Objectives
5.1.1	The primary operational objective of the agency is to convey information to the traveler.
5.2	Operational Policies and Constraints
5.2.1	The operation of the DMS Management System will enforce user access control based on the user's role and permissions as specified by the DMS operational policy.
5.2.2	The DMS Management System will have a limitation of [specify number] of system users at a given time.
5.2.3	The DMS Management System users will follow the DMS System policy guidelines for appropriate display of messages to the public.
5.3	Description of the Proposed System
5.3.1	Operator Access
5.3.1.1	Operators and maintenance staff will be assigned different levels of authority, and access to equipment for which they are authorized, based on their roles and responsibilities. This will allow them to control, view, monitor, analyze and maintain the operation of the DMS Management System as appropriate.
5.3.1.2	The DMS Management System will be connected to the agency's LAN/WAN, allowing access to all authorized users.
5.3.1.3	The DMS Management System will allow access by authorized users outside the agency via a firewall.

ConOps Reference Number	ConOps Sample Statements
5.3.2	Operational Environment
5.3.2.1	The DMS Management System will be housed in a facility with suitable environmental characteristics based on the requirements of the procured DMS System equipment.
5.3.2.2	The DMS Field Equipment will meet the environmental condition requirements of the region where they are deployed.
5.3.2.3	The DMS Management System facility will provide physical access control.
5.3.2.4	The DMS Management System facility will provide access to communication system(s) from the DMS Management System to the DMS Field Equipment.
5.3.3	Major DMS Management System Components
5.3.3.1	The DMS Management System will include DMS Management System software running on one or more computer servers.
5.3.3.2	The DMS Management System will include one or more user workstations containing [specify number] of user workstation displays.
5.3.3.4	The DMS Management System will include a LAN connecting the DMS Management System server(s), and workstation(s)l.
5.3.4	Interfaces
5.3.4.1	The DMS Management System will communicate with external systems over the following communications systems [specify].

ConOps Reference Number	ConOps Sample Statements
5.3.4.2	The DMS Management System will communicate with external systems following standardized communication protocols [specify].
5.3.5	Estimated Cost of DMS Management System Operation
5.3.5.1	The estimated annual cost of DMS Management System operations is [specify].
5.3.6	Operational Risk Factors
5.3.6.1	A DMS Management System operational risk factor includes displaying inappropriate messages, as defined in the DMS Management System policy guidelines.
5.3.6.2	A DMS Management System operational risk factor includes malicious usage of the DMS Management System by authorized and unauthorized users.
5.3.6.3	A DMS Management System operational risk factor includes the loss of electrical power.
5.3.6.4	A DMS Management System operational risk factor includes the loss of communications.
5.3.7	Performance Characteristics
5.3.7.1	The DMS Management System will provide the DMS Management System user with DMS Field Equipment response times of [specify].
5.3.7.2	The DMS Management System will support [specify number] simultaneous users.
6	Chapter 6: DMS System Operational Environment

ConOps Reference Number	ConOps Sample Statements
6-01	The system will be operated and monitored from the [specify agency] [specify overall system name such as TMC].
6-02	The system will be operated and monitored from workstations located [specify who will have workstations and where they will be located].
6-03	The central server equipment will be housed at [specify location] in an [air-conditioned or non-air-conditioned] environment.
6-04	Complaints or requests for changes in operation will be handled by the [in-house operators and/or on-call contract staff] on an as-needed basis.
6-05	Maintenance of all field equipment will be performed by [in-house and/or contract] staff
6-06	Maintenance of the following field equipment will be performed by [in-house and/or contract] staff. [specify what equipment will be maintained by whom]
6-07	Funding for maintenance of the DMS System will come from [specify funding program or source]. An increase of [specify \$] per year will be required to accommodate the additional equipment installed for the DMS System.
6-08	Additional communications equipment and annual fees will be incurred with the DMS System. This will amount to approximately [specify \$] per year, and will be covered by the [specify program or budget allocation details].
6-09	Replacement or repair of defective or failed equipment will be covered for [specify years] by the manufacturers' warranties. The labor cost of replacement during this period will be included in the purchase price.
6-10	The agency expects maintenance of parts and equipment for a period of [specify years] will be included in the purchase price.

ConOps Reference Number	ConOps Sample Statements
6-11	The agency expects maintenance of all DMS Management System software for a period of [specify years] will be included in the purchase price.
6-12	The agency expects to operate this system using the latest software for a period of [specify years].
6-13	The agency will seek technical support from the vendor for assistance in using the adaptive software for [specify years].
6-14	Operations and maintenance staff will have the ability to log in to the system from remote locations via the internet, and have full functionality consistent with their access level.
6-15	Include any additional needs for support or information from the vendor that will be needed by your agency, and that will become requirements in the contract or purchase documents.
6.1	
6.1-1	The central server will be a standard platform maintained by the [specify agency department] and able to be replaced independently from the software.
6.1-2	The agency selection of DMS will not be constrained by the DMS System software.
7	Chapter 7: DMS System Support Environment
7.1	Institutions and Stakeholders

ConOps Reference Number	ConOps Sample Statements
7.1-1	Existing stakeholders utilizing the DMS system include: [list all stakeholders, such as: * Sponsoring agency * Neighboring agencies that will access the DMS System * Etc.]
7.1-2	The stakeholders who will be affected by or have a direct interest in the DMS System are: [list existing and include new stakeholders].
7.1-3	The activities that will be undertaken by the DMS System stakeholders include: system operation, system monitoring and adjustment, system performance monitoring and evaluation.
7.1-4	The organizational structures of the units responsible for installation, operation and maintenance are illustrated in the attached organization chart. The roles, responsibilities and required qualifications and experience are described below. [Describe as appropriate]
7.2	Facilities
7.2-1	Describe the current and/or proposed [TMC or DMS System Center].
7.2-2	Will there be a satellite and/or backup [TMC or DMS System Center]?
7.2-3	Describe the locations elsewhere within the agency, such as on a LAN or WAN, from which access to the system will be required?
7.2-4	Is air-conditioning required?

ConOps Reference Number	ConOps Sample Statements
7.2-5	Describe the location where a separate server will be located. (e.g., IT server room, TMC back room, remote hub)
7.2-6	Describe who is responsible for providing and maintaining staff facilities (e.g., personnel, public works, building services, etc.?)
7.2-7	Describe who is responsible for fire control facilities (e.g., part of operating group's responsibility, or the responsibility of another group, such as building services?)
7.2-8	Describe who is responsible for secure access to the TMC, workshop, or office with DMS system workstations? (e.g., Is it the responsibility of the operating group or another group, such as building services?)
7.3	System Architecture Constraints
7.3-1	The DMS System processor/server will be protected within the agency's firewalls. The IT Department will provide resources, equipment and system management so that operators will have appropriate access to the system locally, from within the agency's LAN and from remote locations.
7.3-2	The communications media available for use by the system will be: [List Available Media, Provide a map or block diagram as appropriate. Show locations of any gaps, bandwidth and latency constraints, protocols and available alternatives.]
7.3-3	The [specify which State or Region] [Statewide or Regional] ITS Architecture provides the context for the DMS System project. The DMS System project fits within the ITS Architecture as illustrated in Figure XX. [Explain each architectural element and information flow in the DMS System project. If additional elements or interfaces are added, explain why].
7.4	Utilities

ConOps Reference Number	ConOps Sample Statements
7.4-1	Are utilities the responsibility of the operating group, or are they the responsibility of another group, such as building services?
7.5	Equipment
7.5-1	Describe what test equipment is required to support the DMS system (e.g., communications testers, fiber testers, DMS sign testers. Is this currently available or is additional equipment required?
7.5-2	Will vehicles be the responsibility of the operating group or another group within the agency? What types of vehicles will be required, and how many?
7.6	Computing hardware
7.6-1	Describe the additional computing equipment required to support DMS system operation, such as printer, copier, additional monitors, and scanner.
7.6-2	Describe who is responsible for maintenance and repair of the computing equipment?
7.6-3	Describe who is responsible for replacement of the computing equipment when it reaches the end of its useful life?
7.7	Software
7.7-1	Who is responsible for keeping software up to date?
7.7-2	Who is responsible for keeping software licenses current?
7.7-3	What controls are proposed governing software use and availability on workstations and other support computers?

ConOps Reference Number	ConOps Sample Statements
7.8	Personnel
7.8-1	Describe how many operators will be available for routine operations. Will this be provided by existing staff or will additional staff be required?
7.8-2	Describe what hours operators will be available.
7.8-3	Describe what training operators will need.
7.8-4	Describe what maintenance staff will be required. Will this be provided by existing staff or will additional staff be required?
7.8-5	What qualifications and training will the maintenance staff require?
7.9	Operating procedures
7.9-1	Describe who will be responsible for backing up databases. How often will backups be required? Will backups be stored off-site?
7.10	Maintenance
7.10-1	Describe the arrangements for maintenance. (E.g., is it done in-house or contracted out? Is it 24/7? Is equipment repair done in-house or externally?)
8	Chapter 8: Operational Scenarios
8.1	Overview

ConOps Reference Number	ConOps Sample Statements
8.1-1	<p>The following operational scenarios describe how the system is expected to operate under various conditions. The proposed DMS Management System is expected to be able to manage the following operational scenarios and issues envisioned for both the current and future project locations. Scenarios are described for the following operational conditions: [Edit to suit your situation.]</p> <ul style="list-style-type: none"> * Configure DMS Management System * DMS Field Equipment Monitoring * Controlling DMS Field Equipment * Controlling External Devices * DMS Management System Logging * DMS Management System Maintenance and Failure Management <p>[For each scenario, describe the following elements:</p> <ul style="list-style-type: none"> * Operational objectives * Users * Summary of operations].
8.2	Configure DMS Management System
8.2.1	Operational Objectives

ConOps Reference Number	ConOps Sample Statements
8.2.1-1	<p>The operational objectives for the configuration of the DMS Management System are to:</p> <ul style="list-style-type: none"> * Provide the capability to configure DMS Management System user access and permissions to and from the DMS Management System * Specify DMS Management System parameters affecting the DMS Management System performance
8.2.2	Users
8.2.2-1	<p>The users involved with the configuration of the DMS Management System are:</p> <ul style="list-style-type: none"> * DMS System Manager is the primary user responsible for setting access and permissions for all users * DMS System User * DMS System Maintainer
8.2.3	Summary of Operations
8.2.3-1	<p>The DMS System Manager will prepare and monitor the DMS Management System operation by controlling access of the various users to the DMS Management System. Specifically the DMS System Manager configures who can select particular DMS Field Equipment, monitor and control these DMS Field Equipment. Additionally, the DMS System Manager gives DMS System Maintainers the ability to run diagnostics and tests on the DMS Management System in order to enact repairs. The DMS System Manager also configures the DMS Management System by setting the number and types of users allowed access to the DMS Management System at any given time. The DMS System Manager also sets other parameters to handle competing user access to shared capabilities as well as DMS Field Equipment ownership, permissions, etc.</p>
8.3	DMS Field Equipment Monitoring

ConOps Reference Number	ConOps Sample Statements
8.3.1	Operational Objectives
8.3.1-1	<p>The operational objective for DMS Field Equipment monitoring is to:</p> <ul style="list-style-type: none"> * Allow the DMS System User to monitor a sign's message
8.3.2	Users
8.3.2-1	<p>The user involved with DMS Field Equipment monitoring is:</p> <ul style="list-style-type: none"> * DMS System User
8.3.3	Summary of Operations
8.3.3-1	<p>The DMS Management System provides DMS System Users the ability to monitor what message is currently being displayed on the DMS Field Equipment.</p>
8.4	Controlling DMS Field Equipment
8.4.1	Operational Objectives
8.4.1-1	<p>The operational objectives for controlling DMS Field Equipment are to:</p> <ul style="list-style-type: none"> * Allow the DMS System User to select and control which messages are displayed on particular DMS Field Equipment or signs.
8.4.2	Users

ConOps Reference Number	ConOps Sample Statements
8.4.2-1	<p>The users involved with controlling DMS Field Equipment are:</p> <ul style="list-style-type: none"> * DMS System User
8.4.3	Summary of Operations
8.4.3-1	<p>This is the primary operational scenario that defines some key operations where DMS Field Equipment, a “Sign”, is used to inform the traveling public. Many agencies default to displaying travel times when there is not a higher priority message. Messages typically have a priority and can be scheduled. Operational scenarios involving different types of messages include: incidents, HOV restrictions, DHS alerts, amber alerts, silver alerts, special events, work zones, weather, ozone, evacuation and congestion/lanes blocked.</p>
8.5	Controlling External Devices
8.5.1	Operational Objectives
8.5.1-1	<p>The operational objectives for controlling external devices are to: Allow the DMS System User to select and and turn on or off external devices such as flashers or beacons</p>
8.5.2	Users
8.5.2-1	<p>The users involved with controlling External Devices are:</p> <ul style="list-style-type: none"> * DMS System User
8.5.3	Summary of Operations

ConOps Reference Number	ConOps Sample Statements
8.5.3-1	The DMS Management System provides DMS System Users the ability to select and turn on or off external devices independent of the message being displayed on the sign. The external devices can be flashers, beacons, speed sensors, etc.
8.6	Logging DMS Management System Data
8.6.1	Operational Objectives
8.6.1-1	<p>The operational objectives for logging DMS Management System data are to:</p> <ul style="list-style-type: none"> * Allow the specification of log events and characteristics * Allow access and review of the DMS Management System log(s)
8.6.2	Users
8.6.2-1	<p>The user involved in logging DMS Management System data is:</p> <ul style="list-style-type: none"> * DMS System Maintainer
8.6.3	Summary of Operations
8.6.3-1	The DMS System Maintainer specifies which DMS Management System events are logged along with the size of the log(s) and each logs duration. The DMS System Maintainer accesses the logs and reviews the history for general system oversight and to perform diagnostics testing due to triggered alarms.
8.7	DMS Management System Maintenance and Failure Management
8.7.1	Operational Objectives

ConOps Reference Number	ConOps Sample Statements
8.7.1-1	<p>The operational objectives for DMS Management System maintenance and failure management are to:</p> <ul style="list-style-type: none"> * Ensure the DMS Management System continues to be operational * Provide serviceable DMS Management System equipment * Allow for remote testing and diagnostics of the DMS Management System * Notification of failure conditions * Remote update of DMS Management System device firmware and software
8.7.2	Users
8.7.2-1	<p>The users involved in DMS Management System maintenance and failure management are:</p> <ul style="list-style-type: none"> * DMS System User * DMS System Maintainer
8.7.3	Summary of Operations
8.7.3-1	<p>Maintaining DMS Management System operations requires equipment designed for their location. Based on a DMS System User request or DMS Management System failure notification, the DMS System Maintainer can remotely test the DMS Management System including running diagnostics and updating device firmware and system software. It is important that the DMS System Maintainer has safe access to all aspects of the DMS Management System for repairs.</p>

APPENDIX B: SYSTEM REQUIREMENTS TABLE OF SAMPLE STATEMENTS

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1	Functional Requirements	
3.1.1	Access Control	4.1 Control Access to DMS Management System (Choose the user needs in this group if you chose the Configuring the DMS Management System use case in Chapter Three)
3.1.1.1	The DMS Management System shall enforce access control of all users.	4.1.1 The DMS System Manager needs access to the DMS Management System.
3.1.1.1	The DMS Management System shall enforce access control of all users.	4.1.1.1 The DMS System Manager needs access for DMS Management System configuration.
3.1.1.2	The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Users.	4.1.1.1.1 The DMS System Manager needs to configure DMS System User access.
3.1.1.3	The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Maintainers.	4.1.1.1.2 The DMS System Manager needs to configure DMS System Maintainer access.
3.1.1.4	The DMS Management System shall allow the DMS System Manager to select the DMS Field Equipment.	4.1.1.2 The DMS System Manager needs access to the DMS Management System to select DMS Field Equipment.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.1.5	The DMS Management System shall allow the DMS System Manager to control the DMS Field Equipment.	4.1.1.3 The DMS System Manager needs access to the DMS Management System to control DMS Field Equipment.
3.1.1.6	The DMS Management System shall allow the DMS System Manager to control external devices attached to the DMS Controller.	4.1.1.4 The DMS System Manager needs access to the DMS Management System to control external devices.
3.1.1.7	The DMS Management System shall allow the DMS System Manager to access its logged data.	4.1.1.5 The DMS System Manager needs access to the DMS Management System logged data.
3.1.1.8	The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System User.	4.1.2 The DMS System User needs access to the DMS Management System as configured by the DMS System Manager.
3.1.1.9	The DMS Management System shall allow the DMS System User to select DMS Field Equipment.	4.1.2.1 The DMS System User needs access to the DMS Management System to select DMS Field Equipment.
3.1.1.10	The DMS Management System shall allow the DMS System User to control DMS Field Equipment.	4.1.2.2 The DMS System User needs access to the DMS Management System to control DMS Field Equipment.
3.1.1.11	The DMS Management System shall allow the DMS System User to control external devices.	4.1.2.3 The DMS System User needs access to the DMS Management System to control external devices.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.1.11.1	The DMS Management System shall control external devices such as flashers or beacons when directed by the DMS System User. Note: Agency policy may dictate when flashers and/or beacons may be used (e.g., lane blockage only).	4.1.2.3 The DMS System User needs access to the DMS Management System to control external devices.
3.1.1.11.2	The DMS Management System shall allow the DMS System User to specify automatically including flashers or beacons based on message type.	4.1.2.3 The DMS System User needs access to the DMS Management System to control external devices.
3.1.1.12	The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System Maintainer.	4.1.3 The DMS System Maintainer needs access to the DMS Management System as configured by the DMS System Manager.
3.1.1.13	The DMS Management System shall allow the DMS System Maintainer to select DMS Field Equipment.	4.1.3.1 The DMS System Maintainer needs access to the DMS Management System to select DMS Field Equipment.
3.1.1.14	The DMS Management System shall allow the DMS System Maintainer to control DMS Field Equipment.	4.1.3.2 The DMS System Maintainer needs access to the DMS Management System to control DMS Field Equipment.
3.1.1.15	The DMS Management System shall allow the DMS System Maintainer to control external devices.	4.1.3.3 The DMS System Maintainer needs access to the DMS Management System to control external devices.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.1.16	The DMS Management System shall allow the DMS System Maintainer to run system diagnostics and testing.	4.1.3.4 The DMS System Maintainer needs access to the DMS Management System to run system diagnostics and testing.
3.1.1.17	The DMS Management System shall provide access to the DMS System Maintainer to repair it.	4.1.3.5 The DMS System Maintainer needs access to the DMS Management System to repair it.
3.1.1.18	The DMS Management System shall organize DMS System Users into groups.	4.1.3.6 The DMS System Manager needs to organize DMS System Users into groups.
3.1.1.18.1	Membership in the group shall be defined by the DMS System Manager.	4.1.3.6 The DMS System Manager needs to organize DMS System Users into groups.
3.1.1.18.1.1	The DMS Management System shall allow the DMS System Manager to specify named user groups and place those users in the group.	4.1.3.6.1 The DMS System Manager needs to specify named groups of DMS System Users and place those users in the group.
3.1.1.18.1.2	The DMS Management System shall allow the DMS System Manager to specify which signs will be shared with individual users or user groups.	4.1.3.6.2 The DMS System Manager needs to specify which signs will be shared by individual or groups of users.
3.1.1.18.1.3	The DMS Management System shall allow the DMS System Manager to specify which individual users or user groups can access the archived logged data.	4.1.3.6.3 The DMS System Manager needs to specify which users or groups of users can access the archived logged data.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.1.18.2	The DMS Management System shall assign which signs are shared by individual users or groups of users.	4.1.3.7 The DMS System Manager needs to protect the integrity of archived and logged data.
3.1.1.18.3	Access to archived data shall be assigned by the DMS System Manager to users or groups.	4.1.3.8 The DMS System Manager needs to specify which users or groups of users can access the archived logged data.
3.1.1.19	The DMS Management System shall not allow archived data to be altered.	4.1.3.9 The DMS System Manager needs to protect the integrity of archived and logged data.
3.1.2	Configure DMS Management System	4.2 Configure DMS Management System (Choose the user needs in this group if you chose the Configuring the DMS Management System use case in Chapter Three)
3.1.2.1	The DMS Management System shall allow the DMS System Manager to configure the DMS Management System data logging parameters.	4.2.1 The DMS System Manager needs to configure the DMS Management System data logging parameters.
3.1.2.2	The DMS System Management System shall accommodate [specify number] users at different physically accessed terminals as configured by the DMS System Manager.	4.2.2 The DMS System Manager needs to accommodate [specify] users with access to the DMS Management System. [This may be further defined by type of user and their bandwidth consumption.]

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.3	The DMS System Management System shall accommodate [specify types of] users as configured by the DMS System Manager.	4.2.2 The DMS System Manager needs to accommodate [specify] users with access to the DMS Management System. [This may be further defined by type of user and their bandwidth consumption.]
3.1.2.4	The DMS System Management System shall arbitrate competing requests for access, including providing automatic timeouts, transfer of access, and other DMS Field Equipment user access issues as configured by the DMS System Manager. [Describe the desired operation, and choose the requirements relevant to the desired operation. Options: DMS Field Equipment ownership, last user control, first-come-first-served, etc.]	4.2.3 The DMS System Manager needs to configure the system to arbitrate competing requests for access, including providing automatic timeouts, transfer of access, and other DMS Field Equipment user access issues. [Describe the desired operation, and choose the requirements relevant to the desired operation. Options: DMS Field Equipment ownership, last user control, first-come-first-served, etc.]
3.1.2.5.1	The DMS Management System shall allow the DMS System Manager to configure message priority for each DMS.	4.2.5.1 The DMS System Manager needs to configure message priority for each DMS.
3.1.2.5.2	The DMS Management System shall allow the DMS System User to create schedules assigning messages to particular DMS according to a start time, duration and message priority.	4.2.5.2 The DMS System User needs to create schedules assigning messages to particular DMS according to a start time, duration and message priority.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.5.3	The DMS Field Equipment shall display the message with the highest priority or the message with the latest start time if at the same priority as the message being displayed.	4.2.5.1 The DMS System Manager needs to configure message priority for each DMS.
3.1.2.5.4	The DMS Management System shall give the highest priority to messages being manually engaged by the DMS System User.	4.2.5.3 The DMS System User needs to be able to override the currently displayed message on a DMS.
3.1.2.6.1	The DMS Management System shall determine the identity of the DMS Field Equipment based on a DMS System User request.	4.2.4.1 The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.
3.1.2.6.2	The DMS Management System shall determine the sign type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign) based on a DMS System User request.	4.2.4.1 The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.6.3	The DMS Management System shall determine the sign technology (mostly LED) based on a DMS System User request.	4.2.4.1 The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.
3.1.2.6.4	The DMS Management System shall determine the manufacturer based on a DMS System User request.	4.2.4.1 The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.
3.1.2.6.5	The DMS Management System shall determine the model and version number for both hardware and software elements based on a DMS System User request.	4.2.4.1 The DMS System User needs to determine the identity of the DMS Field Equipment and its basic information including type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign), technology, manufacturer, model and version number for both hardware and software elements.
3.1.2.6.6	The DMS Management System shall tell the DMS System User if an entered message can be displayed on a given sign.	4.2.4.2 The DMS System User needs to determine the sign display characteristics of the DMS Field Equipment in order to determine if a given message can be displayed on the sign.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.6.7	The DMS Management System shall limit the sign types available to the DMS System User based on a given message and different sign display capabilities.	4.2.4.2 The DMS System User needs to determine the sign display characteristics of the DMS Field Equipment in order to determine if a given message can be displayed on the sign.
3.1.2.6.8	The DMS Management System shall manage variations in a given message to be displayed on signs with different capabilities.	4.2.4.2 The DMS System User needs to determine the sign display characteristics of the DMS Field Equipment in order to determine if a given message can be displayed on the sign.
3.1.2.6.9	The DMS Management System shall allow the DMS System User to define and edit the appearance of fonts (i.e., type, color and size) used to display messages on DMS Field Equipment throughout the DMS Management System.	4.2.4.3 The DMS System User needs to define and edit the appearance of fonts used to display messages on DMS Field Equipment throughout the DMS Management System.
3.1.2.6.10	The DMS Management System shall allow the DMS System User to define the appearance of graphics used to for display on DMS Field Equipment for later use.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.6.11	The DMS Management System shall allow the DMS System User to edit vendor supplied graphics.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.
3.1.2.6.12	The DMS Management System shall allow import of graphics generated independently by the DMS System User.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.
3.1.2.6.13	The DMS Management System shall allow the DMS System User to manage existing graphics.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.
3.1.2.6.14	The DMS Management System shall allow the DMS System User to determine the graphics storage capabilities throughout the DMS Management System.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.2.6.15	The DMS Management System shall assist the DMS System User in determining which graphics are compatible with each sign type.	4.2.4.4 The DMS System User needs to define the appearance of graphics used to for display on DMS Field Equipment for later use, manage existing graphics and determine graphics storage capabilities throughout the DMS Management System.
3.1.2.6.16	The DMS Management System shall allow the DMS System User to configure when the DMS Field Equipment may automatically switch between brightness levels based on changing lighting conditions.	4.2.4.5 The DMS System User needs to configure when the DMS Field Equipment may automatically switch between brightness levels based on changing lighting conditions.
3.1.2.6.17	The DMS Management System shall allow the DMS System User to configure the speed limit applicable to the location of the DMS Field Equipment. Note: this requirement is typically for portable DMS Field Equipment that act a speed warning signs.	4.2.4.6 The DMS System User needs to configure the speed limit applicable to the location of the DMS Field Equipment.
3.1.2.6.18	The DMS Management System shall allow the DMS System User to configure the threshold when the fuel in a generator powering a DMS Field Equipment is considered low. Note: this requirement is typically only for portable DMS Field Equipment that use generators.	4.2.4.7 The DMS System User needs to configure the threshold when the fuel in a generator powering a DMS Field Equipment is considered low. This is typically only for Portable DMS Field Equipment that use generators.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.3	Monitoring DMS Field Equipment	4.3 Monitoring DMS (Choose the user needs in this group if you chose the Monitoring DMS Field Equipment use case in Chapter Three)
3.1.3.1	The DMS Management System shall allow the DMS System User to select which DMS Field Equipment to view the current message displayed on the sign face.	4.3.1 The DMS System User needs to select which DMS Field Equipment to view the current message displayed on the sign face.
3.1.3.2	The DMS Management System shall allow the DMS System Manager to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site).	4.3.2 The DMS System Manager needs to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site).
3.1.3.3	The DMS Management System performance monitoring shall conform, at a minimum, to NEMA TS 4-2016.	4.3.2 The DMS System Manager needs to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site).
3.1.4	Controlling DMS Field Equipment	4.4 Controlling DMS (Choose the user needs in this group if you chose the Controlling DMS Field Equipment use case in Chapter Three)
3.1.4.1	The DMS Management System shall allow the DMS System User control of the DMS Field Equipment from both remote and local locations.	4.4.1 The DMS System User needs to control the DMS Field Equipment from both remote and local locations.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.4.2	DMS Management System shall prevent DMS System Users from interfering with one another for simultaneous control of a DMS Field Equipment.	4.4.2 DMS System Users need to be prevented from interfering with one another for simultaneous control of a DMS Field Equipment.
3.1.4.3	Controlling the DMS Field Equipment Sign Face	4.4.3 Controlling the DMS Field Equipment Sign Face
3.1.4.3.1	The DMS Management System User shall activate a stored message to be displayed on the sign face upon request of a DMS System User.	4.4.3.1 The DMS System User needs to be able to activate a stored message to be displayed on the sign face.
3.1.4.3.2	The DMS Management System shall allow the DMS System User to specify the duration for the display of the activated message including its relative priority in order to possibly override the currently displayed message.	4.4.3.2 The DMS System User needs to specify the duration for the display of the activated message including its relative priority in order to possibly override the currently displayed message.
3.1.4.3.3	The DMS Management System shall allow the DMS System User to prioritize messages.	4.4.3.3 The DMS System User needs to prioritize messages.
3.1.4.3.4	The DMS Management System shall allow the DMS System User to create a message and modify its format and content.	4.4.3.4 The DMS System User needs to create a message and modify its format and content.
3.1.4.3.4.1	The DMS Management System shall allow the DMS System User to uniquely identify a message.	4.4.3.4.1 The DMS System User needs to uniquely identify a message.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.4.3.4.2	The DMS Management System shall assist the DMS System User in ensuring that a message is complete by viewing it in WYSIWYG (What You See Is What You Get) format.	4.4.3.4.2 The DMS System User needs to ensure that a message is complete.
3.1.4.3.4.3	The DMS Management System shall allow the DMS System User to develop an approved word list including standardized abbreviations.	4.4.3.4.3 The DMS System User needs to develop an approved word list including standardized abbreviations.
3.1.4.3.4.4	The DMS Management System shall recommend words and abbreviations from the approved word list to the DMS System User.	4.4.3.4.4 The DMS System User needs to use the approved word list in developing a message.
3.1.4.3.4.5	The DMS Management System shall assist the DMS System User in ensuring that the message does not contain offensive language.	4.4.3.4.5 The DMS System User needs to ensure that a message does not have offensive language.
3.1.4.3.4.6	The DMS Management System shall assist the DMS System User in defining the exact contents of the message to be displayed on the sign face.	4.4.3.4.6 The DMS System User needs to define the exact contents of the message to be displayed on the sign face.
3.1.4.3.4.7	The DMS Management System shall provide the capability for the DMS System User to define if the display of a message activates beacons. [Specify if supported]	4.4.3.4.7 The DMS System User needs to define if the display of a message activates beacons. [Specify if supported]

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.4.3.5	The DMS Management System shall store a newly created or modified message by the DMS System User in a library of messages.	4.4.3.5 The DMS System User needs to store a newly created or modified message in a library of messages.
3.1.4.3.6	The DMS Management System shall blank or remove any messages displayed on a sign upon request by the DMS System User.	4.4.3.6 The DMS System User needs to blank or remove any messages displayed on a sign.
3.1.4.3.7	The DMS Management System shall allow the DMS System User to schedule when messages are displayed on DMS Field Equipment. These are the stored messages that are displayed unless overridden by a manually activated message.	4.4.3.7 The DMS System User needs to schedule when messages are displayed on DMS Field Equipment. These are the stored messages that are displayed unless overridden by a manually activated message.
3.1.4.3.7.1	The DMS Management System shall allow the DMS System User to set a series of times when a stored message, including a blank message, will be activated.	4.4.3.7.1 The DMS System User needs to set a series of times when a stored message, including a blank message, will be activated.
3.1.4.3.8	The DMS Management System shall allow the DMS System User to set which message will be displayed when certain non-scheduled events occur such as loss of communications or power.	4.4.3.8 The DMS System User needs to set which message will be displayed when certain non-scheduled events occur such as loss of communications or power.
3.1.4.3.9	The DMS Management System shall allow the DMS System User to directly control the sign brightness.	4.4.3.9 The DMS System User needs to directly control the sign brightness.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.4.3.10	The DMS Management System shall allow the DMS System User to configure automated algorithms that can adjust brightness levels based on the ambient light levels.	4.4.3.10 The DMS System User needs to configure automated algorithms that can adjust brightness levels based on the ambient light levels.
3.1.5	Controlling External Devices	4.5 Controlling External Devices
3.1.5.1	The DMS Management System shall allow the DMS System User to control external devices through the auxiliary ports of the sign controller.	4.5.1 The DMS System User needs to control external devices through the auxiliary ports of the sign controller.
3.1.5.1.1	The DMS Management System shall allow the DMS System User to control High Occupancy Vehicle (HOV) Lane Gates attached to the DMS Field Equipment.	4.5.1.1 The DMS System User needs to control High Occupancy Vehicle (HOV) Lane Gates attached to the DMS Field Equipment.
3.1.5.1.2	The DMS Management System shall allow the DMS System User to control Beacons attached to the DMS Field Equipment.	4.5.1.2 The DMS System User needs to control Beacons attached to the DMS Field Equipment.
3.1.5.1.3	The DMS Management System shall allow the DMS System User to monitor any speed detectors attached to the DMS Field Equipment.	4.5.1.3 The DMS System User needs to configure and monitor any speed detectors attached to the DMS Field Equipment.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.5.1.4	The DMS Field Equipment shall detect speed and display speed threshold limits with detected speed.	4.5.1.3 The DMS System User needs to configure and monitor any speed detectors attached to the DMS Field Equipment.
3.1.5.1.5	The DMS Management System shall allow the DMS System User to monitor and control environmental sensors attached to the DMS Field Equipment.	4.5.1.4 The DMS System User needs to configure, monitor and control environmental sensors attached to the DMS Field Equipment.
3.1.5.1.6	The DMS Field Equipment shall detect environmental conditions and display environmental conditions.	4.5.1.4 The DMS System User needs to configure, monitor and control environmental sensors attached to the DMS Field Equipment.
3.1.5.1.7	The DMS Management System shall allow the DMS System User to control other external devices. [Specify other types of external devices]	4.5.1.5 The DMS System User needs to control other external devices. [Specify other types of external devices]]
3.1.6	DMS Management System Logging	4.6 DMS Management System Logging (Choose the user needs in this group if you chose the Logging DMS Management System Data use case in Chapter Three)
3.1.6.1	The DMS Management System shall allow the DMS System Maintainer access to the DMS Management System log(s).	4.6.1 The DMS System Maintainer needs to access and review the DMS Management System log(s).

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.6.2	The DMS Management System shall allow the DMS System Maintainer to specify what DMS Management System events are logged.	4.6.2 The DMS System Maintainer needs to specify what DMS Management System events are logged.
3.1.6.3	The DMS Management System shall allow the DMS System Maintainer to specify, for each log, the log size and/or duration for the DMS Management System.	4.6.3 The DMS System Maintainer needs to specify, for each log, the log size and/or duration for the DMS Management System.
3.1.6.4	The DMS Management System shall allow the DMS System Maintainer to access and review a history (log) of the following diagnostic information [specify] and alarms [specify] for a period of [specify] days.	4.6.4 The DMS System Maintainer needs to access and review a history (log) of the following diagnostic information [specify] and alarms [specify] for a period of [specify] days.
3.1.7	DMS Management System Maintenance	4.7 DMS Management System Maintenance (Choose the user needs in this group if you chose the Maintaining the DMS Management System use case in Chapter Three)
3.1.7.1	The DMS Management System operations shall be maintainable by the DMS System Maintainer.	4.7.1 The DMS System Maintainer needs to maintain DMS Management System operations.
3.1.7.1.1	The DMS Field Equipment shall be durable to support operations. [Specify description of what this means]	4.7.1.1 The DMS System User needs durable equipment. [Add descriptions of what this means]

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.2	The DMS Field Equipment shall conform to the environmental conditions specified in NEMA TS 4-2016. [Description needs to include conditions under which the equipment will be operated. Reference NEMA TS 4-2016. Does it need to withstand rain? Inundation? High-pressure hose-down? High wind? High (or low) temperatures? IPC67? IEC 60529? NEMA (Type R, Type X, etc.)? Ground cabinets versus signs.]	4.7.1.2 The DMS System User needs equipment designed for environmental conditions.
3.1.7.1.3	The DMS Field Equipment shall be serviceable. [Specify how to access for maintenance, crane, bucket truck, requirements for maintainer to be protected by elements]	4.7.1.3 The DMS System Maintainer needs serviceable field equipment.
3.1.7.1.4	The DMS Field Equipment shall have readily available replacement parts for the life of the system [specified period of time].	4.7.1.4 The DMS System Maintainer needs to have access to replacement parts for the life of the system [specified period of time].
3.1.7.1.5	The DMS Management System shall allow the DMS System Maintainer to remotely test DMS Field Equipment via IP protocol.	4.7.1.5 The DMS System Maintainer needs to remotely test devices via IP protocol.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.6	The DMS Management System shall provide diagnostic information via NTCIP 1203 protocols that the DMS Field Equipment collects about itself, defined in Section 9 of NEMA TS4-2016 at the direction of the DMS System Maintainer.	4.7.1.6 The DMS System Maintainer needs diagnostic information that the DMS Field Equipment collects about itself at the direction of the Maintainer.
3.1.7.1.7	The DMS Management System shall allow the DMS System Maintainer to enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.	4.7.1.7 The DMS System Maintainer needs to enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.8	<p>The DMS Management System shall allow the DMS System Maintainer to troubleshoot the following failure conditions to trigger alarms visible to the DMS System User. [It is only necessary for the DMS Field Equipment to support information about capabilities actually present in the DMS Field Equipment. For example, a matrix sign does not provide the drum-rotor status items, and a drum sign does not provide the pixel status items.]</p> <ul style="list-style-type: none"> a. Power Sources b. Power Supplies c. Lamps d. Pixels e. Light Level Sensors f. Sign Controller g. Temperature Sensors h. Humidity i. Internal Environmental Systems (Fans and/or Heaters) j. Drum Sign Rotors k. External Device Errors 	<p>4.7.1.8</p> <p>The DMS System Maintainer needs the following failure conditions to trigger alarms visible to the DMS System User. [It is only necessary for the DMS Field Equipment to support information about capabilities actually present in the DMS Field Equipment. For example, a matrix sign does not provide the drum-rotor status items, and a drum sign does not provide the pixel status items.]</p> <ul style="list-style-type: none"> a. Power Sources b. Power Supplies c. Lamps d. Pixels e. Light Level Sensors f. Sign Controller g. Temperature Sensors h. Humidity i. Internal Environmental Systems (Fans and/or Heaters) j. Drum Sign Rotors k. External Device Errors
3.1.7.1.9	<p>The DMS Management System shall allow the DMS System Maintainer to obtain detailed information about a reported warning or error condition within a subsystem (detailed-level diagnostics).</p>	<p>4.7.1.9</p> <p>The DMS System Maintainer needs to obtain detailed information about a reported warning or error condition within a subsystem (detailed-level diagnostics).</p>

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.10	The DMS Management System shall allow the DMS System User to monitor errors associated with defining or activating a particular message.	4.7.1.10 The DMS System User needs to monitor errors associated with defining or activating a particular message.
3.1.7.1.11	The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the sign housing. [Reference NEMA TS 4-2016]	4.7.1.11 The DMS System Maintainer needs to monitor the temperature and humidity within the sign housing and control cabinet.
3.1.7.1.12	The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the control cabinet. [Reference NEMA TS 4-2016]	4.7.1.11 The DMS System Maintainer needs to monitor the temperature and humidity within the sign housing and control cabinet.
3.1.7.1.13	The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the sign housing. [Reference NEMA TS 4-2016]	4.7.1.11 The DMS System Maintainer needs to monitor the temperature and humidity within the sign housing and control cabinet.
3.1.7.1.14	The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the control cabinet. [Reference NEMA TS 4-2016]	4.7.1.11 The DMS System Maintainer needs to monitor the temperature and humidity within the sign housing and control cabinet.
3.1.7.1.15	The DMS Management System shall allow the DMS System Maintainer to monitor for any errors related to the attached external devices to the DMS Field Equipment. [Specify external devices.]	4.7.1.12 The DMS System Maintainer needs to monitor for any errors related to the attached external devices to the DMS Field Equipment. [Specify external devices.]

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.16	The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the sign housing.	4.7.1.13 The DMS System Maintainer needs to monitor the status (opened, closed) of the doors to the sign housing and control cabinet.
3.1.7.1.17	The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the control cabinet.	4.7.1.13 The DMS System Maintainer needs to monitor the status (opened, closed) of the doors to the sign housing and control cabinet.
3.1.7.1.18	The DMS Management System shall allow the DMS System Maintainer to monitor whether the DMS Field Equipment controller software is operating properly through the use of watchdog timers. [Reference NEMA TS 4-2016]	4.7.1.14 The DMS System Maintainer needs to monitor whether the DMS Field Equipment controller software is operating properly through the use of watchdog timers.
3.1.7.1.19	The DMS Management System shall allow the DMS System Maintainer to monitor the automatic display of a blank message when diagnostics detect that too many pixels are non-operational or that the light outputs are faulty. [Reference NEMA TS 4-2016]	4.7.1.15 The DMS System Maintainer needs to monitor the automatic display of a blank message when diagnostics detect that too many pixels are non-operational or that the light outputs are faulty.
3.1.7.1.20	The DMS Management System shall allow the DMS System Maintainer to monitor the source of power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]	4.7.1.16 The DMS System Maintainer needs to monitor the source of power that is being used to operate the DMS sign face.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.1.21	The DMS Management System shall allow the DMS System Maintainer to monitor the voltage level of the power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]	4.7.1.17 The DMS System Maintainer needs to monitor the voltage level of the power that is being used to operate the DMS sign face.
3.1.7.1.22	The DMS Management System shall allow the DMS System Maintainer to monitor the level of fuel within the tank of a generator that is being used to operate the DMS Field Equipment.	4.7.1.18 The DMS System Maintainer needs to monitor the level of fuel within the tank of a generator that is being used to operate the DMS Field Equipment.
3.1.7.1.23	The DMS Management System shall allow the DMS System Maintainer to monitor the engine RPM when a generator is being used to operate the DMS Field Equipment.	4.7.1.19 The DMS System Maintainer needs to monitor the engine RPM when a generator is being used to operate the DMS Field Equipment.
3.1.7.1.24	The DMS Management System shall allow the DMS System Maintainer to run complete diagnostics and store the results for review.	4.7.1.20 The DMS System Maintainer needs to run a complete diagnostic test and review the results.
3.1.7.2	The DMS Field Equipment connected with a DMS Management System shall be uniquely identifiable.	4.7.2 The DMS Field Equipment in a DMS Management System need to be uniquely identifiable and locatable.
3.1.7.3	The DMS Field Equipment connected with a DMS Management System shall be locatable.	4.7.2 The DMS Field Equipment in a DMS Management System need to be uniquely identifiable and locatable.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.7.4	The DMS Management System shall be designed by the DMS System Designer to provide the DMS System Maintainer with safe access to DMS Field Equipment locations for maintenance.	4.7.3 The DMS System Maintainer needs to have safe access to DMS Field Equipment locations for maintenance.
3.1.7.5	The DMS Management System shall provide the DMS System Maintainer with the ability to remotely update DMS Field Equipment controller software and firmware.	4.7.4 The DMS System Maintainer needs to update DMS Field Equipment controller software and firmware remotely.
3.1.8	DMS Field Equipment Characteristics	4.8 DMS Field Equipment Characteristics (Choose the user needs in this group if you chose the Determining DMS Field Equipment Siting use case in Chapter Three)
3.1.8.1	The DMS Management System shall provide the capability for the Traveling Public to read messages on the sign face in reduced visibility conditions. Note: Reference the NEMA TS 4 viewing cone.	4.8.1 The Traveling Public needs to read messages on the sign face in reduced visibility conditions.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.8.2	<p>The DMS Management System shall allow the DMS System User to store the following information in the DMS Management System:</p> <ul style="list-style-type: none"> * DMS Field Equipment Owner * DMS Field Equipment Unique Identifier * DMS Field Equipment Text Description [Specify number of characters of text] * DMS Field Equipment Location (physical, part of a corridor) * DMS Field Equipment Type (Blank Out Sign (BOS), Changeable Message Sign (CMS), or Variable Message Sign (VMS) as defined in NTCIP 1203) * DMS Field Equipment Technology (Fiber Optic, Light Emitting Diode (LED), Flip disk or shutter, Lamp Matrix, or Drum) * DMS Field Equipment Display Matrix Configuration (No Matrix (i.e., not a pixel matrix sign), Matrix Sign, Full Matrix, Line Matrix or Character Matrix) * DMS Field Equipment Fixed versus Portable * [Specify other DMS Field Equipment characteristics] 	<p>4.8.2</p> <p>The DMS System User needs to store the following information in the DMS Management System:</p> <ul style="list-style-type: none"> * DMS Field Equipment Owner * DMS Field Equipment Unique Identifier * DMS Field Equipment Descriptive Name * DMS Field Equipment Location (physical, part of a corridor) * DMS Field Equipment Type * DMS Field Equipment Technology * DMS Field Equipment Display Matrix Configuration * DMS Field Equipment Fixed versus Portable * [Specify other DMS Field Equipment characteristics]
3.1.9	DMS Field Equipment Siting	<p>4.9</p> <p>DMS Field Equipment Siting (Choose the user needs in this group if you chose the Determining DMS Field Equipment Siting use case in Chapter Three)</p>

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.9.1	The DMS Field Equipment shall be placed by the DMS System Designer at locations that provide travelers with actionable information to support the agency's operational objectives.	4.9.1 The DMS System Designer needs to place the DMS Field Equipment at locations that provide travelers with actionable information to support the agency's operational objectives.
3.1.9.2	The DMS Field Equipment sign placement shall conform, at a minimum, to NEMA TS 4-2016.	4.9.1 The DMS System Designer needs to place the DMS Field Equipment at locations that provide travelers with actionable information to support the agency's operational objectives.
3.1.9.3	The DMS Field Equipment siting by the DMS System Designer shall take into account maintenance needs. [specify]	4.9.2 The DMS System Designer needs to have DMS Field Equipment siting take into account maintenance needs. [specify]
3.1.10	Interfaces	4.10 Interfaces (Choose the user needs in this group if you chose the Interfaces use case in Chapter Three)
3.1.10.1	The DMS Management System shall interface with DMS Field Equipment from different manufacturers within the same system in accordance with NTCIP 1203v03 or later at a minimum. [specify NTCIP 1203 mandatory requirements and what optional requirements needed, and what DMS Field Equipment are being used]	4.10.1 The DMS System User needs to interface with DMS Field Equipment from different manufacturers within the same system, while satisfying all the user needs. [specify what DMS Field Equipment are being used]

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.10.1	The DMS Management System shall interface with DMS Field Equipment from different manufacturers within the same system in accordance with NTCIP 1203v03 or later at a minimum. [specify NTCIP 1203 mandatory requirements and what optional requirements needed, and what DMS Field Equipment are being used]	4.10.6 The DMS System Designer needs to design the DMS Management System interface definitions to comply (mandatory and specify optional) with the latest version of NTCIP 1203.
3.1.10.2	The DMS Management System shall support the replacement by the DMS System Maintainer of existing DMS Field Equipment with DMS Field Equipment from different manufacturers. [specify existing system interface in accordance with NTCIP 1203].	4.10.2 The DMS System Maintainer needs to replace DMS Field Equipment with DMS Field Equipment from different manufacturers.
3.1.10.2	The DMS Management System shall support the replacement by the DMS System Maintainer of existing DMS Field Equipment with DMS Field Equipment from different manufacturers. [specify existing system interface in accordance with NTCIP 1203].	4.10.6 The DMS System Designer needs to design the DMS Management System interface definitions to comply (mandatory and specify optional) with the latest version of NTCIP 1203.
3.1.10.3	The DMS Management System shall be designed to support the integration of new DMS Field Equipment with the existing DMS Management System [specify existing system interface in accordance with NTCIP 1203].	4.10.3 The DMS System Designer needs to integrate new DMS Field Equipment with the existing DMS Management System [specify existing system interface].

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.10.3	The DMS Management System shall be designed to support the integration of new DMS Field Equipment with the existing DMS Management System [specify existing system interface in accordance with NTCIP 1203].	4.10.6 The DMS System Designer needs to design the DMS Management System interface definitions to comply (mandatory and specify optional) with the latest version of NTCIP 1203.
3.1.10.4	The DMS Management System shall be designed to accommodate existing communications interfaces [specify].	4.10.4 The DMS System Designer needs to accommodate existing communications interfaces [specify].
3.1.10.5	The DMS Management System shall be designed based on agency IT policies [specify].	4.10.5 The DMS System Designer needs to follow agency IT policies. [specify]
3.1.11	DMS Management System Performance	4.11 DMS Management System Performance
3.1.11.1	The DMS Management System shall accommodate [specify] users at any one time.	4.11.1 The DMS System Owner needs to accommodate [specify] users at any one time.
3.1.11.2	The DMS Management System shall accommodate a minimum of [specify] signs.	4.11.2 The DMS System Owner needs the DMS Management System to accommodate a minimum of [specify] signs.
3.1.11.3	The DMS Management System shall provide confirmation that a new message is placed on the DMS Field Equipment within [specify] seconds.	4.11.3 The DMS System User needs to receive confirmation that a new message is placed on the DMS Field Equipment within [specify] seconds.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.12	Fault Management	4.12 Fault Management
3.1.12.1	The DMS Management System shall detect suspected system faults and report them to the DMS System User.	4.12.1 The DMS System User needs to detect suspected system faults.
3.1.12.2	The DMS Management System shall allow the DMS System User to run diagnostics for suspected system faults.	4.12.2 The DMS System User needs to run diagnostics for suspected system faults.
3.1.12.3	The DMS Management System shall allow the DMS System User to log and report suspected system faults to the DMS System Maintainer.	4.12.3 The DMS System User needs to log and report suspected system faults to the DMS System Maintainer.
3.1.12.4	The DMS Management System shall detect suspected communications faults and report them to the DMS System User.	4.12.4 The DMS System User needs to detect suspected communications faults.
3.1.12.5	The DMS Management System shall allow the DMS System User to run diagnostics for suspected communications faults.	4.12.5 The DMS System User needs to run diagnostics for suspected communications faults.
3.1.12.6	The DMS Management System shall allow the DMS System User to log and report suspected communications faults to the DMS System Maintainer.	4.12.6 The DMS System User needs to log and report suspected communications faults to the DMS System Maintainer.

Requirements Document Reference Number	System Requirements Sample Statement	Need Statements (ConOps)
3.1.12.7	<p>The DMS Field Equipment shall display a user defined indication of the following conditions:</p> <ul style="list-style-type: none"> · Communications fault · [specify other faults] <p>[Specify the specific indicators to be used, e.g., *, 1, +, - at a specific position on the sign display]</p>	<p>4.12.7</p> <p>The DMS System Maintainer needs to know what is causing a DMS system fault by viewing the message display.</p>

APPENDIX C: SUGGESTED REQUIREMENTS VERIFICATION METHODS

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.1.1	The DMS Management System shall enforce access control of all users.	Demonstration
3.1.1.2	The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Users.	Demonstration
3.1.1.3	The DMS Management System shall allow the DMS System Manager to assign access control credentials to DMS System Maintainers.	Demonstration
3.1.1.4	The DMS Management System shall allow the DMS System Manager to select the DMS Field Equipment.	Demonstration
3.1.1.5	The DMS Management System shall allow the DMS System Manager to control the DMS Field Equipment.	Demonstration
3.1.1.6	The DMS Management System shall allow the DMS System Manager to control external devices attached to the DMS Controller.	Demonstration
3.1.1.7	The DMS Management System shall allow the DMS System Manager to access its logged data.	Demonstration
3.1.1.8	The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System User.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.1.9	The DMS Management System shall allow the DMS System User to select DMS Field Equipment.	Demonstration
3.1.1.10	The DMS Management System shall allow the DMS System User to control DMS Field Equipment.	Demonstration
3.1.1.11	The DMS Management System shall allow the DMS System User to control external devices.	Demonstration
3.1.1.11.1	The DMS Management System shall control external devices such as flashers or beacons when directed by the DMS System User. Note: Agency policy may dictate when flashers and/or beacons may be used (e.g., lane blockage only).	Demonstration
3.1.1.11.2	The DMS Management System shall allow the DMS System User to specify automatically including flashers or beacons based on message type.	Demonstration
3.1.1.12	The DMS Management System shall allow the DMS System Manager to grant access to the DMS Management System by the DMS System Maintainer.	Demonstration
3.1.1.13	The DMS Management System shall allow the DMS System Maintainer to select DMS Field Equipment.	Demonstration
3.1.1.14	The DMS Management System shall allow the DMS System Maintainer to control DMS Field Equipment.	Demonstration
3.1.1.15	The DMS Management System shall allow the DMS System Maintainer to control external devices.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.1.16	The DMS Management System shall allow the DMS System Maintainer to run system diagnostics and testing.	Demonstration
3.1.1.17	The DMS Management System shall provide access to the DMS System Maintainer to repair it.	Demonstration
3.1.1.18	The DMS Management System shall organize DMS System Users into groups.	Demonstration
3.1.1.18.1	Membership in the group shall be defined by the DMS System Manager.	Demonstration
3.1.1.18.1.1	The DMS Management System shall allow the DMS System Manager to specify named user groups and place those users in the group.	Demonstration
3.1.1.18.1.2	The DMS Management System shall allow the DMS System Manager to specify which signs will be shared with individual users or user groups.	Demonstration
3.1.1.18.1.3	The DMS Management System shall allow the DMS System Manager to specify which individual users or user groups can access the archived logged data.	Demonstration
3.1.1.18.2	The DMS Management System shall assign which signs are shared by individual users or groups of users.	Demonstration
3.1.1.18.3	Access to archived data shall be assigned by the DMS System Manager to users or groups.	Demonstration
3.1.1.19	The DMS Management System shall not allow archived data to be altered.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.2.1	The DMS Management System shall allow the DMS System Manager to configure the DMS Management System data logging parameters.	Demonstration
3.1.2.2	The DMS System Management System shall accommodate [specify number] users at different physically accessed terminals as configured by the DMS System Manager.	Demonstration
3.1.2.3	The DMS System Management System shall accommodate [specify types of] users as configured by the DMS System Manager.	Demonstration
3.1.2.4	The DMS System Management System shall arbitrate competing requests for access, including providing automatic timeouts, transfer of access, and other DMS Field Equipment user access issues as configured by the DMS System Manager. [Describe the desired operation, and choose the requirements relevant to the desired operation. Options: DMS Field Equipment ownership, last user control, first-come-first-served, etc.]	Demonstration
3.1.2.5.1	The DMS Management System shall allow the DMS System Manager to configure message priority for each DMS.	Demonstration
3.1.2.5.2	The DMS Management System shall allow the DMS System User to create schedules assigning messages to particular DMS according to a start time, duration and message priority.	Demonstration
3.1.2.5.3	The DMS Field Equipment shall display the message with the highest priority or the message with the latest start time if at the same priority as the message being displayed.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.2.5.4	The DMS Management System shall give the highest priority to messages being manually engaged by the DMS System User.	Demonstration
3.1.2.6.1	The DMS Management System shall determine the identity of the DMS Field Equipment based on a DMS System User request.	Demonstration
3.1.2.6.2	The DMS Management System shall determine the sign type (Blank-out Sign, Changeable Message Sign, or Variable Message Sign) based on a DMS System User request.	Demonstration
3.1.2.6.3	The DMS Management System shall determine the sign technology (mostly LED) based on a DMS System User request.	Demonstration
3.1.2.6.4	The DMS Management System shall determine the manufacturer based on a DMS System User request.	Demonstration
3.1.2.6.5	The DMS Management System shall determine the model and version number for both hardware and software elements based on a DMS System User request.	Demonstration
3.1.2.6.6	The DMS Management System shall tell the DMS System User if an entered message can be displayed on a given sign.	Demonstration
3.1.2.6.7	The DMS Management System shall limit the sign types available to the DMS System User based on a given message and different sign display capabilities.	Demonstration
3.1.2.6.8	The DMS Management System shall manage variations in a given message to be displayed on signs with different capabilities.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.2.6.9	The DMS Management System shall allow the DMS System User to define and edit the appearance of fonts (i.e., type, color and size) used to display messages on DMS Field Equipment throughout the DMS Management System.	Demonstration
3.1.2.6.10	The DMS Management System shall allow the DMS System User to define the appearance of graphics used to for display on DMS Field Equipment for later use.	Demonstration
3.1.2.6.11	The DMS Management System shall allow the DMS System User to edit vendor supplied graphics.	Demonstration
3.1.2.6.12	The DMS Management System shall allow import of graphics generated independently by the DMS System User.	Demonstration
3.1.2.6.13	The DMS Management System shall allow the DMS System User to manage existing graphics.	Demonstration
3.1.2.6.14	The DMS Management System shall allow the DMS System User to determine the graphics storage capabilities throughout the DMS Management System.	Demonstration
3.1.2.6.15	The DMS Management System shall assist the DMS System User in determining which graphics are compatible with each sign type.	Demonstration
3.1.2.6.16	The DMS Management System shall allow the DMS System User to configure when the DMS Field Equipment may automatically switch between brightness levels based on changing lighting conditions.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.2.6.17	The DMS Management System shall allow the DMS System User to configure the speed limit applicable to the location of the DMS Field Equipment. Note: this requirement is typically for portable DMS Field Equipment that act a speed warning signs.	Demonstration
3.1.2.6.18	The DMS Management System shall allow the DMS System User to configure the threshold when the fuel in a generator powering a DMS Field Equipment is considered low. Note: this requirement is typically only for portable DMS Field Equipment that use generators.	Demonstration
3.1.3.1	The DMS Management System shall allow the DMS System User to select which DMS Field Equipment to view the current message displayed on the sign face.	Demonstration
3.1.3.2	The DMS Management System shall allow the DMS System Manager to monitor the DMS Field Equipment control source (e.g., central system, DMS time-based scheduler, individual physically present at the DMS site).	Demonstration
3.1.3.3	The DMS Management System performance monitoring shall conform, at a minimum, to NEMA TS 4-2016.	Demonstration
3.1.4.1	The DMS Management System shall allow the DMS System User control of the DMS Field Equipment from both remote and local locations.	Demonstration
3.1.4.2	DMS Management System shall prevent DMS System Users from interfering with one another for simultaneous control of a DMS Field Equipment.	Demonstration
3.1.4.3	Controlling the DMS Field Equipment Sign Face	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.4.3.1	The DMS Management System User shall activate a stored message to be displayed on the sign face upon request of a DMS System User.	Demonstration
3.1.4.3.2	The DMS Management System shall allow the DMS System User to specify the duration for the display of the activated message including its relative priority in order to possibly override the currently displayed message.	Demonstration
3.1.4.3.3	The DMS Management System shall allow the DMS System User to prioritize messages.	Demonstration
3.1.4.3.4	The DMS Management System shall allow the DMS System User to create a message and modify its format and content.	Demonstration
3.1.4.3.4.1	The DMS Management System shall allow the DMS System User to uniquely identify a message.	Demonstration
3.1.4.3.4.2	The DMS Management System shall assist the DMS System User in ensuring that a message is complete by viewing it in WYSIWYG (What You See Is What You Get) format.	Demonstration
3.1.4.3.4.3	The DMS Management System shall allow the DMS System User to develop an approved word list including standardized abbreviations.	Demonstration
3.1.4.3.4.4	The DMS Management System shall recommend words and abbreviations from the approved word list to the DMS System User.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.4.3.4.5	The DMS Management System shall assist the DMS System User in ensuring that the message does not contain offensive language.	Demonstration
3.1.4.3.4.6	The DMS Management System shall assist the DMS System User in defining the exact contents of the message to be displayed on the sign face.	Demonstration
3.1.4.3.4.7	The DMS Management System shall provide the capability for the DMS System User to define if the display of a message activates beacons. [Specify if supported]	Demonstration
3.1.4.3.5	The DMS Management System shall store a newly created or modified message by the DMS System User in a library of messages.	Demonstration
3.1.4.3.6	The DMS Management System shall blank or remove any messages displayed on a sign upon request by the DMS System User.	Demonstration
3.1.4.3.7	The DMS Management System shall allow the DMS System User to schedule when messages are displayed on DMS Field Equipment. These are the stored messages that are displayed unless overridden by a manually activated message.	Demonstration
3.1.4.3.7.1	The DMS Management System shall allow the DMS System User to set a series of times when a stored message, including a blank message, will be activated.	Demonstration
3.1.4.3.8	The DMS Management System shall allow the DMS System User to set which message will be displayed when certain non-scheduled events occur such as loss of communications or power.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.4.3.9	The DMS Management System shall allow the DMS System User to directly control the sign brightness.	Demonstration
3.1.4.3.10	The DMS Management System shall allow the DMS System User to configure automated algorithms that can adjust brightness levels based on the ambient light levels.	Demonstration
3.1.5.1	The DMS Management System shall allow the DMS System User to control external devices through the auxiliary ports of the sign controller.	Demonstration
3.1.5.1.1	The DMS Management System shall allow the DMS System User to control High Occupancy Vehicle (HOV) Lane Gates attached to the DMS Field Equipment.	Demonstration
3.1.5.1.2	The DMS Management System shall allow the DMS System User to control Beacons attached to the DMS Field Equipment.	Demonstration
3.1.5.1.3	The DMS Management System shall allow the DMS System User to monitor any speed detectors attached to the DMS Field Equipment.	Demonstration
3.1.5.1.4	The DMS Field Equipment shall detect speed and display speed threshold limits with detected speed.	Demonstration
3.1.5.1.5	The DMS Management System shall allow the DMS System User to monitor and control environmental sensors attached to the DMS Field Equipment.	Demonstration
3.1.5.1.6	The DMS Field Equipment shall detect environmental conditions and display environmental conditions.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.5.1.7	The DMS Management System shall allow the DMS System User to control other external devices. [Specify other types of external devices]	Demonstration
3.1.6.1	The DMS Management System shall allow the DMS System Maintainer access to the DMS Management System log(s).	Demonstration
3.1.6.2	The DMS Management System shall allow the DMS System Maintainer to specify what DMS Management System events are logged.	Demonstration
3.1.6.3	The DMS Management System shall allow the DMS System Maintainer to specify, for each log, the log size and/or duration for the DMS Management System.	Demonstration
3.1.6.4	The DMS Management System shall allow the DMS System Maintainer to access and review a history (log) of the following diagnostic information [specify] and alarms [specify] for a period of [specify] days.	Demonstration
3.1.7.1	The DMS Management System operations shall be maintainable by the DMS System Maintainer.	Demonstration
3.1.7.1.1	The DMS Field Equipment shall be durable to support operations. [Specify description of what this means]	Inspection

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.7.1.2	The DMS Field Equipment shall conform to the environmental conditions specified in NEMA TS 4-2016. [Description needs to include conditions under which the equipment will be operated. Reference NEMA TS 4-2016. Does it need to withstand rain? Inundation? High-pressure hose-down? High wind? High (or low) temperatures? IPC67? IEC 60529? NEMA (Type R, Type X, etc.)? Ground cabinets versus signs.]	Test
3.1.7.1.3	The DMS Field Equipment shall be serviceable. [Specify how to access for maintenance, crane, bucket truck, requirements for maintainer to be protected by elements]	Inspection
3.1.7.1.4	The DMS Field Equipment shall have readily available replacement parts for the life of the system [specified period of time].	Inspection/Analysis
3.1.7.1.5	The DMS Management System shall allow the DMS System Maintainer to remotely test DMS Field Equipment via IP protocol.	Demonstration
3.1.7.1.6	The DMS Management System shall provide diagnostic information via NTCIP 1203 protocols that the DMS Field Equipment collects about itself, defined in Section 9 of NEMA TS4-2016 at the direction of the DMS System Maintainer.	Demonstration
3.1.7.1.7	The DMS Management System shall allow the DMS System Maintainer to enable or disable the periodic exercise of pixels (activated either manually or via a schedule) to ensure they are performing reliably.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.7.1.8	<p>The DMS Management System shall allow the DMS System Maintainer to troubleshoot the following failure conditions to trigger alarms visible to the DMS System User. [It is only necessary for the DMS Field Equipment to support information about capabilities actually present in the DMS Field Equipment. For example, a matrix sign does not provide the drum-rotor status items, and a drum sign does not provide the pixel status items.]</p> <ul style="list-style-type: none"> a. Power Sources b. Power Supplies c. Lamps d. Pixels e. Light Level Sensors f. Sign Controller g. Temperature Sensors h. Humidity i. Internal Environmental Systems (Fans and/or Heaters) j. Drum Sign Rotors k. External Device Errors 	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.7.1.9	The DMS Management System shall allow the DMS System Maintainer to obtain detailed information about a reported warning or error condition within a subsystem (detailed-level diagnostics).	Demonstration
3.1.7.1.10	The DMS Management System shall allow the DMS System User to monitor errors associated with defining or activating a particular message.	Demonstration
3.1.7.1.11	The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the sign housing. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.12	The DMS Management System shall allow the DMS System Maintainer to monitor the temperature within the control cabinet. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.13	The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the sign housing. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.14	The DMS Management System shall allow the DMS System Maintainer to monitor the humidity within the control cabinet. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.15	The DMS Management System shall allow the DMS System Maintainer to monitor for any errors related to the attached external devices to the DMS Field Equipment. [Specify external devices.]	Demonstration
3.1.7.1.16	The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the sign housing.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.7.1.17	The DMS Management System shall allow the DMS System Maintainer to monitor the status (opened, closed) of the doors to the control cabinet.	Demonstration
3.1.7.1.18	The DMS Management System shall allow the DMS System Maintainer to monitor whether the DMS Field Equipment controller software is operating properly through the use of watchdog timers. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.19	The DMS Management System shall allow the DMS System Maintainer to monitor the automatic display of a blank message when diagnostics detect that too many pixels are non-operational or that the light outputs are faulty. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.20	The DMS Management System shall allow the DMS System Maintainer to monitor the source of power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.21	The DMS Management System shall allow the DMS System Maintainer to monitor the voltage level of the power that is being used to operate the DMS sign face. [Reference NEMA TS 4-2016]	Demonstration
3.1.7.1.22	The DMS Management System shall allow the DMS System Maintainer to monitor the level of fuel within the tank of a generator that is being used to operate the DMS Field Equipment.	Demonstration
3.1.7.1.23	The DMS Management System shall allow the DMS System Maintainer to monitor the engine RPM when a generator is being used to operate the DMS Field Equipment.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.7.1.24	The DMS Management System shall allow the DMS System Maintainer to run complete diagnostics and store the results for review.	Demonstration
3.1.7.2	The DMS Field Equipment connected with a DMS Management System shall be uniquely identifiable.	Inspection
3.1.7.3	The DMS Field Equipment connected with a DMS Management System shall be locatable.	Inspection
3.1.7.4	The DMS Management System shall be designed by the DMS System Designer to provide the DMS System Maintainer with safe access to DMS Field Equipment locations for maintenance.	Inspection
3.1.7.5	The DMS Management System shall provide the DMS System Maintainer with the ability to remotely update DMS Field Equipment controller software and firmware.	Demonstration
3.1.8.1	The DMS Management System shall provide the capability for the Traveling Public to read messages on the sign face in reduced visibility conditions. Note: Reference the NEMA TS 4 viewing cone.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.8.2	The DMS Management System shall allow the DMS System User to store the following information in the DMS Management System: * DMS Field Equipment Owner * DMS Field Equipment Unique Identifier * DMS Field Equipment Text Description [Specify number of characters of text] * DMS Field Equipment Location (physical, part of a corridor) * DMS Field Equipment Type (Blank Out Sign (BOS), Changeable Message Sign (CMS), or Variable Message Sign (VMS) as defined in NTCIP 1203) * DMS Field Equipment Technology (Fiber Optic, Light Emitting Diode (LED), Flip disk or shutter, Lamp Matrix, or Drum) * DMS Field Equipment Display Matrix Configuration (No Matrix (i.e., not a pixel matrix sign), Matrix Sign, Full Matrix, Line Matrix or Character Matrix) * DMS Field Equipment Fixed versus Portable * [Specify other DMS Field Equipment characteristics]	Inspection/Analysis
3.1.9.1	The DMS Field Equipment shall be placed by the DMS System Designer at locations that provide travelers with actionable information to support the agency's operational objectives.	Inspection/Analysis
3.1.9.2	The DMS Field Equipment sign placement shall conform, at a minimum, to NEMA TS 4-2016.	Inspection/Analysis
3.1.9.3	The DMS Field Equipment siting by the DMS System Designer shall take into account maintenance needs. [specify]	Inspection/Analysis
3.1.10.1	The DMS Management System shall interface with DMS Field Equipment from different manufacturers within the same system in accordance with NTCIP 1203v03 or later at a minimum. [specify NTCIP 1203 mandatory requirements and what optional requirements needed, and what DMS Field Equipment are being used]	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.10.2	The DMS Management System shall support the replacement by the DMS System Maintainer of existing DMS Field Equipment with DMS Field Equipment from different manufacturers. [specify existing system interface in accordance with NTCIP 1203].	Demonstration
3.1.10.3	The DMS Management System shall be designed to support the integration of new DMS Field Equipment with the existing DMS Management System [specify existing system interface in accordance with NTCIP 1203].	Demonstration
3.1.10.4	The DMS Management System shall be designed to accommodate existing communications interfaces [specify].	Demonstration
3.1.10.5	The DMS Management System shall be designed based on agency IT policies [specify].	Analysis
3.1.11.1	The DMS Management System shall accommodate [specify] users at any one time.	Demonstration
3.1.11.2	The DMS Management System shall accommodate a minimum of [specify] signs.	Demonstration
3.1.11.3	The DMS Management System shall provide confirmation that a new message is placed on the DMS Field Equipment within [specify] seconds.	Demonstration
3.1.12.1	The DMS Management System shall detect suspected system faults and report them to the DMS System User.	Demonstration
3.1.12.2	The DMS Management System shall allow the DMS System User to run diagnostics for suspected system faults.	Demonstration

Requirements Document Reference Number	System Requirements Sample Statements	Verification Method
3.1.12.3	The DMS Management System shall allow the DMS System User to log and report suspected system faults to the DMS System Maintainer.	Demonstration
3.1.12.4	The DMS Management System shall detect suspected communications faults and report them to the DMS System User.	Demonstration
3.1.12.5	The DMS Management System shall allow the DMS System User to run diagnostics for suspected communications faults.	Demonstration
3.1.12.6	The DMS Management System shall allow the DMS System User to log and report suspected communications faults to the DMS System Maintainer.	Demonstration
3.1.12.7	<p>The DMS Field Equipment shall display a user defined indication of the following conditions:</p> <ul style="list-style-type: none"> · Communications fault · [specify other faults] <p>[Specify the specific indicators to be used, e.g., *, 1, +, - at a specific position on the sign display]</p>	Demonstration

APPENDIX D: VERIFICATION PLAN SAMPLE CASES

Case Number	Case Name	Case Description	High-Level Requirement Number	High-Level Requirement
1	Access Control	<p>This verification case will test the access control requirements of the DMS Management System. Requirements include the DMS System Manager assigning access control to the other user roles as well as the DMS Management System allowing the various users to monitor and change messages on DMS Field Equipment. The requirements also cover the DMS System Maintainer running diagnostics and testing. The DMS System user access control capabilities will be verified in accordance with their corresponding requirements. No additional hardware or software besides the DMS Management System itself is envisioned to accomplish this verification test.</p>	3.1.1	Access Control
2	DMS Management System Configuration	<p>This verification case will test the system configuration requirements of the DMS Management System. Requirements include the DMS Management System allowing DMS System User configuration of the DMS Management System as well as arbitration and configuration of the parameters for data logging and number of users. In addition, requirements also include managing DMS message priority and scheduling and general DMS Field Equipment configuration.</p>	3.1.2	Configure DMS Management System

Case Number	Case Name	Case Description	High-Level Requirement Number	High-Level Requirement
3	DMS Field Equipment Monitoring	This verification case will test the DMS Field Equipment monitoring requirements of the DMS Management System. Requirements include the DMS Management System allowing the DMS System User to select which DMS Field Equipment to view its message being displayed as well as allowing the DMS System Manager to monitor the DMS Field Equipment control source and performance.	3.1.3	Monitoring DMS Field Equipment
4	DMS Field Equipment Control	This verification case will test the DMS Field Equipment control requirements of the DMS Management System. Requirements include the DMS Management System allowing the DMS System User to control what message is displayed on the sign face from both remote and local locations. The requirements include activation of a stored message, message override and scheduling messages.	3.1.4	Controlling DMS Field Equipment
5	External Device Control	This verification case will test the External Device control requirements of the DMS Management System. Requirements include the DMS Management System allowing the DMS System User to control External Devices independently from the message being displayed on the sign.	3.1.5	Controlling External Devices
6	System Logging	This verification case will test the system logging requirements of the DMS Management System. Requirements include the DMS Management System allowing the DMS System Maintainer to specify what is logged by the DMS Management System as well as access to the log.	3.1.6	DMS Management System Logging

Case Number	Case Name	Case Description	High-Level Requirement Number	High-Level Requirement
7	DMS Management System Maintenance	This verification case will test the DMS Management System maintenance requirements. Requirements include how the DMS System Maintainer will maintain DMS System operations, the durability of the DMS Management System equipment, DMS Field Equipment that complies with environmental standards, the serviceability of the DMS Field Equipment, availability of serviceable parts, ability of the DMS System Maintainer to remotely test devices, ability of the DMS System Maintainer to access DMS Field Equipment diagnostic information, ability of the DMS System Maintainer to set DMS Management System failure conditions that trigger alarms visible to the DMS System User, and allow the DMS System Maintainer to remotely update software and firmware.	3.1.7	DMS Management System Maintenance
8	DMS Field Equipment Characteristics	This verification case will test the DMS Field Equipment characteristics requirements of the DMS Management System. Requirements include the DMS Management System and DMS Field Equipment capabilities and characteristic information based in NEMA TS 4 and NTCIP 1203 that is stored within the DMS Management System.	3.1.8	DMS Field Equipment Characteristics

Case Number	Case Name	Case Description	High-Level Requirement Number	High-Level Requirement
9	DMS Field Equipment Siting	This verification case will test the DMS Field Equipment siting and viewing requirements of the DMS Management System. Requirements include how the DMS System Designer located DMS Field Equipment to provide travelers with actionable information based on the sign's location. In addition, requirements include taking into account DMS Field Equipment operations and maintenance activities.	3.1.9	DMS Field Equipment Siting
10	Interfaces	This verification case will test the DMS Management System constraints and external interface requirements in compliance with NTCIP 1203. Requirements include the interoperability and interchangeability of DMS Field Equipment with different interface standards within the DMS Management System, accommodating existing communications interfaces, and accommodating agency IT policies.	3.1.10	Interfaces
11	DMS Management System Performance	This verification case will test the DMS Management System performance requirements. Requirements include the accommodation of multiple DMS System Users on the DMS Management System at one time, accommodation of simultaneous DMS System Users controlling DMS Field Equipment and accommodation of multiple users accessing the DMS Management System software at one time.	3.1.11	DMS Management System Performance

Case Number	Case Name	Case Description	High-Level Requirement Number	High-Level Requirement
12	DMS Management System Fault Management	This verification case will test the DMS Management System handling of faults. Requirements include detection and reporting of suspected system faults, running system diagnostics and detection and reporting of suspected communications faults.	3.1.12	Fault Management

APPENDIX E: VALIDATION PLAN SAMPLE CASES

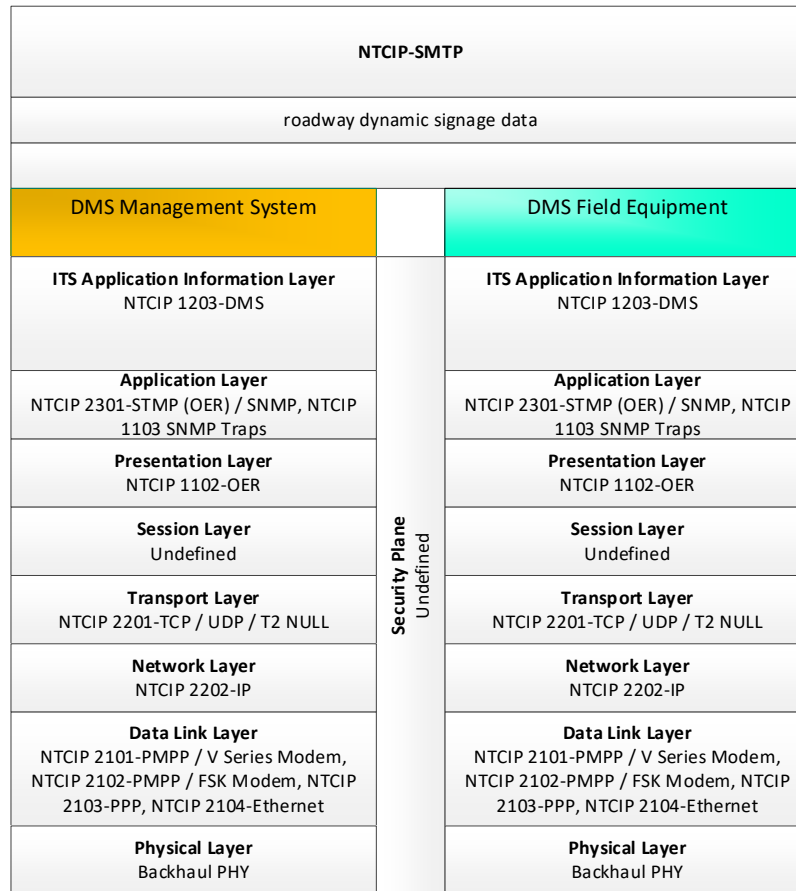
Case Number	Case Name	Case Description	Need Number	Need Category
1	Control Access to the DMS Management System	This validation case will validate the user needs associated with controlling user access to the DMS Management System in accordance with the Configure DMS Management System operational scenario. The capabilities of the DMS System Manager accessing the DMS Management System in order to provide the various DMS System user roles with their proper DMS Management System access will be validated. The DMS Management System user access capabilities will be validated in accordance with their corresponding user needs. It is expected that no additional hardware or software besides the DMS Management System and the DMS Field Equipment is envisioned to accomplish this validation case.	4.1	Control Access to DMS Management System

Case Number	Case Name	Case Description	Need Number	Need Category
2	Configure DMS Management System	This validation case will validate the user needs associated with configuring the DMS Management System in accordance with the Configure DMS Management System operational scenario. The DMS System Manager's user needs of configuring user permissions as well as allowing a set number of users with DMS Management System access with arbitration of user requests for access will be validated. In addition, validation of the ability of the DMS System User to enter and store information about the DMS Management System and DMS Field Equipment characteristics will be covered by this validation case. Validation of the ability of the DMS Field Equipment to provide pertinent actionable messages to the traveling public as well as the needs of the DMS System Maintainer to safely maintain the DMS Field Equipment will be covered by this validation case.	4.2	Configure DMS Management System
			4.8	DMS Field Equipment Characteristics
			4.9	DMS Field Equipment Siting
3	Monitoring DMS	This validation case will validate the user needs associated with DMS Field Equipment monitoring in accordance with the DMS Field Equipment Monitoring operational scenario. The DMS System User's needs of selecting DMS Field Equipment, request for control, control of the DMS Field Equipment to be viewed, and reassignment of DMS Field Equipment control to a different user will be validated.	4.3	Monitoring DMS
			4.10	Interfaces
			4.11	DMS Management System Performance

Case Number	Case Name	Case Description	Need Number	Need Category
4	Controlling DMS	This validation case will validate the user needs associated with controlling the DMS Field Equipment in accordance with the Controlling DMS Field Equipment operational scenario. The DMS System User's capabilities to create, select and have various sign messages displayed on the DMS Field Equipment will be validated.	4.4	Controlling DMS
			4.10	Interfaces
			4.11	DMS Management System Performance
5	Controlling External Devices	This validation case will validate the user needs associated with controlling External Devices in accordance with the Controlling External Devices operational scenario. The DMS System User's capabilities to turn on and off External Devices independently of the message being displayed on the DMS Field Equipment will be validated.	4.5	Controlling External Devices
			4.10	Interfaces
6	DMS Management System Logging	This validation case will validate the user needs associated with DMS Management System logging in accordance with the DMS Management System Logging operational scenario. The ability of the DMS System User to specify, access and review DMS Management System log(s) will be validated.	4.6	DMS Management System Logging

Case Number	Case Name	Case Description	Need Number	Need Category
7	DMS Management System Maintenance and Failure Management	This validation case will validate the user needs associated with DMS Management System maintenance in accordance with the DMS Management System Maintenance and Failure Management operational scenario. This validation case has two primary users: the DMS System Maintainer and the DMS System User. The DMS System Maintainer needs to validate that the DMS Management System allows for maintenance needs to service, test, diagnose and fix the DMS Management System and DMS Field Equipment. The DMS System User needs to validate that the DMS Management System has durable and reliable equipment.	4.7	DMS Management System Maintenance
			4.12	Fault Management

APPENDIX F: STANDARDIZED COMMUNICATIONS PROTOCOL STACK INTERFACE DIAGRAMS



* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 9. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Management System → roadway dynamic signage data → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
roadway dynamic signage status		
DMS Field Equipment		DMS Management System
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 10. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Field Equipment → roadway dynamic signage status → DMS Management System based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment status		
DMS Field Equipment		DMS Management System
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 11. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Field Equipment → field equipment status → DMS Management System based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment configuration settings		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 12. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Management System → field equipment configuration settings → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment commands		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 13. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Management System → field equipment commands → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment software install/upgrade		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 14. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Management System → field equipment software install/upgrade → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
roadway dynamic signage data		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 15. Communications Protocol Standards for the NTCIP-SMTP Triple of Field Support Computer → roadway dynamic signage data → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
roadway dynamic signage status		
DMS Field Equipment		Field Support Computer
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 16. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Field Equipment → roadway dynamic signage status → Field Support Computer based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment status		
DMS Field Equipment		Field Support Computer
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 17. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Field Equipment → field equipment status → Field Support Computer based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment configuration settings		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 18. Communications Protocol Standards for the NTCIP-SMTP Triple of Field Support Computer → field equipment configuration settings → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment commands		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 19. Communications Protocol Standards for the NTCIP-SMTP Triple of Field Support Computer → field equipment commands → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SMTP		
field equipment software install/upgrade		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps		Application Layer NTCIP 2301-STMP (OER) / SNMP, NTCIP 1103 SNMP Traps
Presentation Layer NTCIP 1102-OER		Presentation Layer NTCIP 1102-OER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 20. Communications Protocol Standards for the NTCIP-SMTP Triple of Field Support Computer → field equipment software install/upgrade → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
roadway dynamic signage data		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 21. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Management System → roadway dynamic signage data → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
roadway dynamic signage status		
DMS Field Equipment		DMS Management System
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 22. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Field Equipment → roadway dynamic signage status → DMS Management System based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment status		
DMS Field Equipment		DMS Management System
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 23. Communications Protocol Standards for the NTCIP-SMTP Triple of DMS Field Equipment → field equipment status → DMS Management System based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment commands		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 24. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Management System → field equipment commands → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment configuration settings		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 25. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Management System → field equipment configuration settings → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment software install/upgrade		
DMS Management System		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 26. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Management System → field equipment software install/upgrade → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
roadway dynamic signage data		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 27. Communications Protocol Standards for the NTCIP-SNMP Triple of Field Support Computer → roadway dynamic signage data → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
roadway dynamic signage status		
DMS Field Equipment		Field Support Computer
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 28. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Field Equipment → roadway dynamic signage status → Field Support Computer based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment status		
DMS Field Equipment		Field Support Computer
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 29. Communications Protocol Standards for the NTCIP-SNMP Triple of DMS Field Equipment → field equipment status → Field Support Computer based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment commands		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 30. Communications Protocol Standards for the NTCIP-SNMP Triple of Field Support Computer → field equipment commands → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment configuration settings		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 31. Communications Protocol Standards for the NTCIP-SNMP Triple of Field Support Computer → field equipment configuration settings → DMS Field Equipment based on the DMS System Project Architecture Diagram

NTCIP-SNMP		
field equipment software install/upgrade		
Field Support Computer		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane Undefined	ITS Application Information Layer NTCIP 1203-DMS
Application Layer IETF SNMP		Application Layer IETF SNMP
Presentation Layer ISO ASN.1 BER		Presentation Layer ISO ASN.1 BER
Session Layer Undefined		Session Layer Undefined
Transport Layer NTCIP 2201-TCP / UDP / T2 NULL		Transport Layer NTCIP 2201-TCP / UDP / T2 NULL
Network Layer NTCIP 2202-IP		Network Layer NTCIP 2202-IP
Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet		Data Link Layer NTCIP 2101-PMPP / V Series Modem, NTCIP 2102-PMPP / FSK Modem, NTCIP 2103-PPP, NTCIP 2104-Ethernet
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as I.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 32. Communications Protocol Standards for the NTCIP-SNMP Triple of Field Support Computer → field equipment software install/upgrade → DMS Field Equipment based on the DMS System Project Architecture Diagram

RSE Field to Field		
roadway equipment coordination		
DMS Field Equipment		External Devices
ITS Application Information Layer NTCIP 1203-DMS	Security Plane IEEE 1609.2	ITS Application Information Layer NTCIP 1203-DMS
Application Layer Undefined		Application Layer Undefined
Presentation Layer ISO ASN.1 UPER	Security Plane IETF DTLS, IETF TLS	Presentation Layer ISO ASN.1 UPER
Session Layer IETF DTLS, IETF TLS		Session Layer IETF DTLS, IETF TLS
Transport Layer IETF UDP, IETF TCP		Transport Layer IETF UDP, IETF TCP
Network Layer IETF IPv6		Network Layer IETF IPv6
Data Link Layer LLC and MAC compatible with Physical and Network		Data Link Layer LLC and MAC compatible with Physical and Network
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 33. Communications Protocol Standards for the RSE Field to Field Triple of DMS Field Equipment → roadway equipment coordination → External Devices based on the DMS System Project Architecture Diagram

RSE Field to Field		
roadway equipment coordination		
External Devices		DMS Field Equipment
ITS Application Information Layer NTCIP 1203-DMS	Security Plane IEEE 1609.2	ITS Application Information Layer NTCIP 1203-DMS
Application Layer Undefined		Application Layer Undefined
Presentation Layer ISO ASN.1 UPER	Security Plane IETF DTLS, IETF TLS	Presentation Layer ISO ASN.1 UPER
Session Layer IETF DTLS, IETF TLS		Session Layer IETF DTLS, IETF TLS
Transport Layer IETF UDP, IETF TCP		Transport Layer IETF UDP, IETF TCP
Network Layer IETF IPv6		Network Layer IETF IPv6
Data Link Layer LLC and MAC compatible with Physical and Network		Data Link Layer LLC and MAC compatible with Physical and Network
Physical Layer Backhaul PHY		Physical Layer Backhaul PHY

* Mechanism for transmitting raw bits over a physical link between the center and field, such as 1.430/431, SONET/SDH, IEEE 802.3, IEEE 802.11 or any other viable physical layer specification or standard.

Figure 34. Communications Protocol Standards for the RSE Field to Field Triple of External Devices → roadway equipment coordination → DMS Field Equipment based on the DMS System Project Architecture Diagram

APPENDIX G: ACKNOWLEDGEMENTS

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