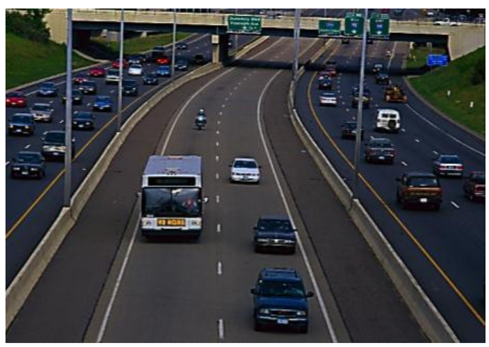
DEPARTMENT OF TRANSPORTATION

Systems Engineering Analysis for Freeway Traffic Management

Concept of Operations



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Introduction

This document presents a ***Concept of Operations*** *(ConOps)* for Freeway Traffic Management. The emphasis of this document is on defining the use of intelligent transportation systems (ITS) tools to manage traffic on the Minnesota Department of Transportation (MnDOT) operated freeways. More specifically, 'who' uses the tools, 'why' are the tools used, and 'how' are the tools used. Examples of ITS 'Tools' include Dynamic Message Signs (DMS), Video (e.g. closed circuit television cameras), and Advanced Traffic Management System (ATMS).

Freeway traffic management is typically defined as a combination of traffic control strategies (e.g. metering the rates of vehicle on-ramps and reversible lanes) and traveler information strategies (e.g. en-route information sharing through DMS, personal communications using computers, smartphones or other mobile devices, or mass media dissemination.) Together, the combination of informing travelers of the current situation and controlling the traffic using physical controllers can effectively manage the traffic in metropolitan areas where demand is nearing the level of capacity.

MnDOT has managed freeway traffic in the metropolitan areas of Minneapolis and St. Paul for decades, using tools such as ramp meters and dynamic message signs. Freeway traffic management also occurs in other metropolitan areas throughout the state, and with traffic technologies expanding in deployment, freeway traffic management will most likely continue to expand throughout the state of Minnesota. As operations of connected and automated vehicles (CAVs) expand, several data exchanges between freeway traffic management and CAVs are anticipated, and these are presented in this document. This document describes the current strategies and tools for freeway traffic management, with the intention of supporting efforts to continue to expand freeway traffic management to new areas of the state.

Intended Use of this Document

The intended uses of this ConOps are:

- To guide future ITS deployments on freeways throughout Minnesota; and
- To be a resource for the operations, maintenance, expansion and enhancements to existing ITS tools used today for freeway traffic management.

To accomplish these uses, the ConOps first introduces the needs for effective traffic management. The ConOps then introduces a number of ITS Tools that are used to satisfy the traffic management needs. Each tool is then addressed in detail, describing 'who' uses the tool, 'why' the tool is used, and 'how' the tool is used.

Consider the following example:

Deployment of freeway travel times on DMS is a popular use of an ITS Tool to address the need travelers have for congestion or travel time notification. A common question asked at ITS conferences after a presentation on DMS travel time displays is, "How much did it cost your agency to implement travel times on DMS"? Often, the incremental step a metropolitan area (such as the Twin Cities) took to achieve travel times on existing (or new) DMS was relatively small and inexpensive. However, the true answer to this question is actually much more complex:

- There is the need for detectors located and spaced appropriately, recording data frequently enough, and communicating the data in real-time to a central location;
- There is the need for automated algorithms to access the detector data, calculate travel times and determine the appropriate message for each DMS;
- There is the need for operating procedures that allow for automated message generation for the DMS, and to prioritize these messages with manually entered messages; and
- Finally, there is the need for DMS located in meaningful locations such that the travel time displays are effective for the travelers.

Similarly, if a metro area wished to deploy ramp meters, there is the need for appropriately located detectors, the need for a ramp meter algorithm, the need for a software system to operate the ramp meter algorithm to process detector data, the need for communication to the ramp meters, and the need for the ramp meter devices.

What these examples illustrate is that each tool (for example: traffic detection) has multiple potential uses for multiple applications (in this example traffic detection is used for both ramp metering and travel times), and therefore the requirements must reflect these, so they can be considered during the design phase. What this also illustrates is that each use of an ITS Tool (e.g. travel times on DMS) may involve multiple other ITS Tools.

The ultimate success of this document will be if future deployments of ITS Tools in Minnesota (new deployments or enhancements) use this document to consider all the likely uses and users of ITS Tools during the design and development phase. Ideally this will optimize the value and efficiency of ITS Tool deployment.

Current Environment

The Freeway Network

The MnDOT statewide freeway network is defined as limited access roads (without signalized intersections) operating any configuration ranging from two lanes per direction to five lanes per direction. The Minneapolis-St. Paul Metro Area (Twin Cities) operates the most complex network of freeways in the state. Two major Interstate highways (I-35 and I-94) converge in the Twin Cities, I-35 splits in to I-35W and I-35E as it passes through Minneapolis and St. Paul respectively, rejoining later as I-35. I-94 passes through Minneapolis and St. Paul, and splits in to two loop roads (I-694 and I-494) as well as a spur road (I-394). In addition, other freeways contribute to the overall network. In summary, the Twin Cities freeway network is used by through traffic heading North/South or East/West, as well as local commuters, leisure travelers, and commercial vehicles.

Rural Minnesota is served by three major Interstates (I-35, I-94, and I-90), as well as other limited access freeways. Some cities (including Duluth, St. Cloud, Rochester, and Moorhead) experience the freeway passing through (or nearby) the city. Otherwise, the majority of freeway travel in the Greater Minnesota is rural freeway travel. Figure 1 depicts the Minnesota Freeway System.

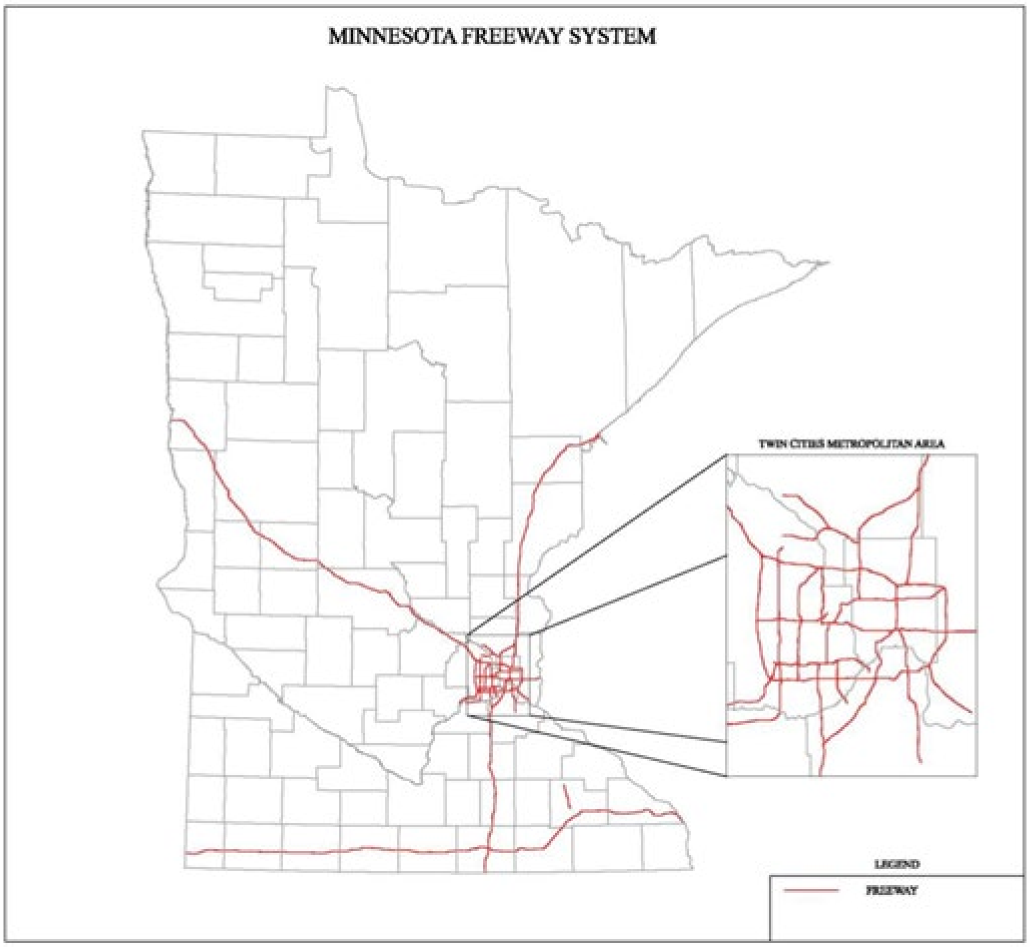

Figure 1. Minnesota Freeway System

Current Traffic Management

Under the current conditions, traffic management actions are most often performed during peak travel hours in the metro areas, and during inclement weather or difficult driving conditions statewide. Traffic management includes restricting vehicle access, informing travelers about conditions, providing alternate routes, and responding to incidents.

Intelligent Transportation Systems

MnDOT has operated ITS since the 1970's. The current use of ITS Tools ranges from very dense coverage of ITS systems in the Twin Cities, to moderate density of coverage in smaller metropolitan areas, to limited ITS Tools in the rural portions of the state freeway network.

MnDOT has a statewide ITS architecture, updated in 2018. The ITS architecture provides a roadmap for how the ITS systems and subsystems interface with each other.

MnDOT ITS Design Manual includes best practices, sample design documents, and captures the experiences and lessons learned from designing ITS in Minnesota as a resource for other deployments.

CAV Infrastructure Systems and CAVs

CAV Infrastructure Systems and CAVs support connected and automated vehicle operations. They are external systems that include both CAV infrastructure (systems operated by MnDOT) and CAVs (vehicles and on-board units in the vehicles). The CAV Infrastructure Systems communicate with on-board units within CAVs. The vehicles and on-board applications communicate with CAV Infrastructure Systems and other CAVs. Freeway traffic management may communicate data with CAV Infrastructure Systems.

MnDOT may deploy CAV Infrastructure Systems that communicate with CAVs, either through roadside units (RSUs), dedicated short-range communications (DSRC), wide area communications (such as cellular), or cloud-based communications. CAV Infrastructure Systems may broadcast messages to CAVs and acquire data from freeway traffic management and CAVs. The current traffic management system identified above may likely be the host/backbone of future CAV Infrastructure Systems, similar to the way the freeway backbone was expanded to host many functions as they evolve over time.

Users

For purposes of this document, stakeholders are defined as any individual, group of individuals, or agency that has a need for traffic management, or the actions related to traffic management. There are essentially two classifications of stakeholders:

1. **Primary Stakeholders** are those stakeholders that MnDOT addresses directly through traffic management. The primary stakeholders include:
    - Commuters to the metro areas;
    - Commercial vehicle operators traveling within or through Minnesota;
    - Leisure travelers within Minnesota;
    - Other state agencies; and
    - Other public sector transportation agencies (e.g. county, city, neighboring states) that benefit from traffic management.

2. **Secondary Stakeholders** are those stakeholders that have needs and benefit from the traffic management actions of MnDOT. However, these stakeholders are typically not the primary purpose for performing specific traffic management actions. Although they are secondary benefactors, their needs are still respected and addressed to the extent possible when designing ITS systems. Secondary Stakeholders include:
    - Information service providers (e.g. private media) that will use outputs of MnDOT systems to provide travel information; and
    - Researchers (public and private) that use traffic management data and information to research many aspects of transportation or the use of technologies.

Challenges and Needs

The challenges that face travelers and operators on freeways have been assessed and a set of problem statements have been prepared based on the input received from MnDOT. These problem statements, and the related needs, are summarized in Table 1.

Table 1. Freeway Traffic Management Needs

Problem	Needs (As a Result of the Problem)
Incidents and events significantly reduce freeway capacity and cause operational problems.	**Need 1: Incident/event verification** There is a need to verify the existence and impacts of incidents and events in real-time.
Heavy traffic volumes can create freeway Levels of Service that impede traffic flow and limit capacity.	**Need 2: Traffic and transportation infrastructure monitoring** There is a need to monitor traffic volumes, congestion levels, and transportation infrastructure in-real time.
Current and future weather conditions (primarily precipitation) and the resulting driving conditions impact traffic flow and the likelihood of incidents.	**Need 3: Weather and driving condition monitoring** There is a need to understand and monitor the current and impending weather conditions in real-time.
Travelers unaware of congestion or delays miss opportunities to divert to alternate routes and encounter delays.	**Need 4: Real-time travel time/congestion notification** There is a need to inform travelers en-route and pre-trip of travel times and congestion.
Travelers unaware of incidents, isolated inclement weather conditions (e.g. spots of black ice, flooding, drifting snow, fog) encounter unexpected stopped traffic and delays without the option to divert or enter the conditions at unsafe speeds.	**Need 5: Real-time unplanned event notification** There is a need to inform travelers en-route and pre-trip of active unplanned events (e.g. crashes, unusual driving conditions, Amber Alerts, special events, weather condition alerts).
Construction, maintenance, or special planned events activities can cause delays to travelers.	**Need 6: Real-time planned event notification** There is a need to alert travelers en-route and pre-trip of planned events (e.g. special events, roadwork)
Numerous factors must be considered when formulating traffic management responses to operational problems.	**Need 7: Freeway operational analysis** There is a need for short-term analysis of multiple data sources and long-term performance measurement analyses.
Traffic lane changes (or lack of lane changes) at some static locations (e.g. tunnels) and near active incidents/congestion creates unsafe conditions and impedes traffic flow.	**Need 8: Individual lane control** There is a need to alert travelers en-route of the status (e.g. open, closed, speed limit) of individual lanes on the freeway.
Traffic platoons entering freeways at or near capacity can create significant bottlenecks, delays and contribute to crashes.	**Need 9: Zonal or isolated freeway access control** There is a need to control access to freeways.
Numerous factors must be considered when planning traffic management adjustments and improvements to operational problems as well as programs and planning projects.	**Need 10: Freeway data storage, archive and access** There is a need to store, archive, and share freeway traffic data in accessible forms.
Many incidents and events are not automatically detected and reported but are known by some member of the operations team.	**Need 11: Manual Event Reporting** There is a need for manual incident and event reporting.

Problem	Needs (As a Result of the Problem)
There are times when vehicles must be restricted from specific lanes in order to maintain desired flows.	**Need 12: Lane access management** There is a need to restrict or allow vehicles in specific lanes in order to maintain desired traffic flows.
Traffic management devices in the field must be controlled by operators without requiring operators to be local to the device.	**Need 13: Manual device control** There is a need to manually control freeway management devices remotely.
Operators are not available to perform all device control.	**Need 14: Automated device control** There is a need to control freeway management devices without operator intervention.
Operators having to manually determine all traffic management strategies can cause delay and inconsistencies in providing real-time traveler information.	**Need 15: Automated algorithm execution** There is a need to automatically compute travel times, activate ramp meters, and compute meter rates.
Travelers unaware of unsafe roads due to weather/traffic conditions can create unsafe driving situations.	**Need 16: Automated/manual road closure** There is a need to close a road due to unsafe weather/traffic conditions.
Inconsistent information can impede incident response and congestion management.	**Need 17: Center-to-Center communications** There is a need for voice, data, and video sharing between public agencies.
Operators unaware of the location of response vehicles can cause delays. Operators unaware of pavement conditions can cause delays or inefficiencies when treating roadways.	**Need 18: Vehicle Tracking** There is a need for tracking the geographic location of vehicles and pavement conditions.
Manual information sharing between public agencies can delay response and information dissemination	**Need 19: Inter-agency incident information sharing** There is a need to share event information in real-time between public agencies.

Operational Concept

MnDOT manages the traffic flowing on freeways throughout the state of Minnesota to promote mobility and safety. Freeways are defined (for the purposes of this document) as all MnDOT-maintained roads that are accessed controlled and do not include at-grade intersections.

Traffic Management Actions

Freeway traffic management is accomplished by a series of actions; these actions are performed by MnDOT staff as well as public (city and county) and private partners. The actions include:

- Observation and detection;
- Data processing and response formulation;
- Information sharing (to other agencies and the traveling public); and
- Traffic control.

Figure 2 illustrates the freeway traffic management actions.

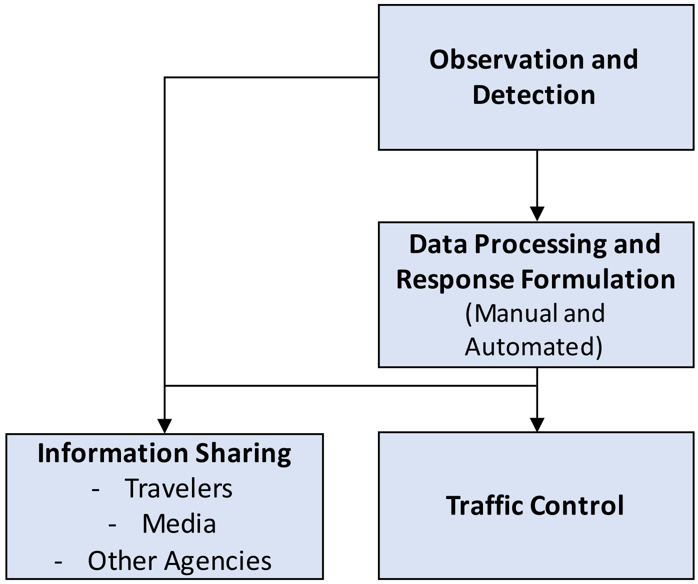

Figure 2. High Level Summary of Freeway Traffic Management Actions

ITS Tools that Support Traffic Management Actions

ITS are technology systems, devices, and applications that work together as 'Tools' to support the actions of freeway traffic management. Each ITS Tool supports one or more of the actions performed for traffic management. Examples of ITS 'Tools' include DMS, video, and ramp meters.

Figure 3 illustrates the 'Tools' that support each of the four traffic management actions.

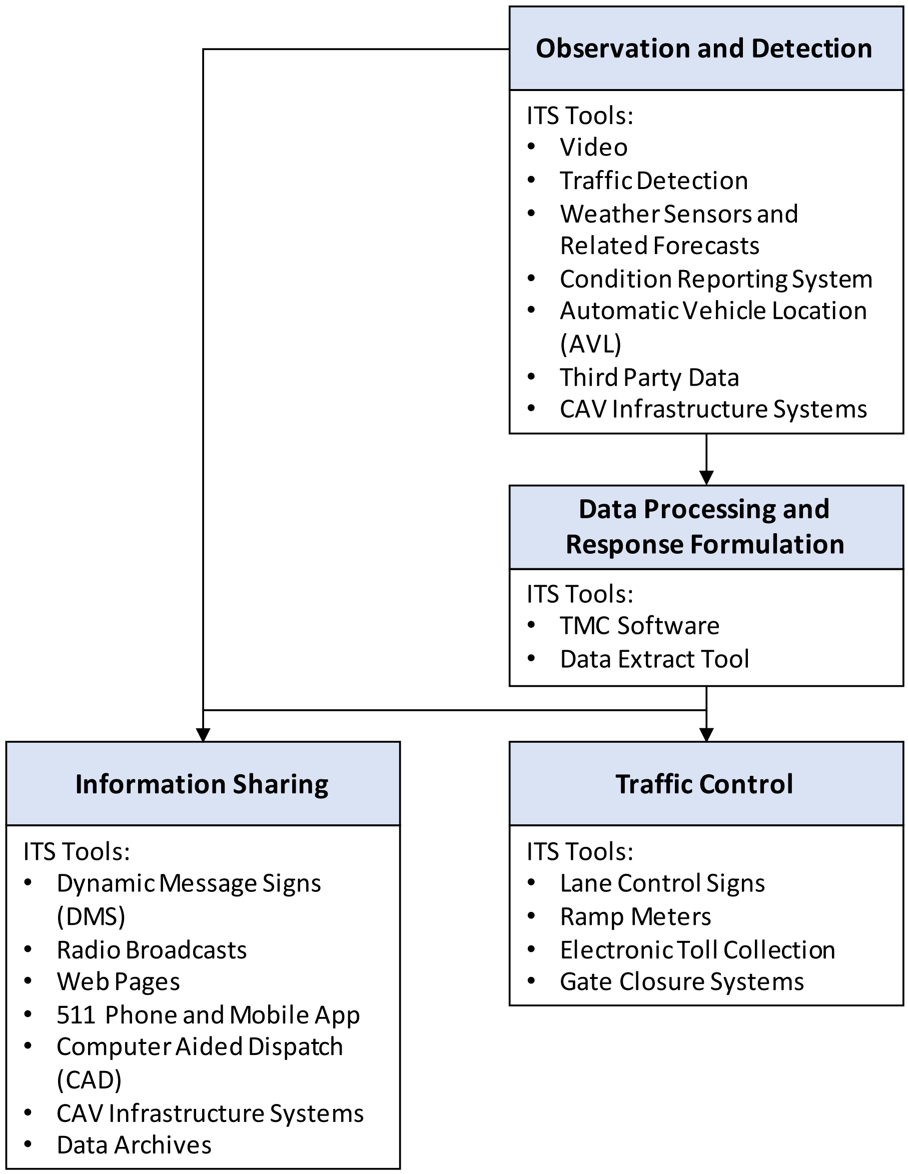

Figure 3. Illustration of ITS Tools that Support Traffic Management

Mapping of ITS Tools to Needs

Table 2 maps the needs presented in the Challenges and Needs section to the ITS Tools introduced in this section. By mapping the needs to the ITS Tools, the intent is to illustrate, at a high level:

- The roles of each ITS Tool (i.e. what needs the tool addresses); and
- The approaches for meeting each need (i.e. what tools support each need).

However, the table goes one step further to illustrate constraints (in addition to the primary mapping of ITS Tools to needs). For example, Need 4: Real-time travel time/congestion notification is primarily addressed by three ITS Tools (DMS, 511, and radio broadcasts). In isolation, these ITS Tools can not address the need; other ITS Tools are needed, (e.g. Traffic Detectors). For these relationships, a ‘C’ is placed in the cell to illustrate that the ITS Tool and the need are constrained to each other, even if the ITS Tool is not a primary tool addressing the need.

Table 2. Map of ITS Tools to Freeway Traffic Management Needs

Need	ITS Tools															
	Observation and Detection					Information Sharing					Data Processing & Response Formulation		Traffic Control			
	Video	Traffic Detection	Weather Sensors & Related Forecasts	Condition Reporting System	AVL	DMS	Radio Broadcasts	Web Display	511 Phone & Mobile App	CAD	ATMS	Data Extract Tool	Lane Control Signs	Ramp Meters	Electronic Toll Collection	Gate Closure
Need 1: Incident/event verification	P															
Need 2: Traffic & transportation infrastructure monitoring	P	P														
Need 3: Weather and driving condition monitoring	P		P													
Need 4: Real-time travel time/congestion notification		C				P	P	P	P		C					
Need 5: Real-time unplanned event notification	C			C		P	P	P	P							
Need 6: Real-time planned event notification				C		P	P	P	P							
Need 7: Freeway operational analysis	C	C		C							P					
Need 8: Individual lane control	C	C									C		P			
Need 9: Zonal or isolated freeway access control		C												P		
Need 10: Freeway data storage, archive and access		C									C	P				
Need 11: Manual event reporting	C	C		P												
Need 12: Lane access management		C													P	
Need 13: Manual device control											P					

Need	ITS Tools															
	Observation and Detection					Information Sharing					Data Processing & Response Formulation		Traffic Control			
	Video	Traffic Detection	Weather Sensors & Related Forecasts	Condition Reporting System	AVL	DMS	Radio Broadcasts	Web Display	511 Phone & Moble App	CAD	ATMS	Data Extract Tool	Lane Control Signs	Ramp Meters	Electronic Toll Collection	Gate Closure
Need 14: Automated device control		C									P					
Need 15: Automated algorithm execution		C									P					
Need 16: Automated/manual road closure	C															P
Need 17: Center-to-Center communications								P								
Need 18: Vehicle Tracking					P											
Need 19: Inter-agency incident information sharing										P						

P = Primary Relationship Between Need and ITS Tool *C= Constraint Between Need and ITS Tool*

Observation and Detection

Observation and detection describes the action of observing conditions, detecting events or incidents, and assembling information through manual or automated processes. This is a key action in freeway traffic management as it provides freeway operations staff with information and visual verification of conditions and events, thereby enabling them to perform analyses of situations and respond by managing traffic or responding to incident emergencies. Data is collected and shared with partner agencies and the traveling public in the observation and detection action. Finally, data acquired by this action is used for long-term analysis of needed infrastructure changes to better manage traffic.

Therefore, nearly every freeway traffic management strategy implemented to address nearly every need identified in previous chapters traces back and is dependent upon observation and detection in some way. The dependency of the other activities upon observation and detection are described in the following subsections.

Based upon research and feedback, freeway traffic management personnel have identified that the following needs are primarily addressed by the Observation and Detection action.

- Need 1: Incident/event verification;
- Need 2: Traffic and transportation infrastructure monitoring;
- Need 3: Weather and driving conditions monitoring;
- Need 11: Manual Event Reporting; and
- Need 18: Vehicle Tracking.

The ITS Tools used to perform traffic observation and detection, and therefore address the stated needs include:

- Video;
- Traffic Detection;
- Weather sensors and related forecasting;
- Condition Reporting Systems; and
- Automatic Vehicle Location.

There are not any interdependencies between the Observation and Detection action and the needs addressed by Observation and Detection as shown in the following table.

Table 3. Observation and Detection Interdependencies of Needs

In Order for Observation and Detection to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 1: Incident/event verification	N/A	*There are no interdependencies for the needs addressed by Observation and Detection*
Need 2: Traffic and transportation infrastructure monitoring		
Need 3: Weather and driving conditions monitoring		
Need 11: Manual Event Reporting		
Need 18: Vehicle Tracking		

Video

Video tools provide a mechanism for traffic operations staff, travelers, information service providers, and law enforcement personnel to view video or static images of events on the roadways. Images are relayed to a central monitoring location where the images are projected onto a video monitor, television screen, internet display, or other related viewing mechanisms.

The operational concept of video for freeway traffic management applications is detailed in the MnDOT Video Systems Engineering Concept of Operations, Requirements and Test Plan document (https://www.dot.state.mn.us/its/projects/2016-2020/systemsengineeringforitsandcav/videose.pdf).

Traffic Detection

Traffic detection refers to a system for indicating the presence or passage of vehicles. The detector data provides input to accurately measure freeway traffic volumes, speed and occupancy and classification.

The operational concept of traffic detection for freeway traffic management applications is detailed in the MnDOT Traffic Detection Systems Engineering Concept of Operations, Requirements and Test Plan (https://www.dot.state.mn.us/its/projects/2016-2020/systemsengineeringforitsandcav/trafficdetectionse.pdf).

Weather Sensors and Related Forecasting

Weather Sensors and Related Forecasting provide current and predicted weather conditions. The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas.

Providers of value-added sector specific meteorological services utilize National Weather Service data and predictions, road condition information, and local environmental data to provide weather observations and forecasts. Examples include the Data Transmission Network (DTN).

MnDOT has deployed a Road Weather Information System (RWIS) statewide. An RWIS uses Environmental Sensor Stations (ESSs) in the field with sensors and processors, a communication system for data transfer, and central systems to collect and disseminate field data. Central RWIS hardware and software are used to process observations from ESSs to develop forecasts and display or disseminate road weather information. ESSs provide basic input to Minnesota's Maintenance Decision Support System (MDSS), an interactive system that assists maintenance supervisors with best management practices or techniques given predicted weather.

Why is it used, Who uses it, How is it used?

The following table describes:

- Why weather sensors and related forecasting is used (the purposes it performs);
- Who uses weather sensors and related forecasting (for each purpose);
- How they use weather sensors and related forecasting; and
- High level requirement considerations based on the use of weather sensors and related forecasting.

Table 4. Observation and Detection Operational Concept: Weather Sensors and Related Forecasting

Traffic Management Action: Observation and Detection **ITS Tool:** Weather Sensors and Related Forecasting			
Why is the Tool Used?	**Who Uses the Tool?**	**How are Weather Sensors and Related Forecasting Used?**	**Requirements**
Need 3: Weather Monitoring	MnDOT Metro Freeway Operations	• Freeway Operations staff members view radar images and Internet weather reports from their workstation. Maintenance staff members have access to Road Weather Information Systems (RWIS) and value added weather services and can verbally relay information in the RTMC. • Weather forecasts and current condition reports are used to verify and assess the expected impacts of weather during peak periods. During inclement weather, operators may manually adjust ramp metering rates, adjust Freeway Incident Response Team (FIRST) Vehicle strategies, and call in additional dispatch staff members to accommodate the unusual traffic patterns expected. • For rare situations where operators feel that unexpected localized weather should be relayed to motorists (e.g. isolated snow drifting of a small section, black ice caused by a local event), operators may post messages to DMS, 511 phone, 511 mobile app, or 511 web describing the local weather or driving condition. However, DMS is not used to describe overall driving or weather conditions (that could be observed by travelers).	WS1: MnDOT Metro Freeway Operators shall have Internet access to outside weather sites (public and private).

Traffic Management Action: Observation and Detection **ITS Tool:** Weather Sensors and Related Forecasting			
Why is the Tool Used?	**Who Uses the Tool?**	**How are Weather Sensors and Related Forecasting Used?**	**Requirements**
	MnDOT Metro Maintenance	• On-line weather resources, MDSS and value added weather services are accessible to maintenance dispatcher's workstations. • Weather sensors and related forecasting is used to plan pre- treatment and removal of snow and ice. • Speed data is used by MnDOT Metro Maintenance to determine when 'bare pavement' is achieved.	WS2: MnDOT Metro Maintenance Operators shall have Internet access to outside weather sites (public and private). WS3: MnDOT Metro Maintenance Operators shall have access to RWIS information.
	MnDOT District Maintenance	• On-line weather resources and value added weather services are accessible to maintenance dispatchers' workstations. • Weather sensors and related forecasting is used to plan pre- treatment and removal of snow and ice.	WS4: MnDOT Maintenance Operators shall have Internet access to outside weather sites (public and private). WS5: MnDOT Maintenance Operators shall have access to RWIS information.

Role of Weather Sensors and Related Forecasting in ITS Architecture

Weather Sensors and Related Forecasting was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for Traveler Information (TI) as shown in the table below.

Table 5. Role of Weather Sensors and Related Forecasting in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TI01 Broadcast Traveler Information	• ATIS04 Provide current and forecast road and weather condition information	• TI02 Personalized Traveler Information

Condition Reporting System

A Condition Reporting System supports the manual creation and assembly of current and planned events to be used to populate traveler information systems.

The following table describes:

- Why the Condition Reporting System is used (the purposes it performs);
- Who uses the Condition Reporting System (for each purpose);
- How they use the Condition Reporting System; and
- High level requirement considerations based on the use of the Condition Reporting System.

Table 6. Observation and Detection Operational Concept: Condition Reporting System

Traffic Management Action: Observation and Detection **ITS Tool:** Condition Reporting System (CRS)			
Why is CRS Used?	**Who Uses CRS?**	**How is the Condition Reporting System Used?**	**Condition Reporting System Requirements**
Need 11: Manual Event Reporting	MnDOT Metro Freeway Operations MnDOT Metro Maintenance MnDOT Districts Minnesota State Patrol (MSP) MnDOT Construction	• Condition Reporting System is available to any authorized user through Internet access • Unplanned events (driving conditions, crashes, closures, Amber Alerts) are entered by authorized users from any Internet accessible location. • Planned events (e.g. roadwork, planned closures) are entered into the system and automatically feed the traveler information systems. • All events are entered with an expiration time (time the event automatically is removed from the system) and an operator can delete the event at any time. • Event locations are described by specifying the highway and the start/end locations on the highway; or an entire county. • An automated connection to the MSP CAD system allows for incident information to be transferred to the CRS. • Loop data is another source of data input to the CRS that has been used in several test applications.	CRS1: MnDOT Freeway Operators, MnDOT Metro Maintenance, MnDOT District Traffic, MSP, and MnDOT Construction shall have access via the internet to the Condition Reporting System CRS2: The Condition Reporting System shall allow for event entry of current events or future planned events. CRS3: The Condition Reporting System shall require that all events include a start time/date, end time/date, highway the event occurs on, location along the highway, and at least one standardized phrase describing the event/incident. CRS4: Events entered in to Condition Reporting System (and all data about the events) shall be communicated to Information Sharing ITS Tools (e.g. web pages, 511 phone, 511 mobile app) automatically.
	MnDOT Freeway Operations	• Authorized MnDOT staff enters Amber Alerts into the Condition Reporting System.	CRS5: The Condition Reporting System shall provide a mechanism for operators to enter Amber Alerts.

Role of the Condition Reporting System in ITS Architecture

The Condition Reporting System was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for Traffic Management (TM) and TI as shown in the table below.

Table 7. Role of Condition Reporting Systems in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM06 Traffic Information Dissemination • TI01 Broadcast Traveler Information	• ATMS05 Provide incident and congestion information to travelers • ATIS01 Provide incident information on freeways and major arterials • ATIS03 Provide traffic flow maps showing recurring freeway congestion levels • ATIS05 Provide information on roadway construction and maintenance activities • ATIS07 Provide information on tollways • ATIS08 Provide information on seasonal road weight restrictions • ATIS09 Provide information on CVO permit restrictions • ATIS10 Operate a statewide web-based and telephone 511 system	• TI01 Broadcast Traveler Information • TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination

Automatic Vehicle Location (AVL)

Automatic Vehicle Location (AVL) is a means for determining the geographic location of a vehicle and transmitting the information.

The following table describes:

- Why AVL is used (the purposes it performs);
- Who uses AVL (for each purpose);
- How they use AVL; and
- High level requirement considerations based on the use of AVL.

Table 8. Observation and Detection Operational Concept: AVL

Traffic Management Action: Observation and Detection **ITS Tool:** Automatic Vehicle Location (AVL)			
Why is AVL Used?	**Who Uses AVL?**	**How is AVL Used?**	**AVL Requirements**
Need 18: Vehicle Tracking	MnDOT Metro Freeway Operations	• MnDOT Metro Freeway Operations utilizes AVL on FIRST vehicles when responding to incidents or vehicle breakdowns. The Freeway Operators are able to determine which FIRST vehicle is in the closest proximity to the incident in order to provide the most efficient response.	AVL1: MnDOT Metro Freeway Operations shall have access to FIRST vehicle AVL data.
	MnDOT Metro Maintenance	• Metro Area Maintenance dispatchers currently use AVL to track maintenance vehicles when clearing the freeways.	AVL2: MnDOT Metro Maintenance shall have access to maintenance vehicle AVL data.
	MnDOT Districts	• MnDOT Districts vehicles with AVL are used to manage fleets of vehicles and provide the most efficient response to an incident.	AVL3: MnDOT Districts shall have access to District AVL data.
	Minnesota State Patrol	• MSP vehicles are equipped with AVL to assist in incident response.	AVL4: MnDOT State Patrol shall have access to State Patrol vehicle AVL data.

Role of AVL in ITS Architecture

AVL was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for Maintenance and Construction (MC) and Public Safety (PS) as shown in the table below.

Table 9. Role of AVL in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• MC01 Maintenance and Construction Vehicle and Equipment Tracking • PS01 Emergency Call-Taking and Dispatch	• MCM01 Track locations of maintenance fleet and personnel and usage of materials • PSFT06 Provide AVL to emergency vehicles	• MC04 Winter Maintenance

Data Processing and Response Formulation

Data Processing and Response Formulation consists of automated and manual processes that are performed to determine or create specific approaches to traffic management. In other words, the Observation and Detection action assembles data, and the data processing and response action uses the data to create the management approaches (manual or automated) that are performed by the information sharing and traffic management actions.

Based upon research and feedback, the following needs are primarily addressed by Data Processing and Response Formulation:

- Need 7: Freeway operational analysis;
- Need 10: Freeway data storage, archive, and access;
- Need 13: Manual device control;
- Need 14: Automated device control; and
- Need 15: Automated algorithm execution.

The ITS Tools used to perform data process and response formulation, and therefore address the stated needs include:

- ATMS; and
- Data Extract Tool.

There are interdependencies between the Data Processing and Response Formulation action and the needs addressed by Data Processing and Response Formulation as shown in the following table.

Table 10. Data Processing and Response Formulation Interdependencies of Needs

In order for Data Processing and Response Formulation to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 10: Freeway data storage, archive, and access	Need 2: Traffic and Transportation Infrastructure monitoring	Observation and Detection
Need 13: Manual Device Control	N/A	N/A
Need 14: Automated Device Control	N/A	N/A
Need 15: Automated algorithm execution.	Need 2: Traffic and Transportation Infrastructure monitoring	Observation and Detection

ATMS

ATMS is a term used to represent the system or systems operating in either a traffic management center or a virtual traffic management center where operations personnel control ITS devices in order to manage traffic. The ITS tool described in this ConOps is not specific to any one software, but rather refers to a collection of software systems that allow operators or automated algorithms to determine activities for devices such as DMS, video, and ramp meters. For example, a TMC may use one software (or hardware/software combination) to control video, and different software to control DMS. For the sake of this ConOps, this collection of different software solutions is collectively referred to as ATMS.

The following table describes:

- Why visual ATMS is used (the purposes it performs);
- Who uses ATMS (for each purpose);
- How they use ATMS; and
- High level requirement considerations based on the use of ATMS.

Table 11. Data Processing and Response Formulation Operational Concept: ATMS

Traffic Management Action: Data Processing and Response Formulation **ITS Tool:** ATMS			
Why is ATMS Used?	**Who Uses ATMS**	**How is ATMS Used?**	**ATMS Requirements**
Need 7: Freeway operational analysis	MnDOT Metro Freeway Operations	• Metro Freeway Operations view detector data, event reports, roadwork reports, and other information displayed by the ATMS to determine the current status of the freeway. Experienced operators can detect incidents by detector value changes. • Freeway operational analysis is a combination of observing conditions, viewing options for response (e.g. pre-defined DMS messages) and selecting the most appropriate response.	N/A
Need 13: Manual Device Control (Operator based)	MnDOT Metro Freeway Operations	• ATMS is the tool that allows operators to view video images and detector data; and to create commands for field devices that are then relayed to the devices (e.g. controlling video tools, posting messages to DMS, activating lane control signs). • Operators use available data and information (volume, occupancy, video views) to determine the most appropriate DMS messages to display. DMS messages are selected from pre-defined message options stored in the ATMS (only managers can create text for DMS) and posted to the sign. • Operators can manually override the automated ramp meter algorithm if deemed necessary. • Operators can change the status of the lane control signs (arrow to 'X'). • Operators use the ATMS to control MnPASS toll sensors, price signs and gates.	TMC 1: The ATMS shall communicate with detectors, DMS, CCTV, Ramp Meters and Intelligent Lane Control Signs (ILCS). TMC2: The ATMS shall present operators with a view of current traffic detector data through color coded maps. TMC3: The ATMS shall provide a mechanism for operators to select a DMS, Lane Control Sign, or ILCS to view current messages displayed and select messages from pre-defined message lists or symbol lists. TMC4: The ATMS shall prioritize DMS message displays according to rules and procedures stored in

Traffic Management Action: Data Processing and Response Formulation ITS Tool: ATMS			
Why is ATMS Used?	**Who Uses ATMS**	**How is ATMS Used?**	**ATMS Requirements**
		• Operators use the ATMS to monitor status of field devices.	the ATMS. TMC5: The ATMS shall provide operators a mechanism to control video. TMC6: The ATMS shall report status of field devices connected to the ATMS.
	MnDOT Metro Maintenance	• Operators control freeway management devices (DMS and video) from their workstations when critical events occur and Freeway Operations staff are not on duty.	
	MnDOT Districts	• State Patrol dispatchers are usually first alerted to crashes or incidents. MSP dispatchers will post messages to be displayed on DMS during afterhours.	TMC7: The ATMS shall be accessible to MnDOT and MSP operators at any location connected to the Internet. TMC8: MSP shall have the ability to use the ATMS to post messages on DMS.
Need 15: Automated Algorithm Execution	MnDOT Metro Freeway Operations	• An algorithm runs regularly using current detector data to compute Travel Times for pre-defined stretches of road. Stretches of road are not necessarily from intersection to intersection, often they are from a DMS location to a known landmark. <Once computed, the Travel Time is sent to the DMS as a message and posted on the website for travelers to view>. • An algorithm automatically determines that ramp meters are to be activated based upon time of day. Then meter rates are determined by the algorithm based upon detector data and an internal algorithm. <The ATMS communicates these rates to the ramp	TMC9: The ATMS shall operate algorithms that execute calculations using data ingested, and control devices automatically based upon the algorithm rules (e.g. calculate freeway travel times and post travel times to DMS automatically). The current algorithms include: Freeway Travel Times, Ramp Meter Rates, managed corridor messages.

Traffic Management Action: Data Processing and Response Formulation **ITS Tool:** ATMS			
Why is ATMS Used?	**Who Uses ATMS**	**How is ATMS Used?**	**ATMS Requirements**
		meter devices in the field. Manual intervention from operators overrides the automated rates>. • An algorithm automatically determines congestion pricing for the MnPASS lanes. • An algorithm compares detector data on managed corridors and determines messages to be presented to operators based upon thresholds being met.	TMC10: The ATMS shall provide a mechanism for operators to override automated algorithms by performing manual controls.
	Information Service Providers	• Information service providers operate automated systems to access the data outputs of the ATMS (e.g. travel times calculated and posted on the MnDOT website).	TMC11: The ATMS shall provide a mechanism to post algorithm calculations to external Internet accessible locations to allow outside agencies to view the information.
Need 14: Automated Device Control	MnDOT Metro Freeway Operations	• The Travel Times <computed by automated algorithms> are sent to the appropriate DMS as a message and posted on the website for travelers to view by the ATMS. • When the ramp meter algorithm determines ramp meters should be operational, and determines rates, the ATMS communicates these rates to the ramp meter devices in the field. Manual intervention from operators overrides the automated rates. • The ATMS displays recommended messages to operators for the managed corridors.	TMC 12: The ATMS shall send control commands to field devices that cause the field devices to perform actions (e.g. display message, display red/green ramp meters) either from manual commands or automated algorithm outcomes.

Role of ATMS in ITS Architecture

ATMS was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 12. Role of ATMS in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM01 Infrastructure-Based Traffic Surveillance • TM05 Traffic Metering • TM06 Traffic Information Dissemination • TM22 Dynamic Lane Management and Shoulder Use	• ATMS20 Operate dynamic shoulders • ATMS22 Provide a system-coordinated response for incidents • ATMS23 Operate ramp meters • ATMS24 Operate freeway/expressway/arterial DMS • ATMS25 Operate video monitoring cameras • ATMS26 Operate and enforce MnPASS lanes • ATMS36 Implement Integrated Corridor Management (ICM) strategies	• TM07 Regional Traffic Management • TM10 Electronic Toll Collection • TM16 Reversible Lane Management • ST06 HOV/HOT Lane Management

Data Extract Tool

Beyond the real-time use of detector data, the detector data for freeways is very valuable for research, planning, and training purposes. Data Extract is a tool for extracting any detector data that is ingested into the ATMS. Data Extract allows any user to access and download data reports over the Internet.

A data extract tool is primarily used for Freeway Operational Analysis. However, there are a variety of users and a variety of reasons why freeway operational analysis is performed.

The following table describes:

- Why the Data Extra Tool is used (the purposes it performs);
- Who uses the Data Extract Tool (for each purpose);
- How they use the Data Extract Tool; and
- High level requirement considerations based on the use of the Data Extract Tool.

Table 13. Data Processing and Response Formulation Operational Concept: Data Extract Tool

Traffic Management Action: Data Processing and Response Formulation **ITS Tool:** Data Extract Tool			
Why is the Data Extract Tool Used?	**Who Uses the Data Extract Tool?**	**How is the Data Extract Tool Used?**	**Data Extract Tool Requirements**
Need 10: Freeway data storage, archive, and access	MnDOT Metro Freeway Operations	• The data extract is accessed over the internet, reports are downloaded as spreadsheets. • Data Extract Tool is used to request and receive reports from any combination of detectors on the freeways for any time periods (pending availability of data). • Volume and occupancy data for mainline and ramps are viewed to study trends, analyze driver reactions to incidents or events, or to understand current traffic patterns.	DET1: The Data Extract Tool shall be accessible to any agency using Internet connectivity. DET2: The Data Extract Tool shall allow downloading of past data that includes any and all data stored in the system.
	MnDOT Metro Planning	• Data Extract Tool is used to access actual traffic data to be used as inputs to the long-term modeling and planning.	DET1: The Data Extract Tool shall be accessible to any agency using Internet connectivity.
	MnDOT Districts	• The data extract is accessed over the internet, reports are downloaded as spreadsheets. • Data Extract Tool is used to request and receive reports from any combination of detectors on the freeways for any time periods (pending availability of data). • Volume and occupancy data are viewed to study trends, analyze driver reactions to incidents or events, or to understand current traffic patterns.	DET1: The Data Extract Tool shall be accessible to any agency using Internet connectivity. DET2: The Data Extract Tool shall allow downloading of past data that includes any and all data stored in the system.
	Other Agencies	• Data Extract Tool allows any user to access historical volume and occupancy data throughout the metro freeway networks. Research agencies and consulting firms can use this to develop algorithms, examine data trends, and understand the impacts of incidents or events.	DET1: The Data Extract Tool shall be accessible to any agency using Internet connectivity.

Role of the Data Extract Tool in ITS Architecture

The Data Extract tool was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 14. Role of the Data Extract Tool in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM09 Integrated Decision Support and Demand Management	• ATMS03 Use archived data for traffic management strategy development and long-range planning	• DM01 ITS Data Warehouse

Information Sharing

In the overall picture of traffic management, once data, visual observations, and manual event reports are gathered (in the Observation and Detection 'Action'), and the data are processed and traffic management responses are formulated, there are three real-time traffic management actions that are performed by traffic management personnel:

- Information is shared with travelers and other agencies;
- Traffic controls are implemented to restrict or allow movement of vehicles; and
- FIRST and other incident management responders are dispatched to respond to incidents.

The emphasis of this section is on information sharing. Information sharing describes the sharing of data and information with agencies outside MnDOT, with the traveling public, and with other sections within MnDOT. The overall role in freeway traffic management is to share real-time and historic data and information to assist travelers' decision making, and to share information with other transportation professionals to support manual and automated traffic control.

Based upon research and feedback, the following needs are primarily addressed by Information Sharing:

- Need 4: En-route travel time/congestion notification;
- Need 5: En-route unplanned event notification;
- Need 6: En-route planned event notification;
- Need 17: Center-to-Center communication; and
- Need 19: Computer Aided Dispatch (CAD).

The ITS Tools used to perform information sharing, and therefore address the stated needs include:

- Dynamic Message Signs (DMS);
- Radio Broadcasts;
- Web Pages (including RSS feeds);
- 511 Phone System and Mobile App: and
- Computer Aided Dispatch.

There are interdependencies between the Action of Information Sharing and the needs addressed by Information Sharing as shown in the following table.

Table 15. Information Sharing Interdependencies of Needs

In Order for Information Sharing to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 4: En-route travel time/congestion notification Need 5: En-route unplanned event notification	Need 6: Freeway Operational Analysis	Data Processing and Response Formulation
	Need 13: Manual Device Control Need 14: Automated Device Control Need 15: Automated Algorithm Execution Need 1: Incident/Event verification Need 2: Traffic and transportation infrastructure monitoring	Observation and Detection
Need 6: En-route planned event notification	Need 11: Manual Event Reporting	
	Need 6: Freeway Operational Analysis Need 13: Manual Device Control	Data Processing and Response Formulation
Need #17: Center-to-Center communication	No Dependencies	N/A

Dynamic Message Signs

DMS are either fixed or portable signs capable of displaying text messages (or text and graphics) selected for display by an operator (either locally or through remote access).

The operational concept of DMS for freeway traffic management applications is detailed in the MnDOT DMS Systems Engineering Concept of Operations, Requirements and Test Plan document (https://www.dot.state.mn.us/its/projects/2016-2020/systemsengineeringforitsandcav/dmsse.pdf).

Radio Broadcasts

Radio broadcasts refer to those tools that broadcast information over a radio frequency to radio receivers owned and operated by travelers. These tools offer extremely low cost options for travelers to hear traffic and weather information. In Minnesota, radio broadcasts may include either public radio systems (e.g. low bandwidth Highway Advisory Radio (HAR) systems using limited frequency ranges), public radio stations (e.g. KBEM), or private sector commercial radio broadcasts that combine traffic reports with news, entertainment and music.

The following table describes:

- Why radio broadcasts are used (the purposes it performs);
- Who uses radio broadcasts (for each purpose);
- How they use radio broadcasts; and
- High level requirement considerations based on the use of radio broadcasts.

Table 16. Information Sharing Operational Concept: Radio Broadcasts

Traffic Management Action: Information Sharing **ITS Tool:** Radio Broadcasts			
Why is the Tool Used?	**Who Uses the Tool?**	**How is are Radio Broadcasts Used?**	**Radio Broadcast Requirements**
Need 5: En-route unplanned event notification Need 6: En-route planned event notification	MnDOT Metro Freeway Operations	• Freeway Operations dispatchers and managers can utilize the RTMC radio broadcasts to alert travelers to major traffic situations by relaying messages to the broadcaster. • During incidents (e.g. weather or major traffic incidents) the RTMC radio broadcaster can operate in continuous traffic reporting mode.	RB1: RTMC Radio Contractor broadcasts shall have metro wide coverage. RB2: RTMC Radio Contractor broadcasters shall have access to video images. RB3: Metro Freeway Operators shall have a mechanism to communicate directly to the RTMC Radio Broadcasters.
	MnDOT Public Affairs	• Private media outlets are used as a tool to reach travelers with non-real-time messages issued as press releases. There is little or no control over how the media outlets use the information.	RB4: MnDOT shall operate a mechanism to post press releases describing traffic events, incidents, or changes in traffic management strategies.
	Information Service Providers	• Media outlets prepare and disseminate traffic reports via the radio	N/A
	Public	• Travelers listen to traffic reports via the radio en-route and pre-trip	RB5: The Traveling Public shall have a mechanism to listen to radio broadcasts.

Role of Radio Broadcasts in ITS Architecture

Radio broadcasts were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TI as shown in the table below.

Table 17. Role of the Radio Broadcasts in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TI01 Broadcast Traveler Information	• ATIS01 Provide incident information on freeways and major arterials • ATIS04 Provide current and forecast road and weather condition information • ATIS05 Provide information on roadway construction and maintenance activities	• TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination

Web Pages

Internet web pages refer to websites that allow travelers to view travel information using such strategies as video image displays, color coded maps, or text descriptions. Web pages that display travel information are operated by MnDOT as well as a variety of other public and private agencies and companies. For example, information service providers operate web pages, and commercial media outlets operate web pages.

The following table describes:

- Why web pages are used (the purposes it performs);
- Who uses web pages (for each purpose);
- How they use web pages; and
- High-level requirement considerations based on the use of web pages.

Table 18. Information Sharing Operational Concept: Web Pages

Traffic Management Action: Information Sharing **ITS Tool:** Web Pages			
Why are Web Pages Used?	**Who Uses Web Pages?**	**How are Web Pages Used?**	**Web Pages Requirements**
Need 5: En-route unplanned event notification Need 6: En-route planned event notification Need 17: Center-to-Center communication	MnDOT Freeway Operations	• All information describing events that is displayed on the website is either automated (i.e. assembled from detectors and displayed on maps automatically) or entered in to the Condition Reporting System. • Video images are displayed on the web site as a mechanism for sharing video views with the traveling public and other transportation agencies.	WP1: MnDOT web pages shall receive data and information describing events, incidents, traffic, and driving conditions. WP2: MnDOT web pages shall format data and information and display content using a combination of map and text-based displays. WP3: MnDOT web pages shall present video images and allow web page users to view the location of the video, as well as the image.
	MnDOT Districts	• Descriptions about roadwork projects are created by District Staff and updated as appropriate.	WP4: MnDOT web pages shall allow for District specific 'pages' to display local content entered locally.
	Public	• Travelers view traveler information via web pages pre-trip • Travelers view travel information via web pages using mobile devices such as smartphones and tablets.	WP5: MnDOT web pages shall load quickly using typical Internet connections. WP6: MnDOT web pages shall provide mobile device specific views.
	Information Service Providers	• Private information service providers may capture data and information from MnDOT websites to rebroadcast on the private website.	WP3: MnDOT web pages shall present video images and allow web page users to view the location of the video, as well as the image.

Role of Web Pages in ITS Architecture

Web Pages were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TI as shown in the table below.

Table 19. Role of Web Pages in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TI01 Broadcast Traveler Information • TI02 Personalized Traveler Information	• ATMS05 Provide incident and congestion information to travelers • ATMS09 Share video, data, and other information with PSAPs	• TM01 Infrastructure-Based Traffic Surveillance • TM06 Traffic Information Dissemination • TM08 Traffic Incident Management System

511 Phone and Mobile App

The Federal Communications Commission (FCC) has designated 511 as the universal three digit telephone number for travel information. Minnesota operates a 511 phone system as an ITS Tool for dissemination of travel information. MnDOT also develops a 511 mobile app for travel information dissemination.

The following table describes:

- Why 511 Phone and Mobile App is used (the purposes it performs);
- Who uses 511 Phone and Mobile App (for each purpose);
- How they use 511 Phone and Mobile App; and
- High level requirement considerations based on the use of the 511 Phone and Mobile App.

Table 20. Information Sharing Operational Concept: 511 Phone and Mobile App

Traffic Management Action: Information Sharing **ITS Tool:** 511 Phone and Mobile App			
Why is 511 Phone/ Mobile App Used?	**Who Uses 511 Phone/Mobile App?**	**How is 511 Phone/Mobile App Used?**	**511 Phone/Mobile App Requirements**
Need 5: En-route Unplanned Event Notification Need 6: En-route Planned Event Notification	MnDOT Public Affairs	• Content for the 511 phone system and mobile app is automatically generated from events in the Condition Reporting System • Amber Alerts may be recorded as a "floodgate message" played at the onset of the call by authorized MnDOT representatives. • The "floodgate message" feature – an announcement played at the onset of the call could allow for manually recorded announcements (e.g. recorded by the RTMC Radio broadcaster).	511P1: The 511 Phone and Mobile App shall automatically create messages to play to callers based upon stored incidents and event descriptions. 511P2: The 511 Phone and Mobile App shall provide a mechanism for manually recorded 'floodgate' messages to be recorded one time and then played each time a caller calls the system.
	Traveling Public	• Travelers call 511 or use the 511 mobile app for real-time traffic reports and receive route-based reports of the conditions they can expect currently on the highway.	511P3: The Traveling Public shall have a mechanism to access the 511 Phone and Mobile App.

Role of 511 Phone and Mobile App in ITS Architecture

511 Phone was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TI as shown in the table below.

Table 21. Role of 511 Phone and Mobile App in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TI01 Broadcast Traveler Information	• ATMS05 Provide incident and congestion information to travelers.	• TI02 Personalized Traveler Information • TM06 Traffic Information Dissemination

Computer Aided Dispatch (CAD)

Computer Aided Dispatch (CAD) refers to software systems that promote efficiency in dispatching field personnel (e.g. maintenance personnel, emergency responders). Operators typically enter incidents or events in to CAD systems and dispatch personnel appropriately. CAD systems are therefore, good sources of information about current incidents or events.

The following table describes:

- Why CAD is used (the purposes it performs);
- Who uses CAD (for each purpose);
- How they use CAD; and
- High level requirement considerations based on the use of CAD.

Table 22. Information Sharing Operational Concept: CAD

Traffic Management Action: Information Sharing **ITS Tool:** Computer Aided Dispatch (CAD)			
Why is CAD Used?	**Who Uses CAD?**	**How is Computer Aided Dispatch Used?**	**CAD Requirements**
Need 19 Inter-agency incident information sharing	MnDOT Freeway Operations	• MnDOT Freeway Operations personnel have a monitor to view incidents in the MSP CAD system. • FIRST units are equipped with CAD mobile workstations to receive dispatch and log their stops and actions taken. • Freeway operators use CAD to understand the impacts and the response actions being performed for active incidents and respond by posting messages to DMS, altering ramp meter rates, or other traffic management response processes. • Freeway operators use the automated link between CAD and the CRS to populate the CRS with incidents in real-time to include as many incidents as possible in the traveler information dissemination.	CAD-1: The CAD system shall publish incident data to an Internet accessible location. CAD-2: The CAD system shall remove any sensitive or restricted information before publishing incident information.
	Minnesota State Patrol	• MSP dispatchers enter incident in the CAD system for their purposes of responding to incidents. • MSP operators use CAD as a mechanism to inform MnDOT of the incident and response actions.	CAD-1: The CAD system shall publish incident data to an Internet accessible location. CAD-2: The CAD system shall remove any sensitive or restricted information before publishing incident information.

Role of CAD in ITS Architecture

There are multiple CAD systems used by emergency responders in Minnesota. These systems are currently not capable of sharing data. CAD was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM and Public Safety (PS) as shown in the table below. A goal is to allow viewing of other agencies' CAD data and potentially for CAD to CAD integration.

Table 23. Role of the CAD in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• PS01 Emergency Call-Taking and Dispatch • SU03 Data Distribution • TM08 Traffic Incident Management System	• ATIS12 Share/integrate public safety CAD data with CARS • ATMS13 Provide incident information to emergency management agencies • PSFT01 Provide CAD to CAD integration for multi-agency coordination at major incidents • PSFT05 Operate and enhance CAD systems	• TM06 Traffic Information Dissemination

Traffic Control

Traffic control describes the action of regulating or guiding traffic on the freeway based upon the data and information gathered and the calculations and assessments performed. Controlling traffic on the freeway is a key component to maintaining traffic flow for the traveling public and is closely related to Information Sharing as a tool to maintain efficient and effective traffic flows.

Based upon research and feedback, the following needs are primarily addressed by Traffic Control:

- Need 8: Individual lane control;
- Need 9: Zonal or isolated freeway access;
- Need 12: Lane access management; and
- Need 16: Automated/manual road closure.

The ITS Tools used to perform traffic observation and detection, and therefore address the stated needs include:

- Lane Control Signs;
- Ramp Meters;
- Electronic Toll Collection; and
- Gate Closure Systems.

There are interdependencies between the Action of Traffic Control and the needs addressed by Traffic Control as shown in the following table.

Table 24. Traffic Control Interdependencies of Needs

In Order for Traffic Control to Meet This Need	This Need Must Be Met (The Dependency)	Action Responsible for Meeting Dependency
Need 8: Individual lane control	Need 2: Traffic and transportation monitoring	Observation and detection
	Need 1: Incident/event verification	Observation and detection
	Need 11: Manual Event Reporting	Data Processing and Response Formulation
	Need 15: Automated Algorithm Execution	Data Processing and Response Formulation
	Need 13: Manual Device Control	Data Processing and Response Formulation
	Need 14: Automated Device Control	Observation and detection
Need 9: Zonal or isolated freeway access	Need 2: Traffic and transportation monitoring	Observation and detection
	Need 15: Automated Algorithm Execution	Data Processing and Response Formulation
	Need 13: Manual Device Control	Data Processing and Response Formulation
	Need 14: Automated Device Control	Data Processing and Response Formulation
Need 12: Lane access management	Need 2: Traffic and transportation monitoring	Observation and detection
	Need 15: Automated Algorithm Execution	Data Processing and Response Formulation
	Need 14: Automated Device Control	Data Processing and Response Formulation
Need 16: Automated/manual road closure	Need 13: Manual Device Control	Data Processing and Response Formulation
	Need 2: Traffic and Transportation Infrastructure monitoring	Observation and detection

Lane Control Signs

Lane Control signs are directional signs which clearly display lane usage (cross and arrow) and advisory speeds as well as text messages.

The following table describes:

- Why lane control signs are used (the purposes it performs);
- Who uses lane control signs (for each purpose);
- How they use lane control signs; and
- High level requirement considerations based on the use of lane control signs.

Table 25. Traffic Control Operational Concept: Lane Control Signs

<table>
<tr><th colspan="4">Traffic Management Action: Traffic Control
ITS Tool: Lane Control Signs (LCS)</th></tr>
<tr><th>Why are LCS Used?</th><th>Who Uses LCS?</th><th>How are Lane Control Signs Used?</th><th>Lane Control Signs Requirements</th></tr>
<tr><td rowspan="2">Need 8: Individual Lane Control</td><td>MnDOT Metro Freeway Operations</td><td>• Operators remotely activate Lane Control Signs for the Lowry Tunnel and the North 52 to West 94 exit underpass from their workstation using ATMS to:
○ Warn motorists of events downstream; and
○ Notify motorists if a lane is open or closed (dynamically assigning traffic to a lane).
• Some decision trees and algorithms are programmed such that as incident locations are entered, a series of sign recommendations are presented to the operator for approval and eventually sent to the lane control signs.</td><td>LCS1: Lane control signs shall receive communications from ATMS and display appropriate messages or graphics based upon the communications received.
LCS2: Lane control signs shall communicate the current message/display and report diagnostics of the signs to the ATMS.</td></tr>
<tr><td>Public</td><td>• Travelers view messages on Lane Control Signs en-route</td><td>LCS3: Lane control signs shall be visible to travelers and present messages that are understandable to travelers at freeway speeds.</td></tr>
</table>

Role of Lane Control Signs in ITS Architecture

Lane Control Signs were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 26. Role of the Lane Control Signs in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM22 Dynamic Lane Management and Shoulder Use	• ATMS07 Provide lane and shoulder control	• TM16 Reversible Lane Management • ST06 HOV/HOT Lane Management

Ramp Meters

Ramp Meters control the flow of traffic entering a freeway facility in order to maintain a steady state flow and spread platoons of vehicles to prevent them from entering the freeway as a group.

The operational concept of ramp metering for freeway traffic management is detailed in the MnDOT Ramp Metering Systems Engineering Concept of Operations, Requirements and Test Plan (https://www.dot.state.mn.us/its/projects/2016-2020/systemsengineeringforitsandcav/rampmeteringse.pdf).

Electronic Toll Collection

Electronic Toll Collection allows for electronic payment of highway lane tolls.

The following table describes:

- Why electronic toll collection is used (the purposes it performs);
- Who uses electronic toll collection (for each purpose);
- How they use electronic toll collection; and
- High level requirement considerations based on the use of electronic toll collection.

Table 27. Traffic Control Operational Concept: Electronic Toll Collection

<table>
<tr><th colspan="4">Traffic Management Action: Traffic Control
ITS Tool: Electronic Toll Collection (ETC)</th></tr>
<tr><th>Why is ETC Used?</th><th>Who Uses ETC?</th><th>How is Electronic Toll Collection Used?</th><th>Electronic Toll Collection Requirements</th></tr>
<tr><td rowspan="2">Need 12: Lane Access Management</td><td>MnDOT Metro Freeway Operations</td><td>• Typically, MnPASS is operated by the MnPASS contractor and primarily operates in automated mode.
• An algorithm determines the price for access to the lane based upon the need to maintain a Level of Service C or better in the HOT lane (e.g. as conditions worsen in the HOT lane, the price goes up).
• During rare and serious incidents, Metro Freeway Operations personnel can request that MnPASS lane status be changed to all vehicles / no tolls (e.g. in the event of multiple lane closures and severe congestion). This would be executed by verbally communicating to the MnPASS contractor.</td><td>ETC1: The MnPASS system performs automated operations to calculate pricing rates.
ETC2: The MnPASS system displays current rates to drivers.
ETC3: The MnPASS system charges customers according to the current rates.
ETC4: The MnPASS system allows manual overrides.</td></tr>
<tr><td>Public</td><td>• Travelers view electronic toll collection signs en-route to understand the rate being charged for access to the lane.
• Single Occupant Vehicle (SOV) drivers may elect to drive in the HOT lane by paying the fee if they have an electronic payment device in their vehicle.
• Vehicles with 2 or more passengers may travel in the HOT lane any time without paying a fee.</td><td>ETC 5: Travelers shall have an unobstructed view of Electronic Toll Collection Signs from vehicle</td></tr>
</table>

Role of Electronic Toll Collection in ITS Architecture

Electronic Toll Collection was identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for Sustainable Travel (ST) as shown in the table below.

Table 28. Role of the Electronic Toll Collection in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM10 Electronic Toll Collection • TM22 Dynamic Lane Management and Shoulder Use • ST06 HOV/HOT Lane Management	• ATMS26 Operate and enforce MnPASS Lanes	• TM16 Reversible Lane Management

Gate Closure Systems

Gate closures provide a means to close and barricade a road.

The following table describes:

- Why gate closure systems are used (the purposes it performs);
- Who uses gate closure systems (for each purpose);
- How they use gate closure systems; and
- High level requirement considerations based on the use of gate closure systems.

Table 29. Traffic Control Operational Concept: Gate Closure System

Traffic Management Action: Traffic Control **ITS Tool:** Gate Closure System			
Why are Gate Closures Used?	**Who Uses Gate Closures?**	**How are Gate Closure Systems Used?**	**Gate Closure System Requirements**
Need 16: Manual Road Closure	MnDOT Metro Maintenance	• Maintenance crews manually activate gate closure system in the field. • Maintenance crews drive the reversible lanes to ensure the lane is cleared before a gate is opened.	GS1: MnDOT Metro Maintenance shall be able to manually activate a gate closure system.
	MnDOT Districts	• Maintenance crews manually activate gate closure system in the field.	GS2: MnDOT District Maintenance shall be able to manually activate a gate closure system.
	Public	• Travelers view gate closure system en-route.	GS3: Travelers shall have an unobstructed view of the Gate Closure System from vehicle.
Need 16: Automated Road Closure	MnDOT Metro Maintenance	• Maintenance crews remotely activate gate closure system.	GS4: MnDOT Metro Maintenance shall be able to automatically activate a gate closure system.
	MnDOT Districts	• Maintenance crews remotely activate gate closure system.	GS5: MnDOT District Maintenance shall be able to automatically activate a gate closure system.
	Public	• Travelers view gate closure system en-route.	GS3: Travelers shall have an unobstructed view of the Gate Closure System from vehicle.

Role of Gate Closure Systems in ITS Architecture

Gate Closure Systems were identified in the *Minnesota Statewide Regional Architecture* as a need/potential solution for TM as shown in the table below.

Table 30. Role of Gate Closure Systems in ITS Architecture

Minnesota Statewide Regional ITS Architecture: Service Package	Minnesota Statewide Regional ITS Architecture: Need/Potential Solutions	Associated National ITS Architecture: Service Package
• TM19 Roadway Closure Management	• ATMS29 Provide automated/remote control gate systems	• TM19 Roadway Closure Management

CAV Infrastructure Systems and CAVs

Table 31 describes the freeway traffic management operational concepts from the perspective of CAV infrastructure systems and CAVs.

Table 31. Freeway Traffic Management Operational Concept: CAV Infrastructure Systems and CAVs

CAV Infrastructure Systems and CAVs Perspective	Operational Concept
Vehicle to Vehicle Data Exchange	• CAVs (including agency owned CAVs) are expected to broadcast the BSM continuously as they drive the Minnesota roadways. • Agency owned CAVs may receive and process BSM messages from other vehicles and use this information to support such applications as: anti-collision applications, ad-hoc string applications, vehicle following applications.
Vehicle to Infrastructure Data Exchange	• MnDOT may deploy and operate CAV Infrastructure Systems on the roadside to receive and process BSM messages at key locations to gather information such as vehicle speeds, volumes and environmental conditions. • As penetration of CAVs increases, MnDOT will increasingly understand the role of CAV generated BSM data and the potential to eventually replace or supplement roadside detection. • MnDOT will develop data retention policies for CAV related data and regularly review these as the CAV industry matures and the amount of data generated is better understood.

CAV Infrastructure Systems and CAVs Perspective	Operational Concept
Vehicle Use of Infrastructure-Generated Traffic Data	• MnDOT may deploy and operate CAV Infrastructure Systems on the roadside to broadcast data, such as real-time speeds, recommended speeds, road surface conditions, queue warnings, that will be received by CAVs. • CAV Infrastructure Systems may receive data or derived values from data management systems, for use by CAVs. • CAVs may ingest this data or derived values from the CAV Infrastructure Systems, to support automated driving features.

Supporting Infrastructure

In addition to the ITS Tools that support traffic management, there is a set of supporting infrastructure that is needed to allow the ITS tools to work effectively. These supporting infrastructures include such things as:

- Land line field communications (e.g. fiber-optic and coaxial cable);
- The Internet;
- Wireless infrastructure such as AM radio, 800 MHz radio, cellular, and point-to-point radio; and
- Electrical power.

Land-line Communications

Land-line communications tools (e.g. fiber optic and coaxial cable) provide for high-speed communications of large volumes of data. Traffic management tools described in this document (especially such tools as surveillance devices, traffic detectors, and DMS) require reliable, fast communications capabilities. The criticality of these devices often mandates redundant communications to allow connectivity during those times when land-line communications may be lost (e.g. during construction or an accidental cut of the line).

The functionality of the traffic management tools described in this document relies upon land-line communications. Therefore, there is a dependency of many of the needs to land-line communications, and land-line communications' deployments shall be considered critical.

The Internet

The Internet plays a critical role in traffic management by allowing software to be accessed through Internet connectivity, and by allowing information (such as video images) to be shared with agencies and individuals who are not connected to the MnDOT Local Area Network (LAN). In addition, the commercial Internet allows traffic management personnel to access non-MnDOT resources (e.g. the WeatherChannel.com).

The functionality of several tools described in this document relies upon the Internet.

Wireless Communications

Wireless communications are used to communicate with individuals while mobile (e.g. FIRST vehicle operators, RTMC operators, managers and other responders) while in the field. In addition, wireless communications are used to communicate to mobile devices, where land-line communications are not practical or possible.

Power Supply

Each traffic management tool that is located in the field requires some power source. The most common power supply is land-line power, however alternate power sources such as solar or wind energy are used in remote locations where power sources are not located nearby. The functionality of the devices, and therefore their ability to address the needs relies upon the power sources.

Roles and Responsibilities

This section of the ConOps describes the Operations and Maintenance roles and responsibilities for each ITS Tool. The roles and responsibilities are borken out by 'Metro Area' and 'Rural Area'. Operations and maintenance of freeway traffic management tools are detailed in the table below.

Table 32. Freeway Traffic Management Operations and Maintenance Responsibilities

ITS Tools	Operations and Maintenance Activities	Metro Area Responsibilities	Rural Area Responsibilities
Weather Sensors and Related Forecasting	Non MnDOT Weather Source Operation: • Many weather sources are accessed over the Internet and MnDOT plays no role in the operation of the systems.	N/A	N/A
	Operations and maintenance of MnDOT owned RWIS detectors and systems.	• MnDOT Metro Area Maintenance	• MnDOT District Maintenance
Condition Reporting System	24/7 hosting and Operations of Condition Reporting System.	• Vendor / Contractor	• Vendor / Contractor
	Manual Entry, Edit, and Removal of Events	• MnDOT Metro Area Freeway Operations • MnDOT Metro Area Construction • MnDOT Metro Area Maintenance	• MnDOT District Construction • MnDOT District Maintenance • MSP
	System management: • User account creation • System Governance • Contractor management • Upgrades and enhancement prioritization	• MnDOT Public Affairs	• MnDOT Public Affairs

ITS Tools	Operations and Maintenance Activities	Metro Area Responsibilities	Rural Area Responsibilities
AVL	Operate and maintain in-vehicle devices	• MnDOT Metro Area FMS Maintenance (FIRST vehicles) • MnDOT Metro Area Maintenance (Maintenance vehicles)	• MnDOT District Maintenance
	Operate and maintain central software and display system	• MnDOT Metro Area FMS Maintenance (FIRST vehicles) • MnDOT Metro Area Maintenance (Maintenance vehicles)	• MnDOT District Maintenance
	Operate and maintain wireless communications network	TBD	• MnDOT District IT
ATMS	Overall operations of software to keep the ATMS running	• MnDOT Metro Area Freeway Operations	• MnDOT Metro Freeway Operations • MnDOT District Traffic Office • MnDOT ESS • MnDOT Metro Arterial Operation • MnDOT District Traffic Office • Software Vendor
	Operate and maintain communications with field devices and server systems	• MnDOT Metro Area FMS Maintenance • MnDOT Metro Area IT	• MnDOT District IT • MnDOT Maintenance • MnDOT ESS

ITS Tools	Operations and Maintenance Activities	Metro Area Responsibilities	Rural Area Responsibilities
	Maintain, support, and update the ATMS Code	• MnDOT Metro Area Freeway Operations • MnDOT Metro Area IT	• MnDOT Freeway Operations • Software Vendor
Data Extract Tool	Software and servers operations and maintenance	• MnDOT Metro Area Freeway Operations	• MnDOT Metro Area Freeway Operations • MnDOT District Traffic Office • MnDOT ESS • MnDOT District Traffic Office • Software vendor
Radio Broadcasts	Operations of RTMC Radio Broadcasts, and related maintenance	• RTMC Radio Contractor • MnDOT Freeway Operations provides workstation and access to video and data views	N/A
	Operating a continuous real-time RSS data feed for all media outlets to access	• MnDOT Freeway Operations	N/A
Web Pages	Information content creation: • Content for the MnDOT websites is provided by the traffic detectors, Condition Reporting System, and visual observation (as described in the 'Observation and Detection' section)	• MnDOT Metro Area Freeway Operations • MnDOT Metro Area Maintenance • MnDOT Metro Area Construction	• State Patrol • MnDOT District Traffic • MnDOT District Construction • MnDOT District Maintenance
	Overall Operations and Maintenance of Websites	• MnDOT Metro Area Freeway Operations (MnDOT site) • Vendor/contractor (statewide site)	• Vendor Contractor

ITS Tools	Operations and Maintenance Activities	Metro Area Responsibilities	Rural Area Responsibilities
	24/7 operations, including monitoring and support to correct system outages	• MnDOT Metro Area Freeway Operations • 511 Contractor	• 511 Contractor
	Monitor bandwidth	• MnDOT Metro Area Freeway Operations • 511 Contractor	• MnDOT IT Maintenance • 511 Contractor
511 Phone and Mobile App	24/7 Operations of the Phone System and Mobile App: • Information for the 511 phone system and the mobile app is pulled from the Condition Reporting System, and therefore requires no manual intervention. However, operations of the servers and connections to CARS must be maintained.	• MnDOT Public Affairs • 511 Contractor	• MnDOT Public Affairs • 511 Contractor
	Maintenance of the 511 Phone System and the Mobile App	• MnDOT Public Affairs • 511 Contractor	• MnDOT Public Affairs • 511 Contractor
CAD	CAD system operations	• MSP	• MSP
	Operations of the automated link to MnDOT Condition Reporting System	• MnDOT Metro Area Freeway Operations	• MnDOT Metro Area Freeway Operations
Lane Control Signs	Operations of Lane Control Signs	• MnDOT Metro Freeway Operations	N/A
	Maintenance of Lane Control Signs and Communications to Signs	• MnDOT Metro FMS Maintenance	N/A
Electronic Toll Collection	Data collection and communications to MnPASS system	• MnDOT Metro Area Freeway Operations	N/A
	Calculation of MnPASS pricing rates and operations of MnPASS systems	• MnPASS contractor	N/A
	Administration of user accounts	• MnPASS contractor	N/A

ITS Tools	Operations and Maintenance Activities	Metro Area Responsibilities	Rural Area Responsibilities
	Maintenance of field equipment	• MnDOT Metro Area FMS Maintenance	N/A
	Enforcement patrol	• MSP	N/A
Gate Closure System	Repair non-functioning gate closure system	• MnDOT Metro Area FMS Maintenance	• MnDOT District Maintenance
	Manually close gates from the field	• MnDOT FIRST vehicle	• MnDOT Maintenance • MSP
	Close gates using remote control devices	N/A	• MnDOT Maintenance

Operational Scenarios

Scenarios are intended to help users understand how they may interact with the freeway traffic management system and one another within the context of those situations that will most commonly require the use of freeway traffic management tools. The following scenarios briefly describe how users will be impacted and how they are expected to respond.

- Scenario A: Typical Weekday Operations
- Scenario B: Freeway Traffic Incidents
- Scenario C: Winter Conditions
- Scenario D: Road Closures due to Construction

Scenario A: Typical Weekday Operations

On a typical weekday morning in the Twin Cities, MnDOT Freeway Operations operators at the MnDOT RTMC actively monitor the freeway traffic flow and conditions in the metro area using traffic detection and video tools. Volumes, speeds and lane occupancy data for each lane of traffic is collected by traffic detection field devices. Freeway travel times are posted on DMS. Speed data is shared with the public via the 511 Travel Information Website, the 511 Phone System and the 511 Mobile App. Video images are also shared with the public via the 511 Website and the Mobile App.

As the morning commute period begins and traffic volumes increase, ramp meters are activated for more effective traffic management. MnDOT Freeway Operations operators continue actively monitor the freeway network using video and traffic detection data. The RTMC Radio broadcaster is on site to report the traffic conditions via the radio station. To avoid delay caused by rush-hour traffic, some travelers opt to utilize the MnPASS lanes for smoother and more reliable travel. At approximately 8:45 AM, as traffic flow returns to less congested conditions, the ramp meter algorithm automatically reduces the metering rates to allow more vehicles to get on to freeways. Eventually, as the morning peak concludes and traffic returns to free-flow conditions, the ramp meters throughout the metro area are deactivated. MnDOT

Freeway Operations operators continue using the observation and detection tools to monitor the traffic and road conditions in preparation for responding to any events.

Scenario B: Freeway Traffic Incidents

A Freeway Operations operator at the MnDOT RTMC is notified of an incident that has been reported to MSP via cell phone call to 911 by a private traveler in the Twin Cities Metro Area. The operator is automatically notified of the incident through MSP's CAD system. State Patrol officers are dispatched to the scene by MSP dispatchers, who can view the locations of MSP vehicles using AVL system. The RTMC operator simultaneously uses ATMS to view the video nearest the incident scene to help assess its severity and its impact to traffic. A FIRST vehicle nearest the incident is also dispatch to the scene to assist in traffic control and incident response. Once the MSP and FIRST vehicles arrive on scene, details of the incident are gathered by MSP officers. Incident information is input into the MSP CAD system then feeds into the MnDOT Condition Acquisition and Reporting System (CARS), which allows for automated communication of event information to the 511 Website, Phone System and Mobile App. MnDOT Freeway Operations operators active the DMS with appropriate messages in areas impacted by the incident to inform en-route travelers. Incident information and alerts are also shared with the public via radio broadcasts by the RTMC radio broadcaster and/or private media radio outlets. As the incident response progressed, the operator modifies the DMS messages and eventually deactivates the DMS as incident clears and traffic returns to normal.

Scenario C: Winter Conditions

A winter storm moves into the Twin Cities Metro Area in the early afternoon hours. During the PM peak hour, a consistent heavy snowfall causes traffic to slow and back up in many locations. At the MnDOT RTMC, Freeway Operations and Maintenance staff monitor the weather and driving conditions via video, weather sensors, satellite radar images, and weather reports. Maintenance staff also monitor roadway weather sensors such as RWIS stations. MSP officers also provide visual observations and report the road driving conditions. Road weather conditions collected from those sources are entered into the CARS, and information is shared with the Freeway Operations operators, maintenance staff and MSP officers. The information is also disseminated to the public via the 511 Website, Phone System and Mobile App. Freeway Operations staff continue to monitor the road and traffic conditions using various tools including video, traffic detection and weather sensors to gain situational awareness and provide information and alerts to FIRST, MSP and maintenance staff to respond to any situations or incidents that require assistance.

Scenario D: Road Closures due to Construction

A stretch of the I-90 will be under construction for 2 months with both short- and longer-term lane closures expected. MnDOT Construction staff communicates the locations, timings and durations of lane closures to the RTMC and MSP staff. The planned construction activities and lane closure information are posted on the project web page and the 511 Website. MnDOT Freeway Operations staff also post messages on DMS in the surrounding area to notify travelers of the upcoming lane closures, as well as broadcasting the information via RTMC and/or private media radio broadcasts.

As construction begins the following Monday morning, Freeway Operations staff use ATMS to monitor video at and near the construction site to identify any traffic backups and/or incidents caused by the lane closures. In addition, they also activate the DMS upstream to lane closures to provide warning messages to travelers. MnDOT Construction staff updates the project web page with current construction activities and lane closures. The information is also disseminated to the public via the 511 Website, 511 Phone and Mobile App. MnDOT Freeway Operations staff also receive updates from the Construction staff to allow for activation of appropriate DMS.

Freeway Operations staff continue monitoring the traffic conditions at and near the construction site and make adjustments or implement additional traffic management strategies for the 2-month construction period. Once all construction operations have ceased and lanes are reopened, Freeway Operations staff remove the construction and lane closure messages from the DMS. Information on the 511 Website, 511 Phone and Mobile App is also updated to reflect the completion of the construction.

Risks and Mitigation

Identifying, monitoring for and mitigating risks are essential to the successful implementation and operation of any system. The following sections present the risks and constraints that have been identified as most significant for the freeway traffic management applications. For each constraint, strategies have been identified to prevent or lessen their impact on the project should they occur. These constraints should be reviewed periodically for relevance and any additional constraints or risks that may be introduced.

Table 33. Freeway Traffic Management Tool Constraints

ITS Tools	Constraints	Descriptions of Constraints
Weather Sensors and Related Forecasting	External weather sources	• MnDOT staff use external weather sources (e.g. weather.com) which are low cost tools. However, these tools are not under any control by MnDOT and may be discontinued at any time requiring a substitute data source.
Condition Reporting System	Participation in a multi- state effort	• MnDOT currently participates in a multi-state program developing and operating the condition reporting system. This may impact the flexibility of the program or the delivery of services.
AVL	Communications medium	• Real-time operations of AVL is constrained by a functioning wireless (currently cellular) data communications medium. The AVL needs should be considered before any changes are made to the wireless data communication medium.

ITS Tools	Constraints	Descriptions of Constraints
ATMS	Open Source Software	• In general, MnDOT Metro Freeway operations are not constrained by any proprietary software (as the metro area ATMS was developed in-house). There are some constraints possible with the use of Java as the user display. A solution is to move to a web-based user interface. The Open source nature allows other agencies to contribute to the software. This may benefit MnDOT and should be considered when enhancements are requested (possible sharing of resources with other states). Some districts also use the software.
	Proprietary control software	• Some districts deployed vendor software for device control. These might constrain future changes to the system.
	Constraint to Observation and Detection	• ATMS places a constraint on Observation and Detection ITS Tools. In order for ATMS to perform properly, Observation and Detection must continue to operate, performing traffic detection.
	Constraint by Information Sharing (DMS)	• The functionalities and requirements of Information Sharing place a constraint on ATMS. Changes to ATMS may impact the ability of Information Sharing ITS Tools (e.g. DMS) to function properly.
Data Extract Tool	Uses outside Traffic Management	• There are a number of uses for the Data Extract Tool outside traffic. Some examples are short and long-term planning, and research. These uses should be considered before any significant changes to the service are made.
	Constraint to Traffic Detectors	• The Data Extract Tool works with existing traffic detectors and detector formats. Any changes to traffic detectors or additions of new types of detectors may require modifications to the data extract tool to maintain compatibility.
Radio Broadcasts	External traveler information source	• MnDOT Metro Area Freeway Operations staff utilizes the RTMC Radio Contractor to alert travelers to traffic situations since they are collocated at the RTMC. The RTMC Radio Broadcaster is a useful tool for MnDOT, however the service is on a contract basis.
	Constraint to Visual Observations	• The RTMC radio broadcasts rely on Visual Observations.

ITS Tools	Constraints	Descriptions of Constraints
Web Pages	Participation in a multi- state effort	• MnDOT participates in a multi-state program developing and operating the condition reporting system which provides the data for the 511 web display. This may impact the flexibility of the program or the delivery of services.
	Traffic Detectors	• The MnDOT Metro Area utilizes traffic detector data to post travel times on the Twin Cities Metro Traffic Map web display. Available traffic detector data may impact the ability to provide travel times.
	Video	• The MnDOT Metro Area displays video images on the Twin Cities Metro Traffic Map web display. Communication to the metro area video may impact the ability to provide images.
	Constraint to Data Processing and Response Formulation	• The ITS Tool 'Web pages' places a constraint on data processing and response formulation as the functionality of web pages are dependent upon the actions performed by data processing and response formulation.
511 Phone and Mobile App	Participation in a multi- state effort	• MnDOT participates in a multi-state program developing and operating the condition reporting system which provides the information for the 511 Phone. This may impact the flexibility of the program or the delivery of services.
	Constraint to Data Processing and Response Formulation	• The ITS Tool 511 Phone places a constraint on data processing and response formulation, as the functionality of 511 Phone is dependent upon the actions performed by data processing and response formulation.
CAD	MSP CAD Operations	• MnDOT's use of CAD for information gathering is constrained by MSP operating the CAD system and allowing MnDOT access to the information.
	CAD-CARS Integration	• The semi-automated CARS ingest of CAD data is constrained by MSP pushing data out of the CAD system, and by MSP ensuring that any 'restricted' information is stripped from the data feed before MnDOT has access to the feed.

ITS Tools	Constraints	Descriptions of Constraints
Lane Control Signs	Lane Control Signs Location	• Lane Control Sign location and spacing is a factor for the usefulness of the device. • The Lane Control Sign should be mounted in a manner that allows maintenance personnel unobstructed access with minimal impact to traffic below. • The role of each user and use case scenario should be considered when deploying lane control signs. • Other factors such as morning and evening glare, and natural and man-made obstructions should also be considered.
	Lane Control Signs Power Source	• The location of the power source for lane control sign deployment should be considered.
	Communications with Lane Control Signs	• Individual use case scenarios for each lane control sign should be considered when designing communications (e.g. whether redundant communication is required).
	Constraint to Data Processing and Response Formulation	• Lane control signs place a constraint on data processing and response formulation, as the functionality of the sign is dependent upon the actions performed by data processing and response formulation.
Electronic Toll Collection	Data coverage	• The MnDOT Electronic Toll algorithm requires volume and occupancy data.
	Constraint to Observation and Detection	• The ITS Tool DMS places a constraint on observation and detection as detector data is needed to operate MnPASS.
Gate Closure Systems	Gate Closure Location	• Gate Closure Location is critical on its usefulness. • The role of each user and use case scenario should be considered when deploying a gate closure system.
	Communication	• The power source and communication to an automated gate closure system is a critical piece of the system, especially in rural areas.
	Visual verification	• When using remote controlled gate closure systems, visual observation is needed to validate that the gate can be closed safely and to ensure the closure has occurred.

ITS Tools	Constraints	Descriptions of Constraints
CAV Infrastructure Systems	Information Security and Privacy	• Management, security and maintenance is essential for CAV applications to freeway traffic management. Privacy is another concern related to CAV applications. It is critical to establish systems to support CAV system monitoring and management, registration, security and credentials management, authorization, and device certification and enrollment.
	Training	• Specialized training in CAV and communications technology needs to be provided to appropriate agency staff for proper operations, management and maintenance of CAV systems.